DETERMINATION OF WATER RESOURCE CLASSES, RESERVE AND RESOURCE QUALITY OBJECTIVES STUDY FOR SECONDARY CATCHMENTS A5 – A9 WITHIN THE LIMPOPO WATER MANAGEMENT AREA (WMA 1) AND SECONDARY CATCHMENT B9 IN THE OLIFANTS WATER MANAGEMENT AREA (WMA 2)

ECOLOGICAL BASE CONFIGURATION SCENARIO REPORT

FINAL

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Cover page photo credit: View of the Luvuvhu River, Makuleke area. Photo from Lee Berger's Lanner Gorge expedition. 29 July 2007. Author Profberger at English Wikipedia

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DOCUMENT INDEX

The project reports are indicated below.

Bold type indicates this report.

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ACRONYMS

BAS	Best Attainable State
DWS	Department of Water and Sanitation
DRIFT	Downstream Response to Imposed Flow Transformation
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category or Condition (used interchangeably)
EFlows	Environmental Flows
ESBC	Ecologically Sustainable Baseline Configuration
EWR	Ecological Water Requirement
FS	Flow State
GIS	Geographical Information System
IUA	Integrated Units of Analysis
LIMCOM	Limpopo Watercourse Commission
MAR	Mean Annual Runoff
Nat	Natural
NWA	National Water Act
PD	Present Day (used interchangeably with Current). Both refer to conditions in 2022.
PES	Present Ecological Status
RDRM	Revised Desktop Reserve Model
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
SC	Secondary Catchment
SPATSIM	Spatial and Time Series Information Modelling
WRCS	Water Resource Classification System
WMA	Water Management Area
WRC	Water Resource Class

Units of measurement

%	percentage
m	meter
Mm^3	Million cubic meters

EXECUTIVE SUMMARY

USE OF BASIN CONFIGURATION TOOL TO SET THE ESBC

In order to set up the ESBC and other scenarios a "**Balancing Tool**" was developed in Excel. Average monthly flows for Natural, Current and each of the ecological categories were used and flows routed from one node to the next in a downstream direction. This was set up so that if a particular ecological category was chosen for a node, the monthly flows associated with that category were selected and routed to the next node (and so on down the system), in order to assess whether those flows would provide what was required for chosen ecological categories at downstream nodes. There are 75 nodes, 14 of which correspond with the sites assessed in more detail in the **EWR Report – Rivers (Vol 3)**. These are referred to as the EWR sites.

The tool reports "surpluses" and "deficits" at each node for the category specified annually and monthly relative to the Present Day (2022) scenario. If the flows at a node, resulting from the category chosen at that and upstream nodes, is greater than Present Day, there is a deficit. If the Present Day flows are greater than the chosen flows, there is a surplus. Flows at nodes can be adjusted so as to meet particular requirement (such as not falling below a D, or have no deficits). In the subsequent scenario analysis, the surface and groundwater yield models will be used to calculate the deficit/surplus of modelled flows relative to the required Ecological Water Requirements (EWRs). Additional water supply interventions to meet any deficits will be identified and the water supply costs of these alternative options estimated. In the case of a surplus, once verified in the yield model, the potential benefits of the additional water available for abstractive uses can be assessed. This is done as part of the scenario evaluation process and in some cases involves additional analysis of potential impacts on yield.

COMPARING THE ESBC TO PES (2022) FLOWS

The volumes resulting from the Ecologically Sustainable Base Configuration scenario are reported as surpluses or deficits relative to the PES scenario at each node. The nodes are grouped in their river basins for the large rivers that have many tributaries and comprise two Integrated Units of Analysis (IUAs). The smaller rivers are reported on in groups of IUAs. The overall results on river ecological condition are summarised in **Figure E1** and **E2**, where nodes are shown as ovals and Ecological Water Requirements sites shown as larger rectangles.

Overall, the ESBC flow scenario (**Figure E1** and **E2** refer):

- Meets and exceeds the annual, and in some cases the seasonal, flow requirements for a D at all nodes except one.
- Results in a D/E at Rvii4 Sterk River in the Upper Nyl IUA.
- Results in relatively few and generally minor flow deficits (i.e. situations where current flows will not be able provide the ESBC at that node, and would need to be augmented in order provide the ESBC flows).
- Creates surpluses in flow at the majority of nodes.
- Keeps current flows at three nodes:
    - Ri6 on the Mokamole River
    - Riii6 (EWR site 10_Latonyanda) on the Latonyanda River
    - Riv24 on the Mbodi River

- Results in RECs not being met at 13 (out of 19) EWR sites, which would be not acceptable, as follows:
    1. Riv11 (EWR site 1_Lephalal): REC=B/C, ESBC=D
    2. Ri1 (EWR site 3_Olifantspruit) REC=B/C, ESBC=C
    3. Ri5 (EWR site 4_Mogalakwena1): REC=C, ESBC=C/D
    4. Rii3 (LIMCOM site MOGA-A63D-LIMPK): REC=C, ESBC=C/D
    5. Riv32 (EWR sites 6_Kolope): REC=B/C, ESBC=C
    6. Ri20 (EWR site 7_Sand): REC=C, ESBC=D
    7. Ri25 (LIMCOM site SAND-A71K-R508B): REC=C, ESBC=C/D
    8. Ri28 (EWR site 9_Nwanedi): REC= C, ESBC=D
    9. Ri30 (EWR site 11_Mutshindudi) REC=C, ESBC=D
    10. Ri32 (EWR site 12_Luvuvhu): REC=B/C, ESBC=C
    11. Ri33 (EWR site 13_Mutale1): REC=C, ESBC=D
    12. Ri34 (EWR site 14_Mutale2): REC=C, ESBC=D
    13. Ri37 (LIMCOM site SHIN-B90H-POACH) REC=B/C, ESBC=D
- Results in significant reductions in flow volumes at most nodes, with the difference in volume being theoretically available for abstraction (**Figure E3)**.

The initial analysis of the ESBC scenario achieved its primary objectives which were to establish the ‘Balancing Tool’ and identify the fact that there are areas of potential surplus and deficit resulting from a minimum sustainable ecological scenario that need to be considered.

THE WAY FORWARD

After completing the ESBC scenario, the ‘Balancing Tool’ will be used to set up the necessary ecological category (EC) requirements to achieve the specific objectives of the alternative proposed classification scenarios including three ecologically-based scenarios (a Present Ecological Status (PES) Scenario, an Ecologically Sustainable Base Configuration (ESBC) Scenario, a Best Attainable State (BAS) Scenario), as well as a development-focused scenario (demand-driven, unconstrained (NoEC) Scenario) and finally a Spatially Targeted Scenario (STS). The analysis will consider the associated social, economic and ecological impacts of these alternative configuration scenarios in order to estimate the overall impact of each and to agree with stakeholders on the final recommended classification scenario for each resource unit and the individual IUAs.

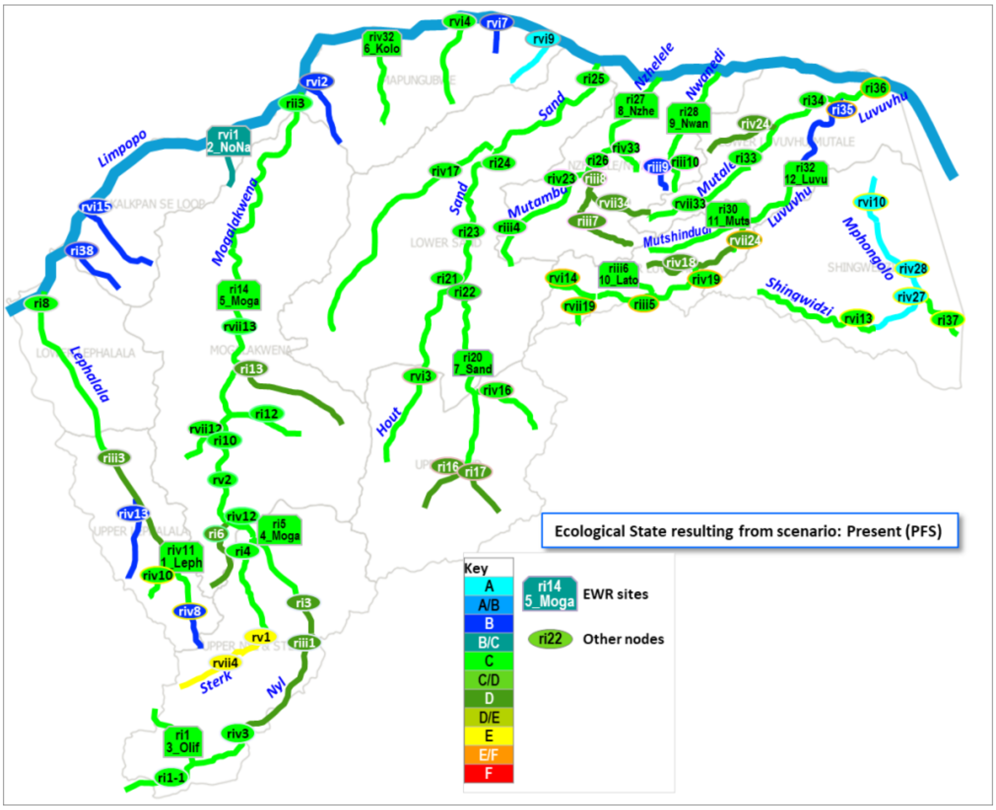

Figure E1: Map showing the EC under the Present Day / Current situation at all nodes and river reaches (nodes are ovals and EWR sites are larger rectangles)

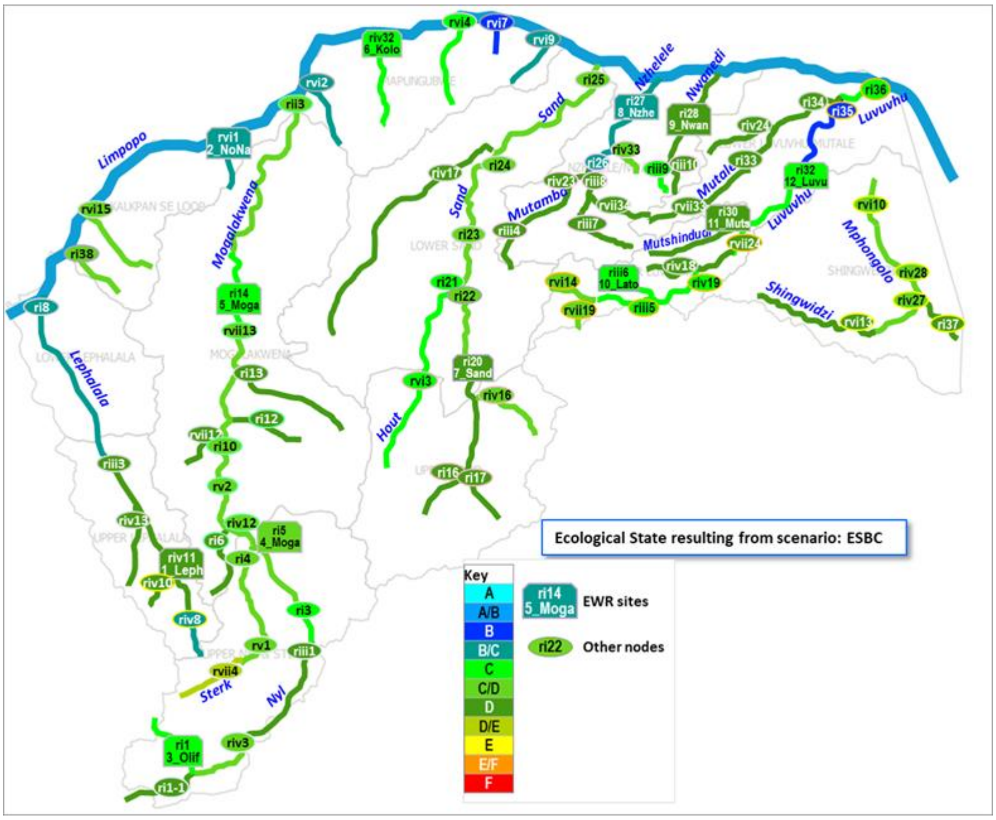

Figure E2: Map showing the EC under the ESBC flow scenario at all nodes and river reaches (nodes are ovals and EWR sites are larger rectangles)

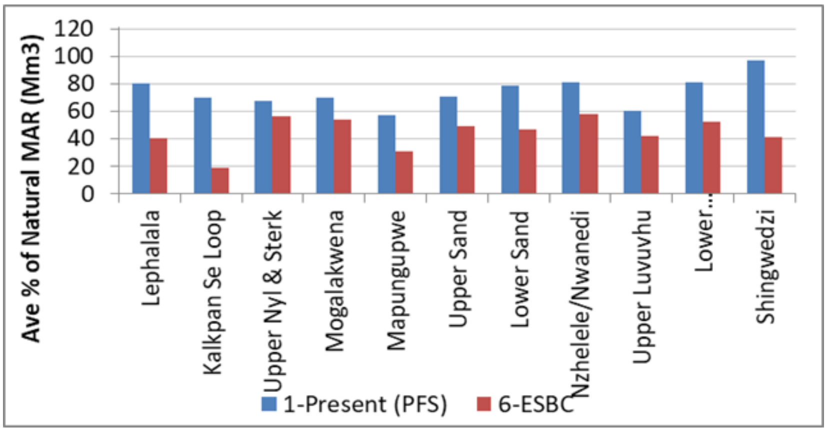

Figure E3: Current MAR compared to ESBC MAR as percentages of natural MAR for each IUA

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1 INTRODUCTION

1.1 Background

Chapter 3 of the National Water Act (NWA) lays down a series of measures which are together intended to ensure protection of the water resources of the country. In accordance with these measures, the Department of Water and Sanitation (DWS), in line with Section 12 of the NWA, established a Water Resources Classification System (WRCS) that is formally prescribed by Regulations 810 dated 17 September 2010.

The WRCS provides guidelines and procedures for determining Water Resource Classes, Reserve and Resource Quality Objectives (RQOs) for all water resources in the country.

The overall objective of the study is to classify and determine the Reserve and Resource Quality Objectives (RQOs) for all significant water resources in Secondary Catchments (SC) A5-A9 in the Limpopo WMA and SC B9 in the Olifants WMA.

The Scope of Work as stipulated in the Terms of Reference calls for:

- Implementation of the Water Resources Classification System (WRCS, Dollar et al. 2006), as required in Regulation 810 in Government Gazette 33541, and classify all significant water resources in the Limpopo WMA (SCs A5-A9) and Olifants WMA (SC B9).
- Determination of the water quantity and quality components of the Reserve for groundwater, rivers and wetlands.
- Determination of the RQOs using the DWS 'Procedures to Determine and Implement Resource Quality Objectives' (DWAF 2011).

There are seven river basins that comprise a main river with tributaries; the Lephalala River (A5), the Mogalakwena River (A6), the Sand River (A7), the Nzhelele River (A8), the Nwanedi River (A8), the Luvuvhu River (A9) and the Shingwedzi River (B9), as seen in **Figure** 1.1.

1.2 Work done to date

The eight step integrated procedure being followed in this project is summarised in **Figure** 1.3.

The first step involved mapping and delineating the main water resources in the study area. As part of this step 75 locations or nodes were positioned on the main rivers and tributaries (**Figure** 1.2**, see Delineation and Status Quo Report**), including 14 nodes which corresponded with sites (EWR sites) studied in detail for the **EWR Report – Rivers (Vol 3)**. These are locations where various modelling is done, most importantly hydrological modelling for the analysis of classification scenarios.

The second step involved collating and collecting information and data that was used to describe the status quo of the water resources and infrastructure, bio-physical characteristics, socio-economic attributes and activities in order to group parts of the study area into 12 Integrated Units of Analysis (IUAs, **Table** 1.1). IUAs are areas that are similar in their attributes and represent the main focus areas for the analysis of classification scenarios. Each IUA has a different number of nodes.

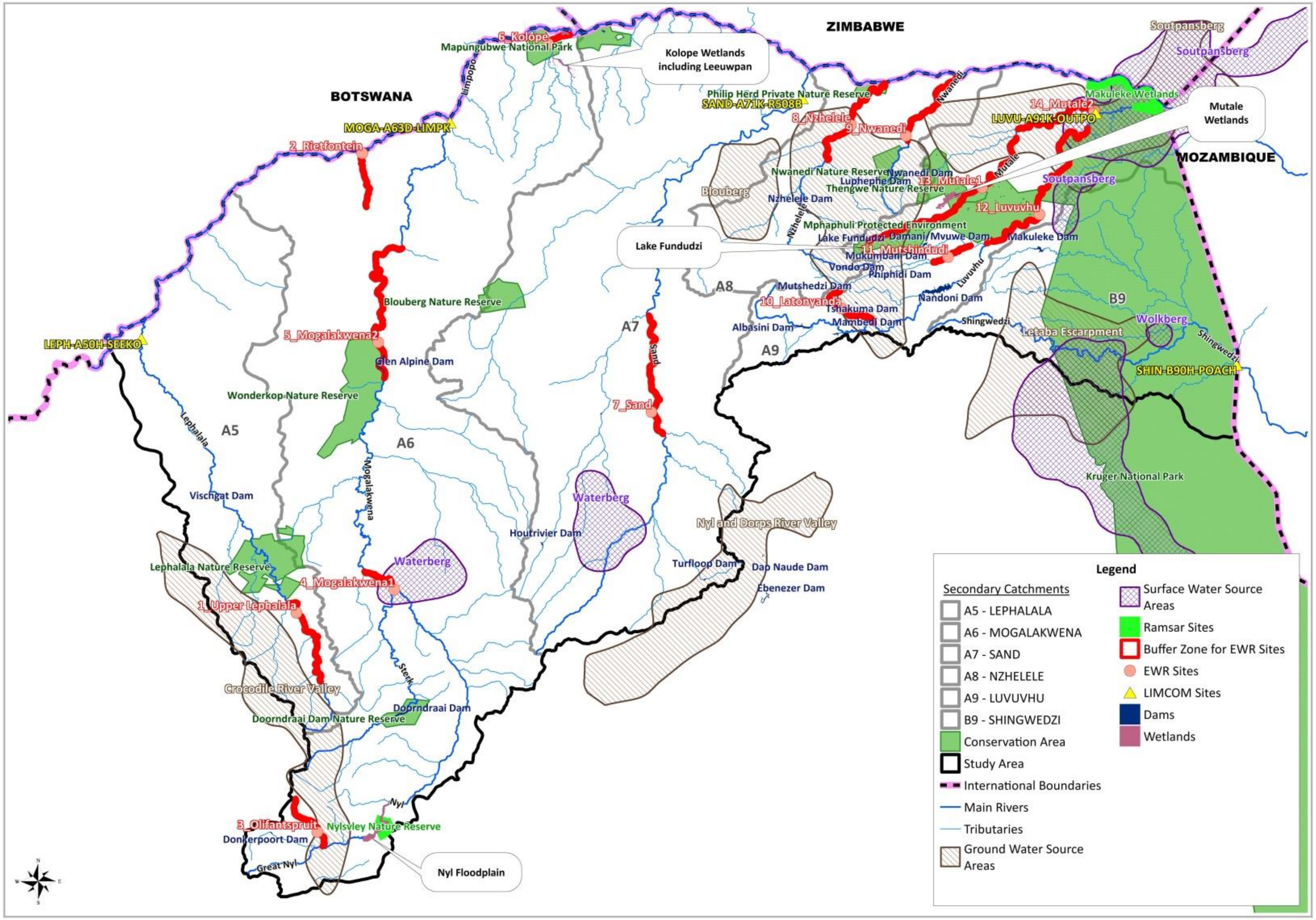

Figure 1.1: Map of the study area

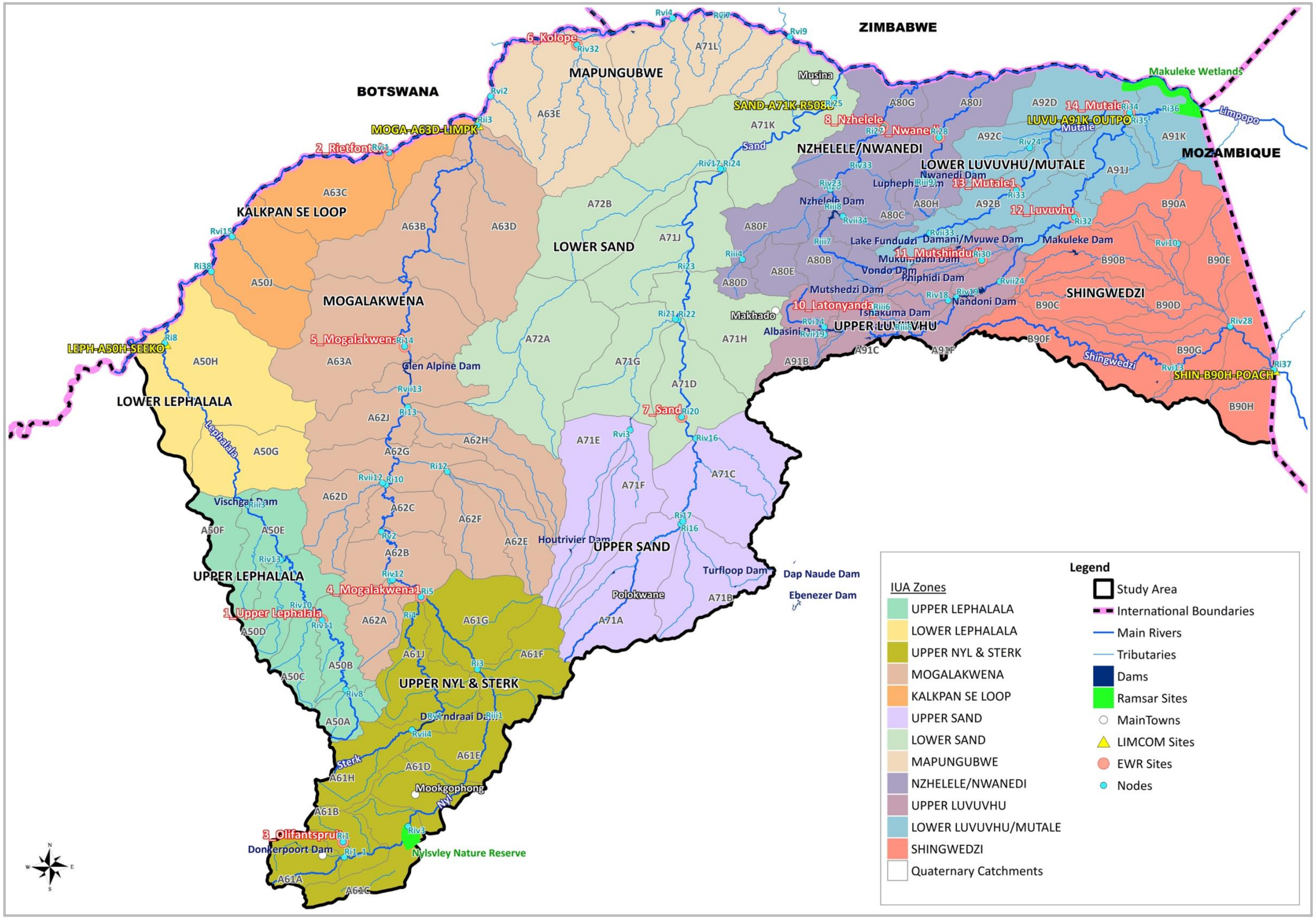

Figure 1.2: Nodes and Integrated Units of Analysis (IUAs)

Table 1.1: Nodes

IUA	Node	Quat	Sub-Quat code	River	X-coordinate	Y-coordinate	EWR sites
Upper Lephalala	Riv8	A50A	A50A-00354	Lephalala	28°29'5.0809"E	24°11'54.6908"S	
Upper Lephalala	Riv11	A50B	A50B-00262	Lephalala	28°22'27.61"E	23°57'15.14"S	1_Lephalala
Upper Lephalala	Riv10	A50C	A50C-00273	Melk	28°22'27.61"E	23°57'15.14"S	
Upper Lephalala	Riv13	A50D	A50D-00237	Boklandspruit	28°22'32.23"E	23°57'20.43"S	
Upper Lephalala	Riii3	A50E	A50H-00110	Lephalala	28°16'10.01"E	23°48'7.83"S	
Lower Lephalala	Ri8	A50H	A50H-00110	Lephalala.	28° 6'58.02"E	23°36'38.23"S	LEPH-A50H-SEEKO*
Kalkpan se Loop	Ri38	A50J	A50J-00073	Kalkpan Se Loop	27°53'6.10"E	23° 8'28.60"S	
Kalkpan se Loop	Rvi15	A50J	A50J-00061	No Name	21°6'30.4779"E	22°49'3.3245"S	
Kalkpan se Loop	Rvi1	A63C	A63C-00033	Rietfontein	28°37'38.91"E	22°33'36.58"S	2_Rietfontein
Upper Nyl & Sterk	Ri1_1	A61A	A61B-00552	Nyl	28°27'59.3704"E	24°42'42.9578"S	
Upper Nyl & Sterk	Ri1	A61B	A61B-00552	Olifantspruit	28°28'46.21"E	24°42'35.18"S	3_Olifantspruit
Upper Nyl/Sterk	Riv3	A61C	A61C-00501	Nyl	28°42'58.54"E	24°34'14.55"S	
Upper Nyl/Sterk	Riii1	A61E	A61E-00386	Nyl	28°37'38.91"E	22°33'36.58"S	
Upper Nyl/Sterk	Ri3	A61F	A61G-00297	Mogalakwena	28°44'29.17"E	23°55'10.03"S	
Upper Nyl/Sterk	Ri5	A61G	A61G-00248	Mogalakwena	28°58'31.10"E	24°16'36.47"S	4_Mogalakwena
Upper Nyl/Sterk	Rv1	A61H	A61H-00395	Sterk	28°55'10.37"E	24° 8'11.48"S	
Upper Nyl/Sterk	Rvii4	A61H	A61H-00395	Sterk	28°55'11.40"E	22°28'34.49"S	
Upper Nyl/Sterk	Ri4	A61J	A61J-00267	Sterk	28°42'12.73"E	24°19'15.74"S	
Mogalakwena	Ri6	A62A	A62A-00253	Mokamole	28°46'41.12"E	24°16'43.09"S	
Mogalakwena	Riv12	A62B	A62B-00223	Mogalakwena	28°41'44.87"E	23°58'16.14"S	
Mogalakwena	Rv2	A62B	A62B-00188	Mogalakwena	28°37'57.33"E	23°51'56.86"S	
Mogalakwena	Ri10	A62C	A62C-00188	Mogalakwena	28°38'22.22"E	23°51'46.86"S	
Mogalakwena	Rvii12	A62D	A62D-00179	Klein Mogalakwena	28°36'10.14"E	23°42'59.95"S	
Mogalakwena	Ri12	A62F	A62G-00167	Matlalane	28°37'1.16"E	23°34'24.04"S	
Mogalakwena	Ri13	A62H	A62H-00148	Seepabana	28°36'23.80"E	23°34'4.37"S	
Mogalakwena	Ri14	A62J	A63A-00071	Mogalakwena	28°49'13.85"E	23°32'0.38"S	5_Mogalakwena
Mogalakwena	Rvii13	A62J	A62J-00143	Mogalakwena	28°41'22.49"E	23°20'10.85"S	
Mogalakwena	Rii3	A63D	A63D-00034	Mogalakwena	28°41'44.87"E	23°58'16.14"S	MOGA-A63D-LIMPK*
Mapungubwe	Riv32	A63E	A63E-00008	Kolope	29°35'34.22"E	23°41'36.63"S	6_Kolope
Mapungubwe	Rvi2	A63E	A63E-00011	Stinkwater	28°57'49.50"E	22°23'18.58"S	
Mapungubwe	Rvi4	A71L	A71L-00005	Kongoloop	31°12'46.50"E	22°25'32.50"S	

IUA	Node	Quat	Sub-Quat code	River	X-coordinate	Y-coordinate	EWR sites
Mapungubwe	Rvi7	A71L	A71L-00003	No Name	29°43'42.26"E	22°8'30.2158"S	
Mapungubwe	Rvi9	A71L	A71L-00015	Soutsloot	29°57'17.666 "E	22°12'28.612 "S	
Upper Sand	Ri16	A71A	A71A-00211	Sand	29°17'5.13"E	22°19'44.92"S	
Upper Sand	Ri17	A71B	A71B-00214	Diep	30° 5'57.85"E	22°23'39.56"S	
Upper Sand	Ri20	A71C	A71D-00118	Sand	30°38'54.64"E	22°57'11.25"S	7_Sand
Upper Sand	Riv16	A71C	A71C-00156	Dwars	29°35'59.96"E	23°41'6.52"S	
Lower Sand	Ri22	A71D	A71D-00118	Sand	29°38'34.16"E	23°25'54.67"S	
Upper Sand	Rvi3	A71F	A71G-00131	Hout	28°9'40.2852"E	23°38'9.5037"S	
Lower Sand	Ri21	A71G	A71G-00107	Hout	29°35'2.52"E	23° 4'10.36"S	
Lower Sand	Ri23	A71H	A71H-00088	Sand	29°34'29.76"E	23° 4'4.32"S	
Lower Sand	Ri24	A71J	A71J-00055	Sand	29°36'37.51"E	22°54'25.73"S	
Lower Sand	Ri25	A71K	A71K-00019	Sand	29°43'56.71"E	22°36'35.47"S	SAND-A71K-R508B*
Lower Sand	Riv17	A72B	A72B-00038	Brak	29°43'27.78"E	22°36'35.21"S	
Nzhelele/Ṅwanedi	Riii7	A80B	A80B-00069	Nzhelele	30° 3'40.50"E	22°49'52.97"S	
Nzhelele/Ṅwanedi	Rvii34	A80C	A80C-00068	Mafungudi	30° 7'45.63"E	22°45'15.65"S	
Nzhelele/Ṅwanedi	Riii4	A80D	A80D-00075	Mutamba	29° 47'48.23"E	22°53'8.20"S	
Nzhelele/Ṅwanedi	Ri26	A80F	A80G-00053	Nzhelele	30° 5'36.74"E	22°39'49.72"S	
Nzhelele/Ṅwanedi	Riv23	A80F	A80F-00063	Mutamba	30° 5'15.89"E	22°40'18.17"S	
Nzhelele/Ṅwanedi	Riii8	A80F	A80F-00065	Nzhelele	30° 5'46.42"E	22°43'28.72"S	
Nzhelele/Ṅwanedi	Ri27	A80G	A80G-00026	Nzhelele	30°11'17.45"E	22°35'55.44"S	8_Nzhelele
Nzhelele/Ṅwanedi	Riv33	A80G	A80G-00054	Tshishiru	31°33'33.09"E	23°13'22.35"S	
Nzhelele/Ṅwanedi	Riii9	A80H	A80H-00064	Ṅwanedi	30°23'56.45"E	22°38'6.08"S	
Nzhelele/Ṅwanedi	Riii10	A80H	A80H-00060	Luphephe	30°24'7.06"E	22°38'0.18"S	
Nzhelele/Ṅwanedi	Ri28	A80J	A80J-00028	Ṅwanedi	27°53'6.10"E	23° 8'28.60"S	9_Ṅwanedi
Upper Luvuvhu	Rvi14	A91A	A91A-00105	Luvuvhu	30° 4'3.09"E	23° 5'32.98"S	
Upper Luvuvhu	Rvii19	A91B	A91B-00120	Doringspruit	30° 4'4.96"E	23° 6'56.11"S	
Upper Luvuvhu	Riii5	A91C	A91C-00115	Luvuvhu	30°19'43.90"E	23° 5'33.46"S	
Upper Luvuvhu	Riii6	A91D	A91D-00108	Latonyanda	30°20'17.38"E	23° 5'31.22"S	10_Latonyanda
Upper Luvuvhu	Riv18	A91E	A91E-00103	Dzindi	30°28'39.11"E	23° 0'38.52"S	
Upper Luvuvhu	Riv19	A91F	A91F-00111	Luvuvhu	30°30'16.60"E	23° 0'4.85"S	
Upper Luvuvhu	Rvii24	A91F	A91F-00093	Luvuvhu	30° 4'3.09"E	23° 5'32.98"S	
Upper Luvuvhu	Ri30	A91G	A91G-00086	Mutshindudi	30°41'7.80"E	22°51'11.99"S	11_Mutshindudi
Lower Luvuvhu/Mutale	Ri32	A91H	A91H-00045	Luvuvhu	30°52'55.81"E	22°44'11.40"S	12_Luvuvhu
Lower Luvuvhu/Mutale	Ri35	A91J	A91J-00040	Luvuvhu	31° 4'52.02"E	22°26'57.10"S	LUVU-A91K-OUTPO*
Lower Luvuvhu/Mutale	Ri36	A91K	A91K-00035	Luvuvhu	30°22'19.87"E	22°20'55.39"S	

IUA	Node	Quat	Sub-Quat code	River	X-coordinate	Y-coordinate	EWR sites
Lower Luvuvhu/Mutale	Rvii33	A92A	NO CODE	Mutale	30°20'41.82"E	22°49'59.38"S	
Lower Luvuvhu/Mutale	Ri33	A92B	A92B-00051	Mutale	30°48'58.13"E	22°31'13.99"S	13_Mutale
Lower Luvuvhu/Mutale	Riv24	A92C	A92C-00049	Mbodi	30°48'49.48"E	22°31'5.27"S	
Lower Luvuvhu/Mutale	Ri34	A92D	A92D-00030	Mutale	30°36'57.41"E	22°19'46.85"S	14_Mutale
Shingwedzi	Rvi10	B90A	B90D-00067	Shisha	31°14'12.2369"E	22° 50'13.875"S	
Shingwedzi	Rvi13	B90F	B90F-00114	Shingwedzi	31°13'9.6229"E	23°12'59.92"S	
Shingwedzi	Riv27	B90G	B90G-00124	Shingwedzi	31°24'37.69"E	23° 5'30.82"S	
Shingwedzi	Ri37	B90H	B90H-00145	Shingwedzi	31° 4'38.82"E	22°26'15.65"S	SHIN-B90H-POACH*
Shingwedzi	Riv28	B90H	B90H-00113	Mphongolo	31°24'39.27"E	23° 5'22.74"S	

* are the site codes for the LIMCOM study sites. An explanation of these is provided in the text that follows Figure 1.3.

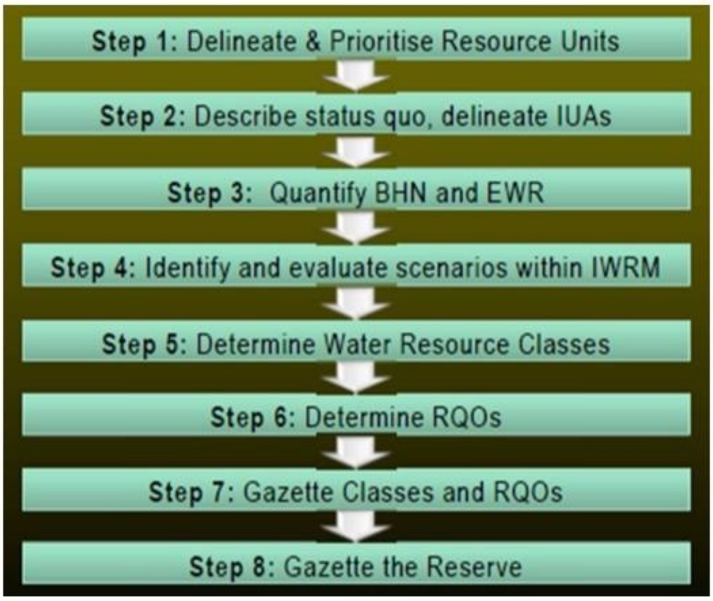

Figure 1.3: The 8 integrated steps to co-ordinate the WRCS, the Reserve and the RQOs

In step three, the Basic Human Needs and Ecological Water Requirements were determined. There are 19 river sites, five of which are being worked upon by another EWR team as part of the LIMCOM transboundary EFlows project. The LIMCOM study is deriving EFlows[1] and analysing water resource protection and development scenarios that will affect the Limpopo River and its tributaries in the four member countries; Botswana, Zimbabwe, South Africa and Mozambique. There are five LIMCOM EFlows sites in South Africa that are all situated at the lower end of the:

- The Lephalala River (site code LEPH-A50H-SEEKO).
- The Mogalakwena River (MOGA-A63D-LIMPK).
- The Sand River (SAND-A71K-R508B).
- The Luvuvhu River (LUVU-A91K-OUTPO).
- The Shingwedzi River (SHIN-B90H-POACH).

The analysis of scenarios and the subsequent decisions about the EFlows for the lower end of these five South African Rivers and how this is predicted to affect flows in the Limpopo River will become part of international water agreements between the four member countries. The LIMCOM study is going to conclude after this study and so the EWRs, analysis of classification scenarios and descriptions of RQOs for the South African rivers will precede whatever decisions are made about the Limpopo River.

The Limpopo River basin study is ongoing (as at August 2024) in a new phase of work in three concurrent projects:

- To harmonise the EWRs for the Limpopo River basin, including making use of the EWRs determined as reported in **EWR Report – Rivers (Vol 3)**.

[1] EFlows and EWRs are different terms that mean similar things; EWRs mean Ecological Water Requirements and is used by the DWS in South Africa. EFlows means Environmental Flows (of water, sediment and biota) and is used internationally.

- To connect and interact with various stakeholders extensively.
- To define and analyse scenarios of possible future outcomes that are likely to influence freshwater ecosystems of the Limpopo River basin.

There are 14 river sites where EWRs were determined in this project that are all located upstream of the LIMCOM sites:

- Upper Lephalala River (site code 1_Lephalala)
- Rietfontein River (2_Rietfontein)
- Olifantspruit River (3_Olifantspruit)
- Upper Mogalakwena River (4_Mogalakwena1)
- Lower Mogalakwena River (5_Mogalakwena2)
- Kolope River (6_Kolope)
- Upper Sand River (7_Sand)
- Nzhelele River (8_Nzhelele)
- Ṅwaneḓi River (9_Ṅwaneḓi)
- Latonyanda River (10_Latonyanda)
- Mutshindudi River (11_Mutshindudi)
- Luvuvhu River (12_Luvuvhu)
- Upper Mutale River (13_Mutale1)
- Lower Mutale River (14_Mutale2).

ALL the EWRs are preliminary at this stage in the project, until the Reserve has been gazetted, which takes place last in Step 8 of the integrated steps. Step 7 must happen first that is the gazetting of the Water Resource Classes and RQOs. This means the EWRs are preliminary until the Water Resource Classes and RQOs have been gazetted, the Reserve (with EWRs) gets gazetted last because the EWRs must be signed off and match those used in the final scenario selected with its target conditions. EWRs were determined for the PES scenario (2022), a future development scenario and a future development with climate change scenario using the Downstream Response to Imposed Flow Transformation (DRIFT) software. The objective of the analysis of EWR scenarios thus far was to look at what the predicted consequences of future planned developments are expected to be on the Recommended Ecological Categories (RECs), viz. if the planned developments go ahead what are the consequences of the changes in flow likely to be for the ecological condition of the rivers. The EWR options explored thus far all go into the analysis of Classification scenarios, which is the next step number four (Identify and evaluate scenarios within IWRM).

Step 4 is where closer attention is given to the social and economic requirements related to water use and the future management of the studied water resources. Stakeholders participate in this process by using the risks identified when evaluating the implication of existing and planned water-resource developments on the surface water flows in rivers (and what impacts are predicted on water quality; river health (**Table** 1.2) wetland health; Ecosystem Goods and Services; surface water yields, groundwater yields and water supply costs).

Table 1.2: Definitions of the ecological categories (Kleynhans and Louw 2007)

ECOLOGICAL CATEGORY	GENERIC DESCRIPTION OF ECOLOGICAL CONDITIONS	SCORE (%)
A	Unmodified/natural. Close to natural or close to predevelopment conditions within the natural variability of the system drivers: hydrology, physico-chemical and geomorphology. The habitat template and biological components can be considered close to natural or to pre-development conditions. The resilience of the system has not been compromised.	>92-100
A/B	The system and its components are in a close to natural condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a B category.	>88-≤92
B	Largely natural with few modifications. A small change in the attributes of natural habitats and biota may have taken place in terms of frequencies of occurrence and abundance. Ecosystem functions and resilience are essentially unchanged.	>82-≤88
B/C	Close to largely natural most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a C category.	>78-≤82
C	Moderately modified. Loss and change of natural habitat and biota have occurred in terms of frequencies of occurrence and abundance. Basic ecosystem functions are still predominantly unchanged. The resilience of the system to recover from human impacts has not been lost and it is ability to recover to a moderately modified condition following disturbance has been maintained.	>62-≤78
C/D	The system is in a close to moderately modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a D category.	>58-≤62
D	Largely modified. A large change or loss of natural habitat, biota and basic ecosystem functions have occurred. The resilience of the system to sustain this category has not been compromised and the ability to deliver Ecosystem Services has been maintained.	>42-≤58
D/E	The system is in a close to largely modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of an E category. The resilience of the system is often under severe stress and may be lost permanently if adverse impacts continue.	>38-≤42
E	Seriously modified. The change in the natural habitat template, biota and basic ecosystem functions are extensive. Only resilient biota may survive, and it is highly likely that invasive and problem (pest) species may dominate. The resilience of the system is severely compromised as is the capacity to provide Ecosystem Services. However, geomorphological conditions are largely intact but extensive restoration may be required to improve the system's hydrology and physico-chemical conditions.	>22-≤38
E/F		>18-≤22
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete change of the natural habitat template, biota, and basic ecosystem functions. Ecosystem Services have largely been lost This is likely to include severe catchment changes as well as hydrological, physico-chemical, and geomorphological changes. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. Restoration of the system to a synthetic but sustainable condition acceptable for human purposes and to limit downstream impacts is the only option.	<18

1.3 Purpose of this report

This report presents the Ecologically Sustainable Base Configuration (ESBC) scenario and is part of one of three reports to determine the water resource classes. The three reports are:

- The Ecologically Sustainable Baseline Configuration Report (this report). The report has also been referred to as the Ecological Base Configuration Scenario Report.
- The Scenarios Evaluation and Draft Water Resource Classes Report.
- The Final Scenarios Report.

The ESBC (or “bottom line”) scenario illustrates a scenario where the maximum volume of water is made available for abstraction from the system for economic activities, with the proviso that river reaches are maintained in at least a D category where possible.

The objective of this report is to describe how the model needed to analyse the data was set up and to demonstrate how the model will be used to generate results that inform discussions on the outcomes of the proposed alternative classification scenarios. There are five scenarios on the table at this stage (**Table** 1.3) and the results of all these will be presented in the Scenarios Evaluation and Draft Water Resource Classes Report. This report presents the outcome of the ESBC scenario on flows at a monthly time-step and on the overall ecological condition of the rivers. These are the two primary outputs from the tool that are used to understand the implications of changes in flow and ecological condition on ecosystems (water quality, river health, wetland health) and ecosystem goods and services, and on water yields and water supply costs. The results of the scenario analysis will be expressed in terms of the direct gains and losses of ecosystem services and water supply costs for each scenario using simple to understand graphics and tables for presentation to stakeholders.

Table 1.3: Classification scenarios

#	Scenario	Abbreviation	Description
1	Maintain Present Ecological Status (Current day)	PES (2022)	Rivers are maintained in their present condition, or where currently in an E or F, improved to a D as far as possible.
2	Ecologically Sustainable Base Configuration Scenario (Bottom-line)	ESBC	The maximum volume of water is made available for abstraction from the system for economic activities, with the proviso that river reaches are maintained in at least a D category (i.e. the "bottom line") where possible.
3	Maximum conservation Scenario or Best attainable state	BAS	The BAS determined for rivers are applied in this scenario which prioritises the study area as a conservation area.
4	Demands prioritised without EC constraints (no EC)	NoEC	This development-focussed scenario presents the situation where the water demand for the future level of development (assuming high growth in future water demands) are met. The resulting ecological conditions are not constrained and may result in worse than a D.
5	Spatially-targeted Scenario	STS	Based on spatial considerations of priority objectives resulting in a blend of targeted ECs for all nodes ranging between BAS and ESBC. The impacts of this scenario are tested against future water demands only.
6	Recommended Ecological Category	REC	The REC determined for rivers are applied in this scenario.

The ESBC is the minimum environmental flow scenario that sustains the lowest acceptable conditions for all the water resources basin-wide. In this report (and in the project from here on) it is suggested that the suffix *bottom line* is attached to the ESBC when describing this scenario, to avoid confusion between this and the baseline scenario that maintains the PES, *viz.* ESBC (bottom line).

In order to determine the configuration of ecological water requirements (EWRs) at all allocation nodes, a '**Balancing Tool'** was set up in Excel to assess whether the Present Day flows are sufficient to meet these EWRs (described in more detail in **Section 3**). Part of the data needed for the tool are EWRs for all the nodes. These were calculated in the Revised Desktop Reserve Model (RDRM) and this is described in more detail in **Section 2**.

Establishing the ESBC scenario aims to route flows and their associated ecological conditions per node, through the network of nodes, such that minimum D-condition flows are met in the rivers basin-wide and finally at the lower end of all the Limpopo River tributaries. Normally, even though flows are finally routed in a downstream direction, establishing this bottom-line configuration is approached first by putting the requirements in place (D-condition) at the lowest node, and then working in an upstream direction through the node network setting flows in place to maintain this. The bottom line condition of each node is then established as either a D or whichever higher category is required to maintain all downstream nodes in at least a D condition (**Figure** 1.4).

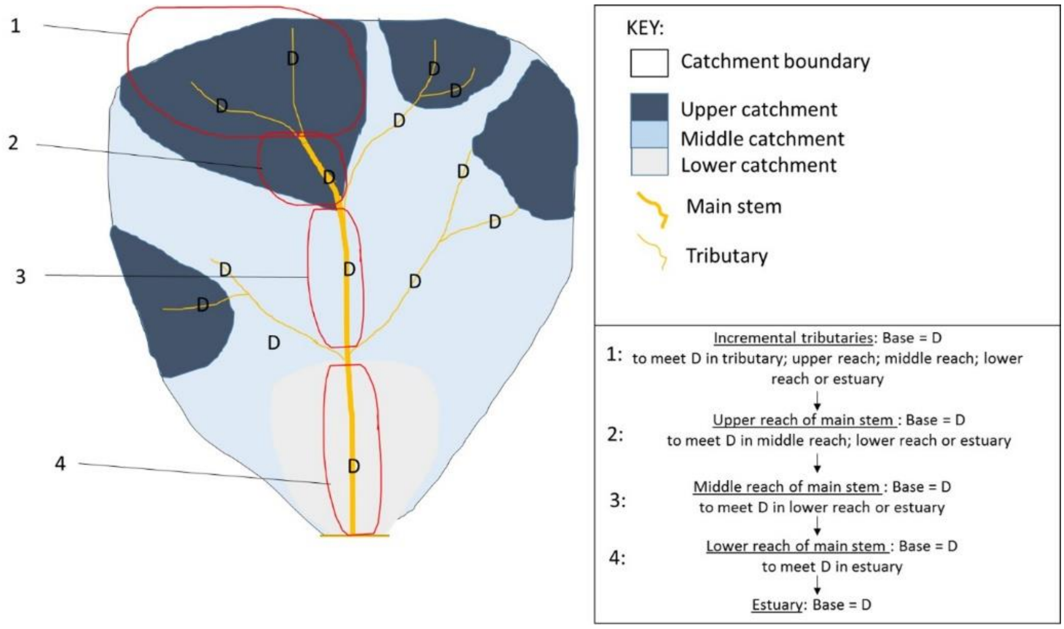

Figure 1.4: Schematic showing hypothetical downstream dependence on upstream condition

Since EWRs are calculated from natural flows, the EWRs for the various Ecological Categories (EC) may exceed flows of the Present Day which are reduced relative to natural by water demands basin-wide. This is especially the case in the Limpopo WMA where water use is high and there are many non-perennial rivers. That being the case, it is necessary to check that these bottom line EWRs can be met by current flows. Deficits will result where the EWRs exceed current flows, usually during the dry season. In these cases it may be possible to increase flow supplied to a node so as to meet the EWR.

The flows required to meet the ecological conditions of the bottom line or ESBC scenario are compared to that of the Present Day using the 'Balancing Tool' in **Section 4.** The results of this analysis will show deficits and surpluses of flow (water volumes) between the EWRs for the ESBC and Present Day flows. A deficit results when EWRs for the targeted Ecological Category (EC) exceed the flows of the Present Day, a surplus occurs when present day flows exceed the EWRs for the target EC.

2 EWRS FOR ALL BIOPHYSICAL AND ALLOCATION NODES

2.1 Terminology

“Biophysical and allocation nodes” are established as part of the WRCS process (DWAF 2007; RSA 2010). This process was undertaken for the study and is described in the **Delineation and Status Quo Report**. In the development of the WRCS, the two types of nodes were distinguished as follows:

- Biophysical nodes: Were intended to be at locations where summarised socio-economic effects based on ecological changes could or should be provided. This is because providing socio-economic effects for **all** nodes is unrealistic and not useful for the purposes of the WRCS. Useful locations for these biophysical nodes would be, for example, at catchment or IUA outlets.
- Allocation nodes: Were to be used as the basis for incorporating planning scenarios into the catchment configuration scenarios.

In essence, the purpose or function of the two types of nodes has merged, and so the biophysical and allocation nodes are both referred to as “nodes” in this document and no distinction is further made. On the other hand, 14 of the nodes correspond to sites assessed in more detail in the EWR Report – Rivers (Vol 3). These 14 sites are referred to as EWR sites.

2.2 Background

The estimation of EWRs for all the nodes applied Version 2 of the Revised Desktop Reserve Model (RDRMv2 – hereafter referred to as the ‘RDRM’). The RDRM is a Desktop application of the Habitat-Flow Stressor-Response Ecological Water Requirement (EWR) Methodology. The RDRM explicitly includes the links and relationships between hydrology, hydraulics and hydraulic-habitat, and ecological response - compared to the original Desktop Reserve Model (refer to Hughes and Hannart 2003). Version 2 of the original RDRM (refer to Hughes *et al.* 2014) was refined under the auspices of a Water Research Commission (WRC) project (WRC 2018a; 2018b).[2]

2.3 Approach

The nodes requiring Desktop EWR assessments are listed under the relevant catchments or IUAs in **Table** 2.2.

The RDRM runs within the Spatial and Time Series Information Modelling (SPATSIM) software.[3] A new SPATSIM application was setup for the study area (viz. Secondary Catchments A5 - A9 within the Limpopo Water Management Area and Secondary Catchment B9 in the Olifants Water Management Area), and includes Geographical Information Systems (GIS) coverages for sub-quaternary catchments, rivers and nodes (refer to **Figure** 2.1). The RDRM application setup is readily transferable to other computers running SPATSIM.

[2] The study reports (Volume 1: Final report, and Volume 2: Manual) are available on the WRC website (https://www.wrc.org.za)

[3] SPATSIM v3 was used in this study (https://www.ru.ac.za/iwr/resources/software/spatsim/)

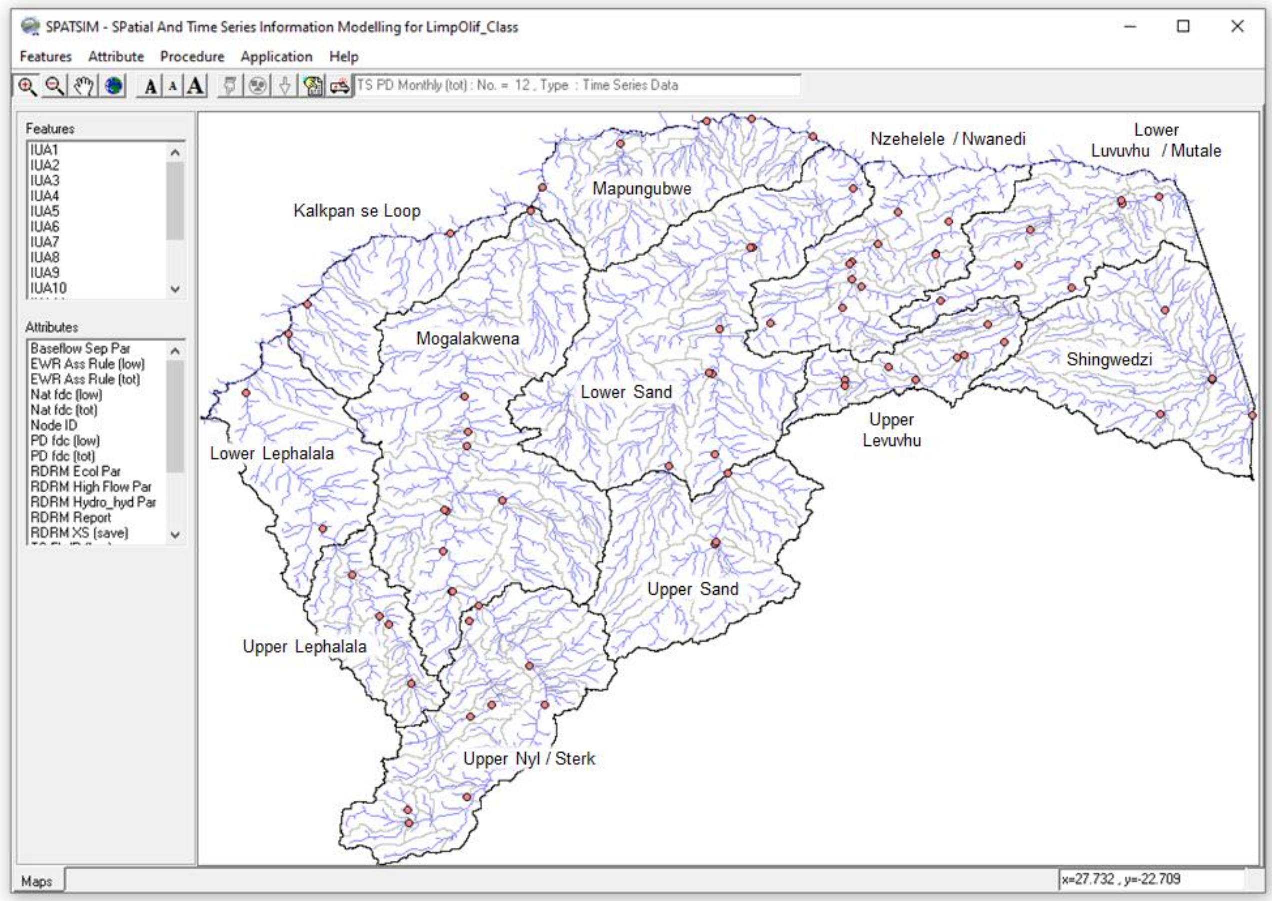

Figure 2.1: User graphical interface of the RDRM setup in SPATSIM, indicating the nodes, rivers, sub-quaternary catchments and IUAs

The RDRM, run as a Desktop application[4], has the following minimum data requirements:

- Hydrology:
  - Timeseries of monthly natural flows
  - Baseflow separation parameters (regionalised values used - see below)
  - Percentage point on the baseflow separated flow-duration curve, to determine the maximum baseflow for wet and dry seasons.
- Hydraulics:
  - Valley slope (longitudinal)
  - Geomorphological zone
  - Catchment area
  - Macro-channel width.
- Ecology:

[4] The RDRM also provides the framework / user interface for EWR assessments at higher levels of assessment (e.g., Rapid III, Intermediate and Comprehensive), with the use of additional information, such as, for example, surveyed cross-sectional river profiles and modelled rating relationships; and externally-determined stress-discharge relationships.

- Low and high percentile shifts in the stress index value relative to natural conditions, for the wet and dry seasons (default values were used which are computed in the ecological sub-model - see below).
- The stress index value, in the range 0 to 10, corresponding to the threshold discharge for the onset / loss of fast flows, i.e., velocities ≥ 0.3 m/s (default values were used - see below).
- The relative weighting of stress index-discharges for three velocity-depth classes, viz., fast-shallow, fast-intermediate, and fast-deep flow (default values were used - see below).

Default parameter values were used for the following variables in this Desktop assessment:

- Hydrology: Regionalised baseflow separation parameters (α and β values) which are available nationally at the quaternary catchment level (Hughes and Watkins 2002).
- Ecology (refer to WRC 2018a; 2018b):
  - Low flows:
    - Low and high percentile stress index values, which represent shifts from natural conditions and are computed in the ecological low flow sub-model.
    - Stress indices for the onset of fast flows and relative velocity-depth class weightings, which are available nationally at the sub-quaternary catchment level based on the presence or absence of fish species and invertebrate taxa.
  - High flows:
    - Parameter values for inter-and intra-annual flow events, which are computed in the high flow sub-model.

In addition to the monthly natural flows, timeseries of Present Day (PD) flows were also modelled and provided. The remaining parameters required for Desktop assessment were determined as follows:

- Hydrology:
  - The baseflow separated flow-duration curves were assessed (in the hydrology sub-model) to select the percentage point (5 to 20%) corresponding to an apparent 'inflection point' where baseflows rise more sharply.
- Hydraulics:
  - Valley slopes were determined from the sub-reaches on which they are located using the River Atlas dataset[5]. Where nodes / sub-reaches are located in impoundments, slopes were determined using either reaches upstream of the backup or downstream of the dams / weirs, as appropriate.
  - The classified geomorphological zones, at a national level, are derived directly from valley slopes, using the gradient classification of Rountree and Wadeson (1999).
  - Upstream catchment areas were calculated using the River Atlas dataset; where nodes fall between adjacent sub-catchments, areas were interpolated between 20m contours using GIS.
  - Macro-channel widths were measured using remote sensing imagery.

2.4 Results

2.4.1 Desktop output for the PES

The EWR results are provided (as part of e-data for this study) in the following formats as text files named according to the nodes' name:

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[5] https://www.hydrosheds.org/hydroatlas.

- RDRM generated reports (includes EWR assurance rules for a range of Ecological Categories (ECs)).
- Assurance rules for EWR low flows and total flows (in 10^6 m^3)[6].
- Time-series of monthly EWR low and total flows (in 10^6 m^3)[7].

The RDRM reports include two sets of EWR assurance (flow-duration) rules: a set constrained to natural flows and a set constrained to PD flows. The reason for including two sets is that the SPATSIM database (where the assurance rules and timeseries are saved) only allow records for a single EC – typically the PES or a Recommended EC (if it differs from the PES – usually an improvement). In this application of the RDRM, however, EWR timeseries were required for alternative categories (one higher and one lower) for input to the 'Balancing Tool' (refer to **Section 3**). Consequently, the two sets of assurance rules saved to the RDRM reports were used to generate EWR timeseries for different ECs (including the PES), since the reports provide assurance rules for a range of ECs.

A summary of RDRM EWR long-term requirements low and total volume requirements (which are computed from monthly EWR timeseries), naturalised and PD MAR, and other supporting information (described previously), is provided in **Table** 2.2. The 'constrained to PD' values in **Table** 2.2 may differ slightly from those saved in the RDRM reports,[8] since computational procedures / data arrays vary between the RDRM and post-processing using flow-duration and assurance rule tables (e.g. available percentage points on the naturalised flow-duration and EWR assurance rule tables).

With the exception of an A[9] EC, there is a general overall reduction in median proportion of naturalised mean annual runoff (MAR) with reducing EC ('B'=32.2%, 'C'=30.2%; 'D'=27.8%), but there is no clear / simple relationship between individual nodes. This is because EWRs are also a function of the links / relationships between *inter alia* hydrological, hydraulic, and ecological characteristics as well as PD flows (when constrained), which vary between nodes. The RDRM was developed to explicitly account for these links / relationships at the Desktop level of assessment.

2.4.2 Generating EWR timeseries for a range of Ecological Categories

The 'Balancing Tool' (refer to **Section 3**) required EWR timeseries for alternative categories to the PES. The alternative categories (lower and higher) for which timeseries were computed are provided in **Table** 2.1, together with their constraint to PD flows. The EWR timeseries for lower and higher ECs - relative to PES, were computed using the naturalised flow-duration tables and EWR assurance rules (i.e. as for the EWR timeseries corresponding to the PES described in **Section 2.4.1**). For nodes where there is no

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[6] These were not constrained to PD flows, to allow them to be used for alternative ECs (refer to Section 2.4.2).

[7] A consequence of the reason given in footnote 6 (all results for a node that are saved to the SPATSIM database are either constrained, or not).

[8] differs by less than 0.4% for the EWR expressed as a percentage of naturalised MAR

[9] The likely reasons that the median proportion of MAR is only 28.4% for the 'A' EC nodes is that firstly there are only 4 nodes in this category, but more importantly, that they are all temporary rivers with minimal low flow EWR requirements. High flows have been set at the max. permitted in the RDRM, and the Desktop analysis only includes annual high flow volumes up to the 1:5 year return period (less than 20% frequency of exceedance)

improvement of the EC (i.e. the PES is maintained , or the desktop analysis is undertaken for a lower EC), the desktop EWRs are necessarily constrained to PD flows. For Desktop analyses for ECs higher than the PES, the EWR is generally not constrained to PD flows since an improvement through *inter alia* additional flows is envisaged. An exception, however, is for an 'A' EC, since there is no improvement from the PES.

Table 2.1: Alternative ECs to the PES

Lower EC		PES		Higher EC	
EC	**Constrain to PD**	**EC**	**Constrain to PD**	**EC**	**Constrain to PD**
B	✓	A	✓	A	✓
C	✓	B	✓	A/B	×
D	✓	C	✓	B	×
D	✓	D	✓	C	×

2.4.3 Desktop EWR high flows with return periods exceeding 1:5

The process of incorporating annual flood events and monthly allocations in the RDRM is based on the natural flow timeseries of separated high flows (i.e. baseflows excluded) and is quite complex (WRC 2018a). Firstly, the methodology compares the total volume of the 1:5 return period with the natural high flow annual volume at the 20% frequency of exceedance. The 1:5 annual Desktop high flow volume is capped[10] at 0.7 times the natural high flow volume (at the 20%), and this maximum (and lower ratios) apply for all years 'wetter' than this exceedance level. Thus, Desktop-derived high flows for years experiencing events exceeding the 1:5 return period are allocated annual volumes that are capped at 0.7 times (or less) natural high flows (at the 20%). While this is practical given that higher return period events / floods are less likely to be affected by depleted reservoir storage, the 'Balancing Tool' (**Section 3**) required Desktop EWRs with a more-complete suite of higher flows / floods.

A set of Desktop EWRs was therefore synthesized that incorporates annual high flow volumes that exceed the 1:5 return period. These were computed for annual high flow volumes where frequencies of exceedance are less than 15% (> ~1:7 year return period). For consistency with the RDRM methodology, the proportion of natural annual high flow volumes (viz. max. of 0.7 times or less as determined at the 20% exceedance) was increased linearly (from the year with 15% exceedance) to 1.0 for the year with the max. natural annual high flow volume (i.e. natural high flows are assumed at the ~1:100 year return period). Annual volumes were distributed proportionally using natural monthly volumes.

In **Table** 2.2, the summary information and desktop EWRs for all the nodes, the data for the larger rivers are arranged into river basins (that comprise two IUAs in some cases) because there are many nodes on the main river and its tributaries that are hydrologically connected with one another. For the smaller rivers, where there may be only one or two nodes on rivers that are not hydrologically connected with one another, these are grouped into the IUAs because there is no large river basin that connects them with one another.

[10] in the model

Table 2.2: Summary information and Desktop EWRs for nodes in Secondary Catchments A5 - A9 within the Limpopo Water Management Area (WMA 1) and Secondary Catchment B9 in the Olifants Water Management Area (WMA 2)

Node	Sub-quaternary	River	Catchment area (km2)	MAR			PES	EWR long-term requirements					
								Constrain to Nat		Constrain to PD			
				10^6 m^3		PD (% Nat)		MAR (10^6 m^3)		MAR (10^6 m^3)		MAR (% Nat)	
				Nat	PD			Low	Total	Low	Total	Low	Total
Lephalala River catchment (Upper and Lower Lephalala IUAs)													
Riv8	A50A-00354	Lephalala	295	32.56	22.93	70.4	B	6.89	12.53	5.51	11.15	16.9	34.2
Riv11	A50B-00262	Lephalala	615	67.63	56.16	83.0	C	12.92	25.28	12.54	24.90	18.5	36.8
Riv10	A50C-00273	Melk	352	14.86	12.43	83.6	C	1.42	5.06	1.42	5.06	9.6	34.1
Riv13	A50D-00237	Boklandspruit	376	13.27	12.83	96.7	B	2.27	4.81	2.27	4.81	17.1	36.2
Riii3	A50H-00110	Lephalala	2298	122.93	96.37	78.4	D	11.70	31.00	10.84	30.15	8.8	24.5
Ri8	A50H-00110	Lephalala	4760	139.46	95.70	68.6	C	18.45	42.81	14.22	38.58	10.2	27.7
Kalkpan se Loop IUA													
Ri38	A50J-00073	Kalkpan Se	380	2.08	1.38	66.3	B	0.19	0.82	0.17	0.80	8.1	38.4
Rvi15	A50J-00061	No Name	413	1.64	1.09	66.5	B	0.16	0.67	0.14	0.65	8.4	39.5
Rvi1	A63C-00033	Rietfontein	86	0.19	0.14	73.7	B/C	0.01	0.06	0.01	0.06	4.0	33.2
Mogalakwena River catchment (Upper Nyl and Sterk, Mogalakwena IUAs)													
Ri1-1	A61B-00552	Nyl	384	23.80	21.41	90.0	C	7.17	9.80	7.01	9.64	29.5	40.5
Ri1	A61B-00489	Olifantspruit	146	8.11	7.61	93.8	C	1.61	2.83	1.61	2.83	19.9	34.9
Riv3	A61C-00501	Nyl	45	23.44	21.55	91.9	C	5.18	7.30	5.05	7.18	21.6	30.6
Riii1	A61E-00386	Nyl	2326	32.69	24.17	73.9	D	1.97	9.61	1.70	9.35	5.2	28.6
Ri3	A61G-00297	Mogalakwena	3112	52.78	36.99	70.1	D	5.51	17.45	4.15	16.08	7.9	30.5
Ri5	A61G-00248	Mogalakwena	4056	133.27	77.49	58.1	C	32.94	59.50	18.25	44.80	13.7	33.6
Rv1	A61H-00395	Sterk	587	39.60	12.13	30.6	D	9.63	14.85	3.43	8.64	8.7	21.8
Rvii4	A61H-00395	Sterk	510	35.56	22.09	62.1	D	8.00	13.57	6.28	11.85	17.7	33.3
Ri4	A61J-00267	Sterk	1336	58.17	22.87	39.3	C	18.16	28.52	7.95	18.31	13.7	31.5
Ri6	A62A-00253	Mokamole	40	15.01	12.55	83.6	D	1.39	3.42	1.27	3.30	8.5	22.0
Riv12	A62B-00223	Mogalakwena	5612	136.05	79.92	58.7	C	30.47	50.51	19.00	39.03	14.0	28.7

Node	Sub-quaternary	River	Catchment area (km2)	MAR			PES	EWR long-term requirements					
				10^6 m^3		PD (% Nat)		Constrain to Nat		Constrain to PD			
								MAR (10^6 m^3)		MAR (10^6 m^3)		MAR (% Nat)	
				Nat	PD			Low	Total	Low	Total	Low	Total
Rv2	A62B-00188	Mogalakwena	6581	161.14	100.98	62.7	C	25.87	50.41	18.28	42.82	11.3	26.6
Ri10	A62C-00188	Mogalakwena	3017	165.59	103.86	62.7	C	35.22	57.76	22.59	45.13	13.6	27.3
Rvii12	A62D-00179	Klein	627	5.04	3.94	78.2	C	0.90	1.80	0.68	1.57	13.4	31.1
Ri12	A62G-00167	Matlalane	604	9.65	8.19	84.9	C	1.13	2.65	1.06	2.58	11.0	26.7
Ri13	A62H-00148	Seepabana	861	4.71	4.14	87.9	D	0.28	1.31	0.27	1.31	5.8	27.8
Ri14	A63A-00071	Mogalakwena	11293	193.27	114.30	59.1	C	39.23	77.76	19.83	58.36	10.3	30.2
Rvii13	A62J-00143	Mogalakwena	10840	190.98	125.31	65.6	C	42.41	72.06	27.30	56.95	14.3	29.8
Rii3	A63D-00034	Mogalakwena	16011	205.52	120.45	58.6	C	36.94	73.93	20.89	57.89	10.2	28.2
Mapungubwe IUA													
Riv32	A63E-00008	Kolope	1189	2.06	1.05	51.0	C	0.13	0.63	0.12	0.62	6.0	30.3
Rvi2	A63E-00011	Stinkwater	143	0.24	0.12	50.0	B	0.01	0.09	0.01	0.09	3.6	37.7
Rvi4	A71L-00005	Kongoloop	906	3.14	1.92	61.1	C	0.28	0.56	0.05	0.34	1.7	10.9
Rvi7	A71L-00003	No Name	62	0.20	0.12	60.5	B	0.02	0.06	0.00	0.04	2.0	21.7
Rvi9	A71L-00015	Soutsloot	241	1.10	0.67	60.9	A	0.16	0.33	0.03	0.20	2.7	17.8
Sand River catchment (Upper and Lower Sand IUAs)													
Ri16	A71A-00211	Sand	1154	11.05	13.11	118.6	D	0.48	2.36	0.48	2.36	4.4	21.4
Ri17	A71B-00214	Diep	863	7.83	6.10	77.9	D	0.30	1.62	0.20	1.52	2.6	19.4
Ri20	A71D-00118	Sand	3522	27.45	23.48	85.5	C	1.67	6.98	1.67	6.98	6.1	25.4
Riv16	A71C-00156	Dwars	478	2.44	1.51	61.9	C	0.08	0.54	0.07	0.53	3.1	21.9
Ri22	A71D-00118	Sand	4214	31.59	24.12	76.4	C	1.39	7.65	1.34	7.60	4.3	24.1
Rvi3	A71G-00131	Hout	1306	6.92	3.06	44.2	C	0.31	1.99	0.15	1.83	2.1	26.4
Ri21	A71G-00107	Hout	2469	11.69	5.88	50.3	C	0.66	3.42	0.30	3.06	2.5	26.2
Ri23	A71H-00088	Sand	7690	52.35	36.90	70.5	C	2.63	13.99	2.34	13.70	4.5	26.2
Ri24	A71J-00055	Sand	8746	62.54	45.82	73.3	C	3.31	21.64	2.74	21.07	4.4	33.7

Node	Sub-quaternary	River	Catchment area (km2)	MAR			PES	EWR long-term requirements					
				10^6 m^3		PD (% Nat)		Constrain to Nat		Constrain to PD			
								MAR (10^6 m^3)		MAR (10^6 m^3)		MAR (% Nat)	
				Nat	PD			Low	Total	Low	Total	Low	Total
Ri25	A71K-00019	Sand	13591	85.32	64.15	75.2	C	5.80	29.80	4.87	28.87	5.7	33.8
Riv17	A72B-00038	Brak	3542	13.55	12.16	89.7	C	0.58	3.56	0.56	3.54	4.2	26.1
Nzhelele and Nwanedi River catchments (Nzhelele and Nwandi IUAs)													
Riii7	A80B-00069	Nzhelele	508	14.81	13.69	92.4	D	2.03	4.22	2.02	4.21	13.6	28.4
Rvii34	A80C-00068	Mafungudi	202	6.68	6.00	89.8	D	1.25	1.98	1.23	1.96	18.4	29.4
Riii4	A80D-00075	Mutamba	141	7.14	6.96	97.5	C	1.67	2.45	1.67	2.45	23.4	34.3
Ri26	A80G-00053	Nzhelele	1852	94.92	61.07	64.3	C	24.79	36.85	22.54	34.60	23.7	36.5
Riv23	A80F-00063	Mutamba	982	18.61	20.99	112.8	C	2.77	6.32	2.77	6.32	14.9	34.0
Riii8	A80F-00068	Nzhelele	828	76.26	56.61	74.2	D	12.85	22.33	12.80	22.28	16.8	29.2
Ri27	A80G-00026	Nzhelele	2522	99.73	59.60	59.8	C	18.26	32.44	15.97	30.15	16.0	30.2
Riv33	A80G-00054	Tshishiru	66	1.27	0.72	57.0	C	0.03	0.27	0.02	0.27	1.5	21.0
Riii9	A80H-00064	Ṅwaned̰i	110	21.85	17.91	82.0	B	6.88	9.29	6.31	8.73	28.9	39.9
Riii10	A80H-00060	Luphephe	154	10.17	8.07	79.4	C	2.53	3.61	2.36	3.43	23.2	33.7
Ri28	A80J-00028	Ṅwaned̰i	552	33.47	26.63	79.6	C	6.68	10.07	6.24	9.63	18.6	28.8
Luvuvhu and Mutale River catchments (Upper Luvuvhu, Lower Luvuvhu/Mutale IUAs)													
Rvi14	A91A-00105	Luvuvhu	233	22.60	8.18	36.2	C	8.18	9.74	2.21	3.77	9.8	16.7
Rvii19	A91B-00120	Doringspruit	249	11.58	6.09	52.6	C	3.33	4.30	1.68	2.65	14.5	22.9
Riii5	A91C-00115	Luvuvhu	762	75.34	21.34	28.3	C	18.84	25.28	6.84	13.28	9.1	17.6
Riii6	A91D-00108	Latonyanda	40	23.55	18.25	77.5	C	5.85	7.82	5.83	7.80	24.8	33.1
Riv18	A91E-00103	Dzindi	162	69.63	66.32	95.2	D	17.67	22.73	17.67	22.73	25.4	32.6
Riv19	A91F-00111	Luvuvhu	1095	172.98	97.62	56.4	C	48.85	64.97	34.49	50.61	19.9	29.3
Rvii24	A91F-00093	Luvuvhu	1534	247.68	138.06	55.7	D	57.77	82.47	33.75	58.45	13.6	23.6
Ri30	A91G-00091	Mutshindudi	198	55.81	46.03	82.5	C	15.13	21.28	14.86	21.02	26.6	37.7
Ri32	A91H-00045	Luvuvhu	2280	398.52	247.76	62.2	C	102.40	143.63	68.51	109.74	17.2	27.5

Node	Sub-quaternary	River	Catchment area (km2)	MAR			PES	EWR long-term requirements					
				10^6 m^3		PD (% Nat)		Constrain to Nat		Constrain to PD			
								MAR (10^6 m^3)		MAR (10^6 m^3)		MAR (% Nat)	
				Nat	PD			Low	Total	Low	Total	Low	Total
Ri35	A91J-00040	Luvuvhu	3124	416.74	265.95	63.8	B	114.07	183.72	75.04	144.68	18.0	34.7
Ri36	A91K-00035	Luvuvhu	3415	573.18	411.08	71.7	C	175.93	259.65	136.41	220.13	23.8	38.4
Rvii33	A92B-00051	Mutale	169	73.89	66.29	89.7	C	15.11	22.81	15.05	22.75	20.4	30.8
Ri33	A92B-00051	Middle Mutale	678	124.65	114.10	91.5	C	26.72	42.51	26.49	42.29	21.3	33.9
Riv24	A92C-00049	Mbodi	169	4.48	4.33	96.7	D	0.20	0.78	0.20	0.78	4.5	17.3
Ri34	A92D-00030	Lower Mutale	2931	154.95	143.64	92.7	C	27.19	53.95	27.16	53.92	17.5	34.8
Shingwedzi River catchment (and IUA)													
Rvi10	B90D-00067	Shisha	695	7.10	7.10	100.0	A	0.58	2.28	0.58	2.28	8.1	32.2
Rvi13	B90F-00114	Shingwedzi	826	18.67	18.14	97.2	C	1.37	7.37	1.37	7.37	7.4	39.5
Riv27	B90G-00124	Shingwedzi	1508	33.80	33.13	98.0	A	2.62	11.77	2.62	11.77	7.7	34.8
Ri37	B90H-00145	Shingwedzi	5545	89.63	85.82	95.7	C	1.87	23.85	1.87	23.85	2.1	26.6
Riv28	B90H-00113	Mphongolo	2990	39.31	36.43	92.7	A	1.62	9.68	1.62	9.68	4.1	24.6

MAR = Mean Annual Runoff (in million cubic metres, i.e., 10^6 m^3); Nat = Natural; PD = Present Day; PES = Present Ecological State; EWR long-term requirements derived from monthly timeseries

3 THE BALANCING TOOL

3.1 Introduction

In order to set up the ESBC and other scenarios, the 'Balancing Tool'[11] (hereafter called the Tool) was used. The purpose of the Tool is to determine the impact of changes in flow on the ecological condition of the river at various points.

In the Tool, the average monthly flows for Natural and Current (present day) are routed from one node to the next in a downstream direction. The nodes are located at 75 points of hydrological, ecological or economic relevance through the system, as described in the **Delineation and Status Quo Report**. Fourteen of the nodes correspond with sites studied in more detail in **EWR Report – Rivers (Vol 3)** and are referred to as EWR sites. The Tool is set up so that if a particular flow condition is chosen for a node, the associated monthly flows are routed to the next node (and so on down the system). Each node has an associated Current ecological condition (Present Ecological Status, PES). The Ecological Category (EC) resulting from a change in flow at any node is reported for that and downstream nodes.

The Tool also reports "surpluses" and "deficits" at each node, specified annually and monthly, relative to current flows. If the chosen flows upstream or at a node do not provide the required flows at a node, the deficit or surplus can be reported and / or the flows can be changed until the requirement is met.

In the subsequent scenario analysis, the surface and groundwater yield models will be used to calculate the deficit/surplus of modelled flows relative to the required ecological flows. Additional water supply interventions to meet any deficits will be identified and the water supply costs of these alternative options estimated. In the case of a surplus, once verified in the yield model, the potential benefits of the additional water available for abstractive uses can be assessed. This is done as part of the scenario evaluation process and in some cases involves additional analysis of potential impacts on yield.

3.2 Balancing Tool inputs and outputs

There are various inputs into the Tool, some of which are related to the background programming and are not discussed here. The following description deals with the main inputs in the Tool and those used to construct the ecological scenarios:

- The location of each node geographically in the study area relative to the other nodes, up- and downstream respectively. These are listed in a downstream direction in the Tool, and equations link upstream nodes and their flows to those downstream (Table 3.1).
- The current ecological condition of each node (the PES).
- The Naturalized monthly flow time series (volumes in million cubic meters (Mm^3).
- Current monthly flow time series (volumes in Mm^3).
- Monthly Reserves (EWRs) flow time series (volumes in Mm^3) for certain ecological categories, as extracted from the Revised Desktop Model (2).

[11] Also called the 'Basin Configuration Tool' due to its function of assisting with the compilation of *configurations* of node ECs.

At each node, the Tool calculates and reports the cumulative average monthly flows and the resulting EC. The Present Day (or Current) and Naturalised flows are the references against which other flows can be compared.

There are a wide range of outputs from the Tool including a range of tables showing different facets of the chosen scenario and a map showing the reaches coloured according to the resulting EC.

Table 3.1: Layout of the nodes in the tool, from upstream to downstream, showing their PESs, RECs and PFSs (Present Flow States). EWR sites are highlighted in yellow, LIMCOM sites are italicised.

EWR and LIMCOM sites	Nodes	Upstream nodes				River	Quat	RU / IUA	PFS	PES	REC
	Riv8					Lephalala	A50A	Upper Lephalala	D/E	B	
1_Leph	Riv11	Riv8				Lephalala	A50B	Upper Lephalala	C	C	B/C
	Riv10					Melk	A50C	Upper Lephalala	B	C	
	Riv13					Boklandspruit	A50D	Upper Lephalala	A	B	
	Riii3	Riv13	Riv10	Riv11		Lephalala	A50E	Upper Lephalala	C/D	D	
LEPH-A50H-SEEKO	Ri8	Riii3				Lephalala	A50H	Lower Lephalala	D/E	C	C
	Ri38					A63C Trib 1	A50J	Kalkpan Se Loop	B/C	B	
	Rvi15					A63C Trib 2	A50J	Kalkpan Se Loop	B/C	B	
2_Riet	Rvi1					Rietfontein	A63C	Kalkpan Se Loop	A	B/C	B/C
	Rvii4					Sterk	A61B	Upper Nyl & Sterk	D	E	
	Rv1	Rvii4				Sterk	A61B	Upper Nyl & Sterk	E/F	E	
	Ri4	Rv1				Sterk	A61C	Upper Nyl & Sterk	E	C	
3_Olif	Ri1					Olifantspruit	A61E	Upper Nyl & Sterk	B	C	B/C
	Ri1-1					Nyl	A61F	Upper Nyl & Sterk	B	C	
	Riv3	Ri1-1	Ri1			Nyl	A61H	Upper Nyl & Sterk	A/B	C	
	Riii1	Riv3				Nyl	A61H	Upper Nyl & Sterk	A/B	D	
	Ri3	Riii1				Mogalakwena	A61J	Upper Nyl & Sterk	D/E	D	
4_Moga	Ri5	Ri3	Ri4			Mogalakwena	A61G	Upper Nyl & Sterk	D/E	C	C
	Riv12	Ri5				Mogalakwena	A62A	Mogalakwena	D/E	C	
	Ri6					Mokamole	A62B	Mogalakwena	A/B	D	
	Rv2	Ri6	Riv12			Mogalakwena	A62B	Mogalakwena	D/E	C	
	Rvii12					Klein Mogolakwena	A62D	Mogalakwena	C/D	C	
	Ri10	Rv2				Mogalakwena	A62C	Mogalakwena	D/E	C	
	Ri12					Matlalane	A62F	Mogalakwena	B/C	C	
	Ri13					Seepabana	A62H	Mogalakwena	B/C	D	
	Rvii13	Ri13	Ri12	Ri10	Rvii12	Mogalakwena	A62J	Mogalakwena	D/E	C	
5_Moga	Ri14	Rvii13				Mogalakwena	A63A	Mogalakwena	E	C	C
MOGA-A63D-LIMPK	Rii3	Ri14				Mogalakwena	A63D	Mogalakwena	E	C	C
	Rvi2					Stinkwater	A63E	Mapungubwe	B	B	
6_Kolo	Riv32					Kolope	A63E	Mapungubwe	B/C	C	B/C
	Rvi4					Kongoloop	A71L	Mapungubwe	A	C	
	Rvi7					A71L Trib 4	A71L	Mapungubwe	A	B	
	Rvi9					Soutsloot	A71L	Mapungubwe	A	A	
	Rvi3					Hout	A71A	Upper Sand	C	C	
	Ri21	Rvi3				Hout	A71B	Upper Sand	B/C	C	
	Ri16					Sand	A71C	Upper Sand	B/C	D	
	Ri17					Diep	A71C	Upper Sand	B	D	
	Riv16					Dwars	A71F	Upper Sand	B/C	C	
7_Sand	Ri20	Riv16	Ri17	Ri16		Sand	A71D	Lower Sand	A	C	C
	Ri22	Ri20				Sand	A71G	Lower Sand	B	C	
	Ri23	Ri22	Ri21			Sand	A71H	Lower Sand	B	C	
	Ri24	Ri23				Sand	A71J	Lower Sand	B	C	
	Riv17					Brak	A72B	Lower Sand	A	C	
SAND-A71K-R508B	Ri25	Riv17	Ri24			Sand	A71K	Lower Sand	B	C	C

EWR and LIMCOM sites	Nodes	Upstream nodes			River	Quat	RU / IUA	PFS	PES	REC
	Riii4				Mutamba	A80D	Nzhelele/Nwanedi	A	C	
	Riv23	Riii4			Mutamba	A80F	Nzhelele/Nwanedi	A/B	C	
	Riii7				Nzhelele	A80B	Nzhelele/Nwanedi	A/B	D	
	Rvii34				Mufungudi	A80C	Nzhelele/Nwanedi	A/B	D	
	Riii8	Rvii34	Riii7		Nzhelele	A80C	Nzhelele/Nwanedi	B/C	D	
	Ri26	Riii8	Riv23		Nzhelele	A80F	Nzhelele/Nwanedi	C/D	C	
	Riv33				Tshishiru	A80G	Nzhelele/Nwanedi	A/B	C	
8_Nzhe	Ri27	Riv33	Ri26		Nzhelele	A80G	Nzhelele/Nwanedi	D	C	C
	Riii9				Nwanedi	A80H	Nzhelele/Nwanedi	C	B	
	Riii10				Luphephe	A80H	Nzhelele/Nwanedi	B	C	
9_Nwan	Ri28	Riii10	Riii9		Nwanedi	A80J	Nzhelele/Nwanedi	C	C	C
	Rvi14				Luvuvhu	A91A	Upper Luvuvhu	E/F	C	
	Rvii19				Doringspruit	A91B	Upper Luvuvhu	E	C	
	Riii5	Rvii19	Rvi14		Luvuvhu	A91C	Upper Luvuvhu	E/F	C	
10_Lato	Riii6				Latonyanda	A91D	Upper Luvuvhu	B	C	C
	Riv18				Dzindi	A91E	Upper Luvuvhu	A/B	D	
	Riv19	Riii6	Riii5		Luvuvhu	A91F	Upper Luvuvhu	E	C	
	Rvii24	Riv19	Riv18		Luvuvhu	A91F	Upper Luvuvhu	E	D	
11_Muts	Ri30				Mutshindudi	A91G	Upper Luvuvhu	B/C	C	C
12_Luvu	Ri32	Ri30	Rvii24		Luvuvhu	A91H	Lower Luv/Mutale	E	C	B/C
	Rvii33				Mutale	A92A	Lower Luv/Mutale	B/C	C	
13_Muta	Ri33	Rvii33			Mutale	A92B	Lower Luv/Mutale	A/B	C	C
	Riv24				Mbodi	A92C	Lower Luv/Mutale	A	D	
14_Muta	Ri34	Riv24	Ri33		Mutale	A92D	Lower Luv/Mutale	A/B	C	C
	Ri35	Ri32			Luvuvhu	A91J	Lower Luv/Mutale	E	B	
LUVU-A91K-OUTO	Ri36	Ri35	Ri34		Luvuvhu	A91K	Lower Luv/Mutale	D/E	C	C
	Rvi10				Shisha	B90A	Shingwedzi	A	A	
	Riv28	Rvi10			Mphongolo	B90H	Shingwedzi	A	A	
	Rvi13				Shingwidzi	B90F	Shingwedzi	A	C	
	Riv27	Rvi13			Shingwidzi	B90G	Shingwedzi	A	A	
SHIN-B90H-POACH	Ri37	Riv27	Riv28		Shingwidzi	B90H	Shingwedzi	A	C	B/C

3.3 Linking flow requirements to ecological condition

The links between flow and ecological condition were programmed into the tool based on a number of standard assumptions common to environmental flow studies in general, including:

- The ecological condition or health of a system is designated an Ecological Category (EC) from A to F (Kleynhans 1996,

- **Table** 1.2).
- Flows were also designated as Flow States (FSs) from A to F. The FSs are based on seasonal percentages of Natural flow. For the Limpopo the seasons were Wet (January to April) and Dry (July to November). There were four different sets of rules which applied to different rivers based on the hydrological index and perenniality of the reach.

3.4 Types of scenarios in the Tool

There are various types of scenarios which can be included in the tool:

1. Ad hoc changes to Flow State (FSs): The impacts of changing flows at particular nodes, the importance of different tributaries, the feasibility of obtaining particular Ecological Condition (EC), etc. can be explored by specifying a target FSs at various nodes, simply by typing the relevant FS letter (A to F) next to the node. Note that, the final FS at a node may differ from the target FS because of changes from upstream.
2. Flow State scenarios: After the exploration in (1), scenarios can be defined which have changed FSs for particular nodes in order to obtain a particular Ecological Condition (EC) at that or downstream nodes. Once defined, these scenarios can be viewed by selecting them from a dropdown menu. The changed FS changes the associated monthly flows at the node, and they are routed downstream. The resulting ECs are shown, as well as other information (e.g. percentage of Natural, deficit or surplus, etc.). For example, a high conservation scenario can be defined by increasing the FSs of specific nodes, or a “hard-working” scenario can be defined by lowering the FSs at specific nodes.
3. Modelled flow scenarios: Average monthly flows from a scenario modelled externally can be entered into the Tool. If this scenario is selected from the dropdown menu, the modelled flows will be inserted into the relevant calculations in the Tool and resulting ECs determined, etc.

As FSs change, the results calculated per node include:

- The final Flow States and Ecological Conditions;
- Annual average monthly flow volumes and as a percentage of natural;
- Surplus/deficit annual flow volumes relative to current flows.

In the tables of results from the tool, colouring is used to guide description and highlight changes. The ECs are coloured according to the colours specified by DWS (

Table 1.2). Other shading (**Table** 3.2) is used for the percentages of flow relative to natural, shown as numbers in columns 8 and 11 (%Nat) in **Tables 4.1 - 4.8,** and **Table 5.1**. These colours are blue where there is a surplus of flow and orange where there is a deficit of flow.

Table 3.2: Colour scheme in results tables for flow relative to natural and for deficits and surpluses

Colours indicating flow as a percentage of natural.						
>300% of natural			Natural			Less than 50% of Natural

Colours indicating the size of deficit flows or if there is a surplus.					
Surplus	Current day		Deficit of more than 5 but less than 15 Mm^3		Deficit of more than 50 Mm^3

4 RESULTS OF THE ESBC SCENARIO

The outcomes of the ESBC flow scenario in this report are a first DRAFT because there are likely to be adjustments made in the tool when the other scenarios are loaded and calibrated, that could change the volumes and Ecological Conditions of the ESBC scenario. DRAFT results of all the scenarios will be presented to stakeholders in the next report. The results of all the scenarios will finalised once the DRAFT results of all the scenarios have been presented to stakeholders.

- The Ecologically Sustainable Baseline Configuration Report (DRAFT results, this report).
- The Scenarios Evaluation and Draft Water Resource Classes Report (DRAFT results, next report).
- The Final Scenarios Report (FINAL results after discussions and adjustments with stakeholders).

The ESBC flow scenario results are reported for each node in the study area as:

- The resulting EC
- Annual flows (including larger floods) as percentages of Natural, and
- Surpluses or deficits relative to current flows.

The results are grouped into the main river basins as the nodes are hydrologically connected and these connections bridge cross IUAs.

Ultimately the overall ecological impact associated with the ESBC and the other scenarios will be reported at the IUA level when taking into account the effect of changes in flow and ecological condition on ecosystems (water quality, river health, wetland health) and ecosystem goods and services, and on water yields and water supply costs. The results of the scenario analysis will be expressed in terms of the direct gains and losses of ecosystem services and water supply costs for each scenario. These will be reported in the report that follows this one: Scenario Evaluation and Draft Water Resource Classes Report.

The description of the ESBC configuration in this report focusses on changes in hydrology and the resulting changes in river ecological condition, relative to the current condition (or PES) for each scenario. The results for the large rivers are arranged into river basins (that comprise two IUAs in some cases) because there are many nodes on the main river and its tributaries that are hydrologically connected with one another. For the smaller rivers, where there may by only one or two nodes on rivers that are not hydrologically connected with one another, these are grouped into the IUAs because there is no large river basin that connects them with one another.

Notes:

1. In some cases the PES of a site may be a C, for example, but with decreased overall flows, the condition improves to say a B. This happens when the seasonal distribution of the flows for the scenario improves, even though the overall quantity decreases.
2. Because the FS and EC categories are in percentage point ranges, a very small change in percentage can cause a drop or increase in condition. It is therefore always useful to look at the numbers as well as the resulting EC categories.

4.1 Lephalala River basin (Upper and Lower Lephalala IUAs)

The modelled ESBC flow scenario (**Table** 4.1):

- Meets or exceeds the ESBC flow requirements of a D all nodes.

- Results in a relatively small deficit in flow volume in the dry season relative to Current at Ri8 (i.e. current flows are lower than the ESBC at this node).
- Creates surpluses in wet and dry season volumes at all nodes apart from the dry season at Ri8.

The EWR site 1_Lephapalal (Riv11) and the Melk River tributary (Riv10) are situated upstream of, and contribute significantly to the flow through, the Lephalala Nature Reserve.

Figure 4.1 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.1 Summary results for the ESBC scenario for the Lephalala River basin, showing the PES, annual percentages of natural, EC and annual deficits/surpluses (Mm³). EWR sites are shaded yellow, LIMCOM sites are in italics.

IUA	EWR sites / *LIMCOM sites*	Node	River	Nat MAR	CURRENT PES	CURRENT MAR	CURRENT %Nat	ESBC EC	ESBC MAR	ESBC %Nat	ESBC Deficit / surplus Wet	ESBC Deficit / surplus Dry
ULeph		Riv8	Lephalala	32.56	B	22.93	70.4	B/C	6.02	18.5	12.26	0.82
ULeph	1_Lephalala	Riv11	Lephalala	67.63	C	56.16	83.0	D	27.32	40.4	20.86	1.07
ULeph		Riv10	Melk	14.86	C	12.42	83.6	D	7.24	48.7	3.09	0.78
ULeph		Riv13	Boklandspruit	13.27	B	12.83	96.7	D	6.61	49.8	3.61	1.26
ULeph		Riii3	Lephalala	122.93	D	96.37	78.4	D	52.06	42.3	33.71	1.21
ULeph	*LEPH-A50H-SEEKO*	Ri8	Lephalala	139.46	C	95.70	68.6	B/C	60.38	43.3	31.57	-1.44

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

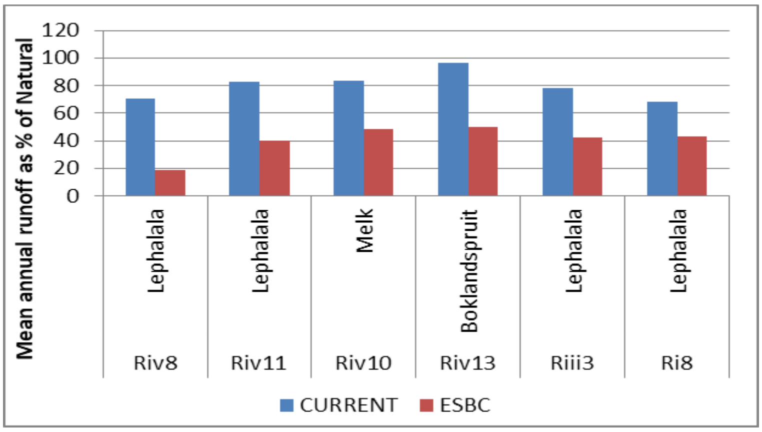

Figure 4.1 Current MAR compared to ESBC MAR as percentages of natural MAR

4.2 Kalkpan se Loop IUA

The modelled ESBC flow scenario (**Table** 4.2):

- Meets or exceeds the ESBC flow requirements for a D at all nodes.
- Results in no deficits in flow volume at any of the nodes.
- Creates small surpluses in wet and dry season flow volume at all nodes.
- ESBC flows were less than current flows at all nodes.

Note that although the percentage of Natural is low, this includes numbers for the dry season months where the Natural flows are extremely low or zero. This means that under Current and ESBC conditions, although the flow changes are very small, the percentage may appear large. Given the accuracy and rounding in the various modelling processes (hydrological, Revised Desktop Reserve Model, and Basin Tool), which are particularly relevant for non-perennial rivers, for these rivers the actual volumes are often more useful than the percentages. For example, if Natural flows in July are 0.006 Mm^3, and in the ESBC they are 0.003 Mm^3, these would be reflected as 50% of Natural.

Figure 4.2 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.2 Summary results for the ESBC scenario for Kalkpan se Loop IUA, showing the PES, annual percentages of natural, EC and annual deficits/surpluses (Mm^3). EWR sites are shaded yellow, LIMCOM sites are in italics.

				Nat	CURRENT			ESBC				
	EWR sites										Deficit / surplus	
IUA	*LIMCOM sites*	Node	River	MAR	PES	MAR	%Nat	EC	MAR	%Nat	Wet	Dry
KsLoop		Ri38	A63C Trib 1	2.08	B	1.38	66.4	C/D	0.41	19.6	0.80	0.06
KsLoop		Rvi15	A63C Trib 2	1.64	B	1.09	66.5	C/D	0.32	19.7	0.63	0.05
KsLoop	2_Rietfontein	Rvi1	Rietfontein farm river	0.19	B/C	0.14	76.2	B/C	0.04	18.5	0.10	0.002

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

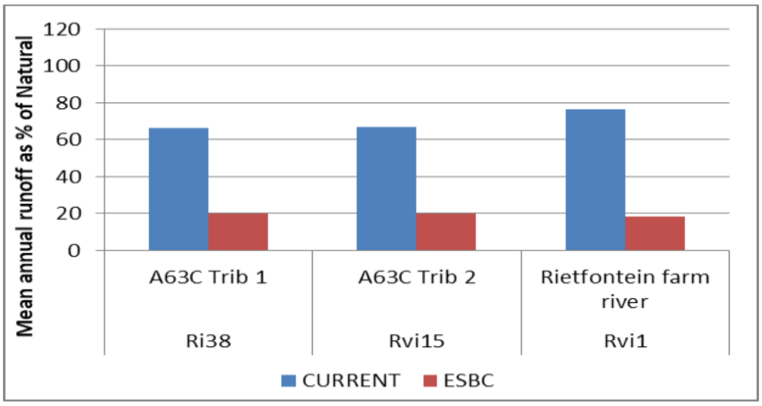

Figure 4.2 Current MAR compared to ESBC MAR as percentages of natural MAR

4.3 Mogalakwena River basin (Upper Nyl and Sterk, Mogalakwena IUAs)

The modelled ESBC flow scenario (**Table** 4.3):

- Meets or exceeds the annual flow requirements for a D at all nodes apart from Rvii4.
- Improves the two E category nodes on the Sterk River up to a D/E (Rvii4) and a D (Rv1). The D/E at Rvii4 was considered acceptable as the flows are better distributed seasonally compared to Current, and narrowly miss the percentage of Natural threshold for a D.
- Results in slight deficits in dry season flow volume and surpluses in the wet season flow volume at Rvii4, Riv3 Riii1, and Ri1.

- Creates surpluses in the wet and dry season flow volumes at all remaining nodes apart from Rv1 and Ri6.
- Rv1 has deficits in both the wet and dry seasons, while Ri6 has no deficit or surplus, as Current day flows were retained.

The EWR site 3_Olifantspruit (Ri1) is an important tributary contributing flow into the Nyl River floodplain along with Ri1_1 on the Nyl River, situated at the head of the floodplain. EWR site 5_Mogalakwena (Ri5) is situated just downstream of Wonderkop Nature Reserve.

Figure 4.3 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.3 Summary results for the ESBC scenario for the Mogalakwena River basin, showing the PES, annual percentages of natural, EC and annual deficits/surpluses (Mm³). EWR sites are shaded yellow, LIMCOM sites are in italics.

				Nat	CURRENT			ESBC				
	EWR sites										Deficit / surplus	
IUA	*LIMCOM sites*	Node	River	MAR	PES	MAR	%Nat	EC	MAR	%Nat	Wet	Dry
UNyl-Sterk		Rvii4	Sterk	35.56	E	22.09	62.1	D/E	17.47	49.1	4.48	-0.29
UNyl-Sterk		Rv1	Sterk	39.60	E	12.13	30.6	C/D	18.50	46.7	-2.58	-2.32
UNyl-Sterk		Ri4	Sterk	58.17	C	22.87	39.3	C/D	22.59	38.8	-0.66	0.78
UNyl-Sterk	**3_Olifantspruit**	Ri1	Olifantspruit	8.11	C	7.61	93.9	C	6.83	84.3	0.53	0.07
UNyl-Sterk		Ri1-1	Nyl	23.80	C	21.41	90.0	D	12.74	53.5	5.65	0.85
UNyl-Sterk		Riv3	Nyl	23.44	C	21.55	91.9	C/D	17.37	74.1	4.14	-0.41
UNyl-Sterk		Riii1	Nyl	32.70	D	24.18	73.9	D	20.00	61.2	4.14	-0.41
UNyl-Sterk		Ri3	Mogalakwena	52.78	D	36.99	70.1	C	27.74	52.6	8.35	-0.12
UNyl-Sterk	**4_Mogalakwena1**	Ri5	Mogalakwena	133.27	C	77.49	58.1	C/D	67.96	51.0	7.70	0.66
Moga		Riv12	Mogalakwena	136.05	C	79.92	58.7	C/D	70.39	51.7	7.70	0.66
Moga		Ri6	Mokamole	15.01	D	12.55	83.6	D	12.55	83.6	0.00	0.00
Moga		Rv2	Mogalakwena	161.14	C	100.98	62.7	C/D	83.19	51.6	12.87	1.75
Moga		Rvii12	Klein Mogolakwena	5.04	C	3.94	78.1	D	2.25	44.7	1.21	0.29
Moga		Ri10	Mogalakwena	165.59	C	103.86	62.7	C/D	85.55	51.7	14.01	1.49
Moga		Ri12	Matlalane	9.65	C	8.19	84.8	D	4.03	41.8	2.92	0.62
Moga		Ri13	Seepabana	4.71	D	4.14	87.9	D	2.77	58.9	0.85	0.20
Moga		Rvii13	Mogalakwena	190.98	C	125.31	65.6	C/D	98.15	51.4	20.43	2.81
Moga	**5_Mogalakwena2**	Ri14	Mogalakwena	193.27	C	114.30	59.1	C	100.49	52.0	11.90	1.19
Moga	*MOGA-A63D-LIMPK*	Rii3	Mogalakwena	205.52	C	120.45	58.6	C/D	100.97	49.1	18.16	0.79

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

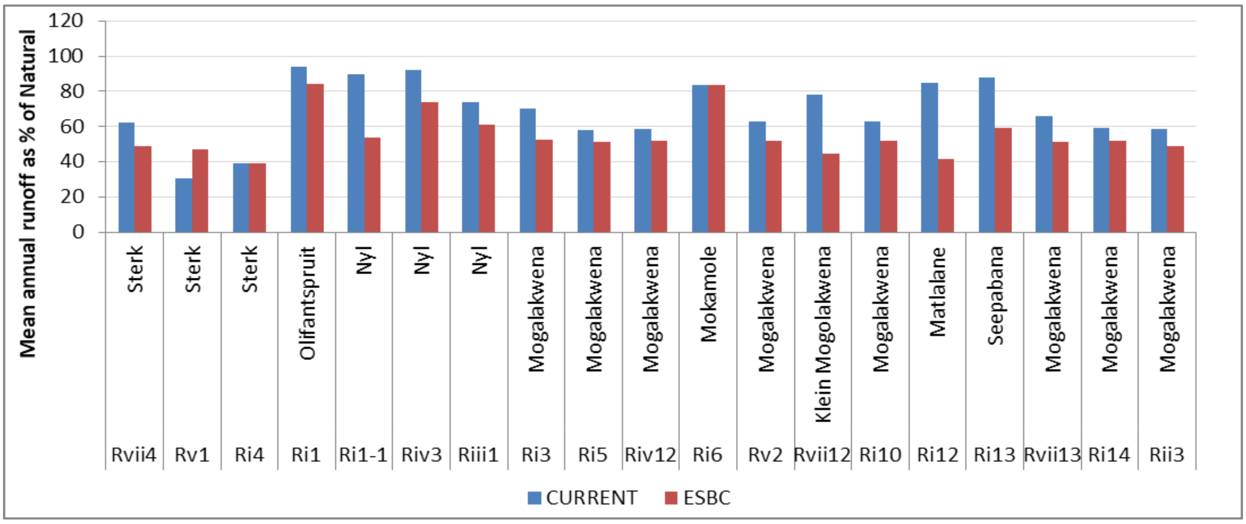

Figure 4.3 Current MAR compared to ESBC MAR as percentages of natural MAR

4.4 Mapungubwe IUA

The modelled ESBC flow scenario (**Table** 4.4):

- Meets or exceeds the annual flow requirements for a D at all nodes.
- There are small surpluses in the wet and dry season at all nodes apart from Rvi4 and Rvi9 which have small deficits in the dry season.

This is an important conservation area with a number of nature reserves and the Mapungubwe National Park, where the Maloutswa Floodplain and Mapungubwe wetlands are located.

Figure 4.4 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.4 Summary results for the ESBC scenario for the Mapungubwe IUA, showing the PES, annual percentages of natural, EC and annual deficits/surpluses (Mm^3). EWR sites are shaded yellow, LIMCOM sites are in italics.

				Nat	CURRENT			ESBC				
	EWR sites										Deficit / surplus	
IUA	*LIMCOM sites*	Node	River	MAR	PES	MAR	%Nat	EC	MAR	%Nat	Wet	Dry
Mapu		Rvi2	Stinkwater	0.24	B	0.12	50.8	B/C	0.05	19.6	0.07	0.00
Mapu	**6_Kolope**	Riv32	Kolope	2.06	C	1.05	51.1	C	1.03	49.8	0.05	0.01
Mapu		Rvi4	Kongoloop	3.14	C	1.92	61.2	C	1.39	44.2	0.60	-0.03
Mapu		Rvi7	A71L Trib 4	0.20	B	0.12	61.1	B	0.04	20.7	0.09	-0.01
Mapu		Rvi9	Soutsloot	1.10	A	0.67	61.0	B/C	0.22	19.7	0.49	-0.02

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

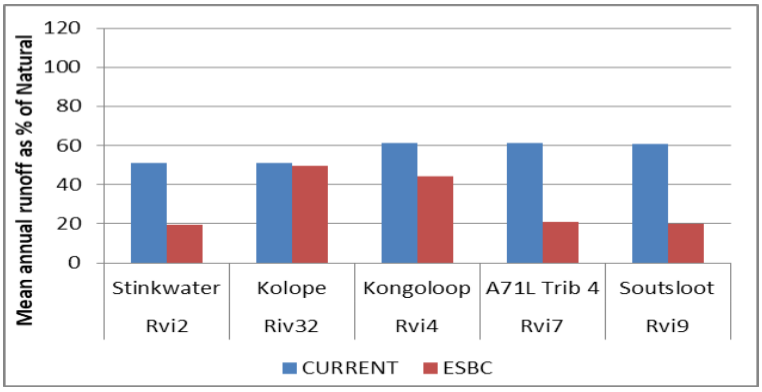

Figure 4.4 Current MAR compared to ESBC MAR as percentages of natural MAR

4.5 Sand River basin (Upper and Lower Sand IUA)

The modelled ESBC flow scenario (**Table** 4.5):

- Meets or exceeds the annual flow requirements for a D at all the nodes.
- Results in slight deficits in dry season flow volume at Rvi3, Ri21, Ri17, Riv16, Ri24 and Ri25.
- Creates surpluses in wet season flows at all sites, and in both wet and dry season flows at Ri16, Ri20, Ri22, Ri23, and Riv17.

Note that currently, the flows at Riv16 on the Sand River are higher than Natural because of irrigation.

Figure 4.5 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.5 Summary results for the ESBC scenario for the Sand River basin, showing the PES, annual percentages of natural, EC and season deficits/surpluses (Mm^3). EWR sites are shaded yellow, LIMCOM sites are in italics.

				Nat	CURRENT			ESBC				
	EWR sites										Deficit / surplus	
IUA	*LIMCOM sites*	Node	River	MAR	PES	MAR	%Nat	EC	MAR	%Nat	Wet	Dry
USand		Rvi3	Hout	6.92	C	3.07	44.3	C	2.97	42.9	0.24	-0.02
USand		Ri21	Hout	11.70	C	5.88	50.3	C	5.16	44.1	1.14	-0.17
USand		Ri16	Sand	11.05	D	13.11	118.7	D	5.00	45.2	4.86	2.01
USand		Ri17	Diep	7.83	D	6.10	77.9	D	5.16	66.0	0.97	-0.01
USand		Riv16	Dwars	2.43	C	1.51	61.9	C/D	1.13	46.3	0.39	-0.003
LSand	7_Sand	Ri20	Sand	27.45	C	23.48	85.5	D	14.22	51.8	7.05	1.34
LSand		Ri22	Sand	31.59	C	24.12	76.4	C/D	15.62	49.4	7.72	0.41
LSand		Ri23	Sand	52.35	C	36.90	70.5	C/D	25.20	48.1	11.74	0.01
LSand		Ri24	Sand	62.54	C	45.82	73.3	C/D	29.52	47.2	16.41	-0.09
LSand		Riv17	Brak	13.55	C	12.16	89.8	D	5.61	41.4	5.26	0.60
LSand	*SAND-A71K-R508B*	Ri25	Sand	85.32	C	64.16	75.2	C/D	37.42	43.8	26.77	-0.13

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

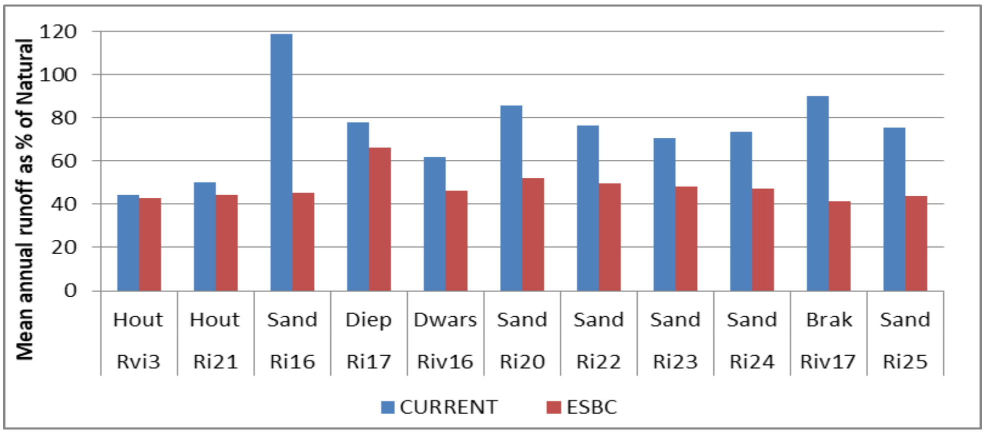

Figure 4.5 Current MAR compared to ESBC MAR as percentages of natural MAR

4.6 Nzhelele and Ṅwaneḓi River basins (Nzhelele/Ṅwaneḓi IUA)

The modelled scenario flow regime (**Table** 4.6):

- Meets or exceeds the annual flow requirements for a D at all nodes.
- Results in small deficits in dry season flow volumes at Ri26 and Ri27.
- Creates surpluses in wet and dry season flow volumes at all other nodes apart from Riv33 which has no dry season surplus.

Note that current flows at Riv23 on the Mutamba River are higher than Natural because of irrigation return flows. Riv26 and Ri27 on the Nzhelele River increase slightly in condition as the dry season flows increased slightly (resulting in small dry season deficits). The EWR site 8_Nzhelele (Ri27) is situated upstream of Philip Herd Nature Reserve and EWR site 9_Ṅwaneḓi is downstream of the Ṅwaneḓi Nature Reserve and upstream of the Adwen Private Nature Reserve.

Table 4.6 Summary results for the ESBC scenario for the Nzhelele and Ṅwaneḓi River basins, showing the PES, annual percentages of natural, EC and season deficits/surpluses (Mm³). EWR sites are shaded yellow, LIMCOM sites are in italics.

				Nat	CURRENT			ESBC				
IUA	EWR sites *LIMCOM sites*	Node	River	MAR	PES	MAR	%Nat	EC	MAR	%Nat	Deficit / surplus Wet	Dry
Nzhe/Nwan		Riii4	Mutamba	7.14	C	6.96	97.5	D	4.31	60.4	1.49	0.61
Nzhe/Nwan		Riv23	Mutamba	18.61	C	20.99	112.8	D	11.79	63.4	5.03	2.16
Nzhe/Nwan		Riii7	Nzhelele	14.81	D	13.69	92.4	D	11.91	80.4	1.01	0.32
Nzhe/Nwan		Rvii34	Mufungudi	6.68	D	6.00	89.8	D	5.38	80.5	0.36	0.11
Nzhe/Nwan		Riii8	Nzhelele	76.26	D	56.61	74.2	D	47.48	62.3	3.77	3.55
Nzhe/Nwan		Ri26	Nzhelele	94.92	C	61.08	64.3	B/C	59.83	63.0	3.10	-0.94
Nzhe/Nwan		Riv33	Tshishiru	1.27	C	0.72	56.9	C/D	0.51	40.2	0.24	0.00
Nzhe/Nwan	8_Nzhelele	Ri27	Nzhelele	99.73	C	59.60	59.8	B/C	60.61	60.8	2.15	-1.96
Nzhe/Nwan		Riii9	Nwanedi	21.85	B	17.91	82.0	C	8.51	39.0	7.06	0.86
Nzhe/Nwan		Riii10	Luphephe	10.17	C	8.08	79.4	D	4.74	46.6	2.45	0.34
Nzhe/Nwan	9_Nwanedi	Ri28	Nwanedi	33.47	C	26.63	79.6	D	13.38	40.0	9.80	1.35

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/ Ṅwaneḓi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

Figure 4.6 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC, both as percentages of Natural MAR.

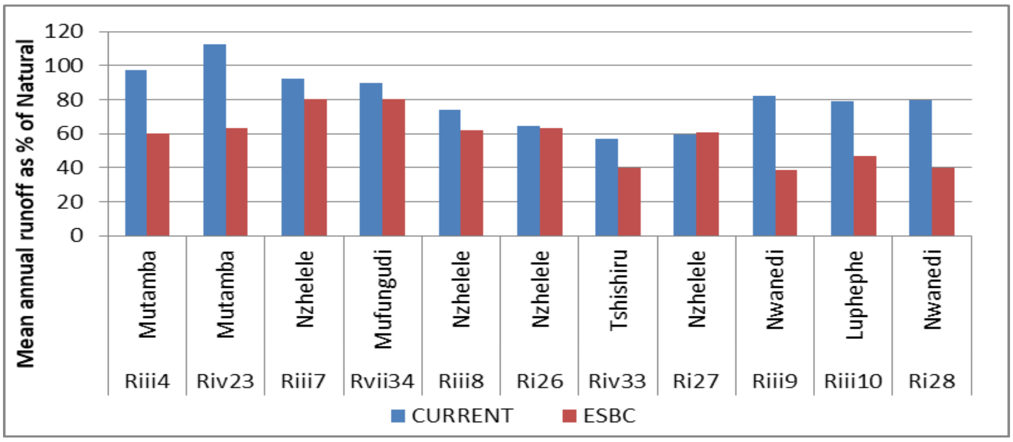

Figure 4.6 Current MAR compared to ESBC MAR as percentages of natural MAR

4.7 Luvuvhu and Mutale River basins (Upper Luvuvhu, Lower Luvuvhu/Mutale IUAs)

The modelled ESBC flow scenario (**Table** 4.7):

- Meets or exceeds the annual flow requirements for a D at all nodes.
- Results in D categories at EWR sites 11_Mutshindudi, 13_Mutale1 (Ri33) and 14_Mutale2 (Ri34), which are not acceptable because they are lower than the REC of C set for all cases.
- Results in a very slight deficit in dry season flow volume Riv19.
- Creates surpluses in wet and dry season flow volumes at all other nodes, apart from at Riii6 (EWR site 10_Latonyanda) and Riv24 on the Mbodi River where Current flows were retained.

This is a very important IUA with a large portion of the basin being within protected areas. The upper Mutale River flows through the Mphaphuli Protected Environment where the EWR site 13_Mutale (Ri33) is situated downstream of the Mutale wetlands. There are two EWR sites on tributaries of the Luvuvhu River (10_Latonyanda (Riii6) and 11_Mutshindudi (Ri30)). They are upstream of the first EWR site on the Luvuvhu River 12_Luvuvhu (Ri32) just before it flows into the Kruger National Park. The lower EWR site 14_Mutale (Ri34) is situated just upstream of the confluence with the Luvuvhu River and the LIMCOM EFlows site LUVU-A91K_OUTPO (Ri36), both in the Kruger National Park and providing critical inflows into the Luvuvhu River floodplain.

Figure 4.7 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.7 Summary results for the ESBC scenario for the Luvuvhu and Mutale River basins, showing the PES, annual percentages of natural, EC and season deficits/surpluses (Mm^3). EWR sites are shaded yellow, LIMCOM sites are in italics.

IUA	EWR sites / *LIMCOM sites*	Node	River	Nat MAR	CURRENT PES	CURRENT MAR	CURRENT %Nat	ESBC EC	ESBC MAR	ESBC %Nat	Deficit / surplus Wet	Deficit / surplus Dry
ULuvu		Rvi14	Luvuvhu	22.60	C	8.18	36.2	C/D	4.62	20.5	3.51	0.04
ULuvu		Rvii19	Doringspruit	11.58	C	6.09	52.6	C/D	2.97	25.6	2.57	0.33
ULuvu		Riii5	Luvuvhu	75.34	C	21.34	28.3	C	14.70	19.5	6.75	0.17
ULuvu	10_Latonyanda	Riii6	Latonyanda	23.55	C	18.25	77.5	C	18.25	77.5	0.00	0.00
ULuvu		Riv18	Dzindi	69.63	D	66.32	95.2	D	56.57	81.3	6.87	1.13
ULuvu		Riv19	Luvuvhu	172.98	C	97.62	56.4	C	62.49	36.1	34.15	-0.13
ULuvu		Rvii24	Luvuvhu	247.68	D	138.06	55.7	D	93.18	37.6	41.02	0.99
ULuvu	11_Mutshindudi	Ri30	Mutshindudi	55.81	C	46.03	82.5	D	21.99	39.4	19.74	1.01
LLuvu/Muta	12_Luvuvhu	Ri32	Luvuvhu	398.53	C	247.76	62.2	C	178.84	44.9	60.76	2.00
LLuvu/Muta		Rvii33	Mutale	73.89	C	66.29	89.7	D	25.61	34.7	30.73	4.02
LLuvu/Muta	13_Mutale1	Ri33	Mutale	124.65	C	114.10	91.5	D	53.43	42.9	47.30	4.62
LLuvu/Muta		Riv24	Mbodi	4.49	D	4.33	96.5	D	4.33	96.5	0.00	0.00
LLuvu/Muta	14_Mutale2	Ri34	Mutale	154.95	C	143.64	92.7	D	67.53	43.6	57.95	6.74
LLuvu/Muta		Ri35	Luvuvhu	416.74	B	265.95	63.8	B	208.94	50.1	51.59	1.20
LLuvu/Muta	*LUVU-A91K-OUTO*	Ri36	Luvuvhu	573.18	C	411.08	71.7	C	299.97	52.3	96.79	2.43

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

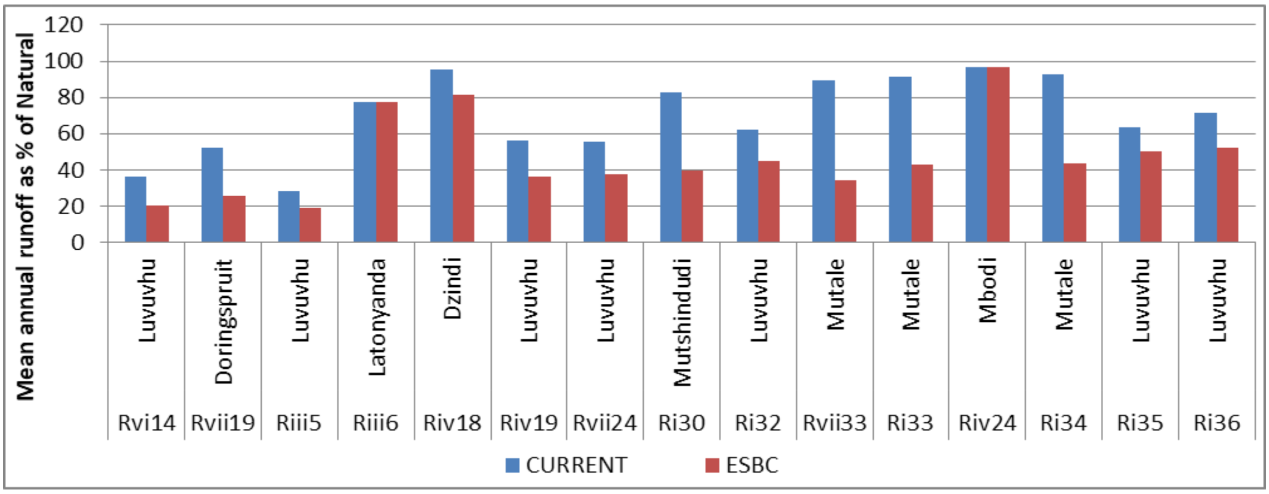

Figure 4.7 Current MAR compared to ESBC MAR as percentages of natural MAR

4.8 Shingwedzi River basin (and IUA)

The modelled ESBC flow scenario (**Table** 4.8):

- Meets and exceeds the annual requirements for a D at all nodes.
- However, this results in a D category at Ri37, the LIMCOM EFlows site SHIN-B90H-POACH, which is not acceptable as the REC for this site is a B/C and it is in the Kruger National Park.
- Results in no deficits in flow volume.
- Creates surpluses in wet and dry season flow volumes at all the nodes.

The majority of the Shingwedzi River basin is situated in the Kruger National Park and the ESBC flow scenario that drops the EC of the LIMCOM EFlows site in this basin is not an acceptable option.

Figure 4.8 graphically compares the mean annual runoff (MAR) of Current Day with that of the ESBC both as percentages of Natural MAR.

Table 4.8 Summary results for the ESBC scenario for the Shingwedzi River basin, showing the PES, annual percentages of natural, EC and season deficits/surpluses (Mm^3). EWR sites are shaded yellow, LIMCOM sites are in italics.

IUA	EWR sites / *LIMCOM sites*	Node	River	Nat MAR	CURRENT PES	CURRENT MAR	CURRENT %Nat	ESBC EC	ESBC MAR	ESBC %Nat	ESBC Deficit / surplus Wet	ESBC Deficit / surplus Dry
Shing		Rvi10	Shisha	7.10	A	7.10	100.0	C/D	2.45	34.5	3.77	0.19
Shing		Riv28	Mphongolo	39.31	A	36.43	92.7	C/D	13.58	34.5	18.88	0.81
Shing		Rvi13	Shingwidzi	18.67	C	18.14	97.1	D	10.64	57.0	6.51	0.20
Shing		Riv27	Shingwidzi	33.80	A	33.13	98.0	C/D	11.30	33.4	17.83	0.96
Shing	*SHIN-B90H-POACH*	Ri37	Shingwidzi	89.63	C	85.82	95.8	D	41.19	46.0	36.65	1.92

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
Moga: Mogalakwena	Mapu: Mapungubwe	USand: Upper Sand	LSand: Lower Sand
Nzhe/Nwan: Nzhelele/Nwanedi	ULuvu: Upper Luvuvhu	LLuvu/Muta: Lower Luvuvhu/ Mutale	Shing: Shingwedzi

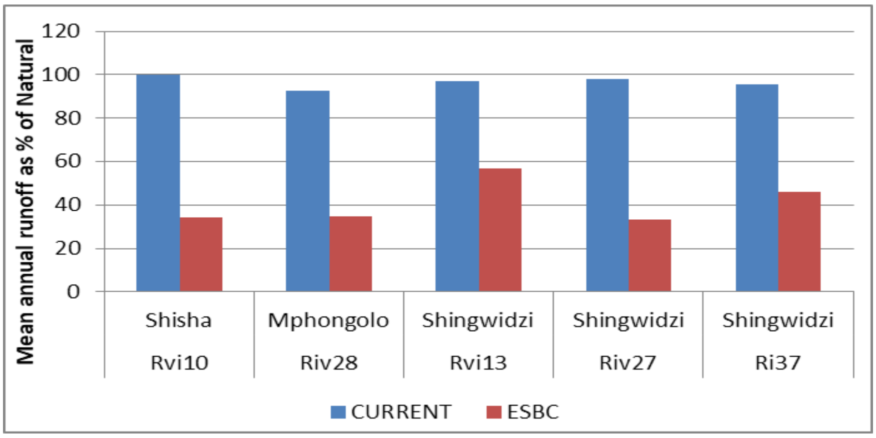

Figure 4.8 Current MAR compared to ESBC MAR as percentages of natural MAR

5 CONCLUSION

The ESBC scenario is a hypothetical scenario intended to illustrate a "bottom line" situation where as much water is abstracted as possible at each, but with the constraint that the node or river reach does not fall below a D ecological condition. Note that the results for the ESBC as presented in this report are draft until such time as the analysis of all other scenarios is complete.

Overall, under the ESBC, the number of lower category EC rivers (C/D and below) increased from 15 to 53; there are no longer any E category rivers, but there is one D/E condition river (**Figure** 5.1). The number of nodes with ECs of C or above decreased from 60 to 22, and no A condition rivers remain.

	Number of nodes	
Ecological Category	Present	ESBC
A	4	0
A/B	0	0
B	8	2
B/C	1	7
C	47	13
C/D	0	22
D	13	30
D/E	0	1
E	2	0
E/F	0	0
F	0	0

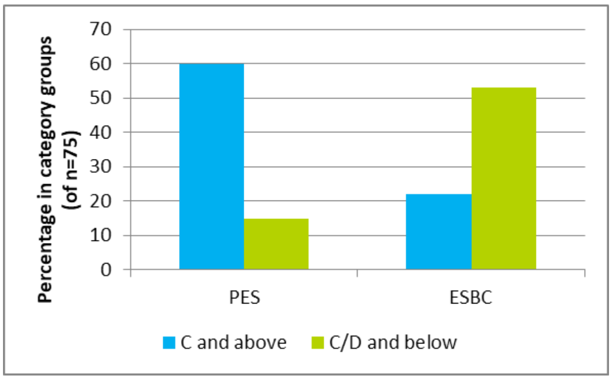

Figure 5.1: The number of nodes / river reaches with the various ECs under Present Day conditions and under the ESBC

A summary of the Current and ESBC flow scenarios is given in **Table** 5.1 and in maps in **Figure** 5.2 **and Figure** 5.3. A comparison shows that the ESBC flow scenario:

- Meets and exceeds the annual, and in some cases the seasonal, flow requirements for a D at all nodes except one.
- Results in a D/E at Rvii4 Sterk River in the Upper Nyl IUA.
- Results in relatively few and generally minor flow deficits (i.e. situations where current flows will not be able provide the ESBC at that node, and would need to be augmented in order provide the ESBC flows).
- Creates surpluses in flow at the majority of nodes.
- Keeps current flows at three nodes:
    - Ri6 on the Mokamole River
    - Riii6 (EWR sites 10_Latonyanda) on the Latonyanda River
    - Riv24 on the Mbodi River
- Results in RECs not being met at 13 (out of 19) EWR sites, which would be not acceptable, as follows:
    1. Riv11 (EWR site 1_Lephalal): REC=B/C, ESBC=D
    2. Ri1 (EWR site 3_Olifantspruit) REC=B/C, ESBC=C
    3. Ri5 (EWR site 4_Mogalakwena1): REC=C, ESBC=C/D
    4. Rii3 (LIMCOM site MOGA-A63D-LIMPK): REC=C, ESBC=C/D
    5. Riv32 (EWR sites 6_Kolope): REC=B/C, ESBC=C

6. Ri20 (EWR site 7_Sand): REC=C, ESBC=D
7. Ri25 (LIMCOM site SAND-A71K-R508B): REC=C, ESBC=C/D
8. Ri28 (EWR site 9_Nwanedi): REC= C, ESBC=D
9. Ri30 (EWR site 11_Mutshindudi) REC=C, ESBC=D
10. Ri32 (EWR site 12_Luvuvhu): REC=B/C, ESBC=C
11. Ri33 (EWR site 13_Mutale1): REC=C, ESBC=D
12. Ri34 (EWR site 14_Mutale2): REC=C, ESBC=D
13. Ri37 (LIMCOM site SHIN-B90H-POACH) REC=B/C, ESBC=D

- Results in significant reductions in flow volumes at most nodes, with the difference in volume being theoretically available for abstraction (**Figure** 5.4).

Table 5.1: Summary results for the ESBC scenario for all nodes, showing the Ecological State, annual percentages of natural and season deficits/surpluses (Mm^3). EWR sites are shaded yellow, LIMCOM sites are in italics.

				Nat	CURRENT			ESBC				
	EWR sites										Deficit / surplus	
IUA	*LIMCOM sites*	Node	River	MAR	PES	MAR	%Nat	EC	MAR	%Nat	Wet	Dry
ULeph		Riv8	Lephalala	32.56	B	22.93	70.4	B/C	6.02	18.5	12.26	0.82
ULeph	1_Lephalala	Riv11	Lephalala	67.63	C	56.16	83.0	D	27.32	40.4	20.86	1.07
ULeph		Riv10	Melk	14.86	C	12.42	83.6	D	7.24	48.7	3.09	0.78
ULeph		Riv13	Boklandspruit	13.27	B	12.83	96.7	D	6.61	49.8	3.61	1.26
ULeph		Riii3	Lephalala	122.93	D	96.37	78.4	D	52.06	42.3	33.71	1.21
LLeph	*LEPH-A50H-SEEKO*	Ri8	Lephalala	139.46	C	95.70	68.6	B/C	60.38	43.3	31.57	-1.44
KsLoop		Ri38	A63C Trib 1	2.08	B	1.38	66.4	C/D	0.41	19.6	0.80	0.06
KsLoop		Rvi15	A63C Trib 2	1.64	B	1.09	66.5	C/D	0.32	19.7	0.63	0.05
KsLoop	2_Rietfontein	Rvi1	Rietfontein farm river	0.19	B/C	0.14	76.2	B/C	0.04	18.5	0.10	0.00
UNyl-Sterk		Rvii4	Sterk	35.56	E	22.09	62.1	D/E	17.47	49.1	4.48	-0.29
UNyl-Sterk		Rv1	Sterk	39.60	E	12.13	30.6	C/D	18.50	46.7	-2.58	-2.32
UNyl-Sterk		Ri4	Sterk	58.17	C	22.87	39.3	C/D	22.59	38.8	-0.66	0.78
UNyl-Sterk	3_Olifantspruit	Ri1	Olifantspruit	8.11	C	7.61	93.9	C	6.83	84.3	0.53	0.07
UNyl-Sterk		Ri1-1	Nyl	23.80	C	21.41	90.0	D	12.74	53.5	5.65	0.85
UNyl-Sterk		Riv3	Nyl	23.44	C	21.55	91.9	C/D	17.37	74.1	4.14	-0.41
UNyl-Sterk		Riii1	Nyl	32.70	D	24.18	73.9	D	20.00	61.2	4.14	-0.41
UNyl-Sterk		Ri3	Mogalakwena	52.78	D	36.99	70.1	C	27.74	52.6	8.35	-0.12
UNyl-Sterk	4_Mogalakwena1	Ri5	Mogalakwena	133.27	C	77.49	58.1	C/D	67.96	51.0	7.70	0.66
Moga		Riv12	Mogalakwena	136.05	C	79.92	58.7	C/D	70.39	51.7	7.70	0.66
Moga		Ri6	Mokamole	15.01	D	12.55	83.6	D	12.55	83.6	0.00	0.00
Moga		Rv2	Mogalakwena	161.14	C	100.98	62.7	C/D	83.19	51.6	12.87	1.75
Moga		Rvii12	Klein Mogolakwena	5.04	C	3.94	78.1	D	2.25	44.7	1.21	0.29
Moga		Ri10	Mogalakwena	165.59	C	103.86	62.7	C/D	85.55	51.7	14.01	1.49
Moga		Ri12	Matlalane	9.65	C	8.19	84.8	D	4.03	41.8	2.92	0.62
Moga		Ri13	Seepabana	4.71	D	4.14	87.9	D	2.77	58.9	0.85	0.20
Moga		Rvii13	Mogalakwena	190.98	C	125.31	65.6	C/D	98.15	51.4	20.43	2.81
Moga	5_Mogalakwena2	Ri14	Mogalakwena	193.27	C	114.30	59.1	C	100.49	52.0	11.90	1.19
Moga	*MOGA-A63D-LIMPK*	Rii3	Mogalakwena	205.52	C	120.45	58.6	C/D	100.97	49.1	18.16	0.79
Mapu		Rvi2	Stinkwater	0.24	B	0.12	50.8	B/C	0.05	19.6	0.07	0.00
Mapu	6_Kolope	Riv32	Kolope	2.06	C	1.05	51.1	C	1.03	49.8	0.05	0.01
Mapu		Rvi4	Kongoloop	3.14	C	1.92	61.2	C	1.39	44.2	0.60	-0.03
Mapu		Rvi7	A71L Trib 4	0.20	B	0.12	61.1	B	0.04	20.7	0.09	-0.01
Mapu		Rvi9	Soutsloot	1.10	A	0.67	61.0	B/C	0.22	19.7	0.49	-0.02
USand		Rvi3	Hout	6.92	C	3.07	44.3	C	2.97	42.9	0.24	-0.02
USand		Ri21	Hout	11.70	C	5.88	50.3	C	5.16	44.1	1.14	-0.17
USand		Ri16	Sand	11.05	D	13.11	118.7	D	5.00	45.2	4.86	2.01
USand		Ri17	Diep	7.83	D	6.10	77.9	D	5.16	66.0	0.97	-0.01
USand		Riv16	Dwars	2.43	C	1.51	61.9	C/D	1.13	46.3	0.39	-0.003
LSand	7_Sand	Ri20	Sand	27.45	C	23.48	85.5	D	14.22	51.8	7.05	1.34
LSand		Ri22	Sand	31.59	C	24.12	76.4	C/D	15.62	49.4	7.72	0.41
LSand		Ri23	Sand	52.35	C	36.90	70.5	C/D	25.20	48.1	11.74	0.01

IUA	**EWR sites** *LIMCOM sites*	Node	River	Nat MAR	CURRENT PES	CURRENT MAR	CURRENT %Nat	ESBC EC	ESBC MAR	ESBC %Nat	ESBC Deficit / surplus Wet	ESBC Deficit / surplus Dry
LSand		Ri24	Sand	62.54	C	45.82	73.3	C/D	29.52	47.2	16.41	-0.09
LSand		Riv17	Brak	13.55	C	12.16	89.8	D	5.61	41.4	5.26	0.60
LSand	*SAND-A71K-R508B*	Ri25	Sand	85.32	C	64.16	75.2	C/D	37.42	43.8	26.77	-0.13
Nzhe/Nwan		Riii4	Mutamba	7.14	C	6.96	97.5	D	4.31	60.4	1.49	0.61
Nzhe/Nwan		Riv23	Mutamba	18.61	C	20.99	112.8	D	11.79	63.4	5.03	2.16
Nzhe/Nwan		Riii7	Nzhelele	14.81	D	13.69	92.4	D	11.91	80.4	1.01	0.32
Nzhe/Nwan		Rvii34	Mufungudi	6.68	D	6.00	89.8	D	5.38	80.5	0.36	0.11
Nzhe/Nwan		Riii8	Nzhelele	76.26	D	56.61	74.2	D	47.48	62.3	3.77	3.55
Nzhe/Nwan		Ri26	Nzhelele	94.92	C	61.08	64.3	B/C	59.83	63.0	3.10	-0.94
Nzhe/Nwan		Riv33	Tshishiru	1.27	C	0.72	56.9	C/D	0.51	40.2	0.24	0.00
Nzhe/Nwan	**8_Nzhelele**	Ri27	Nzhelele	99.73	C	59.60	59.8	B/C	60.61	60.8	2.15	-1.96
Nzhe/Nwan		Riii9	Nwanedi	21.85	B	17.91	82.0	C	8.51	39.0	7.06	0.86
Nzhe/Nwan		Riii10	Luphephe	10.17	C	8.08	79.4	D	4.74	46.6	2.45	0.34
Nzhe/Nwan	**9_Nwanedi**	Ri28	Nwanedi	33.47	C	26.63	79.6	D	13.38	40.0	9.80	1.35
ULuvu		Rvi14	Luvuvhu	22.60	C	8.18	36.2	C/D	4.62	20.5	3.51	0.04
ULuvu		Rvii19	Doringspruit	11.58	C	6.09	52.6	C/D	2.97	25.6	2.57	0.33
ULuvu		Riii5	Luvuvhu	75.34	C	21.34	28.3	C	14.70	19.5	6.75	0.17
ULuvu	**10_Latonyanda**	Riii6	Latonyanda	23.55	C	18.25	77.5	C	18.25	77.5	0.00	0.00
ULuvu		Riv18	Dzindi	69.63	D	66.32	95.2	D	56.57	81.3	6.87	1.13
ULuvu		Riv19	Luvuvhu	172.98	C	97.62	56.4	C	62.49	36.1	34.15	-0.13
ULuvu		Rvii24	Luvuvhu	247.68	D	138.06	55.7	D	93.18	37.6	41.02	0.99
ULuvu	**11_Mutshindudi**	Ri30	Mutshindudi	55.81	C	46.03	82.5	D	21.99	39.4	19.74	1.01
LLuvu/Muta	**12_Luvuvhu**	Ri32	Luvuvhu	398.53	C	247.76	62.2	C	178.84	44.9	60.76	2.00
LLuvu/Muta		Rvii33	Mutale	73.89	C	66.29	89.7	D	25.61	34.7	30.73	4.02
LLuvu/Muta	**13_Mutale1**	Ri33	Mutale	124.65	C	114.10	91.5	D	53.43	42.9	47.30	4.62
LLuvu/Muta		Riv24	Mbodi	4.49	D	4.33	96.5	D	4.33	96.5	0.00	0.00
LLuvu/Muta	**14_Mutale2**	Ri34	Mutale	154.95	C	143.64	92.7	D	67.53	43.6	57.95	6.74
LLuvu/Muta		Ri35	Luvuvhu	416.74	B	265.95	63.8	B	208.94	50.1	51.59	1.20
LLuvu/Muta	*LUVU-A91K-OUTO*	Ri36	Luvuvhu	573.18	C	411.08	71.7	C	299.97	52.3	96.79	2.43
Shing		Rvi10	Shisha	7.10	A	7.10	100.0	C/D	2.45	34.5	3.77	0.19
Shing		Riv28	Mphongolo	39.31	A	36.43	92.7	C/D	13.58	34.5	18.88	0.81
Shing		Rvi13	Shingwidzi	18.67	C	18.14	97.1	D	10.64	57.0	6.51	0.20
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Shing	*SHIN-B90H-POACH*	Ri37	Shingwidzi	89.63	C	85.82	95.8	D	41.19	46.0	36.65	1.92

ULeph: Upper Lephalala	LLeph: Upper Lephalala	KsLoop: Kalkpan Se Loop	UNyl-Sterk: Upper Nyl & Sterk
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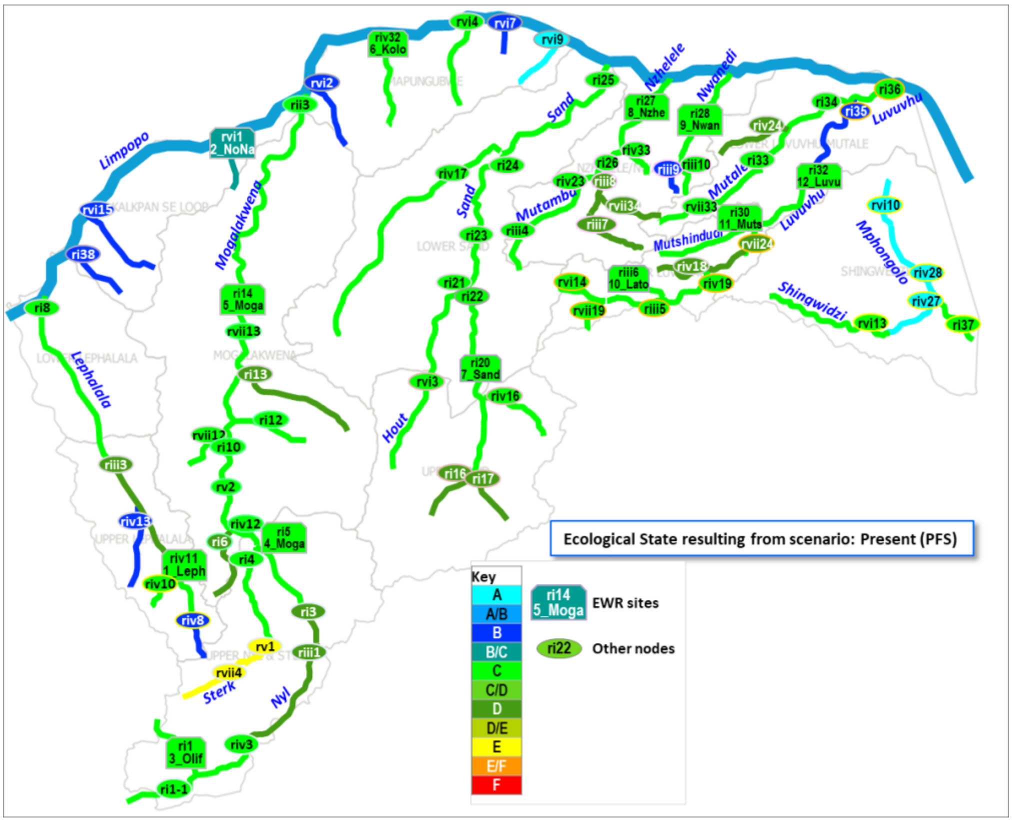

Figure 5.2 Map showing the EC under the Present Day / Current situation at all nodes / river reaches (nodes are ovals and EWR sites are larger rectangles)

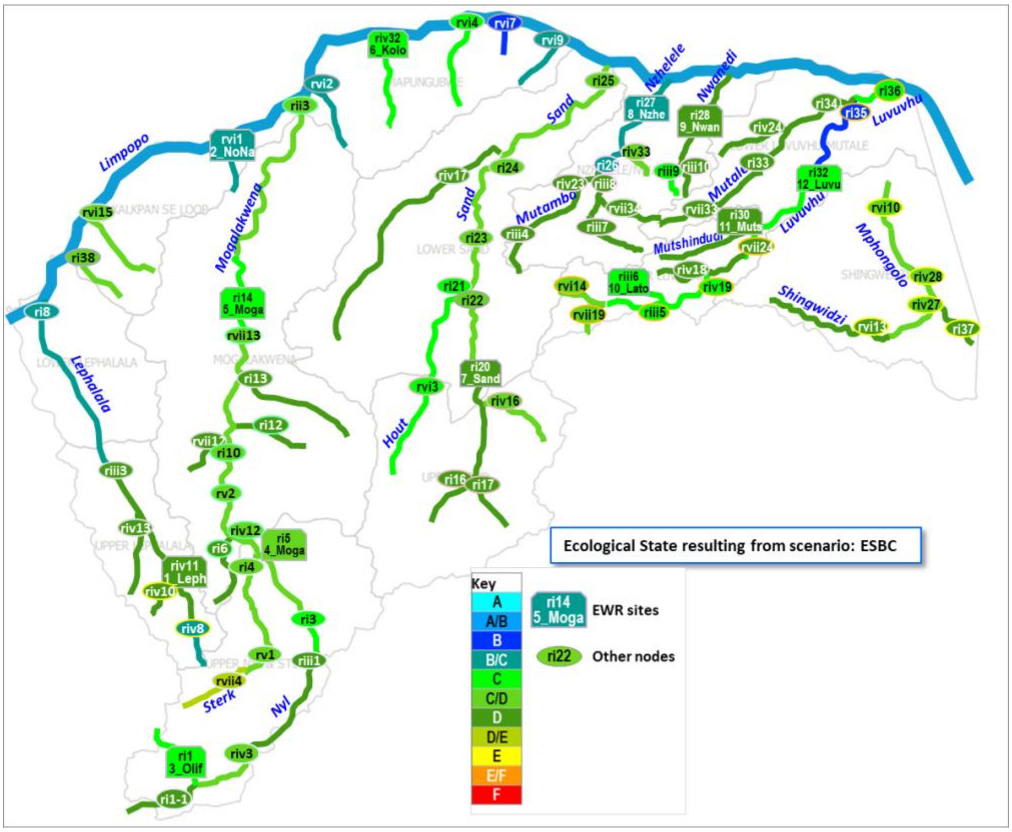

Figure 5.3 Map showing the EC resulting from the ESBC scenario at all nodes / river reaches (nodes are ovals and EWR sites are larger rectangles)

Figure 5.4 compares the average annual volumes as percentages of Natural for the Present Day and ESBC scenarios per IUA. This shows considerable reductions relative to Present Day (over 50%) in two IUAs, while most have 20 to 40% reductions, and two are reduced by less than 20%.

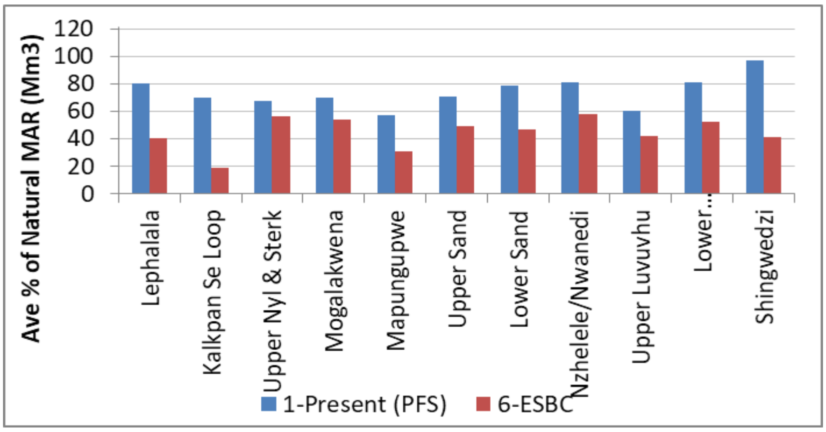

Figure 5.4 Current MAR compared to ESBC MAR as percentages of natural MAR for each IUA

The initial analysis of the ESBC scenario achieves its primary objectives which were to establish the balancing tool and to identify areas of potential surplus and deficit resulting from a minimum sustainable ecological scenario.

After completing the ESBC scenario, the balancing tool will be used to set up the necessary Ecological Category (EC) requirements to achieve the specific objectives of the alternative proposed classification scenarios including three ecologically-based scenarios (a Present Ecological Status (PES) Scenario, an Ecologically Sustainable Base Configuration (ESBC) Scenario, a Best Attainable State (BAS) Scenario), as well as a development-focused scenario (comparable to “Future1” in the **EWR Report – Rivers (Vol 3)** and finally at least one Spatially Targeted Scenario (STS). The analysis will consider the associated social, economic and ecological impacts of these alternative configuration scenarios in order to estimate the overall impact of each and to agree with stakeholders on the final recommended classification scenario for each resource unit and the individual IUAs.

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