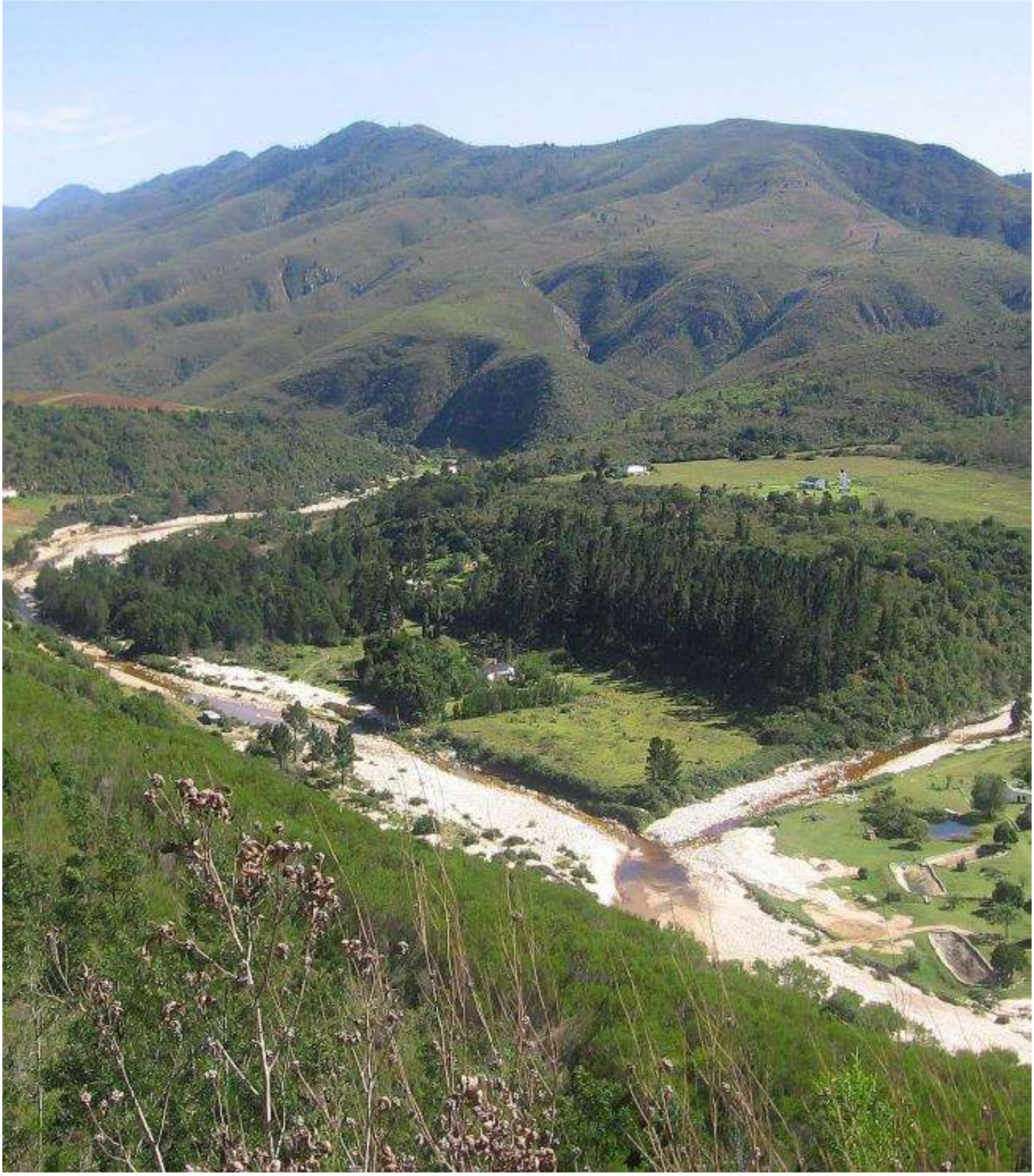

Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz WMA

Quantification of the Ecological Water Requirements and changes in Ecosystems Goods, Services and Attributes

No: RDM/WMA8/00/CON/CLA/0117

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Prepared by:

Aurecon South Africa (Pty) Ltd in sub-consultancy association with Southern Waters Ecological Research and Consulting, Anchor Environmental and Delta-H Water Systems Modelling

Title:	*Quantification of the Ecological Water Requirements and changes in Ecosystem Goods, Services and Attributes*
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Chief Directorate: Water Ecosystems

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Ndileka Mohapi

Chief Director: Water Ecosystems

Document Index

Reports that will be produced as part of this Study are indicated below.

Bold type indicates this Report.

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List of Abbreviations

1999EC	Ecological Condition 1999
2014EC	Ecological Condition 2014
AECs	Alternate Ecological Categories
AHS	Abiotic health score
BBM	Building Block Methodology
D/s	Downstream
DRIFT	Downstream Response to Instream Flow Transformation
DWA	Department of Water Affairs (now the Department of Water and Sanitation)
DWAF	Department of Water Affairs and Forestry (now the Department of Water and Sanitation)
DWS	Department of Water and Sanitation
ER	Ecoregion
EC	Ecological Category
EcoSpec	EcoSpecification
EGSA	Ecological goods, services and attributes
EHI	Estuary health index
EIS	Ecological importance and sensitivity
EWR	Ecological water requirement
FSP	Fine scale planning
GEMS	Global Environment Monitoring System
GIS	Geographical Information System
GRU	Groundwater Resource Unit
GWBF	Groundwater contribution to baseflow
GZ	Geozone
HGM	Hydro geomorphic
HI	Hydrological Index
IBT	Inter Basin Transfer
IUA	Integrated unit of analysis
IWRM	Integrated Water Resources Management
MAP	Mean annual precipitation
MAR	Mean annual runoff
MCM	Million cubic metres
NCWQ	National Chemical Water Quality Network
NCMP	National Chemical Monitoring Programme
NFEPA	National Freshwater Ecosystem Priority Areas
nMAR	natural Mean Annual Runoff
NMMP	National Microbial Monitoring Programme
NWA	National Water Act
PES	Present Ecological Status
pMAR	Present day Mean Annual Runoff
QUAT	Quaternary catchment
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
SASS	Stream Assessment Scoring System
SCB	Southern Coastal Belt
SFM	Southern Fold Mountains
SQ	Sub Quaternary
SWSA	Strategic Water Source Area
U/s	Upstream
WARMS	Water Authorisation Registration Management System

WCD	Western Cape Dry
WCW	Western Cape Wet
WCWSS	Western Cape Water Supply System
WFM	Western Fold Mountains
WQ	Water Quality
WRCS	Water Resources Classification System
WMA	Water Management Area

Executive Summary

INTRODUCTION

The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation has commissioned a study to determine the Water Resource Class and Resource Quality Objectives for all significant water resources in the Breede-Gouritz Water Management Area.

The purpose of this report is to report on the generation of Ecological Water Requirements for the biophysical nodes identified in the study area and to describe the approach to evaluating the changes in ecosystems goods, services and attributes.

These data will be used to evaluate the classification scenarios to inform the recommendations for water resource classes and Resource Class and Resource Quality Objectives (RQOs).

ECOLOGICAL WATER REQUIREMENTS QUANTIFICATION

The biophysical and allocation river nodes for the study area were defined according to the procedures described in DWAF (2007f) and were presented in the *Resource Units and Integrated Units of Analysis Delineation Report* (DWS, 2016a). These were reviewed based on comments on the delineation report.

Eleven "tiers" of information were sequentially assessed, and rules applied, in order to establish nodes for each tier. The provisional nodes identified in the Integrated Unit of Analysis Delineation report were reviewed based on comments received from the Project Management Committee and adjusted accordingly. From these full set of biophysical nodes, for the pragmatic purpose of calculating Ecological Water Requirements (EWRs) and going forward into the scenario analyses, a sub-set of nodes were selected, based on their necessity and suitability for routing flows through the catchment in a downstream direction and their respective importance to capture flows required at estuaries.

In total, 148 river nodes were identified for the Gouritz sub-area and 114 river nodes for the Breede-Overberg sub-area. To facilitate routing of flows through the river catchments and to meet estuary requirements and for other critical environmental areas, Ecological Water Requirements have been generated for 65 nodes in the Gouritz River catchment and Outeniqua region and 76 nodes in the Breede River catchment and Overberg region. These nodes were identified as priority nodes for analysis in the Water Management Area.

Provisional Ecological Water Requirement (EWR) data tables have been produced for these priority nodes for all categories and are summarised in terms of the average annual volume and the percentage of the natural Mean Annual Runoff (MAR) required to maintain the present (2014) ecological condition (EC 2014).

For the river nodes, existing reserve information was used for the Breede and Gouritz catchments. It was however noted that there were no existing reserve sites in the Overberg catchments (G4 and G5). Despite these rivers being relatively short and any local flow requirements likely to be dominated by the demands for maintaining the estuaries, three additional reserve sites were identified and additional Rapid Level III reserve determinations were undertaken. These included the Nuwejaars, Kars and Klein rivers. In addition the PES was updated for all river nodes based on the results of field investigations for a recent study.

For the estuary nodes, data from existing studies and Ecological Water Requirements (EWRs) and recommended ecological categories (REC) are presented. Two additional Reserve studies have been undertaken as part of this study in order to determine the estuary PES and REC as these had not been previously assessed. These were for the Onrus and Rooiels estuaries.

The existing and new (**bold**) river Ecological Water Requirement (EWR) sites are shown in Table E1 and including the Ecological Importance and Sensitivity (EIS), Ecological Category (EC) and Recommended Ecological Category (REC). These are largely based on previous reserve determination studies.

Table E1: The existing and new river EWR sites for the study area including the EC (2014) and REC

	EWR site	IUA	CODE	RIVER	QUAT	EIS	PES (2014EC)	REC
Gouritz	EWR 1_Go	F12	giii8	Duiwenhoks	H80D	L	D	D
	EWR 2_Go	F12	giii7	Goukou	H90C	M	CD	CD
	EWR 3_Go	E8	gv5	Touws	J12M	H	BC	BC
	EWR 4_Go	D7	giv20	Gamka	J25A	H	CD	C
	EWR 5_Go	E8	gv4	Buffels	J11J	M	C	C
	EWR 6_Go	D7	gi4	Gouritz	J40B	M	C	C
	EWR 7_Go	E8	gviii1	Doring	J12L	L	CD	CD
	EWR 8_Go	G15	giv6	Keurbooms	K60C	H	C	BC
	EWR 9_Go	D7	giii2	Olifants	J31C	M	C	C
	EWR 10_Go	D7	gv36	Kammanassie	J34D	L	CD	CD
Outeniqua	EWR 1_Out	G15	gvii14	Knysna	K50A	H	B	B
	EWR 2_Out	G15	gviii11	Gouna	K50B	H	AB	AB
	EWR 3_Out	G15	giii10	Diep	K40A	H	B	B
	EWR 4_Out	G15	gvii13	Karatara	K40C	H	B	AB
	GB1	C6	gviii2	Groot-Brak	K20A	H	BC	BC
	Ka1	G15	gvii11	Kaaimans	K30C	VH	B	B
	Mal1	G15	gvii9	Malgas	K30B	H	C	C
	Gouk1	G15	gviii9	Goukamma	K40E	VH	BC	BC
	Gwa1	G15	gviii6	Gwaiing	K30B	H	E	D
	Maa2	G15	gvii8	Maalgate	K30A	H	D	D
	Sw1	G15	gviii7	Swart	K30C	H	D	D
	Si1	G15	gviii8	Silver	K30C	VH	B	B
	Noe1	G15	gviii10	Noetsie	K60G	VH	B	AB
	Var2	C6	gviii12	Varing	K20A	H	CD	CD
	Var3	C6	gviii3	Varing	K20A	H	D	CD
Breede	EWR 1_Br	A1	Nviii1	Breede	H10F	M	DE	D
	EWR 2_Br	A1	Nvii2	Molenaars	H10J	VH	B	B
	EWR 3 (Hex)	A2	Nvii7	Hex	H20G	M	C	C
	EWR 3_Br	A3	Nvii8	Breede	H40F	M	CD	CD
	EWR 6_Br	B4	Niv28	Baviaans	H60E	H	B	B
	EWR 5_Br	B4	Nv9	Riviersonderend	H60F	H	D	D
	EWR 4_Br	F11	Niii4	Breede	H70G	VH	C	BC
	EWR 1 (Palmiet)	B5	Piii1	Palmiet	G40C	H	C	B
	EWR 3 (Palmiet)	B5	Piii2	Palmiet	G40D	VH	C	BC
	EWR 4 (Palmiet)	B5	Piii3	Palmiet	G40D	VH	B	B
Overberg	**Kle1**	**F10**	**Nv23**	**Klein**	**G40K**	**M**	**CD**	**C**
	Nuw1	**H17**	**Ni4**	**Nuwejaars**	**G50B**	**M**	**D**	**D**
	Kar1	**H17**	**Nv24**	**Kars**	**G50E**	**M**	**BC**	**B**

In addition to the EWR requirements at the priority river and estuary nodes, as determined from previous reserve determination studies, the EWR requirements for all other nodes were determined using the Desktop Reserve model and where appropriate calibrated with data from a related EWR/reserve site.

A summary of the priority estuaries in the study area are shown in Table E2 along with the Present Ecological Status (PES) and Recommended Ecological Category (REC) from previous reserve studies.

Table E2: Summary of Reserve data available for estuaries in the Breede-Gouritz WMA

Estuary	Type	Area (ha) incl. floodplain	Channel area	Catchment size (km^2)	Present day MAR (Mm^3)	Reserve (Scenarios)	PES	REC
Rooiels	Closed	16.03	1.9	21	9.44	Yes 4	B	B
Buffels (Oos)	Micro	4.73	1.3	23	12.70	-	B	B
Palmiet	Closed	28.53	26	470	177.94	Yes 7	C	B
Bot/Kleinmond	Lake	2 039.01	1229.2	887	77.67	Yes 3	C	B
Onrus	Closed	15.13	3.5	58	4.74	Yes 5	E	D
Klein	Lake	1 802.33	113.6	896	51.21	Yes 7	C	B
Uilkraals	Closed	702.31	55.7	377	6.82	Yes 4	D	C
Ratel	Micro	8.63	1.5	95	3.42	-	C	C
Heuningnes	Open	13 125.81	1451.5	3578	29.53	In Prog 5	C	A*
Klipdriftsfontein	Micro	2.23	0.8	27	0.75	-	A	A
Breede	Open	2 079.43	1147.6	12 496	1140.69	Yes 5	B	B
Duiwenhoks	Open	419.33	108.3	1207	81.62	Yes 5	B	A
Goukou	Open	372.33	122.4	1438	89.94	Yes 5	C	B
Gouritz	Open	1 049.41	319	45 544	397.85	Yes 5	C	B
Blinde	Micro	4.13	2.1	28	1.01	-	B	B
Tweekuilen	Micro	9.82	1.6	35	1.25	-	D	D
Gericke	Micro	3.62	0.9	12	0.39	-	D	D
Hartenbos	Closed	236.93	30.5	169	3.74	-	D	C
Klein Brak	Closed	976.93	89.4	556	35.54	Yes 5	C	C
Groot Brak	Closed	205.13	65.6	162	0.92	Yes 10	D	C
Maalgate	Closed	22.23	17	185	35.72	-	B	B
Gwaiing	Closed	10.63	4.2	121	51.16	Yes 5	B	C
Kaaimans	Open	20.63	9	132	26.88	-	B	B
Wilderness	Lake	1 091.73	501.8	173	29.01	Yes 5	B	A
Swartvlei	Lake	2 037.9[1]	114.5	419	92.49	Yes 8	B	B
Goukamma	Closed	213.13	45.3	252	46.25	Yes 8	B	A
Knysna	Bay	2 284.11	1691.7	419	84.32	Yes 10	B	B
Noetsie	Closed	14.83	8	39	5.11	-	B	A
Piesang	Closed	59.53	4.9	48	6.41	-	C	B
Keurbooms	Open	1 523.41	398.2	1123	104.2	Yes 5	A	A
Matjies	Micro	2.53	0.5	25	3.22	Yes 5	B	B
Sout (Oos)	Micro	13.83	1.7	33	3.45	Yes 5	A	A
Groot (Wes)	Closed	64.43	30.2	82	10.88	-	B	A
Bloukrans	River mouth	4.21	2.3	88	31.38	-	A	A

*Best attainable state as determined by specialists due to the occurrence within a protected area.

In addition to determining the provisional EWRs for each river and estuary node, each node was also assessed for significance in terms of the Groundwater Contribution to Baseflow. The nodes for which the Groundwater Contribution to Baseflow was estimated to be above 50% of the Ecological Water Requirements were identified as significant with regards to surface-groundwater interaction.

Significant relationships to wetlands where also identified for each identified river and estuary node.

A groundwater balance model was also used to investigate the current level of groundwater stress in the region as function of the estimate groundwater use relative to the estimated sustainable recharge rate.

CHANGES IN ECOSYSTEM GOODS, SERVICES AND ATTRIBUTES

Determining the changes in Ecosystem Goods, Services and Attributes (EGSAs) is required as the sectors dependent on aquatic ecosystem services could either shrink or expand as a result of moving to a lower or higher ecological category. The availability and quality of water in rivers, wetlands and estuaries and the overall condition of these systems influence their capacity to deliver aquatic ecosystem services. These, in turn, will influence the value of final goods and services generated by activities that depend on them.

The main types of ecosystem services considered are summarised in Table E3. These will be used in the evaluation of alternative classification scenarios based on the resulting ecological category for each node.

Table E3: Main ecosystem services of the study area, and the main flow-related variables that can be derived from Reserve studies to estimate changes in the capacity to deliver these services

Category of service	Types of values	Description	Independent variables related to estuary condition
Goods (Provisioning services)	Subsistence fishing	Invertebrates and fish collected on a subsistence basis for consumption or bait	Invertebrate abundance Freshwater fish abundance Estuary line- and net-fish abundance
Services (Regulating services)	Nursery value	Contribution to marine fish catches due to the nursery habitat provided by estuaries	Abundance of estuary-dependent marine fish
Attributes (Cultural services)	Tourism value & property value	A river, wetland or estuary's contribution to recreation/tourism appeal of a location	Overall health Line-fish abundance Water quality

THE WAY FORWARD

The data on Ecological Water Requirements and changes in the Ecosystem Goods, Services and Attributes will be used to determine the flow requirements at individual nodes based on the recommended ecological category as well as determining the impact of alternative development scenarios on the ecological condition of individual nodes. The change in Ecosystem Goods, Services and Attributes will be used to evaluate the impacts of alternative scenarios.

The approach to scenario analysis has been described in the *Linking the value and condition of the Water Resource Report* (DWS, 2017a) and will be further developed in the *Ecological Sustainable Base Configuration Scenario* report to be prepared following the next phase of analysis. The development of current and future scenarios and the analysis of the impact of these scenarios is the next step. The Ecological Water Requirements determined in this report will be inputs to the above analysis.

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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. 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.

Section 13 of the NWA states that "as soon as reasonable practicable after the Minister prescribed a system for classifying water resources, the Minister must, subject to subsection (4), by notice in the gazette, determine for all or part of every significant water resource-

a) A class in accordance with the prescribed classification system; and

b) Resource quality objectives based on the class determined in terms of paragraph (a)."

The Chief Directorate: Water Ecosystems has therefore commissioned a study to determine Water Resource Class and associated Resource Quality Objectives (RQO) for all significant water resources in the Breede-Gouritz Water Management Area (WMA).

The Breede Catchment area consists of the Breede River, its main tributary, the Riviersonderend River and the Overberg River, as well as other smaller coastal rivers. The Gouritz Catchment consists of the Gouritz River, as well as other rivers such as the Buffels, Touws, Groot, Gamka, Olifants, Kammanassie, and catchments of smaller coastal rivers.

The 7-step WRCS procedure is prescribed in the WRCS Overview Report (DWAF, 2007) leading to the recommendation of the Class of a water resource (the outcome of the Classification Process).

Following the classification process a further seven step process (DWA, 2012) is followed leading to the determination of the RQOs which are then presented to the DWS for gazetting along with the classifications.

1.2 Objectives of the Study

The main objectives of the Study are to undertake the following:

- Co-ordinate the implementation of the WRCS, as required in Regulation 810 in Government Gazette 33541, by classifying all significant water resources as part of the Breede-Gouritz WMA.
- Determine RQOs using the DWS Procedures to Determine and Implement RQOs for all significant water resources in the Breede-Gouritz WMA.

In addition the project will require extensive stakeholder engagement and capacity building of DWS and Breede-Gouritz Catchment Management Agency staff.

The final outcome from the study will be the recommended WRCs and associated RQOs for the Breede-Gouritz WMA presented to DWS for gazetting.

1.1 Extent of the Study Area

The study area covers all significant water resources of the Breede-Gouritz WMA. The Breede and Gouritz Catchments and their primary tributaries, Riviersonderend, Groot, Gamka and Olifants rivers, dominate the study area, but it also includes numerous smaller coastal catchments. The Breede-Overberg region is characterised by mountain ranges in the north and west, the wide Breede River valley, and the rolling hills of the Overberg in the south. The Gouritz region is characterised by mountain ranges in the south-west, south and south-east and the vast flat landscape of the Karoo in the north. The smaller coastal rivers include the Palmiet, Rooiels, Onrus, Klein, Bot, Stanford, Uilenkraals, Ratel, Heuningnes, Klipdriftsfontein, Duiwenhoks, Hartenbos, De Hoop, Goukou, Klein-Brak, Groot-Brak, Kaaimans, Touws, Karatara, Goukamma, Swart, Maalgate, Gwaiing, Malgas, Noetsie and Knysna.

1.2 Purpose of this Report

This report presents the results of step three in the seven step process (DWAF, 2007) for determination of the water resources classes (Table 1.1). Step 3, is associated with and provides the introductory tasks for step 4 and 5 of the WRCS which involves the determination of classification and development scenarios to support the evaluation of the proposed classification systems in the Integrated Water Resources Management (IWRM) framework prescribed by DWS.

STEP 1: Delineate Resource Units & describe Status Quo of water resource
STEP 2: Link value & condition of water resource
STEP 3: Quantify EWRs and changes in non-water quality EGSAs
STEP 4: Determine scenarios
STEP 5: Evaluate scenarios within IWRM process
STEP 6: Evaluate scenarios with stakeholders
STEP 7: Gazette & Class configuration

Table 1.1 Prescribed process for determining water resources classes showing the step relevant for this report in the red block. (Source: after DWA, 2012)

The *objective* of Step 3 of the classification procedure is to *quantify the Ecological Water Requirements (EWRs)* and to *describe the changes in non-water quality Ecological Goods, Services and Attributes (EGSAs)*. While the quantification of EWRs is part of the Reserve Determination process (see NWA, Chapter 3), the determination of the ecological reserve is part of the Classification Process.

In this study area there are already a number of existing sites for which preliminary Reserves have been determined. The purpose of this report is to review these preliminary Reserve determinations and where possible to extrapolate the EWR requirements associated with these preliminary Reserve sites to other nodes identified.

Where necessary additional studies are undertaken to either update the existing information at these sites or to determine new EWR requirements. In this case field visits were undertaken to update the Present Ecological Status (PES) at all the identified river node and additional EWRs were determined for three sites (Nuwejaars, Kars and Klein) for which no preliminary Reserve determination information was available.

Groundwater information required prior to step 5 includes information on recharge, groundwater use, the current “stress”, and the relationship between changing use, availability, and “stress” (i.e. groundwater balance model). This information is included in this report, in addition to information on surface – groundwater interactions and groundwater’s link to EWR.

The objective in describing changes in the non-water quality EGSAs is to provide the information that will be used in later steps of the classification procedure (see DWAF, 2007) to assess the impacts of changes in catchment configuration scenarios on non-water quality EGSAs.

To incorporate these objectives, Step 3 consists of the following three sub-steps:

- **Step 3a:** Identify nodes to which existing Reserve study data can be extrapolated and extrapolate;
- **Step 3b:** Develop rule curves, summary tables and modified time series for all nodes for all categories; and
- **Step 3c:** Quantify the changes in relevant ecosystem components, functions and attributes for each category for each node.

The details of the approach and outcome from the sub-steps of Step 3 in the Classification Procedure are presented in this report and in the accompanying Appendices and electronic data files. These will then be used to inform the final recommendations for the water resource class for each IUA in the final Report.

2 SELECTION OF NODES

2.1 Integrated Units of Analysis and Biophysical Nodes

Eighteen IUAs were determine for the study area based on a combination of hydrological, ecological and socio-economic factors. A total of 262 river nodes were identified in the study area. 148 river nodes for the Gouritz sub-area and 114 river nodes for the Breede-Overberg sub-area were defined according to the procedures described in DWAF (2007f). Thirty four estuary nodes were also identified and twenty six of these were considered to be priority estuary nodes for the purpose of the study.

The detail of the delineation process for the IUAs and identified river and estuary nodes for the study are presented in the *Resource Units and Integrated Units of Analysis Delineation Report* (DWS, 2016b).

2.2 Identification of River Nodes and EWR sites

Eleven "tiers" of information were sequentially assessed, and rules applied, in order to establish nodes for each tier. Nodes were added sequentially for Tiers I to Tier VIII, where after rationalisation rules were applied to eliminate nodes for which EWRs were not required, e.g. impoundments (Tier VII). Then additional nodes were added as required for Tiers V-IX, and rationalisation rules were applied again to eliminate nodes for which appropriate hydrological information was not available and/or nodes that were too close to each other (Tier IX). Thereafter, nodes were again added where additional information was likely to be needed at a particular sub-quaternary catchment level for planning or allocation purposes.

There are already sites in the study area for which high confidence Reserve determinations have been done. These are listed in Table 2.1 and Table 2.2. These sites are all located in the Breede, Gouritz and Coastal catchments and were considered sufficient for EWR information to be extrapolated to all other river nodes in the catchments.

It was, however, noted that there are no existing EWR sites within the Overberg region and it was requested that additional sites be identified in these catchment for which at least a Rapid Level III Reserve determination study should be undertaken.

The Resource Unit (RU) prioritisation tool was used to identify the most significant resource units for which EWR site could be determined for catchments outside of the main Berg River Catchment. The results of this analysis identified the Nuwejaars, Kars and Klein Rivers as the priority resource units in the Overberg sub-area.

A field trip and rapid Level III Reserve determination study was undertaken on the Nuwejaars, Kars and Klein rivers. The results of this study and a summary of the previous Reserve determination studies are presented in Section 3 and Appendix A. Field visits were undertaken at all existing EWR sites and river nodes in the study area and were used to update the PES for each river node.

Preliminary EWRs are determined for all nodes using the Desktop Reserve Model and where possible these sites are calibrated using the EWR data extrapolated from the existing and new Reserve sites.

During the scenario analysis the flow requirements at some of these river nodes may be updated based on the need to achieve EWRs at the priority river and estuary nodes when routed down the system.

The existing and new EWR sites are shown in Table 2.1 and on Figure 2.1 and Figure 2.2.

Table 2.1 The existing and new EWR sites (in bold) for the study area

	EWR site	IUA	CODE	RIVER	QUAT	EIS	PES (2014EC)	REC
Gouritz	EWR 1_Go	F12	giii8	Duiwenhoks	H80D	L	D	D
	EWR 2_Go	F12	giii7	Goukou	H90C	M	CD	CD
	EWR 3_Go	E8	gv5	Touws	J12M	H	BC	BC
	EWR 4_Go	D7	giv20	Gamka	J25A	H	CD	C
	EWR 5_Go	E8	gv4	Buffels	J11J	M	C	C
	EWR 6_Go	D7	gi4	Gouritz	J40B	M	C	C
	EWR 7_Go	E8	gviii1	Doring	J12L	L	CD	CD
	EWR 8_Go	G15	giv6	Keurbooms	K60C	H	C	BC
	EWR 9_Go	D7	giii2	Olifants	J31C	M	C	C
	EWR 10_Go	D7	gv36	Kammanassie	J34D	L	CD	CD
Outeniqua	EWR 1_Out	G15	gvii14	Knysna	K50A	H	B	B
	EWR 2_Out	G15	gviii11	Gouna	K50B	H	AB	AB
	EWR 3_Out	G15	giii10	Diep	K40A	H	B	B
	EWR 4_Out	G15	gvii13	Karatara	K40C	H	B	AB
	GB1	C6	gviii2	Groot-Brak	K20A	H	BC	BC
	Ka1	G15	gvii11	Kaaimans	K30C	VH	B	B
	Mal1	G15	gvii9	Malgas	K30B	H	C	C
	Gouk1	G15	gviii9	Goukamma	K40E	VH	BC	BC
	Gwa1	G15	gviii6	Gwaiing	K30B	H	E	D
	Maa2	G15	gvii8	Maalgate	K30A	H	D	D
	Sw1	G15	gviii7	Swart	K30C	H	D	D
	Si1	G15	gviii8	Silver	K30C	VH	B	B
	Noe1	G15	gviii10	Noetsie	K60G	VH	B	AB
	Var2	C6	gviii12	Varing	K20A	H	CD	CD
	Var3	C6	gviii3	Varing	K20A	H	D	CD
Breede	EWR 1_Br	A1	Nviii1	Breede	H10F	M	DE	D
	EWR 2_Br	A1	Nvii2	Molenaars	H10J	VH	B	B
	EWR 3 (Hex)	A2	Nvii7	Hex	H20G	M	C	C
	EWR 3_Br	A3	Nvii8	Breede	H40F	M	CD	CD
	EWR 6_Br	B4	Niv28	Baviaans	H60E	H	B	B
	EWR 5_Br	B4	Nv9	Riviersonderend	H60F	H	D	D
	EWR 4_Br	F11	Niii4	Breede	H70G	VH	C	BC
	EWR 1 (Palmiet)	B5	Piii1	Palmiet	G40C	H	C	B
	EWR 3 (Palmiet)	B5	Piii2	Palmiet	G40D	VH	C	BC
	EWR 4 (Palmiet)	B5	Piii3	Palmiet	G40D	VH	B	B
Overberg	**Kle1**	**F10**	**Nv23**	**Klein**	**G40K**	**M**	**CD**	**C**
	Nuw1	**H17**	**Ni4**	**Nuwejaars**	**G50B**	**M**	**D**	**D**
	Kar1	**H17**	**Nv24**	**Kars**	**G50E**	**M**	**BC**	**B**

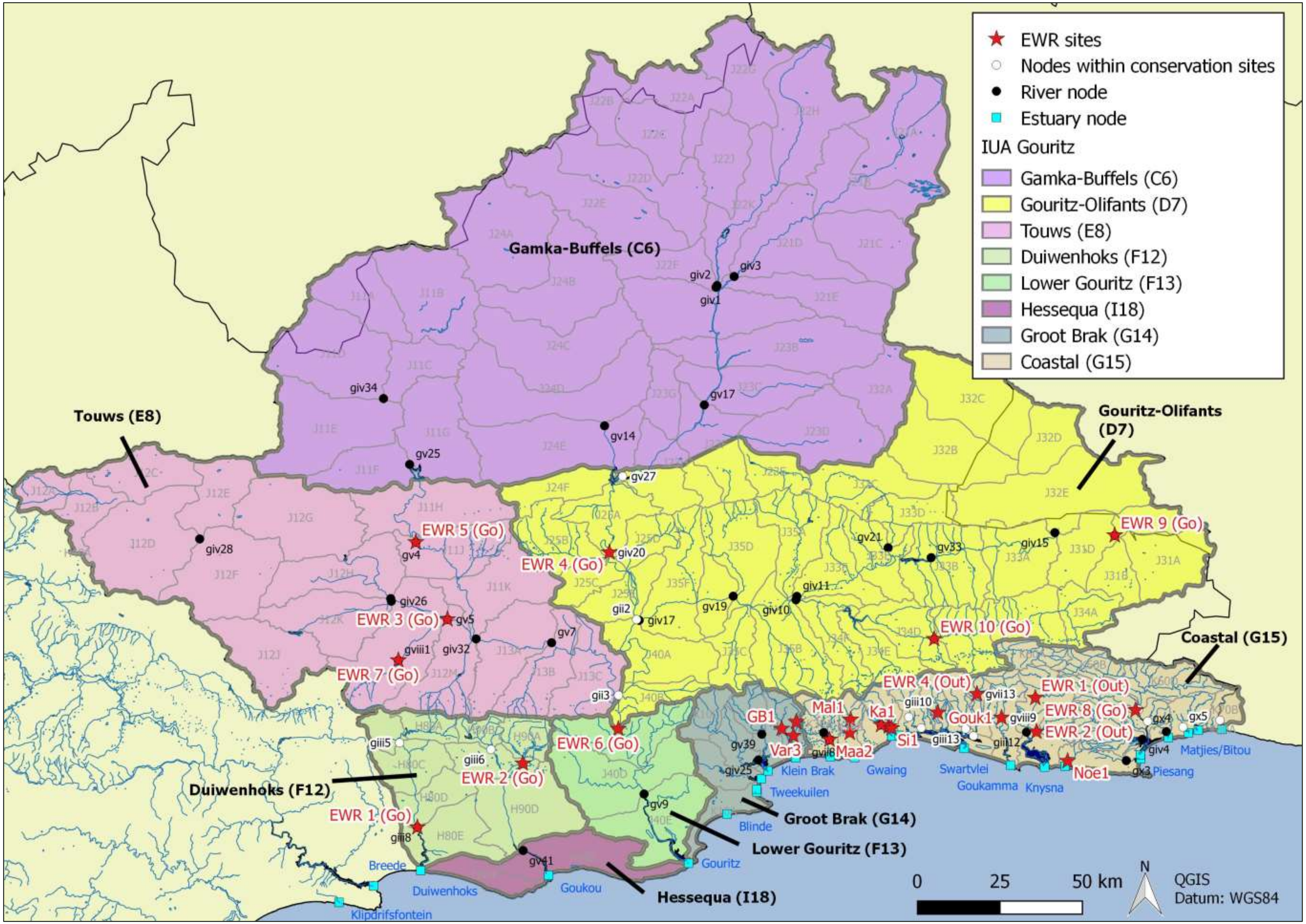

Figure 2.1 **Locations of Gouritz region river/estuary nodes and EWR sites**

Figure 2.2 Locations of Breede-Overberg region river/estuary nodes and EWR sites

2.3 Estuary Nodes and EWR Sites

There are thirty four priority estuary nodes within the Breede-Gouritz WMA. Twenty six of these are significant estuaries (i.e. open water area exceeds 2 ha in extent) and are further subdivided as follows: seven permanently open systems, one estuarine bay (Knysna), four estuarine lakes (Bot, Klein, Wilderness and Swartvlei), 1 temporarily open, 12 temporarily closed estuaries and one river mouth (Bloukrans). The eight remaining estuaries are all micro-estuaries whose open water area does not exceed 2 ha in extent. Reserve studies have been carried out for 19 of the 26 significant estuaries in the Breede-Gouritz WMA as well as for two of the micro-estuaries (i.e. 21 estuaries in total).

Two additional Reserve studies were undertaken as part of this study in order to determine the EWRs for the Onrus and Rooiels estuaries. These included a field visit to each estuary as well as a specialist workshop to determine the PES and REC for each. The details of these additional estuary Reserve studies are given in **Appendix I** and **Appendix J** of this report.

A summary of the approach and results for determining the EWRs for each of the priority estuary nodes is presented in **Section 3.11**. A summary of the final Present Ecological Status (PES) and REC are given in Table 2.2.

Table 2.2 The estuary nodes considered for EWRs in the study area (new sites in bold)

CODE	Estuary	QUAT	PES	REC
gxi1	Gouritz Estuary	J40E	C	B
gxi2	Duiwenhoks Estuary	H80E	B	A
gxi3	Goukou Estuary	H90E	C	B
gxi4	Klein Brak Estuary	K10F	C	C
gxi5	Groot Brak Estuary	K20A	D	C
gxi7	Gwaiing Estuary	K30B	B	C
gxi9	Wilderness Estuary	K30D	B	A
gxi10	Swartvlei Estuary	K40B	B	B
gxi11	Goukamma Estuary	K40E	B	A
gxi12	Knysna Estuary	K50B	B	B
gxi15	Keurbooms Estuary	K60G	A	A
gxi16	Matjies Estuary	K70A	B	B
gxi17	Sout (Oos) Estuary	K70A	A	A
Nxi2	Breede Estuary	H70K	B	B
Nxi9	**Rooiels Estuary**	**G40B**	**B**	**B**
Pxi1	Palmiet Estuary	G40D	C	B
Nxi6	Bot/Kleinmond Estuary	G40G	C	B
Nxi8	**Onrus Estuary**	**G40H**	**E**	**D**
Nxi7	Klein Estuary	G40L	C	B
Nxi5	Uilkraals Estuary	G40M	D	C
Nxi1	**Heuningnes Estuary**	**G50F**	**C**	**A***

*Best attainable state as determined by specialists due to the location within a protected area.

2.4 Groundwater Contribution to Baseflow at River Nodes

Each river node was assessed for GWBF and compared to the provisional EWRs as an indication of the relative importance of GWBF. Nodes with GWBF above 50% are considered to significant dependent on groundwater contribution and are highlighted in green in Table 2.3.

Details of the methodology used to determine the groundwater present status and including the level of stress for individual resource units and groundwater resource units are given in **Section 4**.

2.5 Wetland links to River Nodes

Wetlands receive water inputs from either, or both, surface water and groundwater and as such may be related to the groundwater and surface water EWR assessments. The nodes associated with wetlands are also identified in Table 2.3. It is notable that nodes with a significant contribution to baseflow have Depression or Seep wetlands, which are indicative of the interaction between surface and groundwater.

2.6 Summary of Nodes and EWR Sites

A summary of all river and estuary nodes for the study area are given in Table 2.3. The following is displayed (this colour scheme is also used in further tables in the report):

- The estuary nodes are highlighted in blue.
- The nodes with a significant contribution from groundwater flow are highlighted in green.
- The nodes associated with EWR sites are indicated in **red**.
- The node type and considerations are indicated. This includes a short description of the location of the node as well as whether the node is associated with wetlands or wetlands systems. An extra column is also included indicating whether or not the node overlaps with important conservation plans or management areas.

Table 2.3 Final nodes in the Gouritz River basin and Outeniqua region

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
E8	giv28	J12D	D	U/s confluence Touws Kragga; Channelled valley bottom and Floodplain wetlands; Valley head Seep, Seep and Depression wetlands.	N/A
	giv27	J12H	B	U/s confluence Touws Brak; Channelled valley bottom wetlands; Seep wetlands.	N/A
	giv26	J12K	C	U/s confluence Brak Touws; Channelled valley bottom and floodplain flat wetlands; Valley head Seep, Seep and Depression wetlands.	N/A
	gviii1	**J12L**	**CD**	**EWR 7; Channelled valley bottom wetlands; Seep wetlands.**	N/A
	gv5	J12M	BC	D/s confluence Touws Doring; EWR 3; Channelled valley bottom wetlands; Seep wetlands.	N/A
	gv4	**J11J**	**C**	**EWR5; Channelled and unchannelled valley bottom wetlands**	N/A
	giv32	J11K	D	U/s confluence Groot Touws; Channelled valley bottom wetlands; Seep wetlands.	N/A
	gv7	J13B	C	D/s confluence Groot Huis; Channelled valley bottom wetlands; Seep wetlands.	N/A
	gii3	J13C	B	U/s confluence Groot Gouritz.	N/A
C6	giv34	J11C	B	U/s confluence Buffels Meintjiesplaas; Channelled valley bottom wetlands; Depression wetlands.	N/A
	gv25	J11F	C	Placed u/s of Floriskraal reservoir; Channelled valley bottom wetlands; Depression wetlands.	N/A
	giv3	J21D	B	U/s confluence Gamka Veldmans; Channelled valley bottom wetlands; Depression wetlands.	N/A
	giv1	J22F	C	U/s confluence Koekemoer Leeu; Channelled valley bottom wetlands; Depression wetlands.	N/A
	giv2	J22K	C	U/s confluence Leeu Koekemoer; Channelled valley bottom wetlands; Depression and Valley head Seep wetlands.	N/A
	gv17	J23F	B	D/s confluence Gamka Gedenksteen se leegte; Small channelled valley bottom wetlands; Small seep wetlands.	N/A

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
	gv14	J24E	A	D/s Dwyka Jakkals/Vlakkraal; Channelled valley bottom and flat wetlands; Small seep wetlands.	N/A
D7	gv27	J23J	C	Placed u/s of Gamkapoort reservoir; Channelled valley bottom wetlands.	SWSA, NFEPA Fish1
	giv20	**J25A**	**CD**	**U/s confluence Gamka Kobus; EWR 4; Small channelled/ unchannelled valley bottom and flat wetlands**	**SWSA, NFEPA Fish1**
	gii2	J25E	C	U/s confluence Gamka Olifants/Gouritz; Small channelled/unchannelled valley bottom wetlands; Small valley head seep wetlands.	NFEPA Fish1
	giii2	**J31C**	**C**	**D/s confluence No Name Olifants; EWR 9; Small channelled valley bottom wetlands**	**N/A**
	giv15	J32E	C	U/s confluence Traka Olifants; Small channelled/ unchannelled valley bottom and flat wetlands	N/A
	gv33	J33B	D	Place u/s Stompdrif reservoir; Small channelled/unchannelled valley bottom and flat wetlands	N/A
	gv21	J33E	C	U/s confluence Gamka Kat	N/A
	giv11	J33F	E	U/s confluence Olifants Kammanassie Small channelled/unchannelled valley bottom and flat wetlands; Small valley head seep wetlands.	N/A
	gv36	**J34D**	**CD**	**U/s confluence Kammanassie Gansekraal; EWR 10; Small channelled/unchannelled valley bottom wetlands; Seep wetlands.**	**N/A**
	giv10	J34F	E	U/s confluence Leeu Koekemoer; Small channelled/unchannelled valley bottom and flat wetlands; Small seep wetlands.	N/A
	gv19	J35E	E	D/s confluence Olifants Wynands; Small channelled valley bottom wetlands; Small valley head seep and Depression wetlands.	N/A
	giv17	J35F	D	U/s confluence Olifants Gouritz; Small channelled/unchannelled valley bottom and flat wetlands; Small depression wetlands.	N/A
	gi4	**J40B**	**C**	**Quaternary outlet J40B; EWR 6; Small channelled valley bottom wetlands**	**SWSA, NFEPA Fish1**
F13	gv9	J40E	C	Floodplain flat and channelled valley-bottom wetlands; Hillslope seep wetlands.	N/A
	gxi1	J40E	C	Gouritz Estuary; Floodplain flat and channelled valley-bottom wetlands	N/A
F12	giii5	H80B	E	Floodplain flat and channelled valley-bottom wetlands; Hillslope seep wetlands.	NFEPA Fish 1
	giii8	**H80D**	**D**	**EWR 1; Floodplain flat and channelled valley-bottom wetlands; Hillslope seep wetlands.**	N/A
	gxi2	H80E	B	Duiwenhoks Estuary; Floodplain flat and channelled valley-bottom wetlands	N/A
	giii6	H90C	D	Channelled valley-bottom wetlands; Hillslope seep wetlands.	SWSA
	giii7	**H90C**	**CD**	**D/s confluence Goukou Kruis; EWR 2; Significant groundwater contribution; Channelled valley-bottom wetlands; Hillslope seep wetlands.**	**SWSA, NFEPA Fish1**
I18	gv41	H90E	C	Floodplain flat and channelled valley-bottom wetlands; Hillslope seep wetlands.	N/A
	gxi3	H90E	C	Goukou Estuary; Channelled valley-bottom wetlands	N/A
G14	gxi19	K10A	B	Blinde Estuary; Floodplain flat and channelled valley-bottom wetlands	N/A
	gxi20	K10A	-	Tweekuilen Estuary; Floodplain flat and channelled valley-bottom wetlands	N/A

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
	gxi21	K10A	-	Gericke Estuary; Floodplain flat and channelled valley-bottom wetlands	N/A
	gxi22	K10B	D	Hartenbos Estuary; Channelled valley-bottom wetlands	N/A
	gxi4	K10F	C	Klein Brak Estuary; Channelled valley-bottom wetlands	N/A
	gviii2	K20A	BC	Significant groundwater contribution	N/A
	gviii3	K20A	D	Significant groundwater contribution	N/A
	gvii7	K20A	BC	Gauge K2H002; Hillslope seep wetlands.	N/A
	gxi5	K20A	D	Groot Brak Estuary; Channelled valley-bottom wetlands	N/A
G15	gviii4	K30A	B	Small seep wetlands.	N/A
	gvii8	**K30A**	**D**	**Gauge K3H003; Maa2**	**N/A**
	gvii9	**K30B**	**C**	**Mal1; Gauge K3H004**	**SWSA, NFEPA Fish1**
	gxi6	K30A	B	Maalgate Estuary; Channelled valley-bottom wetlands	N/A
	gviii6	**K30B**	**E**	**Gwa1; Depression wetlands.**	**SWSA, NFEPA Fish1**
	gxi7	K30B	B	Gwaiing Estuary; Channelled valley-bottom and flat wetlands	N/A
	gviii7	**K30C**	**D**	**Sw1; Significant groundwater contribution; Hillslope seep wetlands.**	**N/A**
	gxi8	K30C	B	Kaaimans Estuary; Channelled valley-bottom wetlands	N/A
	gxi9	K30D	B	Wilderness Estuary; Channelled/ unchannelled valley bottom, floodplain and flat wetlands	N/A
	gvii11	**K30C**	**B**	**Ka1; Gauge K3H001**	**SWSA, NFEPA Fish1**
	gviii8	**K30C**	**B**	**Si1**	**SWSA, NFEPA Fish1**
	gvii12	**K30D**	**B**	**Gauge K3H005; Var2**	**SWSA, NFEPA Fish1**
	giii10	**K40A**	**B**	**EWR 3; Significant groundwater contribution**	**N/A**
	giii13	K40B	B	Gauge K4G002	SWSA, NFEPA Fish1
	gviii9	**K40E**	**BC**	**Gouk1**	**SWSA, NFEPA Fish1**
	gvii14	**K50A**	**B**	**Gauge K5H002; EWR 1**	**SWSA**
	gviii11	**K50B**	**AB**	**EWR 2 Outeniqua**	**N/A**
	gviii12		**CD**	**EWR 3 Varing**	
	gvii10	K60G	B		N/A
	giv4	K60F	C	U/s confluence Bitou Keurbooms	N/A
	giv6	**K60C**	**C**	**U/s confluence Keurbooms Palmiet; EWR 8**	**Garden Route National Park**
	giv5	K60D	A	U/s confluence Palmiet Keurbooms	SWSA, NFEPA Fish1, Garden Route National Park
	gx9	K60E	C	D/s confluence Keurbooms Duiwelsgat	Keurboomsrivier Nature Reserve
	gx4	K70A	B	U/s confluence; Significant groundwater contribution	N/A
	gx5	K70A	B	U/s confluence; Significant groundwater contribution	Garden Route National Park
	gvii15	K70B	B	gauge K7H001	SWSA. NFEPA Fish1, Garden Route National Park

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
	gx8	**K30D**	**D**	**DWS reserve; Significant groundwater contribution; Channelled valley bottom and flat wetlands**	**SWSA**
	gvii13	**K40C**	**B**	**EWR 4; Flat wetlands**	N/A
	giii11	K40C	AB	Channelled/ unchannelled valley bottom and flat wetlands	SWSA
	gxi10	K40B	B	Swartvlei Estuary; Floodplain and channelled valley bottom wetlands	N/A
	giii12	K50A	B	Significant groundwater contribution	N/A
	gxi12	K50B	B	Knysna Estuary; Floodplain wetlands	N/A
	gx3	K60G	D	Piesang River EWR site	N/A

Where EWR = Ecological Water Requirement: PES = Present Ecological Status, QUAT = Quaternary Catchment; IBT = Inter Basin Transfer, U/s = upstream; D/s = downstream, SWSA = Strategic Water Source Area; NFEPA = National Freshwater Ecosystem Priority Area

Table 2.4 Final biophysical nodes in the Breede River catchment and Overberg region

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
A1	Niv2	H10C	C	U/s of confluence with Koekedou, Flat wetlands	SWSA
	Niv1	H10C	D	U/s of confluence with Dwars	SWSA, NFEPA Fish1
	Niv3	H10C	C	U/s of confluence with Titus, at gauge H1H016	SWSA
	Niv4	H10D	A	U/s of confluence with Breede	SWSA, Ceres Mountain Fynbos Nature Reserve
	Nvi3	H10D	C	2 km d/s of confluence with Dwars/ Titus	SWSA, Ceres Mountain Fynbos Nature Reserve
	Nvii16	H10E	A	U/s of confluence with Breede, Channelled valley bottom wetlands	SWSA, NFEPA Fish1, Haweqwa Nature Reserve
	Niv5	H10F	A	U/s of confluence with Breede, Channelled valley bottom wetlands	NFEPA Fish1
	Niv6	H10F	D	U/s of confluence with Breede	N/A
	Nviii1	**H10F**	**DE**	**D/s confluence Waboom, EWR 1**	**N/A**
	Niv40	H10J	B	U/s of confluence with Molenaars	SWSA, Haweqwa Nature Reserve
	Niv41	H10J	B	U/s of confluence with Molenaars, Flat wetlands	SWSA, Haweqwa Nature Reserve
	Nvii2	**H10J**	**B**	**At gauging weir H1H018, EWR 2, Channelled valley bottom wetlands**	**SWSA, Haweqwa Nature Reserve**
A2	Niv7	H10G	D	U/s of confluence with Slanghoek, Channelled/unchannelled valley bottom wetlands	SWSA
	Niii1	H10G	D	U/s of confluence with Molenaars (Smalblaar), Floodplain, Flat and Channelled valley bottom wetlands	N/A
	Niv8	H10H	D	U/s of confluence with Breede, Floodplain wetlands	N/A
	Nvii6	H10H	D	At gauging weir H1H020, 7.5 km North of Worcester	SWSA, Matroosberg Mountain Catchment Area

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
	Niv9	H10H	D	U/s of confluence with Breede, Floodplain, Flat, Channelled valley bottom wetlands. Papenkuils wetland.	N/A
	Niv12	H10K	C	Just South of Rawsonville	SWSA
	Nv3	H10L	C	U/s of confluence with Hex (at Brandvlei reservoir), Floodplain wetland	NFEPA Fish2
	Nvii7	**H20G**	**C**	**Gauging weir H2H006, offtake to OverHex u/s, EWR 3; Channelled valley bottom wetlands**	**N/A**
	Niv10	H20H	D	U/s of confluence with Breede, Channelled valley bottom wetlands	NFEPA Fish2
	Nii1	H40C	C	D/s of Hex/Breede confluence, Floodplain wetland	NFEPA Fish2
	Nvii5	H40B	D	At gauging weir H4H008, 2.3 km North of Worcester	
	Niv11	H40C	E	U/s of confluence with Breede	NFEPA Fish2
	Niv15	H40H	D	U/s of confluence with Breede, Floodplain flat wetlands	N/A
A3	Niv42	H10J	E	Just South of Rawsonville, Channelled valley bottom wetlands	SWSA
	Niv13	H40D	E	Gauge, Floodplain flat and Channelled valley bottom wetlands	N/A
	Nvii8	**H40F**	**CD**	**Gauging weir H4H017, EWR 3, pumping scheme agterkliphoogte, Floodplain flat wetland**	**N/A**
	Nvii11	H40G	D	Gauge, Floodplain flat wetland	N/A
	Nvii19	H40J	B	At outlet H40J, for Kogmanskloof et al offtakes IBT	N/A
	Niv14	H40K	D	U/s of confluence with Breede	N/A
	Niv20	H30C	D	Mont Rochelle offtake to Franschhoek, at pump station IBT	N/A
	Nvii9	H30D	D	At outlet H40J, for Kogmanskloof et al offtakes IBT, Floodplain wetland	N/A
	Niv18	H30B	D	U/s of confluence with Kogmanskloof, Channelled valley bottom wetlands	N/A
	Nii2	H30E	D	At gauging weir H3H011, u/s of confluence with Breede, Floodplain flat wetland	N/A
	Ni2	H50B	D	U/s of confluence with Riviersonderend, Floodplain flat wetland	N/A
B4	Nvii10	H60B	B	U/s of Theewaterskloof Dam; Floodplain wetland	SWSA, NFEPA Fish2, Theewaters Nature Reserve
	Nv7	H60D	C	2.5 km u/s of confluence with Meul; Floodplain wetland	N/A
	Niv28	**H60E**	**B**	**U/s confluence Riviersonderend, d/s of EWR 6; Floodplain wetland**	**N/A**
	Niv29	H60E	D	U/s of confluence with Riviersonderend; Floodplain wetland	N/A
	Niv30	H60F	C	U/s of confluence with Riviersonderend; Floodplain wetland	NFEPA Fish2
	Nv9	**H60G**	**D**	**EWR 5**	**N/A**
F9	Ni3	H60L	D	U/s of confluence with Breede	N/A
	Niv31	H60G	D	U/s of confluence with Riviersonderend	N/A
	Niv33	H60H	D	U/s of confluence with Riviersonderend	N/A
	Niv34	H60H	D	U/s of confluence with Riviersonderend; Floodplain wetland	N/A
	Nv10	H60H	D	D/s of confluence with Slang and Lindeshof town	N/A
	Niv35	H60K	E	U/s of confluence with Riviersonderend; Floodplain wetland	N/A
F11	Niv24	H70A	E	U/s of confluence with Riviersonderend; Significant groundwater contribution	N/A
	Nv2	H70B	C		N/A

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
	Niv26	H70J	E	U/s of confluence with Breede; Significant groundwater contribution	N/A
	Nii3	H70D	B	U/s of confluence with Breede; Floodplain wetland	NFEPA Fish1, Langeberg East Mountain Catchment Area
	Niv25	H70F	E	Floodplain wetland	N/A
	Niii4	**H70G**	**C**	**D/s of EWR 4, at Napkei confluence**	**N/A**
	Nxi2	H70K	B	Breede Estuary; Floodplain wetlands	N/A
H16	Nxi9	G40B	B	Rooiels Estuary; Channelled valley bottom wetlands	N/A
	Nxi10	G40B	B	Buffels Oos Estuary; Channelled/Unchannelled valley bottom wetlands	N/A
	Nxi6	G40G	C	Bot/Kleinmond Estuary; Floodplain and Channelled valley bottom wetlands	N/A
	Nxi8	G50H	E	Onrus Estuary; Channelled valley bottom wetlands	N/A
	Nx6	G40H	E	Was in reservoir; Significant groundwater contribution	N/A
	Niii5	G40G	C	Floodplain wetland	N/A
F10	Niv43	G40F	E	Floodplain wetland	N/A
	Niv45	G40K	E	Significant groundwater contribution	N/A
	Nii4	G40J	D	Significant groundwater contribution	N/A
	Nv23	**G40K**	**CD**	**Kle1**	**N/A**
	Nii6	G50H	D	Significant groundwater contribution	N/A
	Nii7	G50H	B		NFEPA Fish2
H17	Nx8	G40M	C		NFEPA Fish2
	Nxi7	G40L	C	Klein Estuary; Floodplain and Channelled/Unchannelled valley bottom wetlands	N/A
	Nxi5	G40M	D	Uilkraals Estuary; Channelled valley bottom wetlands	N/A
	Nxi3	G50A	C	Ratel Estuary; Floodplain, Flat and Channelled valley bottom wetlands	N/A
	Nxi1	G50F	C	Heuningnes Estuary; Floodplain, Flat and Unchannelled valley bottom wetlands	N/A
	Ni4	**G50B**	**D**	**Nuw1; Significant groundwater contribution; Floodplain wetland**	**NFEPA Fish2**
	Nvii15	G50C	D	U/s dam; Floodplain wetland	N/A
	Niv44	G50C	D	Floodplain wetland	N/A
	Nv24	**G50E**	**BC**	**Kar1; Floodplain wetland**	**N/A**
	Nii5	G50C	E	Floodplain wetland	N/A
B5	**Piii1**	**G40C**	**C**	**U/s Eikenhof Dam at EWR 1; Floodplain wetland**	**SWSA, NFEPA Fish1**
	Piv10	G40C	D	U/s of confluence with Palmiet, 0.5km West of R231; Floodplain wetland	SWSA, NFEPA Fish1
	Piv9	G40C	D	U/s of confluence with Klipdrif, 0.5km u/s of R231; Floodplain wetland	SWSA, NFEPA Fish1
	Piv8	G40C	D	U/s of confluence with Palmiet, 0.5km u/s of R231; Floodplain wetland	NFEPA Fish1
	Piv4	G40D	D	U/s of Applethwaite reservoir; Floodplain wetland	SWSA, NFEPA Fish1
	Piv7	G40D	D	U/s of confluence with Palmiet; Floodplain wetland	SWSA
	Piii2	**G40D**	**C**	**At EWR 3; Channelled valley bottom wetlands**	**SWSA, NFEPA Fish1, Kogelberg Nature Reserve**
	Piv12	G40D	C	D/s confluence of Dwars and Louws, =100% MAR; Channelled valley bottom wetlands	SWSA, NFEPA Fish1, Kogelberg Nature Reserve

IUA	Node	Quat	PES	Node Type And Considerations	Conservation considerations
	Piii3	**G40D**	**B**	**Top of estuary. Just below or at EWR4; Channelled valley bottom wetlands**	**SWSA, NFEPA Fish1, Kleinmond Coast and Mountain**
	Pxi1	G40D	C	Palmiet Estuary; Channelled/Unchannelled valley bottom wetlands	N/A

Where EWR = Ecological Water Requirement: PES = Present Ecological Status, QUAT = Quaternary Catchment U/s = upstream; D/s = downstream SWSA = Strategic Water Source Area; NFEPA = National Freshwater Ecosystem Priority Area

3 QUANTIFICATION OF EWRs

3.1 Overview

EWRs were extrapolated from previous Reserve studies at thirty six existing locations in the study area. In addition Rapid Level III Reserve determination studies (quantify only) were undertaken at three additional EWR sites located in the Overberg catchments G40 and G50.

Provisional EWRs were also determined for all other river nodes using the Desktop Reserve Determination model. Where appropriate these were calibrated based on the EWRs for the river Reserve sites.

EWRs were also determined for the twenty six priority estuaries based on previous Reserve studies as well as two additional estuary Reserve studies undertaken for the Onrus and Rooiels estuaries.

The PES and Recommended Ecological Category (REC) were also determined for all river nodes and for the eight priority estuary nodes. These EWRs, PES and RECs for all sites will be used to determine the changes in ecological goods, services and attributes (EGSA) necessary for the analysis of base line and alternative development scenarios as the next step in the classification process.

3.2 Ecological water requirements for rivers

The first step in determining EWRs is to assess whether existing high-confidence Reserve data at established EWR sites is available and can be extrapolated to any of the biophysical nodes established in Step 1d (Section 7.1.2. of DWAF, 2007). This should be followed by an extrapolation procedure based on the outcome of the assessment and where necessary additional studies would be undertaken.

In order to identify which nodes can be extrapolated to, a distinction needs to be made between:

- nodes that are suitable for extrapolation from high-confidence Reserve data; the EWR quantification for those nodes should be based on those data rather than a desktop model (e.g. Hughes and Hannart, 2003); and

- nodes that are not suitable for extrapolation from sites with high-confidence Reserve data; the EWR quantification for those nodes should be based on a desktop model (e.g. Hughes and Hannart, 2003).

Step 3a also has implications for Step 3c, in that changes in some biophysical EGSAs can only be provided:

- at nodes that are suitable for extrapolation from sites with high-confidence Reserve data; and

- for EGSAs that were considered during the Reserve determination process.

The objective of developing flows for different ecological conditions (rule curves, summary tables and modified time series) for the rivers nodes (Step 3b in the WRCS) is to provide hydrological inputs into the analysis of ecological and developmental scenarios, Steps 4 to 6 of the classification procedure (DWAF 2007). Step 3b requires generating the EWRs using the Desktop Model (Hughes and Hannart, 2003) both for nodes identified as not being suitable for extrapolation and those that may be calibrated using flows prescribed from preliminary Reserve determination studies.

In total, 148 river nodes were introduced for the Gouritz sub-area and 114 river nodes for the Breede-Overberg sub-area. For the pragmatic purpose of calculating EWRs and during the scenario analyses, this list of nodes may change based on their necessity and suitability for routing flows through the catchment in a downstream direction, their individual importance to capture flows required at estuaries and also their usefulness in being used to describe and represent the locations of the points of interest in the future development scenarios. During the scenario analyses, nodes may be added, their locations changed or deleted as required.

3.2.1 Conceptual framework

In considering the ecological flow requirements at each river node it is useful to understand the linkages between flow and ecological condition as flow in a river has a direct influence on riverine biota (Naiman *et al.* 2005). Key principles are summarised in the Natural Flow Regime paradigm (Poff *et al.* 1997), which included much of the environmental flow theory upon which methods for determining environmental flows (and Reserve assessments) have been based. The guiding principle of the Natural Flow Regime paradigm is that the integrity of flowing ecosystems depends largely upon their natural dynamic character (Poff *et al.* 1997). The natural flow regime varies over time-scales from hours and days, to seasons and years, and flow is considered the 'master variable' that dictates the abundance and distribution of riverine species (Resh *et al.* 1998). Components of the flow regime are described in terms of magnitude, frequency, duration, timing and rate of change of flow. These characterise the range of river flows from floods to low flows, each of which is critical for different species in some way (Poff *et al.* 1997).

Surface flow in rivers ultimately derives from precipitation but, at any given time, may comprise a combination of surface runoff, soil water and groundwater (Viddon and Hill 2004). Climate, geology, topography, soils and vegetation all play a role in water supply and the path that flow may take (Gurnell, 1997). Variability in intensity, timing and duration of precipitation combined with the effects of soil texture, topography and plant evapotranspiration contribute to locally- and regionally-variable flow patterns (Poff and Ward 1989). Generalisations about hydrological properties, between headwater streams and lowland rivers for example, should be made with caution, since natural flow characteristics are highly variable across river catchments in response to properties such as climate, geology and topography (Naiman *et al.* 2008).

Rivers are dynamic and the relative dominance of species changes from river source to river mouth. Areas of broadly similar physical habitat contain broadly similar communities, but the species composition and density at any one site is affected by changes in sediment moisture, nutrient status and topography (Van Coller, 1992); the frequency and intensity of droughts and floods, fire, plant disease and grazing, biogeographical distributions (Naiman *et al.* 2005); and species interactions (Francis, 2006).

Methods for assessing and monitoring river health and environmental flow requirements of rivers are based on assumptions about how changes to a natural flow regime affect the structure and functioning of an aquatic ecosystem. In many environmental flow studies the assessment of river health forms an integral component of the establishment of baseline conditions against which future states are monitored.

3.2.1.1 Environmental Flow Requirements in South Africa

Environmental flows describe the pattern of flows (magnitude, timing, frequency, duration, variability and quality) of water required to sustain freshwater and estuarine ecosystems and the livelihoods of subsistence users that depend on these ecosystems (Hirji and Davis 2009). Identifying flow components; such as the range of low flows in the dry and wet seasons; the size, numbers and timing of small floods; the size and timing of large floods, and; the temporal characteristics of the flow regime; and understanding the consequences of their loss, to the ecosystem under investigation, is central to a flow assessment (King *et al.* 2003).

Work on environmental flows began in the 1940s in western United States with simple hydrological approaches to determine minimum flows, usually at an annual, seasonal or monthly basis, for some ecological feature of a river ecosystem (Gordon *et al.* 1992). Further developments in the 1970s focussed on quantifying the relationship between the quantity and quality of an aquatic resource, such as seasonal changes in the distribution of flow-related fish habitat required for passage and spawning, with discharge (Tharme, 2003).

Since then, two approaches to flow assessments have developed (Brown and King, 2006):

1. *Prescriptive*, in which flows are described to achieve a narrow and specific objective; and
2. *Interactive*, which focus on changes in river flow and one or more aspects of the river to provide a range of options for river condition.

In South Africa, initial work in the 1990s led to the development of the Building Block Methodology (BBM) (King and Louw, 1998), a *prescriptive* approach that formed the basis of the determination of the Ecological Reserve in the South African NWA (Act 36 of 1998) (King and Pienaar, 2008). The BBM method was abandoned as the outcome did not lend itself to negotiation between water users nor provide sufficient information about the implications of not meeting the recommended values. Since then, two other interactive and holistic methods (Arthington, 1998) are in use in South Africa, DRIFT (Downstream Response to Instream Flow Transformation, King *et al* 2003) and the Flow Stressor-Response method (Hughes and Louw, 2010). Both incorporate assessments of changes in a range of biophysical disciplines, such as hydrology, hydraulics, fluvial geomorphology, sedimentology, chemistry, botany and zoology; and socio-economic disciplines where there are subsistence users, such as sociology, anthropology, water supply, public health, livestock health and resource economics (King *et al.* 2003). The consequences of flow changes to aquatic ecosystems are predicted by understanding how flow influences aquatic organisms and aquatic habitat, based on assumptions about responses, for example when thinking about riparian vegetation; extreme floods reset physical river and riparian habitat (Naiman *et al.* 2008); medium floods flush riparian vegetation from the channel and small floods recharge groundwater for shallow rooted species (Naiman *et al.* 2000); normal low flows maintain the wet bank community (Boucher 2002); and drought lows enable recruitment and purge invasive riparian and aquatic species (Naiman *et al.* 2000).

Many of these assumptions remain hypotheses to be tested, which requires empirical data collected with this purpose in mind.

Environmental flows were recognised as the foundation of integrated water-resources management (King and Pienaar, 2011) during the writing of the NWA, which stipulated that water must be secured as a basic water supply to satisfy basic human needs and to protect aquatic ecosystems sustainably during water resource development (NWA ,1998). These two components were collectively called the Reserve and are stipulated in terms of quantity and quality of water required (King and Pienaar, 2011). Determination of the Ecological Reserve for a water resource follows an eight step procedure (DWAF, 1999) the main outcomes of which are as follows:

- the study area is delineated in terms of significant biophysical features;
- the present condition is determined;
- the EWRs are calculated, using either the DRIFT or Flow Stressor-Response methods, and;
- the consequences of different operational scenarios determined on the available water resources (King and Pienaar, 2011).

The results are presented to the Department of Water Affairs Directorate: Resource Directed Measures who make a decision on the condition of the water resources that are to be maintained and then sign off on these preliminary Reserves, which are legally binding and represent water quality and quantity parameters that must be adhered to.

Most Reserves determined thus far are preliminary as they have been completed without consideration of catchment-wide water issues. This is because development and testing of the WRCS (Brown *et al.* 2007), designed to address this issue, has lagged behind that of the Reserve determination procedures. The WRCS addresses the economic, social and ecological implications of various permutations of managing the catchment-wide water resources in one of three classes; minimally, moderately and heavily used. The water resource class is set for integrated units of analysis throughout the catchment. In this way, the WRCS establishes the boundaries of the volume, distribution and timing of the water needed for ecosystem maintenance for that river resource unit, and the amount of water potentially available for off-stream use.

The next step is to calculate the RQOs (DWA, 2011), which are the requirements for agreed water quantity, quality, and the associated habitat and biotic integrity to maintain the agreed conditions. RQOs are defined in terms of EcoSpecification (EcoSpec), descriptors of the ecosystem and Thresholds of Potential Concern, points along a continuum of change for each EcoSpec, which may highlight the need for some action in response to a measured change in one of the indicators. RQOs include both ecological requirements and user requirements. EcoSpecs are recognised for major ecosystem components, including hydrology, geomorphology, water quality, riparian vegetation, macroinvertebrates and fish. The final step in this process is implementation of the Reserve flows and any other mitigation measures as well as establishing a monitoring programme to monitor the EcoSpecs.

3.2.2 Ecological Condition of Rivers

Kleynhans (1996) and his later research have been the primary sources for the assessment of aquatic ecosystem conditions for the last 20 years and this has been based largely on calculating a condition score, relative to a hypothetical reference condition. In the table below, percentage scores are decreased relative to natural for increasingly degraded river conditions, A to F. It is important to note that the condition assessments using this table include both flow- and non-flow-related impacts on the condition. It follows that translating flow estimates using these ecological conditions scores, as is the norm, requires specifying whether the conditions predicted to change will do so as a result of changes in flow and/or in response to non-flow-related changes, or both.

Table 3.1 Ecological categories, scores and descriptions (adapted from Kleynhans, 1996)

Ecological Category	PES % Score	Description of the habitat
A A/B	92-100% 87-92%	Still in a Reference Condition.
B B/C	82-87% 77-82%	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
C C/D	62-77% 57-62%	Moderately modified from the Reference Condition. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D D/E	42-57% 37-42%	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E E/F	22-37% 17-22	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-17%	Critically/Extremely modified from the Reference Condition. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

In general there are few A and B category rivers in the Western Cape, these generally being restricted to the upper reaches of tributaries (mountain streams) that are usually not cultivated, due to being situated in narrow valleys with limited or with no floodplain development. Similarly, and for the same reasons, there are a dearth of foothill and lowland river reaches in good condition (A or B category) since the floodplains and wetlands situated here are usually targeted for agricultural or urban development. For this reason, the condition of such foothill and lowland rivers tends to be at best C, but generally are in a D-F category, depending upon the extent to which water is abstracted (zero dry season flow in most cases), the riparian area is transformed (e.g. cleared of indigenous vegetation and cultivated) and the channel disturbed (e.g. bulldozed to facilitate transfer of flood flows downstream).

The basis for the latter is much the same logic that is applied when designing canals, shown as the category F River. Looking at the rivers we can make some generalisations about the composition of rivers at different ecological conditions. In the generic descriptions that follow, the general principle is that diversity (of flow, sediment texture, channel shape and sinuosity, the size, shape and number of different kinds of riparian plants present, and other aquatic biota) reflects better conditions, whereas homogeneity reflects poorer conditions. Also the descriptions below are for perennial rivers only; the situation for seasonal and non-perennial rivers is less well documented and less obviously (visually) descriptive.

Characteristics of rivers with different ecological categories:

- **A** or a **B** category rivers:
  - Generally has flowing water that is clean and free of odour, indicating no water quality problems at the site.
  - Normally a range of substratum particles present (boulders, cobbles and gravels higher up; gravels, sands and muds lower down the system) that are distributed across and along the river channel in pockets with similarly-sized particles forming clumps.
  - Aquatic plants may or may not be present. These are more frequently present lower down in the river system, as they tend to be scoured out higher up where flows carry more energy.
  - The riparian area normally comprises a range of different flexible and evergreen growth forms (grasses, reeds, restios, sedges, algae, small pioneering trees) in the marginal area of the channel *viz.* adjacent to the low flow water's edge. This area is often called the wet bank and is where flow (water) is available to plants most of the year.
  - There normally is an obviously different plant layer higher up the bank, called the dry bank, where woodier and larger plants (normally shrubs and trees but also grasses, reeds and restios) may be found. These plants tend to be inundated by the larger floods that recur inter-annually.
  - Since there is a diversity of different aquatic habitats (represented by the range of sediment particles of different sizes and the presence of aquatic and marginal vegetation, as well as flow being present at different velocities) the abundance and diversity of aquatic organisms should be high (macroinvertebrates, crustaceans, fish) but so also should be the presence of birds and other riparian or terrestrial fauna that visit the river and/or riparian area.

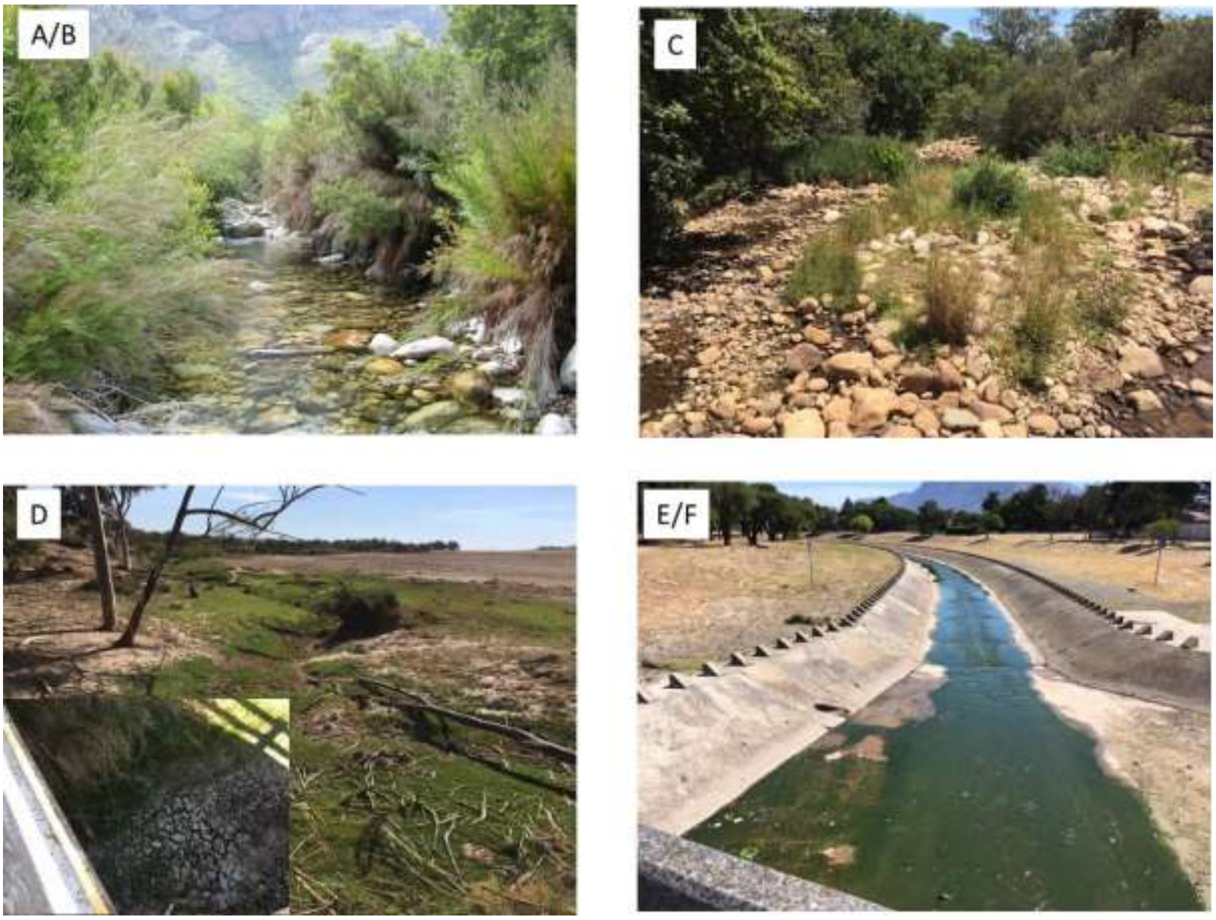

Figure 3.1 Examples of rivers in different ecological conditions, A to F

- **C** category river:
    - Normally has water present but this may not necessarily be flowing during the dry season; it may be that standing pools are present or that flow is barely perceptible.
    - The water present is normally NOT polluted, it may be clear or slightly opaque but would not have an obvious odour (and/or the presence of over-growing algae feeding off an oversupply of nutrients from agricultural runoff that normally carries fertilisers, or cow dung or sewage releases).
    - The diversity of different sediment particles is reduced, due to changes in flow that have taken place. Either low flows or intra-annual floods are reduced and thus the sorting of aquatic sediments is reduced, or there has been collection or mining of these sediments.
    - The channel shape may be less sinuous and/or the channel bank may be less diverse in slope and form, often due to the trapping of sediments and floods upstream in reservoirs.
    - There normally are riparian plants present, but the ratio of indigenous to exotic plants now may be lower, *viz.* there are more exotic plants present.
    - So too may be the variety of growth forms and sizes of plants present. There should however be some variety of plants present, exotic or indigenous, and there should still be an obvious separation of the wet from the dry bank - still normally represented by flexible green specimens lower down on the wet bank and dry woody specimens higher up on the dry bank. It could be that this situation is reversed, and woody plants dominate the wet bank while herbaceous plants dominate the dry bank.
    - Since the diversity of habitat is somewhat compromised, one would expect there to be a lesser abundance of aquatic biota for some or other reason. It could be that water quality is impaired, or flows are compromised, or exotic plants or fish are present. Whatever the case, C category rivers have one or other component either missing or in a degraded state that is countered by the others still in relatively good condition.
- **D** category river:
    - Normally one where the stratification or types, be that of flows, sediment textures, plants or biota, are normally at a reduced abundance but mostly that a diversity of types is no longer present.
    - There may be a handful of aquatic organisms present and there may only be exotic and no indigenous fish.
    - There may be no flow in the dry season and the only flows to pass are the intra-annual floods.
    - It could be that there is a strong odour of sewage/agricultural pollutants present, be there water or not, that indicates an unnatural oversupply of nutrients.
    - This monoculture of type, typical of rivers in a D category, offers little diversity of habitat to aquatic biota.
- **E/F** category river:
    - Monoculture type in the extreme.
    - A canal is shown in that represents a void of variety or shape. It could also be that a natural river is channelized, meaning that it is straightened, cleared of vegetation, and bulldozed into a geometric shape that offers little resistance to flow.
    - These types of channels tend to end up being comprised entirely of one sediment type, cobbles if higher up, and sand/mud if lower down.
    - Also, rivers in this final and degraded condition tend to be kept up in this way for the purposes of flood conveyance. This means that they are cleared or cleaned out each autumn prior to the onset of floods, which bring with them sediments, plant propagules and

organisms that get washed downstream and would settle in eventually if given reprieve from the clean-out.

3.2.3 Calculating Ecological Water Requirements for rivers

The desktop Reserve model of Hughes and Münster (2000) was used to generate EWR estimates for the biophysical nodes identified in the study area. The results of the desktop model were calibrated using the results from past EWR assessments. The assurance rules together with the time series of natural flows per node were used to construct representative time series of EWR requirements. These DRAFT EWRs are available electronically but remain under consideration as adjustments are likely to be required as flows are routed and scenarios analysed. The final EWRs will be written and made available in the templates when final considerations and adjustments are concluded.

A short summary of the model is provided below (unless otherwise indicated, taken from Hughes and Hannart (2003)):

- The Desktop Model is based on the assumption that total water requirements for a river decrease as the ecological category changes from A through to D.
- The model consists of three components;
  - estimation of the maintenance/drought and high/low flows,
  - estimation of the seasonal distribution of annual total flows based upon the natural flow regime separated into high/low flows, and
  - estimation of the rules that combine the maintenance/drought requirements into continuous assurance frequency curves.
- The final output is a table of flows for each month of the year for a range of percentage assurances. The flows are expressed as volumes (m^3x10^6) or as mean monthly discharge (m^3/s).
- The frequency component of the estimated flows is based upon the assumption that drier areas with more variable flows have substantially greater maintenance flows but with lower levels of assurance. The numerical rules in the model that describe this function are set such that the maximum low flow value is a scaling factor, which varies with ecological category, such that lower categories have higher maximum values. These standardised settings for this maximum low flow value that increases from ecological category B through D created some problems with the validity of estimated (extrapolated) monthly flows.
- At sites where there was no existing EWR data in close enough proximity to justify extrapolation of EWR data, a generic desktop run, with either Western Cape wet or Western Cape dry selected (depending on location) was performed. All the data generated in this way produced valid comparative monthly flows between different ecological categories using the standard assurance level settings in the desktop for classes B through D. The problem described above with the assurance levels resulted in the generation of invalid data at some of the nodes that made use of extrapolated EWR data, where flows in some months exceeded those occurring naturally. Therefore, these were adjusted downwards to resolve this anomaly.
- The EWR data for each node comprise the following data: a summary of the desktop estimate (*.tab), the assurance table (*.rul) and the finally the time series of monthly flows (*.mrv) for each determined ecological category. In most cases there are data for three ecological categories, B through D. There are some instances where other categories were determined, for example a BC or CD and other cases where only one or two classes were determined. With water availability being limited in general, it is expected that there will be few opportunities to meet the existing Reserve requirements and fewer to improving ecological conditions by providing more flow beyond these.

- This will be determined during the analyses undertaken to produce the Ecological Bottom line Configuration Scenario[1], which will be written into the next report.

3.3 Previous Reserve Studies and Determined EWRs

The presentation of EWR data for rivers follows in two parts:

1. SUMMARY OF EWR SITE DATA

   Due to the data being represented directly from the preliminary Reserve studies, a small summary table is presented for each EWR site with relevant information for this study.

2. SUMMARY OF EXISTING DATA

   Section 3.4 to Section 3.11 summarises data directly from the preliminary Reserve studies themselves. Different modelling methods were used to calculate EWRs in different studies therefore results are inherently different and cannot be presented in the same way.

   The data were used to calculate calibration settings for extrapolating these Reserve data to the Reserve sites themselves, since the hydrology of many of the nodes has been updated since the studies were concluded, but also to other nodes.

3. INTERPRETATION OF EXISTING DATA

   Data derived from the data is presented in Section 3.12 that follow.

Information on the Gouritz River catchment and the Outeniqua region can be found in Section 3.4. Information on the Breede River catchment, the Palmiet River catchment and the Hex River catchment are contained in Section 3.5. The main studies that provided EWR related data to calibrate river flows were:

- Gouritz River catchment and in the Outeniqua region:
  - The Intermediate and Rapid Reserve determination studies for the Gouritz River catchment (DWS 2014, DWS 2015) where Reserves were calculated for five rapid and five intermediate river EWR sites.
  - The Intermediate and Rapid Outeniqua Ecological Water Requirements study (DWAF 2009, DWAF 2010) where Reserves were calculated for eight intermediate and eight rapid river EWR sites.
- Breede River catchment:
  - The Intermediate Reserve determination study for the Breede River catchment (DWAF 2003) that calculated Reserve requirements for six river sites,
  - the Palmiet River instream flow assessment study (DWA 2000) that calculated Reserve requirements for four river sites, and
  - The Intermediate Reserve determination study for the Hex River (2002) that calculated Reserve requirements for three river sites.

The Western Cape Water Supply System (WCWSS) study synthesized the Reserve work previously undertaken in the study area including the extrapolated of EWR data to 63 nodes throughout the Breede River catchment (DWA 2012a) and to 10 nodes in the Palmiet River catchment (DWA 2012b) for different ecological conditions using all the available Reserve-related data described above (adjusted and refined as needed).

[1] In this project, the ESBC is taken to be the minimum BOTTOM LINE, an ecological category D, which is applied to nodes across the catchment and adjusted so that flows routed downstream meet, or maintain the estuaries in a D ecological category.

These determinations were considered suitable for the purposes of generating EWR estimates for the Breede and Palmiet River catchments, as part of the WCWSS study (DWA 2012c). The calibrations used during that study remain applicable going forward, given that there have been no notable developments in the catchments but were re-calculated as the hydrology was updated for this project.

A summary description of the following existing EWR sites in the study area is provided below.

- **Gouritz River catchment**:
  EWR3, EWR4, EWR5, EWR6, EWR8 (Intermediate: Gouritz study)
  EWR1, EWR2, EWR7, EWR9, EWR10 (Rapid: Gouritz study)
- **Outeniqua region**:
  EWR 3, EWR 4, EWR5, EWR 6, EWR8 (Groot Brak study)
  EWR 1, EWR 2, EWR 7, EWR9, EWR 10 (Knysna study)
- **Breede region**:
  EWR1, EWR2, EWR3, EWR4, EWR5, EWR6 (Breede)
  EWR1, EWR3, EWR4 (Palmiet)
- **Overberg region**:
  Kle1, Nuw1, Kar1

3.4 Existing River EWRs in the Gouritz Catchment

A summary of the EcoStatus, natural Mean Annual Runoff (nMAR), present day Mean Annual Runoff (pMAR), and long-term average annual flow requirements of the five Intermediate EWR sites in the Gouritz Catchment are summarised in Table 3.2.

Table 3.2 Summary table of Intermediate EWRs for Gouritz River catchment

Characteristics				Long term mean					
Site	EcoStatus	nMAR (million m^3/a [1])	pMAR[2] (million m^3/a)	Low flows (million m^3/a)	Low flows (%)	High flows (million m^3/a)	High flows (%)	Total flows (million m^3/a)	Total (%)
J1TOUW-EWR3	Instream: C	45.20	22.26	1.15	2.6	11.54	25.6	12.69	28.2
J2GAMK-EWR4	PES: C/D	85.54	61.69	3.94	4.6	17.44	20.4	21.38	25.0
J1BUFF-EWR5	PES; REC: C	29.31	18.67	1.37	4.7	6.85	23.3	8.22	28.0
J4GOUR-EWR6	PES; REC: C	543.52	310.35	27.12	5.0	102.47	18.8	129.59	23.8
K6KEUR-EWR8	Instream PES: C	49.81	30.45	10.66	21.4	8.66	17.4	19.32	38.8
	Instream REC: B			13.93	28.0	9.27	18.6	23.30	46.7

A summary of the EcoStatus, nMAR, pMAR, and long-term average annual flow requirements of the five Rapid EWR sites are summarised in Table 3.3.

Table 3.3 Summary table of Rapid EWRs for Gouritz River catchment

Characteristics				Long-term mean					
EWR site	EcoStatus	nMAR (million m^3/a)	pMAR (million m^3/a)	Low flows (million m^3/a)	Low flows (%nMAR)	High flows (million m^3/a)	High flows (%nMAR)	Total flows (million m^3/a)	TOTAL (%nMAR)
H8DUIW-EWR1	PES; REC: D	83.7	79.8	14.2	17	8.2	10.2	22.7	27.1

Characteristics				Long-term mean					
EWR site	**EcoStatus**	**nMAR (million m^3/a)**	**pMAR (million m^3/a)**	**Low flows (million m^3/a)**	**Low flows (%nMAR)**	**High flows (million m^3/a)**	**High flows (%nMAR)**	**Total flows (million m^3/a)**	**TOTAL (%nMAR)**
H9GOUK-EWR2	PES; REC: C/D	54.1	46	7.1	13.1	4.3	13.9	11.4	21
J1DORI-EWR7	PES; REC: C/D	4.52	2.01	0.386	8.5	0.644	14.3	1.03	22.8
J3OLIF-EWR9	PES; REC: C	13.76	11.32	0.54	3.9	3.05	22.2	3.59	26.1
J3KAMM-EWR10	PES; REC: C/D	20.6	19.6	1.8	8.9	2.8	13.5	4.6	21

A short description of the flows and conditions at each site are given below, along with the motivations for the determination of the PES and the REC. The flows prescribed at each site are also tabulated.

3.4.1 F12 Duiwenhoks River - EWR1_Go

Site	IUA	River	PES	EIS	REC
EWR 1_Go	F12	Duiwenhoks	D	LOW	D

The nMAR was 83.67 million cubic metres per annum (million m^3/a) and the pMAR was 79.8 million m^3/a (95.4% of the nMAR). There was a small difference (less than 5%) in MAR between the observed and present day flow. The impact of development was shown on the low flows. The baseflow volumes decreased significantly in volume but not in seasonal distribution and appeared to be continuous throughout the year. Base flows decreased mainly due to dams, afforestation, irrigation, grazing and domestic water use. No changes in seasonality were observed for low flows and moderate and large floods have decreased.

The PES was a D. The major issues that caused the change from reference condition were mainly flow and some non-flow related issues. Abstraction decreased base flows and possibly created zero flows at times. Irrigation return flows resulted in elevated nutrients and salinity and an overall deterioration in water quality. Alien invasive vegetation and agricultural practices in the riparian zones led to bank modification and instability in the reach while alien fish species were present.

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability thereof. As the EIS was LOW, no improvement was required. The REC was therefore set to maintain the PES. No Alternate Ecological Category[2] (AEC) was assessed as the instream components were already in a D EC. As there was a level of correlation between the instream REC and the riparian vegetation REC, the flows were set to maintain the REC EcoStatus of a D EC.

The wettest and driest months were identified as October and February respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow).

Flood requirements (inter-annual floods) are indicated in Table 3.4, with Table 3.5 indicating low and high flow requirements.

[2] Alternative Ecological Categories (AECs) may eiher be one category up or one category down from the PES

Table 3.4 Flood requirements EWR1 Duiwenhoks River - D

Flood class (Peak in m³/s)	Flood requirements*	Months	Daily ave.	Duration (days)
CLASS I (3 – 5)	3	June, March, October	2.7	3
CLASS II (16 - 20)	1	August	13	5
CLASS III (28)	1:2	September or November	21	6
CLASS IV (40)	1:3	October	30	8

Table 3.5 Summary table low and high flows EWR1 Duiwenhoks River - D

Month	Low flows			High flows (m³/s)	
	Drought (90%) (m³/s)	60% (m³/s)	50% (m³/s)	Daily average (m³/s)	Duration (days)
October	0.391	0.573	0.666	2.7; 30 (1:3)*	3; 8
November	0.340	0.531	0.650		
December	0.143	0.342	0.432		
January	0.016	0.166	0.243		
February	0.009	0.131	0.203		
March	0.037	0.205	0.293	2.7	3
April	0.052	0.240	0.334		
May	0.094	0.269	0.368		
June	0.120	0.302	0.393	2.7	3
July	0.174	0.356	0.453		
August	0.297	0.452	0.535	13	5
September	0.337	0.504	0.590	21 (1:2)	6

3.4.2 F12 Goukou River – EWR2_Go

Site	IUA	River	PES	EIS	REC
EWR 2_Go	F12	Goukou	C/D	MOD	C/D

The nMAR was 54.1 million m³/a and the pMAR was 46.04 million m³/a (85.8% of the nMAR). There was a small difference in MAR between the observed and present day flow. The observed and present flows both showed that zero flows occur. The observed record is from the late 1960's up to date and land-use practices have changed little during this period. Baseflows have decreased significantly in volume with flows during the summer months (Nov to Mar) showing a larger decrease than the flows in winter. Natural seasonal distribution had changed and the reduction in flow volume was more during the summer months.

This was mainly due to farm dams, afforestation, irrigation; grazing and domestic water use. Moderate and large floods have decreased.

The PES was a C/D. The major issues that had caused the change from reference condition were mainly flow and some non-flow related. Abstraction and upstream farm dams had resulted in decreased base flows and zero flows at times. The cumulative effects of agriculture and return flows, e.g. elevated nutrients, salts and some toxicity had resulted in deteriorated water quality. Alien invasive vegetation and agriculture in the riparian zones had led to bank modification and instability in the reach. Alien fish species were present. Wood was also being removed from the riparian zones.

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was MODERATE, no improvement was required. The REC was therefore set to maintain the PES. No AEC was set as the instream components were already in a D EC. Both the instream REC and the riparian vegetation REC was impacted on by flows as well as anthropogenic impacts. The EWRs was therefore set to maintain the REC EcoStatus of a C/D EC.

The wettest and driest months were identified as October and July, respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow).

Flood requirements (inter-annual floods) are indicated in Table 3.6, with Table 3.7 indicating low and high flow requirements.

Table 3.6 Flood requirements EWR2 Goukou River - CD

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
CLASS I (2)	3	September, October, February	2.6	3
CLASS II (6.8)	2	September, January	6	4
CLASS III (10.8)	1	October, November	9	5
CLASS IV (19.2)	1:3 – 1:5	May	15.2	6

Table 3.7 Summary table low and high flows Goukou River - CD

Month	Low flows			High flows (m3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.000	0.252	0.315	2.6; 9	3; 5
November	0.000	0.250	0.313	9	5
December	0.000	0.000	0.068		
January	0.000	0.000	0.000	6	4
February	0.000	0.000	0.061	2.6	3
March	0.000	0.210	0.273		
April	0.054	0.213	0.282		
May	0.058	0.194	0.259	15.2 (1:3–1:5)*	5
June	0.043	0.191	0.245		
July	0.067	0.181	0.225		

Month	Low flows			High flows (m3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
August	0.075	0.229	0.274		
September	0.077	0.236	0.268	2.6; 6	3; 4

3.4.3 E8 Touws River - EWR3_Go

Site	IUA	River	PES	EIS	REC
EWR 3_Go	E8	Touws	B/C	HIGH	B/C

The hydrological modelling indicated that the site was perennial under natural conditions. Present day conditions, however, were characterised by very short periods of wet season base flows, interspersed with periods of no flow. The site therefore had present day flow characteristics that are ephemeral to seasonal. The nMAR was 45.02 million m^3/a, and the pMAR was 22.26 million m^3/a (49.4% of the nMAR). The observed record was only accurate for low flows. There was good correspondence between the low flows of the observed and simulated present day flow records since 80% of the flows in both records had flows lower than 0.5 million m^3/month. A large change in the seasonal variation of flow from natural to present day was evident. Under natural conditions the average monthly peak flow occurred in April/May but the peak flow had shifted to July under present day conditions. The monthly seasonal distribution changed dramatically from natural to present day with reduced baseflows during the summer months as a result of storage and controlled releases from Floriskraal Dam as well as the impact of smaller farm dams, irrigation, grazing and domestic water use. It was evident that the natural flows had been changed dramatically in terms of volume, with the pMAR only half of the nMAR and also in terms of the seasonal characteristics of the flow regime.

The PES was a B/C. The major causes of the change were mainly flow related. Farm dams and irrigation had resulted in reduced base flows and small floods, which also influenced the duration of the seasons (longer dry and shorter wet seasons). Deteriorated water quality was due to elevated nutrient loads. Alien plant species were present.

The REC was determined based on ecological criteria only and considered the EIS and the restoration potential of the site. The EIS was HIGH and, according to the Reserve study policy, the REC should be set to improve the PES. However there is uncertainty in what aspects were needed to improve the site as the impacts and the causes were not well understood and known at the time. It was likely that some of the ratings for the PES should have been higher, which would have resulted in a B EC. In light of this uncertainty and that improvement would have required an increase in base flows and small floods, which cannot be supplied without additional infrastructure or restrictions of allocation, the PES was set to maintain the REC.

The wettest and driest months were identified as May and February, respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow).

Flood requirements (inter-annual floods) are indicated in Table 3.8, with Table 3.9 indicating low and high flow requirements.

Table 3.8 Flood requirements EWR 3 Touws River - BC

Flood class (Peak in m³/s)	Flood requirements*	Months	Daily ave.	Duration (days)
CLASS I (2 - 4)	2	September – November	3.6	6
CLASS II (7 - 10)	1	April – August	8.3	3
CLASS III (30)	1	May – June	23	3.54
CLASS IV (70 - 90)	1:3		50	5
CLASS V (>120)	1:5		82	6

Table 3.9 Summary table low and high flows EWR 3 Touws River - BC

Month	Low Flows			High Flows (m³/s)	
	Drought (90%) (m³/s)	60% (m³/s)	50% (m³/s)	Daily average (m³/s)	Duration (days)
October	0.000	0.005	0.015		
November	0.000	0.006	0.014	3.6	6
December	0.000	0.005	0.013		
January	0.000	0.004	0.005		
February	0.000	0.000	0.000		
March	0.000	0.003	0.004		
April	0.000	0.003	0.009		
May	0.000	0.009	0.023	23	3.54
June	0.000	0.007	0.016		
July	0.000	0.006	0.016	8.3	3
August	0.000	0.006	0.017		
September	0.000	0.005	0.010	3.6	6

3.4.4 D7 Gamka River - EWR4_Go

Site	IUA	River	PES	EIS	REC
EWR 4_Go	D7	Gamka	C/D	HIGH	C

The site was situated in Gamkapoort downstream of the bridge. There were three upstream dams; two of which supply Beaufort West with domestic water and Gamkapoort Dam upstream of the site which supported domestic water requirements and irrigation downstream. The river was therefore used as a conduit to supply downstream users. The manner of operation was pulsed flow releases with no other releases from the dam apart from a constant leak and spills. The Gamkapoort Dam is located upstream of the site. It has a capacity of 36 million m³ and was built in 1967. The nMAR was 85.54 million m³/a and the pMAR was 61.69 million m^3/a (72.1% of the nMAR). There were no major differences between the observed hydrology and modelled present day hydrology, but the monthly flows obscured the current flow regime, which comprised intermittent flood releases from the dam (one approximately every two months) and only leakage in-between. This means that artificial floods were being released through the year, i.e. unseasonably.

The PES was a C/D. The major issues resulting in the change from reference condition were the alteration in sediment regime due to the upstream impoundment, the small regular and unseasonal floods being released from the Gamkapoort Dam, and the decreased frequency of large floods. Key non-flow-related impacts include the presence of alien vegetation species and predation and competition from alien and non-indigenous fish species.

The REC was determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS was HIGH, improvement was required. The REC was therefore set to improve the PES from a C/D to a C. Improvement required an improved flooding regime. Acknowledging the current operating rules and possible constraints, the following recommendations were made.

A 50 m^3/s flood was required once a year during the wet season. Furthermore, during the wet season the current events should be released in a different fashion, i.e. the receding limb shape should change to be a more natural hydrograph shape. These changes, even with the winter unseasonal floods, should result in the improvement in category. Further improvement could be achieved if the unseasonal releases during the dry season were minimised. These improvements were predicted to allow successful spawning of fish species in this river reach that utilised these high flows to access suitable habitats for spawning during summer (September to March). These spawning habitats included riffle areas, as well as newly inundated marginal vegetation. Spawning usually takes place on the receding limb of the hydrograph, after the flood peak so a gently sloping receding limb of the hydrograph over at least 4 to 5 days would be required to prevent the stranding and drying out of newly laid eggs.

The instream and riparian vegetation REC were impacted by flow reductions and other anthropogenic impacts. The EWRs were set to maintain the PES of a C/D. Improvement to the REC requires different operating rules using the same volume as being released currently. Setting an EWR for an improved state will not be required as the low flows and the volume of released floods will stay the same. The distribution and shape of released floods will however change according to the recommendations made. Only descriptive requirements are provided.

The wettest and driest months were identified as March and July. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow). The monthly modelled flows obscured the current flow regime, which comprises intermittent flood releases from the dam (one approximately every two months) and only leakage in-between. To achieve the REC, the operating rules for the flood releases must be revised.

Flood requirements (inter-annual floods) are indicated in Table 3.10, with Table 3.11 indicating low and high flow requirements.

Table 3.10 Flood requirements for EWR 4 Gamka River – C and CD

Flood class (Peak in m^3/s)	**Flood requirements***	**Months**	**Daily ave.**	**Duration (days)**
PES: C/D				
CLASS I (1.7)	5	September – December for fish	1.6	6
CLASS II (5)	4	October – April (earlier rather than later within this period for fish)	4.4	6
CLASS III (10 - 20)	2	December – April	16	4
CLASS IV (50)	1:3	March	37	5

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
CLASS V (>120)	1:5		82	7
REC: C				
CLASS I (1.7)	6	September	1.6	6
CLASS II (5)	4	October - April	4.4	6
CLASS III (10 - 20)	2	December - April	16	4
CLASS IV (50)	1	March	37	5
CLASS V (>120)	1		82	7

Table 3.11 Summary table of low and high flows EWR 4 Gamka River - C and CD

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.014	0.060	0.077	1.6	6
November	0.014	0.065	0.096	1.6 4.4	6 6
December	0.013	0.068	0.105	1.6 16	6 4
January	0.011	0.057	0.093	4.4	6
February	0.011	0.066	0.107	4.4	6
March	0.024	0.129	0.195	16	4
April	0.017	0.103	0.158	4.4	6
May	0.018	0.065	0.088		
June	0.015	0.047	0.066		
July	0.010	0.046	0.065		
August	0.012	0.049	0.063		
September	0.012	0.043	0.069	1.6	6

3.4.5 E8 Buffels River - EWR5_Go

Site	IUA	River	PES	EIS	REC
EWR 5_Go	E8	Buffels	C	MOD	C

The main dam in the Buffels River was the Floriskraal Dam (with a capacity of 50 million m^3) in the Buffels River at the outlet of J11G. The catchment area upstream of this dam was typical Karoo with very little development. Some irrigation (9 million m^3/a) was practised downstream of this dam. The catchment was stressed as a result of irrigation demands exceeding supply. The EWR site was situated about 20 km downstream of Floriskraal Dam on a private reserve at Wagendrift Lodge. There was extensive irrigation downstream of Floriskraal Dam. Flood releases (not pulsed) were being made irregularly based on requirements to supply downstream users. The nMAR was 29.31 million m^3/a and the pMAR was 18.67 million m^3/a (63.7% of the nMAR) at a distance from Floriskraal Dam. The flow contribution of the in-between catchment was very small relative to the larger catchment. Between March and September, baseflows had decreased significantly from natural which affected the seasonal distribution of the flow regime. This was mainly due to Floriskraal Dam and regulated irrigation releases. The dam and releases had also impacted on the frequency of floods and had resulted in decreased flood volumes and frequency.

The PES was a C. The major causes of the change were mainly flow related, and included decreased baseflows and reduced flood frequencies. The seasonal distribution of baseflow was greatly affected between March and September showing significantly decreased flows from natural. Poor water quality, higher water temperatures and woody vegetation encroachment also contributed to the PES.

The REC was determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS was MODERATE, no improvement was required. The REC was therefore set to attain the PES. No AEC was set due to limited release options from Floriskraal Dam. Both the instream REC and the riparian vegetation REC were impacted by flows and therefore the EWRs are set to maintain an REC of a C.

The wettest and driest months were identified as April and September. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 50% exceedance (flow). No reliable gauge was present to verify high flows as the EWR site is downstream of Floriskraal Dam.

Flood requirements (inter-annual floods) are indicated in Table 3.12, with Table 3.13 indicating low and high flow requirements.

Table 3.12 Flood requirements EWR 5 Buffels River - C

Flood class (Peak in m^3/s)	**Flood requirements***	**Months**	**Daily ave.**	**Duration (days)**
Class I (3)	2	October – February	2.7	5
Class II (10)	2	September – January	8.3	5
Class III (30)	1:3	March	30	7
Class IV (150)	1:3	Winter months (macroinvertebrates)	101	8

Table 3.13 Summary table of low and high flows EWR 5 Buffels River - C

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.000	0.016	0.027	2.7	5
November	0.000	0.016	0.031	2.7 8.3	5 5
December	0.000	0.016	0.031	2.7	5
January	0.000	0.013	0.028	2.7	5
February	0.000	0.013	0.025	2.7	5
March	0.000	0.016	0.033	30	7
April	0.000	0.021	0.040		
May	0.000	0.022	0.045		
June	0.000	0.026	0.046	101	8
July	0.000	0.021	0.044		
August	0.000	0.023	0.042		
September	0.001	0.022	0.030	8.3	5

3.4.6 D7 Gouritz River - EWR6_Go

Site	IUA	River	PES	EIS	REC
EWR 6_Go	D7	Gouritz	C	MOD	C

The EWR site was downstream of the confluence with the Buffels (Groot) River. It was situated just upstream of a gorge in the Langeberg Mountains. The site was situated quite far upstream from the gauging weir J2H002 which had a rated section. Although extremely inaccurate for low flows, the flow regime showed that this area was prone to very low flows in the dry season and very large floods in the wet season. The nMAR was 543.52 million m^3/a and the pMAR was 310.35 million m^3/a (57.1% of the nMAR). The hydrology at this point was a culmination of all the J catchments' confidence issues. The gauge close to the site was extremely inaccurate in terms of low flows. Flood flow measurements were also unreliable due to lack of calibration. J4H002 was used to verify high flows although it must be noted that the data record has many gaps and the gauge is a rated alluvial section downstream of the site. The period 1990 to date was used.

The Gouritz River was short compared to the extensive upstream catchments with the Olifants, Gamka, Buffalo and Touws rivers. J2 and J3 were extensively impacted by flow related activities. Localised impacts in the Gouritz River consisted of irrigation of mainly lucerne and pastures on the banks of the Gouritz River. Various farm dams were found in the Lower Gouritz River.

The REC was determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS was MODERATE, no improvement were required. The REC was therefore set to maintain the PES. No AEC was set. Both the instream REC and the riparian vegetation REC were impacted on by flows as well as anthropogenic impacts. The EWRs were set to maintain the REC of a C.

Flood requirements (inter-annual floods) are indicated in Table 3.14, with Table 3.15 indicating low and high flow requirements.

Table 3.14 Flood requirements EWR6 Gouritz River - C

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
Class I (8 - 16)	5	October - May (fish early spring)	12.8	5
Class II (25 - 30)	2	October - December	23	6
Class III (50 - 60)	3	March - April	43	7
Class IV (350)	1:3		219	9
Class V (>700)	1:3		415	10

Table 3.15 Summary table low and high flows EWR 6 Gouritz River - C

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.386	0.793	1.123	12.8 23	5 6
November	0.326	0.787	1.043	12.8	5
December	0.326	0.701	0.925	12.8 23	5 6
January	0.292	0.594	0.736	12.8	5
February	0.276	0.490	0.735	12.8	5
March	0.318	0.693	0.907	43	7
April	0.202	0.682	0.900	43	7
May	0.327	0.647	0.833	43	7
June	0.334	0.632	0.852		
July	0.329	0.688	0.872		
August	0.644	0.715	0.903		
September	0.582	0.722	0.933		

3.4.7 E8 Doring River – EWR7_Go

Site	IUA	River	PES	EIS	REC
EWR 7_Go	E8	Doring	C/D	LOW	C/D

The nMAR was 4.52 million m³/a and the pMAR was 2.01 million m³/a (44.4% of the nMAR). There were no available observed data. Baseflows had decreased significantly in volume due to Tierpoort Dam, farms dams, irrigation, and grazing. Decreased flow appeared to be continuous throughout the year. The seasonal distribution had changed with peak flows now in March instead of May. Distribution of monthly flows was flattened throughout the year. Note that there was low confidence in the hydrology but there was however substantial anecdotal evidence that the river had stopped flowing and that some pools had even dried up in recent years.

The PES was a C/D. The major issues that had caused the changed were flow and non-flow related issues. Abstraction and upstream dams as well as flow diversions had resulted in decreased base flows and zero flows at times. Deterioration in water quality was mainly due to agricultural return flows. Alien invasive vegetation occurred in the lower and upper zones. Alien fish species were also present. Clearing and overgrazing as well as catchment erosion also contributed to bank and bed modification.

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was LOW, no improvement was required. The REC was therefore set to maintain the PES. No AEC was set as the Macroinvertebrates were already in a D category. As there is a correlation between the instream REC and the riparian vegetation REC, the flows will be set to maintain the REC EcoStatus of a C/D EC.

The wettest and driest months were identified as April and July respectively. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow).

Flood requirements (inter-annual floods) are indicated in Table 3.16, with Table 3.17 indicating low and high flow requirements.

Table 3.16 Flood requirements EWR7 Doring River - CD

Flood class (Peak in m³/s)	Flood requirements*	Months	Daily ave.	Duration (days)
Class I (0.41)	2	October, November, January	0.4	2
Class II (0.84)	1	Spring/Summer	0.8	3
Class III (2.1)	1:2	Spring/Summer	2	3.5
Class IV (7.2)	1:5	Spring/Summer	6.1	5

Table 3.17 Summary table low and high flows EWR7 Doring River - CD

Month	Low Flows			High Flows (m³/s)	
	Drought (90%) (m³/s)	60% (m³/s)	50% (m³/s)	Daily average (m³/s)	Duration (days)
October	0.000	0.007	0.010	0.4	2
November	0.000	0.007	0.013	0.4	2

Month	Low Flows			High Flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
December	0.000	0.007	0.011	6.1 (1:5)	5
January	0.000	0.005	0.007	0.4	2
February	0.000	0.005	0.006		
March	0.000	0.006	0.009	2 (1:2)1	3.5
April	0.000	0.007	0.010	0.8	3
May	0.000	0.006	0.010		
June	0.000	0.004	0.008		
July	0.000	0.004	0.006		
August	0.001	0.005	0.007		
September	0.000	0.005	0.007		

3.4.8 G15 Keurbooms - EWR8_Go

Site	IUA	River	PES	EIS	REC
EWR 8_Go	G15	Keurbooms	C	HIGH	BC

The area surrounding EWR site 8 is dominated by forestry and irrigated agriculture. There were no gauging weirs near the EWR site. The river was perennial with low flows being impacted on by forestry and abstraction. An upstream and downstream gauge were been used to demonstrate the flow variability and perenniality that was very different from the drier systems dealt with in the rest of the Gouritz.

The nMAR was 49.81 million m^3/a and the pMAR was 30.45 million m^3/a (61% of the nMAR). Baseflows had decreased from natural to present day in volume with insignificant changes to the overall monthly distribution of flows. Most of the changes in flow occurred in the intermediate to high flow ranges. Baseflows were not significantly impacted.

The PES was a C. Non flow-related impacts were the major cause for the PES and included the high occurrence of alien species (plantation species that encroach on the natural habitat) as well as vegetation clearing. Reduced baseflows, flood frequencies and deteriorated water quality during the dry season were the main flow-related impacts.

The REC was determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS was HIGH, improvement was required. The REC was therefore set to improve the PES of a C to a BC but this required alien vegetation to be cleared and an improvement in baseflows. The wettest and driest months were identified as September and February. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow).

Flood requirements (inter-annual floods) are indicated in Table 3.18, with Table 3.19 and Table 3.20 indicating low and high flow requirements.

Table 3.18 Flood requirements EWR 8 Keurbooms River - C

Flood class (Peak in m³/s)	Flood requirements*	Months	Daily ave.	Duration (days)
PES and REC				
Class I (2 - 4)	4	May – November (September – December for fish)	4	5
Class II (10 - 20)	1	August/September (September/October for fish)	16	6
Class III (50 - 90)	1:3		63	7
Class IV (> 100)	1:5		69	8

Table 3.19 Summary table low and high flows EWR 8 Keurbooms River C

Month	Low flows (m³/s)			High flows	
	Drought (90%) (m³/s)	60% (m³/s)	50% (m³/s)	Daily average (m³/s)	Duration (days)
October	0.252	0.405	0.520	4	5
November	0.256	0.368	0.459		
December	0.146	0.279	0.355		
January	0.090	0.175	0.240		
February	0.074	0.137	0.170		
March	0.083	0.146	0.190		
April	0.091	0.162	0.210		
May	0.104	0.193	0.254	4	5
June	0.111	0.213	0.276		
July	0.144	0.262	0.345		
August	0.171	0.316	0.432	4	5
September	0.190	0.370	0.520	4 16	5 6

Table 3.20 Summary table EWR 8 Keurbooms River - BC

Month	Low flows (m³/s)			High flows	
	Drought (90%) (m³/s)	60% (m³/s)	50% (m³/s)	Daily average (m³/s)	Duration (days)
Oct	0.287	0.514	0.685	4	5
Nov	0.285	0.467	0.604		

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
Dec	0.166	0.356	0.467		
Jan	0.102	0.220	0.318		
Feb	0.083	0.170	0.227		
Mar	0.094	0.183	0.253		
Apr	0.103	0.204	0.279		
May	0.117	0.244	0.336	4	5
Jun	0.126	0.270	0.365		
Jul	0.164	0.334	0.453		
Aug	0.196	0.405	0.563	4	5
Sep	0.218	0.476	0.604	4 16	5 6

3.4.9 D7 Olifants River – EWR9_Go

Site	IUA	River	PES	EIS	REC
EWR 9_Go	D7	Olifants	C	MOD	C

The nMAR was 13.76 million m^3/a and the pMAR was 11.32 million m^3/a (82.3% of the nMAR). Baseflows had decreased from natural although timing and distribution remained the same. These changes seemed continuous throughout the year due to irrigation and farm dams.

The PES was a C. The major issues were both flow and non-flow related. Baseflows and moderate flood frequencies had decreased due to abstraction for irrigation while water quality had deteriorated especially when flows were low leading to high temperatures and low oxygen rates. Overgrazing also occurred in the riparian zone leading to bank modification and decreased longitudinal connectivity.

The REC was determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS was MODERATE, no improvement was required so the REC was set to maintain the PES. Both the instream REC and the riparian vegetation REC were impacted on by flows and anthropogenic impacts. The EWRs were set to maintain the REC of a C.

Flood requirements (inter-annual floods) are indicated in Table 3.21, with Table 3.22 indicating low and high flow requirements.

Table 3.21 Flood requirements EWR9 Olifants River - C

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
PES				
Class I (2.8)	1	March - April	2.3	3
Class II (10 - 15)	1:3	March - April	6.8	5
Class III (>50	1:10	March - April	37	6

Table 3.22 Summary table low and high flows EWR9 Olifants River - C

Month	Low Flows (m^3/s)		High Flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.000	0.000		
November	0.000	0.000		
December	0.000	0.000	2.3	3
January	0.000	0.000	6.8	5
February	0.000	0.000		
March	0.000	0.000		
April	0.000	0.000		
May	0.000	0.000		
June	0.000	0.000		
July	0.000	0.000		
August	0.000	0.000		
September	0.000	0.000		

3.4.10 D7 Kammanassie River - EWR10_Go

Site	IUA	River	PES	EIS	REC
EWR 10_Go	D7	Kammanassie	C/D	LOW	C/D

The nMAR was 20.57 million m^3/a and the pMAR was 19.63 million m^3/a (95.4% of the nMAR). No observed flow record was available. Inflow at Kammanassie Dam (J3R001) was measured downstream of the EWR site. Inflows at dams were not a good indication of low flow. Baseflows had decreased significantly from natural and these changes seemed continuous; the river was often dry. Although the modelled natural hydrology indicated natural perenniality, it is likely that the river could have stopped flowing during droughts.

Changes in present hydrology were mainly due to farm dams, irrigation along the river and livestock watering. Seasonality had not changed.

The PES was a C/D. The major issues were flow and non-flow related. Irrigation return flows, abstraction and farm dams had resulted in decreased base flows with zero flows at times. Intensive farming impacted on water quality through irrigation return flows. Elevated sediment inputs reduced pool depths and degraded the substrate for biota. Alien vegetation occurred in the upper riparian zone whereas the indigenous *C. textillis* (Flat Sedge) had encroached significantly into the channel. This was possibly due to nutrient enrichment from consistent agricultural return flows. Alien fish were also present.

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was LOW, no improvement was required. The REC was therefore set to maintain the PES. No AEC was set as the instream condition was already in a D. Both the instream REC and the riparian vegetation REC were impacted on by flows as well as anthropogenic impacts. The EWRs were therefore the REC C/D.

Flood requirements (inter-annual floods) are indicated in Table 3.23, with Table 3.24 indicating low and high flow requirements.

Table 3.23 Flood requirements EWR10 Kammanassie River - CD

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
Class I (0.7)	3	October, November, February	0.7	3
Class II (3)	2	July	3	4
Class III (7.5)	1	Mid-Summer	6.4	5
Class IV (10)	1:3	Late Summer	8.3	6

Table 3.24 Summary table low and high flows EWR10 Kammanassie - CD

Month	Low flows			High flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.009	0.052	0.081	0.7	3
November	0.009	0.052	0.083	0.7	3
December	0.013	0.048	0.061		
January	0.003	0.027	0.047	6.4	5
February	0.000	0.020	0.037	0.7	3
March	0.002	0.022	0.034	8.3 (1:3)1	6
April	0.000	0.021	0.035		
May	0.002	0.022	0.040		
June	0.003	0.025	0.046		
July	0.007	0.034	0.058	3	4

Month	Low flows			High flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
August	0.012	0.049	0.071		
September	0.015	0.054	0.068		

3.5 Existing River EWRs in the Outeniqua Catchment

The EcoStatus and long-term average annual flow requirements of the four Intermediate EWR sites in the Knysna River Study are summarised in Table 3.25. Those of the Groot Brak River study are summarised thereafter in Table 3.26. A summary of the EcoClassification results for the Groot Brak is also in Table 3.26.

Table 3.25 Annual estimates for Knysna River Study EWRs

EWR site	Ecological condition	Maintenance low flows (%MAR)	Drought low flows (%MAR)	High flows (%MAR)	Long term mean (%MAR)
Knysna River – EWR1	B PES/REC	23.52	8.07	9.32	33.1
	C AEC	13.69	80.7	6.4	23.3
Gouna River – EWR2	A/B PES/REC	43.87	5.2	10.32	46.5
	B/C AEC	31.89	5.2	7.36	35.7
Diep River – EWR3	B PES/REC	21.7	3.23	8.55	26.9
	C AEC	12.97	3.23	4.54	17.7
Karatara River – EWR4	A/B PES/REC	27.9	4.68	13.19	36.4
	B/C AEC	16.94	4.68	10.39	26

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e., ≥ 1:2 year return period[3]). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using the Desktop, the DRIFT volumes in Table 3.26 are reported both including and excluding the volumes of the ≥ 1:2 year return period flood. Similarly, DRIFT long-term averages include ≥ 1:2 year return period floods, while the Desktop results do not. Thus, they are not directly comparable.

Table 3.26 Annual Reserve estimates for Groot Brak River Study EWRs

River	Site	Portion of the EWR	PES	EIS	REC	Method/ Calculation Notation	Million m^3/a	%nMAR	Million m^3/a	%nMAR
							(incl. ≥ 1:2 year floods)		(excluding ≥ 1:2 year floods[4])	
Groot Brak	GB 1	MAINTENANCE TOTAL (Volume)	B/C	H	B/C	DRIFT Annual[5]		54%	**6.3**	**34%**

[3] Previously all inter-annual floods were excluded in the reported volume, but recent studies have started to include floods with a 1:2 year return period, i.e., Komati Basin EWR Study.
[4] For comparison with Desktop results.
[5] Calculated as the volume of water required to meet the full requirements.

River	Site	Portion of the EWR	PES	EIS	REC	Method/ Calculation Notation	Million m^3/a	%nMAR	Million m^3/a	%nMAR
							(incl. ≥ 1:2 year floods)		(excluding ≥ 1:2 year floods[4])	
						Long-term average[6]	5.5	30%		
Malgas	Mal 1	MAINTENANCE TOTAL (Volume)	C	H	C	DRIFT Annual	5.4	50%	**3.8**	**35%**
						Long-term average	3.5	31%		
Kaaimans	Ka 1	MAINTENANCE TOTAL (Volume)	B	VH	B	DRIFT Annual	8.5	63%	**6.5**	**48%**
						Long-term average	6.7	50%		
Goukamma	Gou 1	MAINTENANCE TOTAL (Volume)	B/C	VH	B/C	DRIFT Annual	14.1	53%	**9.6**	**36%**
						Long-term average	12.4	47%		
Gwaiing	Gwa 1	MAINTENANCE TOTAL (Volume)	E	H	D	Calibrated Desktop			**2.7**	**16%**
Maalgate	Maa 2	MAINTENANCE TOTAL (Volume)	D	H	D	Calibrated Desktop			**5.6**	**16%**
Moeras	Moe 1	MAINTENANCE TOTAL (Volume)	D	H	D	**Maa 2 site was used for the Reserve determination site**				
Swart	Sw 1	MAINTENANCE TOTAL (Volume)	D	H	D	Calibrated Desktop			**1.8**	**14%**
Silver	Si 1	MAINTENANCE TOTAL (Volume)	B	VH	B	Calibrated Desktop			**3.2**	**40%**
Noetsie	Noe 1	MAINTENANCE TOTAL (Volume)	B	VH	A/B	Calibrated Desktop			**3.8**	**60%**
Moordkuil	Moo 1	MAINTENANCE TOTAL (Volume)	D	H	B/C	Rapid III			**8.9**	**26.2%**

[6]Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

Table 3.27 Summary table of Groot Brak River Study EWRs

River	EWR Site	Quat. Catchment	PES	EIS	REC	AEC 1	AEC 2	Level of determination
Groot Brak	GB 1	K20A	B/C	HIGH	B/C	C	B	Intermediate
Kaaimans	Ka 1	K30C	B	VERY HIGH	B	C	A/B	Intermediate
Malgas	Mal 1	K30B	C	HIGH	C	D	None	Intermediate
Goukamma	Gou 1	K40E	B/C	VERY HIGH	B/C	C	None	Intermediate
Gwaiing	Gwa 1	K30B	E	HIGH	D	None	None	Rapid II
Maalgate	Maa 1 and Maa 2	K30A	D	HIGH	D	C	None	Rapid II
Moeras	Moe 1	K30A	D	HIGH	D	C	None	
	Moe 2		C	HIGH	C	D	None	
Swart	Sw 1	K30C	D	HIGH	D	None	None	Rapid II
Silver	Si 1	K30C	B	VERY HIGH	B	C	None	Rapid II
Noetsie	Noe 1	K60G	B	VERY HIGH	A/B	B	C	Rapid I
Moordkuil	Moo 1	K10F	D	HIGH	B/C	C	None	Review Rapid III

It is important to note that the Desktop requires specification of flood flows for a particular month. If the flood does not occur in the specified month, then the long-term average will exclude that flood, even if it occurs early in the following month. In reality, floods for EWRs are recommended for a suite of months. This makes the chances of the flood actually occurring higher, which makes the long-term average higher. This should be taken into consideration when modelling EWR requirements for water resource developments and/or management, and when reviewing these results. Also, the Desktop Model does not include floods with a return period of two years or greater, and these are required if these rivers are to be maintained in their target conditions.

Table 3.28 Annual estimates for Knysna River Study EWRs

EWR site	Ecological condition	Maintenance low flows (%MAR)	Drought low flows (%MAR)	High flows (%MAR)	Long term mean (%MAR)
Knysna River – EWR1	B PES/REC	23.52	8.07	9.32	33.1
	C AEC	13.69	80.7	6.4	23.3
Gouna River – EWR2	A/B PES/REC	43.87	5.2	10.32	46.5
	B/C AEC	31.89	5.2	7.36	35.7
Diep River – EWR3	B PES/REC	21.7	3.23	8.55	26.9
	C AEC	12.97	3.23	4.54	17.7
Karatara River – EWR4	A/B PES/REC	27.9	4.68	13.19	36.4
	B/C AEC	16.94	4.68	10.39	26

A summary of the ecological conditions at the Knysna River EWR sites is provided followed by a summary of the flood requirements and low and high flows respectively for each site in turn.

3.5.1 G15 Knysna River – EWR1_Out

Site	IUA	River	PES	EIS	AEC	REC
EWR 1_Out	G15	Knysna	B	HIGH	C	B

Table 3.29 Flood requirements Knysna River EWR1 – B and C

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
PES and REC Scenario : B				
CLASS I (1 – 2)	4	Oct, Nov, Mar, Apr	0.5	2
CLASS II (2 - 6)	2	Feb, Mar	2	3
CLASS III (7 - 12)	2	Apr, Oct	4	3
CLASS IV (12-18)	1	Nov	6	4
CLASS V (22- 45)	1:2			
CLASS VI (>50)	1:5 or >			
AEC down SCENARIO: C				
CLASS I (1 – 2)	4	Nov, Dec, Feb, Mar	0.5	2
CLASS II (2 - 6)	2	Dec, Feb	2	3
CLASS III (7 - 12)	2	Feb	4	3
CLASS IV (12-18)	1	Jan	6	4
CLASS V (22- 45)	1:2			
CLASS VI (>50)	1:5 or >			

Table 3.30 Summary table high and low flows Knysna River EWR1 - B

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.333	0.126	0.5 4	2 3	4 2
November	0.333	0.125	0.5 6	2 4	4 1
December	0.265	0.095			
January	0.212	0.071			
February	0.221	0.073	2	3	2

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
March	0.214	0.072	0.5 2	2 3	4 2
April	0.221	0.074	0.5 4	2 3	4 2
May	0.231	0.080			
June	0.224	0.062			
July	0.230	0.063			
August	0.281	0.097			
September	0.323	0.120			

Table 3.31 Summary table high and low flows Knysna River EWR1 - C

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.192	0.126			
November	0.192	0.125	0.5 6	2 4	4 1:2
December	0.154	0.095	0.5 2	2 3	4 2
January	0.125	0.071	6	4	1
February	0.130	0.073	20.5 2 4	2 3 3	4 2 2
March	0.125	0.072	0.5	2	4
April	0.130	0.074	4	3	1
May	0.135	0.080			
June	0.131	0.062			
July	0.134	0.063			
August	0.163	0.097			
September	0.187	0.120	2	3	1

3.5.2 G15 Gouna River – EWR2_Out

Site	IUA	River	PES	EIS	AEC	REC
EWR 2_Out	G15	Gouna	A/B	HIGH	B/C	A/B

Table 3.32 Flood requirements Gouna River EWR2 - AB and BC

Flood class (Peak in m³/s)	**Flood requirements***	**Months**	**Daily ave.**	**Duration (days)**
PES and REC Scenario : A/B				
CLASS I (1 – 3)	4	Sep, Nov, Mar, Apr	0.5	2
CLASS II (5 - 10)	2	Oct, Apr	2	3
CLASS III (10 - 12)	1	Mar	4	3
CLASS IV (15 - 20)	1	Nov	6	4
CLASS V (20 - 45)	1:2 – 1:3			
CLASS VI (50 – 60)	1:5			
AEC down SCENARIO: B/C				
CLASS I (1 – 3)	3	Sep, Nov, Apr	0.5	2
CLASS II (5 - 10)	1	Oct	2	3
CLASS III (10 - 12)	1	Mar	4	3
CLASS IV (15 - 20)	1	Nov	6	4
CLASS V (20 - 45)	1:2			
CLASS VI (50 – 60)	1:5 or >			

Table 3.33 Summary table high and low flows Gouna River EWR2 AB

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.489	0.072	2	3	2
November	0.466	0.070	0.5 6	2 4	4 1
December	0.346	0.045			
January	0.264	0.020			
February	0.260	0.020			
March	0.258	0.040	0.5 4	2 3	4 1
April	0.274	0.045	0.5 2	2 3	4 2
May	0.305	0.040			
June	0.307	0.020			
July	0.324	0.020			
August	0.408	0.040			
September	0.483	0.060	0.5	2	4

Table 3.34 Summary table Gouna River EWR2 - BC

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.489	0.072	2	3	2
November	0.466	0.070	0.5 6	2 4	4 1
December	0.346	0.045			
January	0.264	0.020			
February	0.260	0.020			
March	0.258	0.040	0.5 4	2 3	4 1
April	0.274	0.045	0.5 2	2 3	4 2

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
May	0.305	0.040			
June	0.307	0.020			
July	0.324	0.020			
August	0.408	0.040			
September	0.483	0.060	0.5	2	4

3.5.3 G15 Diep River – EWR3_Out

Site	IUA	River	PES	EIS	AEC	REC
EWR 3_Out	G15	Diep	B	HIGH	B/C	B

Table 3.35 Flood requirements Diep River EWR3 – B and C

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
PES and REC Scenario : B				
CLASS I (0.1 – 1)	4	Oct, Nov, Jan, Mar	0.2	2
CLASS II (1 - 2)	2	Nov, Apr	1	2
CLASS III (3 - 8)	1	Oct, Mar	3	3
CLASS IV (12 - 20)	1:3			
CLASS V (25 - 40)	1:4 – 1:5			
CLASS VI (>60)	1:5 >			
AEC down SCENARIO: C				
CLASS I (0.1 – 1)	4	Nov, Mar	0.2	2
CLASS II (1 - 2)	2	Nov	1	2
CLASS III (3 - 8)	1	Oct	3	3
CLASS IV (12 - 20)	1:3			
CLASS V (25 - 40)	1:4 – 1:5			
CLASS VI (>60)	1:5 >			

Table 3.36 Summary table high and low flows Diep River EWR3 - B

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.140	0.022	0.2 3	2 3	4 1
November	0.150	0.022	0.2 1	2 2	4 2
December	0.100	0.010			
January	0.076	0.010	0.2	2	4
February	0.081	0.009			
March	0.087	0.020	0.2 3	2 3	4 1
April	0.087	0.020	1	2	2
May	0.085	0.012			
June	0.077	0.007			
July	0.073	0.007			
August	0.090	0.012			
September	0.110	0.021			

Table 3.37 Summary table high and low flows Diep River EWR3 - C

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.064	0.022	3	3	1:3
November	0.067	0.022	0.2 1	2 2	2 1
December	0.055	0.010			
January	0.055	0.010			
February	0.055	0.009			
March	0.060	0.020	0.2	2	2
April	0.056	0.020			
May	0.055	0.012			
June	0.055	0.007			

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
July	0.055	0.007			
August	0.053	0.012			
September	0.061	0.021			

3.5.4 G15 Karatara River – EWR4_Out

Site	IUA	River	PES	EIS	AEC	REC
EWR 4_Out	G15	Karatara	B	HIGH	B/C	A/B

Table 3.38 Flood requirements Karatara River EWR4 – AB and BC

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
PES and REC Scenario : A/B				
CLASS I (0.3 – 0.5)	5	Oct, Nov, Jan, Mar, Apr	0.2	2
CLASS II (1 - 4)	3	Nov,Mar, Sep	1.5	3
CLASS III (6 - 10)	1:2	Oct	2.5	3
CLASS IV (10 - 15)				
CLASS V (18 - 24)				
CLASS VI (>30)				
AEC down SCENARIO: B/C				
CLASS I (0.3 – 0.5)	5	Oct, Nov, Jan, Mar, Apr	0.2	2
CLASS II (1 - 4)	3	Nov,Mar	1.5	3
CLASS III (6 - 10)	1:24	Oct	2.5	3
CLASS IV (10 - 15)				
CLASS V (18 - 24)				
CLASS VI (>30)				

Table 3.39 Summary table high and low flows Karatara River EWR4 – AB

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.110	0.017	0.2 2.5	2 3	5 1:2
November	0.110	0.017	0.2 1	2 2	5 3
December	0.084	0.011			
January	0.073	0.011	0.2	2	5
February	0.079	0.012			
March	0.083	0.016	0.2 1.5	2 3	5 3
April	0.081	0.016	0.2	2	5
May	0.075	0.015			
June	0.065	0.008			
July	0.059	0.014			
August	0.073	0.011			
September	0.086	0.016	1:5	3	3

Table 3.40 Summary table high and low flows Karatara River EWR4 - BC

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
October	0.058	0.017	0.2 2.5	2 3	4 1:4
November	0.061	0.017	0.2 1.5	2 3	4 2
December	0.052	0.011			
January	0.046	0.011			
February	0.049	0.012			
March	0.052	0.016	0.2 1.5	2 3	4 2
April	0.051	0.016	0.2	2	4

Month	Low flows		High flows (m^3/s)		
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s)	Duration (days)	Frequency
May	0.047	0.015			
June	0.041	0.008			
July	0.037	0.014			
August	0.046	0.011			
September	0.054	0.016			

3.5.5 C6 Groot Brak River – EWR GB1

Site	IUA	River	PES	EIS	REC
GB1	C6	Groot Brak	B/C	HIGH	B/C

To be met at inflow to Wolwedans Dam.

Table 3.41 Flood requirements Groot Brak River EWR GB1 - BC

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood requested has a return period of 1:1)					
Class 1	1	2	0.183	3.5	August - April
Class 2	2.12	4	0.469	3.5	October - May
Class 3	3.56	5	0.944	0	Not applicable
Class 4	6.95	6	1.878	1	Any time
Inter-annual Class (return period given below)					
1:2	11	6	3.76	Present	Not stipulated
1:5	22	8	5	Present	Not stipulated
1:10	40	8	6	Present	Not stipulated
1:20	64	8	6	Present	Not stipulated

Table 3.42 Flood requirements Groot Brak River EWR GB1 - B

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood requested has a return period of 1:1)					
Class 1	1	2	0.183	3.5	August - April
Class 2	2.12	4	0.469	1	October - May
Class 3	3.56	5	0.944	0	Not applicable
Class 4	6.95	6	1.878	1	Any time
Inter-annual Class (return period given below)					
1:2	11	6	3.76	Present	Not stipulated
1:5	22	8	5	Present	Not stipulated
1:10	40	8	6	Present	Not stipulated
1:20	64	8	6	Present	Not stipulated

Table 3.43 Flood requirements Groot Brak River EWR GB1 - C

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood requested has a return period of 1:1)					
Class 1	1	2	0.183	2	August - April
Class 2	2.12	4	0.469	1	October - May
Class 3	3.56	5	0.944	0	Not applicable
Class 4	6.95	6	1.878	0	Any time
Inter-annual Class (return period given below)					
1:2	11	6	3.76	Present	Not stipulated
1:5	22	8	5	Present	Not stipulated
1:10	40	8	6	Present	Not stipulated
1:20	64	8	6	Present	Not stipulated

Table 3.44 Summary table high and low flows Groot Brak River EWR GB1 - BC

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 18.7 million m^3/a (estimated). pMAR = 10.2 million m^3/a														
EWR EcoStatus Category = B/C.														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.051	0.141	0.131	0.091	0.071	0.061	0.121	0.031	0.041	0.051	0.061	0.071	2.15	11.5%
FLOOD Class 1: 1: m^3/s	2					1				0.5		With Oct	0.64	3.4%
FLOOD Class 2: 2.12: m^3/s	1					2				0.5		With Oct	1.64	8.7%
FLOOD Class 3: 3.56: m^3/s	-												0	0%
FLOOD Class 4: 6.95: m^3/s	1												1.88	10.1%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												3.78	20.2%
MAINTENANCE TOTAL (Volume)	**Annual[7]**												**10.09**	**54%**
	Long-term average[8]												**5.52**	**30%**
DROUGHT														
LOW FLOWS m^3/s	0.05	0.05	0.04	0.03	0.03	0.02	0.04	0.03	0.04	0.05	0.06	0.07	1.33	7%
FLOOD Peak m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[7] Calculated as the volume of water required to meet the full requirements.
[8] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

Table 3.45 Summary table high and low flows Groot Brak River EWR GB1 - B

<table>
<tr><th></th><th>OCT</th><th>NOV</th><th>DEC</th><th>JAN</th><th>FEB</th><th>MAR</th><th>APR</th><th>MAY</th><th>JUN</th><th>JUL</th><th>AUG</th><th>SEP</th><th>VOL (million m^3)</th><th>nMAR %</th></tr>
<tr><td colspan="15">nMAR = 18.7 million m^3/a (estimated). pMAR = 10.2 million m^3/a</td></tr>
<tr><td colspan="15">EWR EcoStatus Category = B.</td></tr>
<tr><td colspan="15">MAINTENANCE</td></tr>
<tr><td>LOW FLOWS Q m^3/s</td><td>0.051</td><td>0.141</td><td>0.131</td><td>0.091</td><td>0.071</td><td>0.061</td><td>0.121</td><td>0.031</td><td>0.041</td><td>0.051</td><td>0.061</td><td>0.071</td><td>2.15</td><td>11.5%</td></tr>
<tr><td>FLOOD Class 1: 1: m^3/s</td><td colspan="5">2</td><td colspan="4">1</td><td>0.5</td><td></td><td>With Oct</td><td>0.64</td><td>3.4%</td></tr>
<tr><td>FLOOD Class 2: 2.12: m^3/s</td><td colspan="9">1</td><td></td><td></td><td>With Oct</td><td>0.47</td><td>2.5%</td></tr>
<tr><td>FLOOD Class 3: 3.56: m^3/s</td><td colspan="12">-</td><td>0</td><td>0%</td></tr>
<tr><td>FLOOD Class 4: 6.95: m^3/s</td><td colspan="12">1</td><td>1.88</td><td>10.1%</td></tr>
<tr><td>Inter-annual floods</td><td colspan="12">Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)</td><td>3.78</td><td>20.2%</td></tr>
<tr><td rowspan="2">MAINTENANCE TOTAL (Volume)</td><td colspan="12">Annual</td><td>8.92</td><td>48%</td></tr>
<tr><td colspan="12">Long-term average</td><td>8.06</td><td>43%</td></tr>
<tr><td colspan="15">DROUGHT</td></tr>
<tr><td>LOW FLOWS m^3/s</td><td>0.05</td><td>0.05</td><td>0.04</td><td>0.03</td><td>0.03</td><td>0.02</td><td>0.04</td><td>0.03</td><td>0.04</td><td>0.05</td><td>0.06</td><td>0.07</td><td>1.33</td><td>7%</td></tr>
<tr><td>FLOOD Peak m^3/s</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>0</td><td>0%</td></tr>
</table>

Table 3.46 Summary table high and low flows Groot Brak River EWR GB1 - C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 18.7 million m^3/a (estimated). pMAR = 10.2 million m^3/a														
EWR EcoStatus Category = C.														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.051	0.141	0.131	0.091	0.071	0.061	0.121	0.031	0.041	0.051	0.061	0.071	2.15	11.5%
FLOOD Class 1: 1: m^3/s						1						With Oct	0.37	2.0%
FLOOD Class 2: 2.12: m^3/s						1						With Oct	0.47	2.5%
FLOOD Class 3: 3.56: m^3/s	-												0	0%
FLOOD Class 4: 6.95: m^3/s	-												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												0	0%
MAINTENANCE TOTAL (Volume)	**Annual[9]**												**2.99**	**16%**
	Long-term average[10]												**3.49**	**19%**
DROUGHT														
LOW FLOWS m^3/s	0.05	0.05	0.04	0.03	0.03	0.02	0.04	0.03	0.04	0.05	0.06	0.07	1.33	7%
FLOOD Peak m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[9] Calculated as the volume of water required to meet the full requirements.
[10] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

3.5.6 G15 Kaaimans River – EWR Ka1

Site	IUA	River	PES	EIS	REC
Ka 1	G15	Kaaimans	B	VERY HIGH	B

To be met at Gauge K3H001.

Table 3.47 Flood requirements Kaaimans River EWR Ka1 - B

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.15	2	0.18	4	March-May September - November
Class 2	2.25	3	0.38	2	March-May September - November
Class 3	4.49	4	0.76	2	March-May September - November
Inter-annual Class (return period given below)					
1:2 year	-	-	2.7[11]	Present	Not stipulated

Table 3.48 Flood requirements Kaaimans River EWR Ka1 - C

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.15	2	0.18	4	March-May September - November
Class 2	2.25	3	0.38	2	March-May September - November
Inter-annual Class (return period given below)					
1:2 year	-	-	2.7[12]	Present	Not stipulated

Table 3.49 Flood requirements Kaaimans River EWR Ka1 - AB

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.15	2	0.18	6	March-May September - November
Class 2	2.25	3	0.38	2	March-May September - November
Class 3	4.49	4	0.76	2	March-May September - November
Class 4	9.03	4	1.37	1	Not stipulated - anytime
Inter-annual Class (return period given below)					
1:2	-	-	2.7[13]	Present	Not stipulated - anytime

[11] Combined annual volume.
[12] Combined annual volume.
[13] Combined annual volume.

Table 3.50 Summary table high and low flows Kaaimans River EWR Ka1 - B

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 13.46 million m^3/a (estimated). pMAR = 11.65 million m^3/a														
EWR EcoStatus Category = B.														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.16	0.15	0.12	0.10	0.10	0.12	0.15	0.13	0.10	0.10	0.10	0.10	3.46	25.7%
FLOOD Class 1: 1.15[14]: m^3/s		2					2				With Oct		0.72	5.3%
FLOOD Class 2: 2.25 m^3/s		1					1				With Oct		0.76	5.6%
FLOOD Class 3: 4.49 m^3/s		1					1				With Oct		1.52	11.3%
FLOOD Class 4: 9.03 m^3/s													0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												2	14.9%
MAINTENANCE TOTAL (Volume)	**Annual[15]**												**8.5**	**63.2%**
	Long-term average[16]												**6.7**	**49.7%**
DROUGHT														
LOW FLOWS m^3/s	0.05	0.05	0.05	0.03	0.05	0.10	0.07	0.06	0.05	0.05	0.05	0.05	1.736	13%
FLOOD Peak m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[14] Daily average peak.
[15] Calculated as the volume of water required to meet the full requirements.
[16] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

Table 3.51 Summary table high and low flows Kaaimans River EWR Ka1 - C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 13.46 million m^3/a (estimated). pMAR = 11.65 million m^3/a														
EWR EcoStatus Category = C.														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.13	0.06	0.05	0.03	0.05	0.04	0.07	0.1	0.07	0.07	0.09	0.09	2.96	18%
FLOOD Class 1: 1.15[17]: m^3/s	2					2					With Oct		0.72	5.3%
FLOOD Class 2: 2.25 m^3/s	1					1					With Oct		0.76	5.7%
FLOOD Class 3: 4.49 m^3/s													0	-
FLOOD Class 4: 9.03 m^3/s													0	-
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												2	14.9%
MAINTENANCE TOTAL (Volume)	**Annual[18]**												**6.44**	**51%**
	Long-term average[19]												**4.64**	**35%**
DROUGHT														
LOW FLOWS m^3/s	0.05	0.05	0.05	0.03	0.05	0.10	0.07	0.06	0.05	0.05	0.05	0.05	1.736	13%
FLOOD Peak m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[17] Daily average peak.
[18] Calculated as the volume of water required to meet the full requirements.
[19] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

Table 3.52 Summary table Kaaimans River EWR Ka1 - AB

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 13.46 million m^3/a (estimated). pMAR = 11.65 million m^3/a														
EWR EcoStatus Category = A/B (provided non-flow related impacts are addressed successfully)														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.16	0.15	0.12	0.10	0.10	0.12	0.15	0.13	0.10	0.10	0.10	0.10	3.46	25.7%
FLOOD Class 1: 1.15[20]: m^3/s	3					3					With Oct		1.08	8.3%
FLOOD Class 2: 2.25 m^3/s	1					1					With Oct		0.76	5.7%
FLOOD Class 3: 4.49 m^3/s	1					1					With Oct		1.52	11.4%
FLOOD Class 4: 9.03 m^3/s	1												1.37	10.2%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												2	14.9%
MAINTENANCE TOTAL (Volume)	**Annual[21]**												**10.19**	**76%**
	Long-term average[22]												**7.23**	**54%**
DROUGHT														
LOW FLOWS m^3/s	0.05	0.05	0.05	0.03	0.05	0.10	0.07	0.06	0.05	0.05	0.05	0.05	1.56	12%
FLOOD Peak m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[20] Daily average peak.
[21] Calculated as the volume of water required to meet the full requirements.
[22] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

3.5.7 G15 Malgas River – EWR Mal1

Site	IUA	River	PES	EIS	REC
Mal 1	G15	Malgas	C	HIGH	C

To be met at Gauge K3H004.

Table 3.53 Flood requirements Malgas River EWR Mal1 - C

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	0.95	2	0.139	5.5	September - April
Class 2	1.76	2	0.249	0	November - March
Class 3	3.57	3	0.523	2	September - March
Class 4	6.53	3	0.943	1	Anytime
Inter-annual Class (return period given below)					
1:2 year	11	4	1.6	Present	Not stipulated
1:5 year	23	4	2	Present	Not stipulated
1:10 year	26	4	2.8	Present	Not stipulated
1:20 year	34	4	2.8	Present	Not stipulated

Table 3.54 Flood requirements Malgas River EWR Mal1 - B

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	0.95	2	0.139	5.5	September - April
Class 2	1.76	2	0.249	3	November - March
Class 3	3.57	3	0.523	2	September - March
Class 4	6.53	3	0.943	1	Anytime
Inter-annual Class (return period given below)					
1:2 year	11	4	1.6	Present	Not stipulated
1:5 year	23	4	2	Present	Not stipulated
1:10 year	26	4	2.8	Present	Not stipulated
1:20 year	34	4	2.8	Present	Not stipulated

Table 3.55 Flood requirements Malgas River EWR Mal1 - D

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	0.95	2	0.139	5.5	September - April
Class 2	1.76	2	0.249	0	November - March
Class 3	3.57	3	0.523	0	September - March
Class 4	6.53	3	0.943	0	Anytime
Inter-annual Class (return period given below)					
1:2 year	11	4	1.6	Present	Not stipulated
1:5 year	23	4	2	Present	Not stipulated
1:10 year	26	4	2.8	Present	Not stipulated
1:20 year	34	4	2.8	Present	Not stipulated

Table 3.56 Summary table high and low flows Malgas River EWR Mal1 - C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 11 million m^3/a (estimated). pMAR = 8 11 million m^3/a														
EWR EcoStatus Category = C														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.07	0.02	0.01	0.01	0.02	0.02	0.03	0.05	0.05	0.04	0.05	0.05	1.05	9.5%
FLOOD Class 1: 0.95 m^3/s	5.5											With Oct	0.76	6.9%
FLOOD Class 2: 1.76 m^3/s	-												0	0%
FLOOD Class 3: 3.57 m^3/s	2											With Oct	1.05	9.5%
FLOOD Class 4: 6.53 m^3/s	1												0.94	8.6%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												1.62	14.7%
MAINTENANCE TOTAL (Volume)	**Annual[23]**												**5.43**	**49%**
	Long-term average[24]												**3.5**	**32%**
DROUGHT														
LOW FLOWS m^3/s	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.421	4%
FLOOD Peak[25] m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[23] Calculated as the volume of water required to meet the full requirements.
[24] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[25] Daily average peak.

Table 3.57 Summary table high and low flows Malgas River EWR Mal1 - B

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 11 million m^3/a (estimated). pMAR = 8 million m^3/a														
EWR EcoStatus Category = B														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.07	0.06	0.04	0.04	0.04	0.06	0.08	0.05	0.05	0.04	0.05	0.05	1.45	13.2%
FLOOD Class 1: 0.95 m^3/s	5.5								Only if not met			With Oct	0.76	6.9%
FLOOD Class 2: 1.76 m^3/s		3					Only if not met						0.75	6.8%
FLOOD Class 3: 3.57 m^3/s	2						Only if not met					With Oct	1.05	9.5%
FLOOD Class 4: 6.53 m^3/s	1												0.94	8.5%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												1.62	11.7%
MAINTENANCE TOTAL (Volume)	**Annual[26]**												**6.8**	**60%**
	Long-term average[27]												**4.5**	**40%**
DROUGHT														
LOW FLOWS m^3/s	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.421	4%
FLOOD Peak[28] m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[26] Calculated as the volume of water required to meet the full requirements.
[27] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[28] Daily average peak.

Table 3.58 Summary table high and low flows Malgas River EWR Mal1 - D

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 11 million m^3/a (estimated). pMAR = 8 million m^3/a														
EWR EcoStatus Category = D														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.07	0.02	0.01	0.01	0.02	0.02	0.03	0.05	0.05	0.04	0.05	0.05	1.05	9.5%
FLOOD Class 1: 0.95 m^3/s	5.5								Only if not met			With Oct	0.76	6.9%
FLOOD Class 2: 1.76 m^3/s	None												0	0%
FLOOD Class 3: 3.57 m^3/s	None												0	0%
FLOOD Class 4: 6.53 m^3/s	None												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												1.62	14.7%
MAINTENANCE TOTAL (Volume)	**Annual[29]**												**3.4**	**31%**
	Long-term average[30]												**2.38**	**22%**
DROUGHT														
LOW FLOWS m^3/s	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.421	4%
FLOOD Peak[31] m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[29] Calculated as the volume of water required to meet the full requirements.
[30] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[31] Daily average peak.

3.5.8 G15 Goukamma River – EWR Gou1

Site	IUA	River	PES	EIS	REC
Gou1	G15	Goukamma	B/C	VERY HIGH	B/C

To be met at the bridge over the old road.

Table 3.59 Flood requirements Goukamma River EWR Gou1 - BC

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)[32]	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	2.08	3	0.39	5	Sept-May
Class 2	3.73	3	0.72	2	Anytime
Class 3	7.04	4	1.41	0	Not applicable
Class 4	14.06	4	2.74	0	Not applicable
Inter-annual Class (return period given below)					
1:2	23	4	3.4	Present	Not stipulated
1:5	50	7	7	Present	Not stipulated
1:10	67	7	8	Present	Not stipulated
1:20	100	7	12	Present	Not stipulated

Table 3.60 Flood requirements Goukamma River EWR Gou1 - C

Flood type	Daily average peak (m^3/s)	Duration (days)	Volume (Million m^3)[33]	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	2.08	3	0.39	5	Sept-May
Class 2	3.73	3	0.72	2	Anytime
Class 3	7.04	4	1.41	0	Not applicable
Class 4	14.06	4	2.74	0	Not applicable
Inter-annual Class (return period given below)					
1:2	23	4	3.4	0	Not applicable
1:5	50	7	7	0	Not applicable
1:10	67	7	8	0	Not applicable
1:20	100	7	12	0	Not applicable

[32] per event.
[33] per event.

Table 3.61 Summary table high and low flows Goukamma River EWR Gou1 - BC

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 26.6 million m (estimated). pMAR = 23.1 million m^3														
EWR EcoStatus Category = B/C														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.211	0.38	0.27	0.21	0.2	0.25	0.32	0.131	0.131	0.141	0.181	0.181	6.17	19.9%
FLOOD Class 1: .95: m^3/s	3					2						With Oct	1.95	7.3%
FLOOD Class 2: 1.76 m^3/s	2												1.44	5.4%
FLOOD Class 3: 3.57: m^3/s	None requested												0	0%
FLOOD Class 4: 6.53 m^3/s	None requested												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												4.5	16.9%
MAINTENANCE TOTAL (Volume)	**Annual[34]**												**14.1**	**53%**
	Long-term average[35]												**12.4**	**47%**
DROUGHT														
LOW FLOWS m^3/s	0.14	0.12	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.1	2.236	8%
FLOOD Peak[36] m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[34] Calculated as the volume of water required to meet the full requirements.
[35] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[36] Daily average peak.

Table 3.62 Summary table high and low flows Goukamma River EWR Gou1 - C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (million m^3)	nMAR %
nMAR = 26.6 million m (estimated). pMAR = 23.1 million m^3														
EWR EcoStatus Category = C														
MAINTENANCE														
LOW FLOWS Q m^3/s	0.211	0.321	0.221	0.161	0.161	0.201	0.271	0.131	0.131	0.141	0.181	0.181	5.31	19.9%
FLOOD Class 1: .95: m^3/s	3					2						With Oct	1.95	7.3%
FLOOD Class 2: 1.76 m^3/s	2												1.44	5.4%
FLOOD Class 3: 3.57: m^3/s	None requested												0	0%
FLOOD Class 4: 6.53 m^3/s	None requested												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												0	0%
MAINTENANCE TOTAL (Volume)	**Annual[37]**												**8.7**	**33%**
	Long-term average[38]												**7.5**	**28%**
DROUGHT														
LOW FLOWS m^3/s	0.14	0.12	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.1	2.236	8%
FLOOD Peak[39] m^3/s	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

[37] Calculated as the volume of water required to meet the full requirements.
[38] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[39] Daily average peak.

3.5.9 G15 Gwaiing River – EWR Gwa1

Site	IUA	River	PES	EIS	REC
Gwa 1	G15	Gwaiing	E	HIGH	D

Only a D-Category determination was done for the Gwaiing River, as the river flowed through the outskirts of Blanco in an E-Category, largely as a result of non-flow related issues, such as development in the riparian zone, alien tree infestations, hard engineers and pollution.

Table 3.63 Summary table high and low flows Gwaiing River EWR Gwa1 – D

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.260	0.107	0.175	0.435
November	0.076	0.076	0.175	0.252
December	0.041	0.031	0	0.041
January	0.041	0.031	0.175	0.217
February	0.072	0.061	0.175	0.247
March	0.076	0.076	0.175	0.252
April	0.111	0.107	0.175	0.287
May	0.200	0.107	0	0.200
June	0.195	0.107	0	0.195
July	0.151	0.076	0	0.151
August	0.202	0.107	0	0.202
September	0.186	0.061	0	0.186

3.5.10 G15 Maalgate River – EWR Maa1 and Maa2

Site	IUA	River	PES	EIS	REC
Maa 2	G15	Maalgate	D	HIGH	D

There was no means of measuring flow at Maa 1, so the determination were for a Reserve to be monitored at Maa 2, at the DWAF gauging weir no. K3H003.

Table 3.64 Summary table high and low flows Maalgate River EWR Maa2 - D

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.545	0.172	0.368	0.913
November	0.160	0.083	0.368	0.529
December	0.087	0.064	0	0.087
January	0.087	0.064	0.368	0.455
February	0.151	0.078	0.368	0.519
March	0.160	0.086	0.368	0.529
April	0.234	0.166	0.368	0.602
May	0.420	0.172	0	0.420
June	0.410	0.166	0	0.410
July	0.317	0.086	0	0.317
August	0.423	0.172	0	0.423
September	0.391	0.083	0	0.391

Table 3.65 Summary table high and flow flows Maalgate EWR Maa2 – C

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.545	0.172	0.368	0.913
November	0.160	0.415	1.576	1.736
December	0.087	0.087	0	0.087
January	0.087	0.064	0.368	0.455
February	0.151	0.078	0.368	0.519
March	0.160	0.086	1.576	1.736
April	0.234	0.166	2.966	3.200
May	0.420	0.172	0	0.420
June	0.410	0.166	0	0.410
July	0.288	0.172	0	0.288
August	0.423	0.172	0	0.423
September	0.391	0.083	0	0.391

3.5.11 G15 Swart River – EWR Sw1

Site	IUA	River	PES	EIS	REC
Sw 1	G15	Swart	D	HIGH	D

The Garden Route Dam was situated on the Swart River just upstream of Reach Sw 1. The location was significant because the ecological condition of the Swart River was markedly lower in the section downstream of the dam, *viz*. B/C-Category upstream (Dr C. Brown, pers. obs.) and D-Category downstream of the dam. The two facts are not unrelated, and the presence of the dam is a major contributing factor in the decline in ecological condition. Other contributing factors include: encroachment of alien vegetation (partly related to a reduction in floods) and manual manipulation of the river channel (mainly associated with roads). Only a D-Category determination was done for the Swart River, as it was the opinion of the specialists that additional flow would not necessarily translate into better ecological condition.

Table 3.66 Summary table high and low flows Swart River EWR Sw1 – D

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.172	0.172	0	0.172
November	0.139	0.139	0	0.139
December	0.122	0.122	0	0.122
January	0.073	0.073	0	0.073
February	0.110	0.110	0	0.110
March	0.099	0.099	0.134	0.234
April	0.160	0.160	0.134	0.294
May	0.143	0.143	0	0.143
June	0.117	0.117	0	0.117
July	0.122	0.122	0	0.122
August	0.161	0.161	0	0.161
September	0.141	0.141	0	0.141

3.5.12 G15 Silver River – EWR Si1

Site	IUA	River	PES	EIS	REC
Si 1	G15	Silver	B	VERY HIGH	B

The bridge on old Knysna –George Road was situated on the Silver River just within the Reach Si 1, with typical tannin rich dark waters of the acidic system. The location was significant because of the presence of nearby gauging weir and also a variety of substrates present (i.e. Bedrock, boulders and cobble bed). The hydrology and macroinvertebrates were in very good conditions. The most widespread tree species was the exotic invasive *Acacia melanoxylon* (blackwood). The underlying geology was Bokkeveld Group shale. The contributing factors to the current B-Category were mainly encroachment of alien vegetation, and unstable geomorphology. It was the opinion of the specialists that additional flow would not necessarily translate into better ecological condition. For this reason, the Reserves were determined (using the desktop), for C and B- categories, with the latter the REC and the former an Alternative Ecological Category (AEC).

Table 3.67 Summary table high and low flows Silver River EWR Si1 – B

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.206	0.105	0.759	0.964
November	0.176	0.085	0	0.176
December	0.159	0.074	0	0.159
January	0.145	0.045	0	0.145
February	0.138	0.067	0	0.138
March	0.173	0.061	0,082	0.254
April	0.176	0.098	0.082	0.258
May	0.170	0.087	0	0.170
June	0.145	0.071	0	0.145
July	0.136	0.074	0	0.136
August	0.166	0.098	0.082	0.248
September	0.169	0.086	0.206	0.375

Table 3.68 Summary table high and low flows Silver River EWR Si1 – C

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.172	0.100	0.206	0.378
November	0.202	0.082	0.082	0.283
December	0.159	0.071	0	0.159
January	0.145	0.059	0	0.145
February	0.138	0.059	0	0.138
March	0.173	0.059	0.082	0.254
April	0.196	0.082	0.082	0.278
May	0.129	0.087	0	0.129
June	0.092	0.071	0	0.092
July	0.096	0.074	0	0.096
August	0.120	0.098	0.082	0.202
September	0.117	0.086	0.206	0.323

3.5.13 G15 Noetsie River – EWR Noe1

Site	IUA	River	PES	EIS	REC
Noe 1	G15	Noetsie	B	VERY HIGH	A/B

Taken in its totality, the PES of the Noetsie River was a B Category. However, there were sections of the river that were in a high A/B Category. For this reason, the Reserve was been determined (using the desktop), for a C-, B- and an A/B Category, with the latter the REC. The results were slightly HIGHER (%MAR) than previously recommended (*viz*. 51% for an A Category).

The reason for this is that – here, the Desktop has been calibrated using the outputs from the Intermediate Reserve Determination study (using Ka 1 and Gou 1) whereas previously there were no studies that could be used to calibrate the Desktop for this region, thus the extrapolated values were from outside the study area. The main difference between the results lies in the recognition, of the extremely strong perennial nature of the systems. The Reserve was for the whole river, i.e., compliance should be monitored at the head of the estuary.

Table 3.69 Summary table Noetsie River EWR Noe1 – AB

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.205	0.064	0	0.205
November	0.186	0.062	0.273	0.460
December	0.154	0.064	0.090	0.243
January	0.128	0.038	0	0.128
February	0.116	0.058	0.273	0.389
March	0.154	0.128	0.376	0.530
April	0.186	0.087	0.656	0.842
May	0.167	0.077	0	0.167
June	0.124	0.062	0	0.124
July	0.128	0.064	0	0.128
August	0.128	0.064	0	0.128
September	0.124	0.062	0.367	0.491

Table 3.70 Summary table high and low flows Noetsie River EWR Noe1 - B

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.166	0.064	0.614	0.780
November	0.143	0.062	0	0.143
December	0.128	0,060	0	0.128
January	0.117	0.025	0	0.117
February	0.112	0.054	0.332	0.444
March	0.140	0.049	0.066	0.206
April	0.143	0.062	0.549	0.692
May	0.137	0.064	0	0.137
June	0.117	0.058	0	0.117
July	0.110	0.060	0	0.110
August	0.135	0.064	0.066	0.201
September	0.137	0.062	0.166	0.303

Table 3.71 Summary table high and low flows Noetsie River EWR Noe1 C

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.139	0.064	0.166	0.306
November	0.163	0.062	0.066	0.229
December	0.128	0.057	0	0.128
January	0.117	0.038	0	0.117
February	0.112	0.046	0	0.112
March	0.140	0.038	0.066	0.206
April	0.159	0.062	0.066	0.225
May	0.105	0.064	0	0.105
June	0.075	0.058	0	0.075
July	0.077	0.060	0	0.077
August	0.097	0.064	0.066	0.164
September	0.095	0.062	0.166	0.261

3.5.14 C6 Varing River – EWR Var2 and Var3

Site	IUA	River	PES	EIS	REC
Var 2	C6	Varing	C/D	High	C/D
Var 3	C6	Varing	D	High	C/D

Three additional EWR sites were added later on during the study on the Varing River; little data associated with these sites was written up, only the calibrated EWRs were presented. Var 1 was not considered for the EWR study. Var 2 had a nMAR of 6.746 m^3/a and Var 3 a nMAR of 11.432 m^3/a.

Table 3.72 Summary table high and low flows Varing River EWR Var2 - CD

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.079	0.059	0.081	0.160
November	0.082	0.039	0.072	0.154
December	0.073	0.029	0	0.073

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
January	0.066	0.029	0	0.066
February	0.062	0.027	0	0.062
March	0.075	0.032	0	0.075
April	0.073	0.031	0	0.073
May	0.067	0.030	0.049	0.116
June	0.057	0.029	0.023	0.079
July	0.055	0.041	0.082	0.138
August	0.066	0.041	0.041	0.107
September	0.073	0.039	0.236	0.309

Table 3.73 Summary table high and low flows Varing River EWR Var2 – C

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.101	0.059	0.089	0.190
November	0.104	0.039	0.080	0.184
December	0.093	0.029	0	0.093
January	0.083	0.029	0	0.083
February	0.0079	0.029	0	0.079
March	0.095	0.027	0	0.095
April	0.093	0.029	0	0.093
May	0.084	0.031	0.054	0.138
June	0.071	0.029	0.025	0.096
July	0.069	0.032	0.091	0.160
August	0.083	0.040	0.045	0.128
September	0.092	0.039	0.260	0.353

Table 3.74 Summary table high and low flows Varing River EWR Var2 – D

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.059	0.054	0.081	0.140
November	0.061	0.040	0.072	0.134
December	0.055	0.029	0	0.055
January	0.049	0.029	0	0.049
February	0.047	0.027	0	0.047
March	0.056	0.029	0	0.056
April	0.055	0.031	0	0.055
May	0.050	0.029	0.049	0.099
June	0.042	0.029	0.023	0.065
July	0.041	0.040	0.082	0.124
August	0.049	0.040	0.041	0.090
September	0.054	0.039	0.236	0.290

Table 3.75 Summary table high and low flows Varing River EWR Var3 - CD

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.134	0.100	0.137	0.271
November	0.139	0.066	0.123	0.261
December	0.124	0.050	0	0.124
January	0.112	0.050	0	0.112
February	0.106	0.045	0	0.106
March	0.127	0.054	0	0.127
April	0.124	0.053	0	0.124
May	0.113	0.050	0.083	0.296
June	0.096	0.048	0.038	0.134
July	0.094	0.070	0.139	0.233
August	0.112	0.070	0.070	0.181
September	0.123	0.066	0.400	0.523

Table 3.76 Summary table high and low flows Varing River EWR Var3 – C

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.171	0.100	0.151	0.322
November	0.177	0.066	0.135	0.312
December	0.158	0.050	0	0.158
January	0.141	0.050	0	0.141
February	0.133	0.045	0	0.133
March	0.161	0.050	0	0.161
April	0.157	0.053	0	0.157
May	0.143	0.050	0.091	0.234
June	0.120	0.048	0.042	0.162
July	0.118	0.054	0.154	0.271
August	0.141	0.068	0.077	0.218
September	0.156	0.066	0.441	0.597

Table 3.77 Summary table high and low flows Varing River EWR Var3 – D

Month	Low flows		High flows	Total Flows
	Maintenance (m^3/s)	Drought (m^3/s)	Maintenance (m^3/s)	Maintenance (m^3/s)
October	0.100	0.091	0.137	0.237
November	0.104	0.067	0.123	0.226
December	0.093	0.050	0	0.093
January	0.084	0.050	0	0.084
February	0.079	0.045	0	0.079
March	0.095	0.050	0	0.095
April	0.092	0.053	0	0.092
May	0.085	0.050	0.083	0.168
June	0,071	0.048	0.038	0.110
July	0.070	0.068	0.139	0.209
August	0.083	0.068	0.070	0.153
September	0.092	0.066	0.400	0.492

3.6 Existing River EWRs in the Breede Catchment

There were six sites chosen (and used) as EWR sites in the Breede Catchment:

- EWR SITE 1: Breede River downstream of Wit Brug on the farm Mooiplaas.
- EWR SITE 2: Molenaars River downstream of DWAF gauging weir.
- EWR SITE 3: Breede River upstream of Le Chasseur.
- EWR SITE 4: Breede River downstream of Felix Unite camp on the Farm Ou Werf.
- EWR SITE 5: Riviersonderend at Greyton Campsite.
- EWR SITE 6: Baviaans River upstream of DWAF weir.

Each site is taken in turn, where a summary of the PES and REC are followed by the flood requirements and low and high flows respectively.

3.6.1 A1 Breede River - EWR1_Br

Site	IUA	River	PES	EIS	REC
EWR 1_Br	A1	Breede	D/E	MOD	D

A summary of the PES and long-term REC for Breede River EWR site 1 are given in Table 3.78. Addressing the summer low flows could achieve the improvement from a D/E to a D ecological category for aquatic invertebrates and riparian vegetation. It was doubtful whether the fish class could be improved due to the presence of alien fish species and the difficulty of addressing this problem. In the long term, geomorphology could be improved if the non-flow related issue of the mechanical disturbance to the channel was addressed.

To ensure the ecological category of a D, the summer low flows needed to be addressed; however the non-flow related aspect of the bulldozing will also have to be addressed to ensure that in the long term, the REC of a D could be achieved. Realistically, it was predicted that it would be very difficult to improve the overall status of this river due to the presence of the alien fish and the structural changes that had taken place.

Table 3.78 Summary of PES and REC – Breede River EWR 1

EWR site	Discipline	Ecological category
EWR1_Br	Hydrology	D
	Water quality	B
	Geomorphology	D/E
	Riparian vegetation	D/E
	Fish	D/E
	Aquatic macroinvertebrates	D/E
	PES	D/E
	EIS	Moderate
	REC	D

Table 3.79 Flood requirements at Breede River EWR site 1 - D

Flood Class	Monthly Distribution	Size (m^3/s) Daily Average	Number of events			Distr
			Natural	Present Day	D Category	
<I	10-4	8.7	Included in I	Included in I	1	10-4
I	10-4	10	7	7	1	10-4
II	5-6	28	3	3	1	5-6
III	8-10	57	3	2	1	8-10
IV	6-9	111	2	2	1	6-9

Flood Class	Monthly Distribution	Size (m^3/s) Daily Average	Number of events			Distr
			Natural	Present Day	D Category	
1 : 2	211					
1 : 5	343					
1 : 10	399					
1 : 20	417					

Table 3.80 Summary table for Breede River EWR 1 - D

EWR 1: BREEDE RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) nMAR: 332.87 pMAR: 287.43										
Months	Maintenance Low Flows			High Flows				Drought Low Flows		
	DEPTH[4]	FLOW	VOLUME	DEPTH[4]	FLOW	DURATION	VOLUME[1]	DEPTH[4]	FLOW	VOLUME
	(m)	($m^3 s^{-1}$)	($10^6 m^3$)	(m)	$m^3 s^{-1}$ Daily average	(days)	($10^6 m^3$)	(m)	($m^3 s^{-1}$)	($10^6 m^3$)
Oct	0.17	1.90	5.09	0.41	10	3	1.26	0.11	0.83	2.22
Nov	0.13	1.18	3.06					0.09	0.50	1.30
Dec	0.09	0.60	1.61	0.38	8.7	3	1.26	0.06	0.27	0.72
Jan[2]	0.09	0.55	1.47					0.06	0.26	0.70
Feb	0.08	0.40	0.97					0.05	0.19	0.46
Mar	0.09	0.50	1.34					0.05	0.21	0.56
Apr	0.10	0.69	1.79					0.07	0.31	0.80
May	0.12	1.01	2.71	0.70	28	3	4.20	0.08	0.43	1.52
Jun	0.17	1.90	4.93					0.11	0.83	2.15
Jul[3]	0.19	2.20	5.89					0.12	0.96	2.57
Aug	0.22	3.00	8.04	1.44	111	6	24.73	0.14	1.34	3.59
Sep	0.19	2.30	5.96	1.02	57	4	9.93	0.12	1.00	2.59
TOTAL			42.84				41.37			18.82
% OF nMAR			12.87				12.43			5.65
Long term % of nMAR: 25.3 % (84.213 million m^3/a)										

1	The volume represents the daily average less the low flows
2	January was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.
3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.
4	Depths taken from cross-section 3.

3.6.2 A1 Breede River - EWR2_Br

Site	IUA	River	PES	EIS	REC
EWR 2_Br	A1	Breede	B	VERY HIGH	B

The river was in an excellent state and (aside from controlling effluent quality) it was predicted to be difficult to improve the condition so the attainable ecological category was set to maintain the PES with minimal to no risk of moving to a lower ecological category (Table 3.81).

Table 3.81 Summary of PES and REC – Breede River EWR 2

EWR site	Discipline	Ecological category
EWR2_Br	Hydrology	A/B
	Water quality	A/B
	Geomorphology	B
	Riparian vegetation	B/C
	Fish	E
	Aquatic macroinvertebrates	A/B
	PES	B
	EIS	Very High
	REC	B

Table 3.82 Flood requirements at Breede River EWR site 2 - B

FLOOD CLASS	MONTHLY DISTRIBUTION	SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NUMBER OF EVENTS			DISTR	C Category
			NATURAL	PRESENT DAY	MIN DEG: B Category		
I	10 - 4	5	8	8	3	10-4	
II	5-6	16	3	3	3	5-9	
III	8-10	31	4	4	3	8-10	
IV	6-9	61	3	3	1	6-9	
1 : 2	98						
1 : 5	153						
1 : 10	189						
1 : 20	196						

Table 3.83 Summary table Breede River EWR site 2 - B

EWR 2: MOLENAARS RIVER
ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter)
nMAR: 157.9 pMAR: 131

MONTHS	MAINTENANCE LOW FLOWS			HIGH FLOWS				DROUGHT LOW FLOWS		
	DEPTH[4]	FLOW	VOLUME	DEPTH4	FLOW	DURATION	VOLUME[1]	DEPTH[4]	FLOW	VOLUME
	(m)	($m^3 s^{-1}$)	(106 m^3)	(m)	$m^3 s^{-1}$ Daily average	(days)	(106 m^3)	(m)	($m^3 s^{-1}$)	(106 m^3)
Oct	0.99	1.7	4.6	1.16	5	3	0.51	0.88	0.6	1.61
Nov	0.94	1.1	2.8					0.85	0.42	1.09
Dec	0.92	0.93	2.49					0.85	0.38	1.02
Jan[2]	0.9	0.73	1.96					0.83	0.3	0.8
Feb	0.88	0.61	1.48	1.16	5	3	0.68	0.83	0.3	0.73
Mar	0.88	0.6	1.61					0.83	0.28	0.75
Apr	0.89	0.63	1.63	1.16	5	3	0.68	0.83	0.3	0.78
May	0.94	1.16	3.11	1.43	16	4	2.69	0.86	0.44	1.18
Jun	1	1.9	4.93	1.43	16	4	2.56	0.89	0.65	1.69
Jul[3]	1.04	2.5	6.7	1.94	61	5	11.98	0.91	0.8	2.14
Aug	1.05	2.7	7.2	1.65	31	4	5.14	0.91	0.86	2.3
Sep	1.05	2.6	6.74	1.65	31 + 16	3 + 4	5.15	0.91	0.84	2.18
TOTAL			45.27				35.43			16.26
% OF nMAR			28.7				22.44			10.3
Long term % OF nMAR: 49.73 (78.54 million m^3/a)										

1	The volume represents the daily average less the low flows
2	January was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.

3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.
4	Depths taken from cross-section 3.

Table 3.84 EWR table Breede River EWR 2 - C

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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLEWR												
(m^3/s)	1.000	0.600	0.500	0.400	0.350	0.300	0.400	0.700	1.100	1.500	1.600	1.500
(million m^3)	2.678	1.555	1.339	1.071	0.847	0.804	1.037	1.875	2.851	4.018	4.285	3.888
(%MAR)	1.70	0.98	0.85	0.68	0.54	0.51	0.66	1.19	1.81	2.54	2.71	2.46
DLEWR												
(m^3/s)	0.600	0.420	0.380	0.300	0.300	0.280	0.300	0.440	0.650	0.800	0.860	0.840
(million m^3)	1.607	1.089	1.018	0.804	0.726	0.750	0.778	1.178	1.685	2.143	2.303	2.177
(%MAR)	1.02	0.69	0.64	0.51	0.46	0.47	0.49	0.75	1.07	1.36	1.46	1.38
MHEWR												
(m^3/s)	4.000	0.000	0.000	0.000	0.000	0.000	4.620	15.300	14.800	59.500	29.300	29.400
(million m^3)	0.622	0.000	0.000	0.000	0.000	0.000	0.719	2.776	2.685	12.184	5.316	5.334
(%MAR)	0.39	0.00	0.00	0.00	0.00	0.00	0.45	1.76	1.70	7.71	3.37	3.38
(Days)	3	0	0	0	0	0	3	4	4	5	4	4

Annual Totals

	MLEWR	DLEWR	MHEWR	DHEWR	Maint.	Drought
million m^3	26.248	16.257	29.636	0.000	55.884	16.257
% Nat. MAR	16.62	10.29	18.77	0.00	35.39	10.29

3.6.3 A3 Breede River - EWR3_Br

Site	IUA	River	PES	EIS	REC
EWR 3_Br	A3	Breede	C/D	MOD	C/D

The major issue at this site was the increased summer base flows, lack of flow variability and the associated turbid water from Brandvlei Dam. If this problem could be addressed, the maintenance of the PES of a C/D ecological category was predicted to be possible.

The reach of the Breede River represented by EWR Site 3 has received irrigation releases from Brandvlei Dam since the early 1970s, resulting in unnaturally elevated summer baseflows in the system. It is possible/likely that the system has adjusted somewhat to these elevated baseflows, and thus the site information used by the specialists to recommend flows was set in response to the elevated irrigation flows, rather than to the natural hydrology. The upshot of this was that the recommended summer lowflows may be slightly higher than would have been recommended under natural conditions. However this made these data difficult to use for the extrapolation exercise because the irrigation releases made from Brandvlei Dam, in the summer months were incorporated into the Reserve requirements for EWR Sites 3. In order to generate the files for the extrapolation we:

- Maintained the C/D wet season lowflows and floods and reduced the dry season lowflows.
- Use the C/D Reserve requirements for C/D and C ecological category.
- Adjusted the flows for B and D pro rata.

Despite these adjustments, the EWRs represented a more conservative estimate for rivers in the area that would be generated by the Desktop Model without local calibration.

Table 3.85 Summary of PES and REC - Breede River EWR 3

EWR site	Discipline	Ecological category
EWR3_Br	Hydrology	C/D
	Water quality	B
	Geomorphology	C
	Riparian vegetation	C
	Fish	D
	Aquatic macroinvertebrates	D
	PES	C/D
	EIS	Moderate
	REC	C/D

Table 3.86 Flood requirements for Breede River EWR site 3 - CD

Within-Year Floods	Minimum Degradation Number Per Annum
Class I	3-4
Class II	2
Class III	1-2
Class IV	1-2

Table 3.87 Flood requirements for Breede River EWR site 3 – CD

Flood Class	Monthly Distribution	Size ($m^3\ s^{-1}$) Daily Average	Number Of Events			Distribution
			Natural	Present Day	Min Deg: C/D	
I	10 - 4	31.5	7	9	3	11 - 3
II	5 - 9	87.95	3	3	2	9-11 4-5
III	5 - 9	176.58	3	3	2	5 - 8
IV	5 - 9	370.06	1.7	1	1	5 - 9
1 : 2	533					
1 : 5	714					
1 : 10	882					
1 : 20	882					

Table 3.88 Summary table Breede River EWR site 3 – CD

EWR 3: BREEDE RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) nMAR: 1210 pMAR: 763										
	MAINTENANCE LOW FLOWS			HIGH FLOWS				DROUGHT LOW FLOWS		
	DEPTH[4]	FLOW	VOLUME	DEPTH[4]	FLOW	DURATION	VOLUME[1]	DEPTH[4]	FLOW	VOLUME
MONTHS		($m^3\ s^{-1}$)	($10^6\ m^3$)		$m^3\ s^{-1}$ Daily average		($10^6\ m^3$)		($m^3\ s^{-1}$)	($10^6\ m^3$)
Oct	0.61	7.6	20.4	1	31.5	4	4.3	0.42	2.7	7.2
Nov	0.55	5.8	15					0.41	2.5	6.5
Dec2	0.48	4	10.7					0.39	2.2	5.9
Jan	0.56	6	16					0.40	2.4	6.4
Feb	0.45	3.3	8					0.39	2.2	5.3
Mar	0.49	4.1	11					0.39	2.2	6
Apr	0.51	4.6	12	1	31.5	4	4.9	0.39	2.3	6
May	0.57	6.4	17.1	1.35	88	6	18.7	0.41	2.5	6.7
Jun	0.67	10	26	1.6	177	6	38.2	0.44	3.2	8.3

Jul3	0.79	16	43	2	370	7	89.3	0.48	4	11
Aug	0.76	14.5	39	1.6	177	6	37.3	0.47	3.8	10.2
Sep	0.71	12	31	1.35 & 1	88 & 31.5	6 & 4	22	0.46	3.5	9
TOTAL			249.2				214.7			88.5
% OF nMAR			20.57				17.75			7.3
3.6.3.1 Long term % OF nMAR: 44.6										

1	The volume represents the daily average less the low flows
2	Dec was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.
3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.
4	Depths taken at cross section 3

Table 3.89 EWR table for Breede River EWR site 3 – C

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
MLEWR
(m^3 /s) 9.486 7.300 5.000 7.400 4.100 5.100 5.700 8.000 12.500 20.000 18.000 22.000
(million m^3) 25.406 18.922 13.392 19.820 9.919 13.660 14.774 21.427 32.400 53.568 48.211 57.024
(%MAR) 2.10 1.56 1.11 1.64 0.82 1.13 1.22 1.77 2.68 4.42 3.98 4.71

DLEWR
(m^3 /s) 2.700 2.500 2.200 2.400 2.200 2.200 2.300 2.500 3.200 4.000 3.800 3.500
(million m^3) 7.232 6.480 5.892 6.428 5.322 5.892 5.962 6.696 8.294 10.714 10.178 9.072
(%MAR) 0.60 0.54 0.49 0.53 0.44 0.49 0.49 0.55 0.69 0.88 0.84 0.75

MHEWR
(m^3 /s) 22.000 0.000 0.000 0.000 0.000 0.000 25.800 80.000164.500359.000159.000 97.500
(million m^3) 3.992 0.000 0.000 0.000 0.000 0.000 4.681 18.317 37.664 90.571 36.405 19.965
(%MAR) 0.33 0.00 0.00 0.00 0.00 0.00 0.39 1.51 3.11 7.48 3.01 1.65
(Days) 4 0 0 0 0 0 4 6 6 7 6 5

Annual Totals
MLEWR DLEWR MHEWR DHEWR Maint. Drought
million m^3 328.523 88.163 211.594 0.000 540.118 88.163
% Nat. MAR 27.14 7.28 17.48 0.00 44.61 7.28

Table 3.90 EWR table for Breede River EWR site 3 - D

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
MLEWR
(m^3 /s) 7.600 5.800 4.000 6.000 3.300 4.100 4.600 6.400 10.000 16.000 14.500 12.000
(million m^3) 20.356 15.034 10.714 16.070 7.983 10.981 11.923 17.142 25.920 42.854 38.837 31.104
(%MAR) 1.68 1.24 0.89 1.33 0.66 0.91 0.99 1.42 2.14 3.54 3.21 2.57

DLEWR
(m^3 /s) 2.700 2.500 2.200 2.400 2.200 2.200 2.300 2.500 3.200 4.000 3.800 3.500
(million m^3) 7.232 6.480 5.892 6.428 5.322 5.892 5.962 6.696 8.294 10.714 10.178 9.072
(%MAR) 0.60 0.54 0.49 0.53 0.44 0.49 0.49 0.55 0.69 0.89 0.84 0.75

MHEWR
(m^3 /s) 23.900 0.000 0.000 0.000 0.000 0.000 26.900 81.600167.000354.000162.500107.500

(million m^3)	4.336	0.000	0.000	0.000	0.000	0.000	4.881	18.683	38.236	89.310	37.206	22.013
(%MAR)	0.36	0.00	0.00	0.00	0.00	0.00	0.40	1.54	3.16	7.38	3.07	1.82
(Days)	4	0	0	0	0	0	4	6	6	7	6	5

Annual Totals

	MLEWR	DLEWR	MHEWR	DHEWR	Maint.	Drought
million m^3	248.918	88.163	214.665	0.000	463.583	88.163
% Nat. MAR	20.57	7.29	17.74	0.00	38.31	7.29

3.6.4 F11 Breede River – EWR4_Br

Site	IUA	River	PES	EIS	REC
EWR 4_Br	F11	Breede	C	VERY HIGH	B/C

Non-flow related impacts, such as irrigation return flows and overgrazing were the major reasons for the decline in condition of the river reach represented by EWR Site 4 (Table 3.91). If measures to mitigate these, such as the creation of buffer riparian zones and overall improved catchment management, were implemented then the negative trajectory for vegetation and geomorphology could be halted. Indeed, if the non-flow related impacts were reduced, and provided other factors did not worsen, there could be an improvement from the overall C to a BC ecological category.

Table 3.91 Summary of PES and REC - Breede River EWR 4

EWR site	Discipline	Ecological category
EWR3_Br	Hydrology	C
	Water quality	C
	Geomorphology	B
	Riparian vegetation	C
	Fish	C
	Aquatic macroinvertebrates	C
	PES	C
	EIS	Very High
	REC	B/C

EWR Site 4 was a difficult site to assess. There were no observed hydrological data for this reach of the river, and flow in the river during field visits was often too high to allow for discharge readings to be taken. Consequently, calibration of the hydraulic cross-sections was difficult. In addition, the site represents a large lower river, a type of river that is often difficult to assess in terms of its flow requirements.

Table 3.92 Flood requirements Breede River EWR site 4 – BC, B and C

FLOOD CLASS	MONTHLY DISTRIBUTION	SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NUMBER OF EVENTS				
			NATURAL	PRESENT DAY	B/C	B	C
I	10 and 4	26	3	4	4	4	2
II	5-6	59	4	4	1	1	2
III	8-10	119	4	3	3	3	2
IV	6-9	233	3	2	1	1	1
1 : 2	714						
1 : 5	878						
1 : 10	1576						
1 : 20	2 335						

** at the scenario meeting, the specialists agreed that in order to ensure that EWR Site 4 was maintained in a B or BC ecological category the frequency of within year flood events needed to approximate that of present day conditions.*

Table 3.93 Summary table for Breede River EWR site 4 – B/C

EWR 4: BREEDE RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) nMAR: 1719.56 10^6m^3 pMAR: 1059.31 10^6m^3										
MONTHS	MAINTENANCE LOW FLOWS			HIGH FLOWS				DROUGHT LOW FLOWS		
	DEPTH	FLOW ($m^3 s^{-1}$)	VOLUME (10^6m^3)	DEPTH[4]	FLOW ($m^3 s^{-1}$) Daily average	DURATION	VOLUME[1] (10^6m^3)	DEPTH	FLOW ($m^3 s^{-1}$)	VOLUME (10^6m^3)
Oct	1.30	21.2	56.8	*c.* 8.3	26.04	4	4.73	1.10	12.2	32.7
Nov	1.18	15.0	38.8	*c.* 8.3	26.04	4	4.73	0.90	8.5	21.9
Dec	0.82	6.1	16.4					0.63	3.2	8.5
Jan	0.76	5.1	13.7					0.57	2.6	6.9
Feb	0.82	6.3	15.2	*c.* 8.3	26.04	4	4.73	0.63	3.2	7.8
Mar2	0.64	3.5	9.4					0.45	1.6	4.3
Apr	0.85	6.6	17.2	*c.* 8.3	26.04	4	4.73	0.64	3.5	9.0
May	0.90	8.0	21.5	1.5	59.55 & 119.5	4 & 5	54.92	0.69	4.3	11.6
Jun	1.26	16.7	43.2		119.5	5	24.47	1.00	9.5	24.6
Jul	1.32	22.2	59.4		232.5	6	53.21	1.10	12.8	34.3
Aug3	1.5	31.0	83.1		119.5	5	24.47	1.27	18.1	48.4
Sep	1.42	28.0	72.4					1.26	16.2	42.1
TOTAL										
% OF nMAR			26.00		10.23					14.65
Long term % of nMAR: 36.23 (62.304 million m^3)										
1	The volume represents the daily average less the low flows									
2	February was the month identified by the specialists to determine the dry season flows.									
3	August was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Cross-section 2 was used to calculate the depths provided.									
5	Distributions: Drought = 2. Main. = 3.87									

Table 3.94 EWR table for Breede River EWR 4 - B

EWR Table for Breede EWR 4 B
Latitude 0.00, Longitude 0.00
nMAR = 1719.57

Note : MLEWR -> Maintenance Low Flows
: DLEWR -> Drought Low Flows
: MHEWR -> Maintenance High Flows
: DHEWR -> Drought High Flows
: MHDur -> Event Duration for MHEWR
: DHDur -> Event Duration for DHEWR
: High flows (MHEWR & DHEWR) represent peaks less low flows.
: Where there are two or more high flow events, they are lumped together

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLEWR												
(m^3/s)	25.75	17.24	5.38	4.06	5.30	1.87	5.98	7.18	19.52	27.04	38.96	34.72
(million m^3)	68.96	44.69	14.42	19,87	12.83	5.00	15.51	21.38	50.59	72.42	104.33	90.01
(%MAR)	4.01	2.60	0.84	0.63	0.75	0.29	0.90	1.24	2.94	4.21	6.07	5.23
DLEWR												
(m^3/s)	12.2	8.5	3.2	2.6	3.2	1.6	3.5	4.3	9.5	12.8	18.1	16.2
(million m^3)	32.7	21.9	8.4	6.9	7.8	4.3	9.0	11.6	24.6	34.3	48.4	42.1
(%MAR)	1.45	0.89	0.33	0.44	0.21	0.27	0.42	0.53	1.12	1.87	2.67	2.15
MHEWR												
(m^3/s)	1.76	1.82	0.000	0.000	1.95	0.000	1.82	20.50	9.44	19.88	9.14	0.000
(million m^3)	4.73	4.72	0.000	0.000	4.72	0.000	4.72	54.90	24.47	53.22	24.47	0.000
(%MAR)	0.27	0.27	0.00	0.00	0.27	0.00	0.27	3.19	1.42	3.10	1.42	0.00
(Days)	4	4	0	0	4	0	4	9	5	6	5	0
DHEWR												
(m^3/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(million m^3)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(%MAR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(Days)	0	0	0	0	0	0	0	0	0	0	0	0

Annual Totals

	MLEWR	DLEWR	MHEWR	DHEWR	Maint.	Drought
million m^3	447.047	251.933	175.990	0.000	623.037	251.933
% nMAR	26.00	14.65	10.23	0.00	36.23	14.65

Table 3.95 EWR table for Breede River EWR 4 - C

Note : MLEWR -> Maintenance Low Flows
: DLEWR -> Drought Low Flows
: MHEWR -> Maintenance High Flows
: DHEWR -> Drought High Flows

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLEWR												
(m^3/s)	15.09	10.11	3.16	2.38	3.11	1.09	3.51	4.68	11.44	15.85	22.83	20.35
(million m^3)	40.42	29.19	8.45	6.37	7.50	2.93	9.09	12.53	42.47	61.15	52.75	50.00
(%MAR)	2.35	1.52	0.49	0.37	0.44	0.17	0.53	0.73	1.72	2.47	3.56	3.07
DLEWR												
(m^3/s)	12.2	8.5	3.2	2.6	3.2	1.6	3.5	4.3	9.5	12.8	18.1	16.2
(million m^3)	32.7	21.9	8.4	6.9	7.8	4.3	9.0	11.6	24.6	34.3	48.4	42.1
(%MAR)	1.45	0.89	0.33	0.44	0.21	0.27	0.42	0.53	1.12	1.87	2.67	2.15
MHEWR												
(m^3/s)	0.000	26.04	0.000	0.000	0.000	0.000	26.04	59&120	119.5	232.5	59.5	0.000
(million m^3)	0.000	4.72	0.000	0.000	0.000	0.000	4.72	54.90	10.71	53.22	24.47	0.000
(%MAR)	0.000	0.27	0.00	0.00	0.000	0.00	0.27	3.19	0.62	3.10	1.42	0.00
(Days)	0	4	0	0	0	0	4	9	5	6	5	0
DHEWR												
(m^3/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(million m^3)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(%MAR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(Days)	0	0	0	0	0	0	0	0	0	0	0	0

Annual Totals

	MLEWR	DLEWR	MHEWR	DHEWR	Total
million m^3	299.498	250.213	152.758	0.00	452.256
% nMAR	17.42	14.55	8.88	0.0	26.30

3.6.5 B4 Breede River - EWR5_Br

Site	IUA	River	PES	EIS	REC
EWR 5_Br	B4	Riversonderend	D	HIGH	D

Flow related impacts due to the present operation of Theewaterskloof Dam (especially the lack of a flooding regime) were the main reason for the decline in condition. Associated with these issues was the presence of alien vegetation and fish as well as the physical manipulation of the channel. If these activities were addressed the situation could be improved in the long term to a D ecological category (Table 3.96). Due to the significant changes presently in the system, this was predicted to be very difficult.

Table 3.96 Summary of PES and REC – Breede River EWR 5

EWR site	Discipline	Ecological category
EWR5_Br	Hydrology	E
	Water quality	B
	Geomorphology	E
	Riparian vegetation	E

EWR site	Discipline	Ecological category
	Fish	E
	Aquatic macroinvertebrates	C/D
	PES	E
	EIS	High
	REC	D

The data generated in the BRBS for Site 5 were extremely difficult to use for the extrapolation exercise. This was mainly because the irrigation releases made from Theewaterskloof Dam in the summer months were incorporated into the Reserve requirements for EWR Site 5. In order to generate the files for the extrapolation the following was done:

1. D- category: Maintained the D wet season lowflows and floods and reduced the dry season lowflows.
2. C- and B-Class. Use Desktop lowflows, elevated slightly in dry season to match D-category dry season flows for Jan-March/April. Use EWR Workshop flood recommendations, adjusted for category.

Despite these adjustments, the EWRs represented a more conservative estimate for rivers in the area that would be generated by the Desktop Model without local calibration.

Table 3.97 Flood requirements for EWR site 5

Flood Class	Monthly Distribution	Size ($m^3 s^{-1}$) Daily Average	Natural	Present Day	E - D	Distrib.
< I	10 - 4	4	Included in class I	Included in class I	3	12 - 2
I	10 - 4	7	6	0.5	1	11 - 12
II	5 - 9	20.7	4	0	1	5 - 6
III	5 - 9	41.4	3	0	2	5 - 6
IV	5 - 9	85.8	1.7	0.2	1	6 - 9
1:2	129					
1:5	209					
1:10	416					
1:20	467					

Table 3.98 Summary table for EWR site 5

EWR SITE 5: RIVIERSONDEREND RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) nMAR: 347.41 pMAR: 93.50										
MONTH	MAINTENANCE LOW FLOWS			HIGH FLOWS				DROUGHT LOW FLOWS		
	DEPTH[4]	FLOW ($m^3 s^{-1}$)	VOLUME ($10^6 m^3$)	DEPTH[4]	FLOW ($m^3 s^{-1}$) Daily average	DURATION	VOLUME[1] ($10^6 m^3$)	DEPTH[4]	FLOW ($m^3 s^{-1}$)	VOLUME ($10^6 m^3$)
Oct	0.47	2.7	7.23					0.34	0.93	2.5
Nov	0.46	2.5	6.48	0.65	7.5	2	0.61	0.33	0.85	2.2
Dec	0.31	0.7	1.88	0.53	4	2	0.40	0.24	0.35	0.94
Jan 2	0.29	0.6	1.61	0.53	4	2	0.41	0.24	0.35	0.94
Feb	0.28	0.5	1.21	0.53	4	2	0.423	0.24	0.35	0.85
Mar	0.26	0.4	1.07					0.23	0.3	0.80
Apr	0.41	1.8	4.67					0.24	0.4	1.04
May	0.43	2.0	5.36	0.90	20.6	3	2.89	0.32	0.8	2.1
Jun	0.49	3.0	7.78	1.10	21	3	2.80	0.33	0.9	2.3
Jul3	0.51	3.5	9.37	1.15	44.5	4	7.44	0.34	0.96	2.6

Aug	0.53	3.8	10.18	1.40	84.9	6	18.57	0.34	0.99	2.7
Sep	0.53	4.0	10.37	1.16	45	4	7.44	0.34	1	2.6
TOTAL			67.19				40.98			21.55
% OF nMAR			19.34				11.80			6.20
Long term % OF nMAR					38.65 (134.27 $10^6 m^3$)					
1	The volume represents the daily average less the low flows									
2	December was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.									
3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	As per cross-section 2.									

3.6.6 B4 Breede River – EWR6_Br

Site	IUA	River	PES	EIS	REC
EWR 6_Br	B4	Baviaans	B	HIGH	B

As there was no negative trajectory of change predicted here, no actions were recommended to maintain the river in its present state (Table 3.99).

Table 3.99 Summary of PES and REC – Breede River EWR 6

EWR site	Discipline	Ecological category
EWR6_Br	Hydrology	B
	Water quality	A/B
	Geomorphology	B
	Riparian vegetation	C
	Fish	A/B
	Aquatic macroinvertebrates	A/B
	PES	B
	EIS	High
	REC	B

Setting the EWRs at EWR site 6 was a special case since the flows were set using geomorphological and riparian vegetation cues over and above what high flows were predicted from the hydrological analyses, since there is an abstraction point upstream of the local gauge used to calibrate flows. In essence, the shape and size of the river was larger than was shown based on the hydrology alone; *viz,* the mean annual runoff at the gauge downstream of the abstraction weir underestimated the flows moving down the river. There are no clear notes made of the calculations undertaken to complete this assessment, other than that provided in the summary table below.

Table 3.100 Flood requirements Breede River EWR site 6 – B, C and D

Within Year Floods					
Class Floods	**Estimated Peak**	**Class B**	**Class C**	**Class D**	**Distribution**
Class I	0.8 $m^3 s^{-1}$	3	2	2	10-11 and 3-4
Class II	1.6 $m^3 s^{-1}$	2	2	1	5 and 6
Class III	3 $m^3 s^{-1}$	2	2	1	6-7 and 8-10
Class IV	6 $m^3 s^{-1}$	1	1	1	6-9
OTHER FLOODS					
1:2	Not known	yes	yes	yes	
1:5	Not known	yes	yes	no	
1:10	Not known	yes	yes	yes	
1:20	Not known	yes	yes	yes	

Table 3.101 Summary table Breede EWR site 6 - B

EWR 6: BAVIAANS RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) nMAR: Not known pMAR: Not known										
Months	**Maintenance Low Flows**			**High Flows**				**Drought Low Flows**		
	DEPTH	**FLOW (m^3/s)**	**VOLUME (million m^3)**	**DEPTH**	**FLOW m^3/s Daily average**	**DURATION**	**VOLUME[1] (million m^3)**	**DEPTH**	**FLOW (m^3/s)**	**VOLUME (million m^3)**
Oct	0.46	0.4	1.07	0.53	0.8	2	0.048	0.33	0.03	0.08
Nov	0.43	0.34	0.88					0.43	0.027	0.07
Dec	0.4	0.15	0.4					0.33	0.016	0.04
Jan	0.4	0.16	0.43					0.33	0.017	0.05
Feb[2]	0.35	0.09	0.22	0.53	0.8	2	0.086	0.33	0.013	0.03
Mar	0.33	0.04	0.11					0.33	0.01	0.03
Apr	0.37	0.07	0.18	0.53	0.8	2	0.086	0.33	0.012	0.03
May	0.33	0.04	0.11	0.6	1.6	3	0.243	0.33	0.01	0.03
Jun	0.4	0.13	0.34	0.6	1.6	3	0.229	0.33	0.015	0.04
Jul	0.43	0.21	0.56	0.73	3	3	0.434	0.33	0.019	0.05
Aug[2]	0.43	0.27	0.72	0.88	6	4	1.04	0.33	0.023	0.06
Sep	0.43	0.35	0.91	0.73	3	3	0.412	0.35	0.028	0.07
TOTAL : 5.93										
	% OF nMAR		20.57				2.58			0.58
Long term % OF nMAR: Not known										
1	The volume represents the daily average less the low flows									
2	February was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.									
3	August was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Cross-section 2 used to determine depths provided. Assuming uniform flow conditions.									

3.7 Existing River EWRs in the Palmiet Catchment

The Palmiet River preliminary Reserve was one of the first Reserve studies in the Western Cape and there are many technical terms that do not translate easily, for example the habitat integrity score from 1-5 instead of A-F. The original work also did not follow the standard PES, EIS, REC descriptions as these terms did not exist at the time of the study. Instead there was an Ecological Management Class, representing the proposed EWR (that was not split into flows for PES and flows for REC), and a habitat Integrity Class, representing the PES.

The Palmiet River was divided into two distinct sections on the basis of water resource structures present on the river:

- A highly regulated upper section from the origin to the wall of Arieskraal Dam, and
- The section from immediately downstream of the Arieskraal Dam to the estuary.

The upper section was highly developed and the lower section flows through an area of high conservation status and importance. Of the 37 kilometres of river that comprise the upper section, 13 of these consisted of impounded water bodies. In addition, the walls of the five impoundments constitute insurmountable barriers to most riverine animals. In the consideration of the EWR sites it was noted that there was little scope for the implementation of EWRs in the upper section of the Palmiet River.

There were three zones described along the Palmiet River, and EWR sites selected within these. The first was the upper reaches through Nuweberg up to Eikenhof Dam, where one EWR site was chosen. The second was from Eikenhof Dam down past the N2 (via Grabouw and Elgin) and continuing past the N2 to Arieskraal Dam, where the second EWR site was selected. The third were the reaches downstream of Arieskraal Dam, the final impoundment, after which flow recovers to some extent as the Klein Palmiet, the Louws and Dwars rivers contribute flow. There were two further EWR sites selected in this lower zone.

The Huis, Koos Koster and Krom tributaries are heavily impacted by abstraction, and water is also abstracted from the Klein Palmiet River. On the other hand, the flow in the Louws and Dwars rivers is completely natural. These two tributaries, along with the Klein Palmiet, supply the natural hydrological cues in the lower Palmiet River, such as the first annual elevated flows.

It is understood that successful implementation of the EWRs will be virtually impossible in practice mainly because of the limitations imposed by the design of the Lower Arieskraal outlet structure. The release of large quantities of water to the lower river could only be done through the release of water from Kogelberg Dam and allowing Lower Arieskraal Dam to spill. This would be subject to dam safety regulations. The Klein Palmiet, Louws and Dwars rivers therefore assume a critical level of importance and it is strongly recommended that any further abstraction from, or regulation of these three tributaries, be prohibited by legislation.

Three of the four EWR sites on the Palmiet River were used in the calibrations, the original Reserve estimates are provided for these three sites below. EWR 2 was not taken forward as it was located between dams where flows are regulated and there was no ability to make Reserve flow releases. This was considered a poor EWR site for this reason.

3.7.1 B5 Palmiet River - EWR1 (Palmiet)

Site	IUA	River	PES	EIS	REC
EWR 1 (Palmiet)	B5	Palmiet	C	HIGH	B

Co-ordinates:	Longitude: S34º06.82 - Latitude: E19º 03.29
Locality:	Between Nuweberg and Eikenhof Dams
Surrounding land-use:	Natural and State Forest
River reach:	Foothill

Reasons for choosing the site:

- it is situated in a river zone identified as desirable for the location of an EWR site;
- it provides adequate habitat diversity for fish;
- the site has varied instream habitats, in terms of riffles, pools, etc.;
- the site has both marginal and instream vegetation;
- the site is easily accessible;

- it is located upstream of an irrigation offtake.

Disadvantages of the site:

- it is downstream of Nuweberg Dam
- it is invaded by alien vegetation

Salient features of the site:

Habitat Integrity: Ecological Status Class[40]: 3

Riparian Vegetation: The site has been largely invaded by exotic alien vegetation. The larger exotics such as *Acacia longifolia* and *Pinus pinaster* have been selectively cleared in this area, with this disturbance resulting in a grassier habitat than natural at the site. The exotic aquatic moss*, Fontinalis antipyretica,* was also recorded here. Stream margins are dominated by the indigenous palmiet, *Prionium serratum*.

Fish: This is the only reach in which the two endemics, *Sandelia capensis* and *Galaxias zebratus* may still be found. Exotic fish species do not appear to be present in this reach.

Macroinvertebrates: Indicator taxa were identified as: Amphipoda; Ephemerellidae; Leptophlebiidae; Notonemouridae; Helodidae; Petrothrinicidae; Blephariceridae; Athericidae. Stream Assessment Scoring System (SASS) Score (January 1998) = 181 ("least impacted" site)

Water Quality: Water chemistry conditions recorded during previous studies appeared to be within the range expected under natural conditions.

Table 3.102 Summary table for Palmiet River EWR site 1 - B

Annual Flows: (million m^3/a)							
	Naturalised MAR = 19.30 million m^3/a						
	Present Day (1998) MAR = 16 million m^3/a						
	S. Dev = 5.34						
	CV = 27.68						
EWR Ecological Management Class = Class B[41]							
Summary of flows required for ecological Reserve (million m^3/a)							
	Total Maintenance EWR = 9.1 million m^3/a (excl. > 1:2 year floods) ≅ 47% vMAR						
	Maintenance Lowflow = 7.08 million m^3/a						
	Drought Lowflow = 1.08 million m^3/a						
	Maintenance Highflow = 3.98 million m^3/a						
Required month distribution (million m^3/ month)							
Distribution type:							
Month	**Natural Flows**			**Required flows (ecological Reserve)**			
				Lowflows		**High flows**	**Total flows**
	Mean	**SD**		**Maintenance**	**Drought**		
				million m^3/a	**million m^3/a**	**million m^3/a**	**million m^3/a**
Oct	1.62	0.9		0.93	0.13	0.02	0.95
Nov	0.78	0.5		0.70*	0.13	0.04	0.94
Dec	0.31	0.2		0.16	0.05	0.10	0.26
Jan	0.19	0.1		0.10	0.06	0.05	0.15
Feb	0.15	0.0		0.08	0.05	0.05	0.13
Mar	0.13	0.0		0.06	0.04	0.05	0.11
Apr	0.34	0.6		0.12	0.05	0.05	0.17
May	1.51	1.5		0.30	0.05	1.00	1.3

[40] Habitat Integrity Class represents the PES

[41] Ecological Management Class represents the REC

Jun	3.38	1.9		0.87	0.13	0.32	1.19
Jul	4.10	1.7		1.19	0.13	1.14	2.33
Aug	4.00	1.4		1.24	0.14	1.14	2.38
Sep	2.79	1.1		1.13	0.13	0.02	1.15

3.7.2 B5 Palmiet River - EWR3 (Palmiet)

Site	IUA	River	PES	EIS	REC
EWR 3 (Palmiet)	B5	Palmiet	C	VERY HIGH	B/C

Co-ordinates: Longitude: S 34º16.9 - Latitude: E18º58.87
Locality: Within the Kogelberg State Forest, downstream of Stokoes Bridge
Surrounding land-use: Kogelberg State Forest Reserve
River reach: Foothill

Reasons for choosing site

- the site is located within a river zone identified as desirable for the location of an EWR site;
- it is situated in a relatively unimpacted area;
- the reach of river is indicative of a rejuvenated foothill zone, which is a rare feature in Western Cape rivers;
- adequate habitat diversity for fish is available at the site;
- the site has varied instream habitats, in terms of riffles, pool etc.;
- both marginal and instream vegetation are present;
- the site is accessible by vehicle.

Salient features of the site:

Habitat Integrity: Ecological Status Class: 2.

Riparian Vegetation: Little invasion by exotic alien plants, and bank vegetation comprises largely indigenous species. The site differs from upstream sites due to the presence of floating mats of *Paspalum distichum*. Vegetation on the river banks in the vicinity of the site has been damaged by fire, but vegetation downstream includes mature trees.
Example of one of very few near-pristine lower river reaches of the south western Cape.

Fish: Although the highest densities of fish were observed at this site, they were all introduced species. Fish here showed clear habitat partitioning, both between species and between juveniles and adults.
Migrations of indigenous fish from smaller tributaries into the Palmiet River mainstream during periods of slow flow probably do occur, but such fish are unlikely to survive here long, in the presence of high densities of introduced fish.

Macroinvertebrates: Indicator taxa were identified as: Notonemouridae; Elmidae; *Cheumatopsyche thomassetti;* Cordulidae; Chlorocyphidae.
SASS Score (January 1998) = 128 ("moderately impacted" site)

Water Quality: Historical data at this site are severely limited, and those used are largely *in situ* measurements taken in January 1998. On the basis of these data, it seems that dissolved oxygen and conductivity are the two variables outside the expected natural range for equivalent unimpacted sites.

Table 3.103 Summary table for Palmiet River EWR site 3 - BC

Annual Flows: (million m³/a)							
	Naturalised MAR = 207 million m³/a						
	Present Day (1998) MAR = 135 million m³/a						
	S. Dev = 56.51						
	CV = 27.67						
EWR Ecological Management Class = B/C							
Summary of flows required for ecological Reserve (million m³/a)							
	Total Maintenance EWR = 70.6 million m³/a (excl. ≥ 1:2 year floods) ≅ 34% vMAR						
	Maintenance Lowflow = 57.36 million m³/a						
	Drought Lowflow = 12.60 million m³/a						
	Maintenance Highflow = 27.74 million m³/a (excl. ≥ 1:2 year flood events)						
Required month distribution (million m³/a`)							
Distribution type:							
Month	**Natural Flows**			**Required flows (ecological Reserve)**			
				Lowflows		**High flows**	**Total flows**
	Mean	**SD**		**Maintenance**	**Drought**		
Oct	16.63	9.9		7.78	1.43	0.35	8.13
Nov	8.56	5.2		3.56	1.53	0.70	4.27
Dec	4.06	2.1		1.94	1.59	1.06	3.00
Jan	2.54	2.5		1.63	1.50	0.53	2.16
Feb	2.07	3.3		0.86	1.55	0.53	1.39
Mar	2.67	3.2		1.18	1.35	0.53	1.88
Apr	8.87	10.3		1.41	0.69	0.53	1.22
May	21.37	18.5		1.96	0.68	6.06	8.02
Jun	36.65	24.6		7.69	0.47	1.35	9.04
Jul	39.29	19.1		9.35	0.58	5.7	15.05
Aug	39.88	17.8		10.08	0.60	10.05	20.13
Sep	25.22	10.7		9.92	0.63	0.35	10.37

3.7.3 B5 Palmiet River - EWR4 (Palmiet)

Site	IUA	River	PES	EIS	REC
EWR 4 (Palmiet)	B5	Palmiet	B	VERY HIGH	B

Co-ordinates: Longitude: S34º19.819 - Latitude: E18º 59.362
Locality: Between DWAF gauging weir G4H007 and the road bridge at the estuary
Surrounding land-use: Kogelberg State Forest Reserve
River reach: Transitional

Reasons for choosing the site:

- this was the only possible location in this reach upstream of the estuary.

Disadvantages of site:

- the site is located between a DWAF gauging weir and a road bridge;
- there is only a short reach of river available to work in;
- the site is impacted by recreational use of the area.

Salient features of the site:

Habitat Integrity: Ecological Status Class: 2.

Riparian Vegetation: None of the aquatic plant species associated with rocky substrata upstream are found here, with the exception of *P. serratum*, which is dominant here. Exotic alien vegetation such as *A. longifolia* is periodically cleared from the site.

Fish: Estuarine-dependent marine species (*Myxus capensis* and *Monodactylus falciformis*) were caught in the riffle area at this site. The DWAF gauging weir appears to constitute a barrier to the upstream movement of these species.

Macroinvertebrates: Indicator taxa identified as: Ephemerellidae, Leptophlebiidae, Heptageniidae, Barbarochthonidae, Tricorythidae, Petrothrinicidae, Corydalidae, Elmidae, Pyraustidae, Athericidae.
SASS Score (January 1998) = 134 (“least-impacted” site)

Water Quality: Water chemistry conditions derived from DWAF station G4 H007 indicate that most variables were within the range expected under natural conditions. Insufficient information on temperature and dissolved oxygen prevented examination of current conditions for these variables.

Table 3.104 Summary table for Palmiet River EWR site 4 - AB

Annual Flows: (million m^3/a)							
	Naturalised MAR = 257.30 million m^3/a						
	Present Day (1998) MAR = 186 million m^3/a						
	S. Dev = 75.86						
	CV = 28.70						
EWR Ecological Management Class = Class A/B							
Summary of flows required for ecological Reserve (million m^3/a)							
	Total Maintenance EWR = 99.85 million m^3/a (excl. ≥ 1:2 year floods) ≅ 38% nMAR						
	Maintenance Lowflow = 79.23 million m^3/a						
	Drought Lowflow = 20.19						
	Maintenance Highflow = 42.06						
Required month distribution (million m^3/month)							
Distribution type:							
Month	**Natural Flows**			**Required flows (ecological Reserve)**			
				Lowflows		**High flows**	**Total flows**
	Mean	**SD**		**Maintenance**	**Drought**		
Oct	20.32	11.7		10.30	2.57	0.05	10.35
Nov	10.23	6.6		4.84	2.30	0.1	4.94
Dec	4.83	4.6		2.53	0.95	1.96	4.49
Jan	3.06	4.1		2.01	0.94	0.98	2.99
Feb	2.74	4.5		1.15	0.63	0.98	2.13
Mar	3.46	4.5		1.53	0.83	0.98	2.51
Apr	11.76	14.0		2.20	0.89	0.98	3.18
May	26.88	21.9		3.10	0.95	8.86	11.96
Jun	45.33	29.7		11.39	2.45	2.45	13.84
Jul	48.66	23.4		13.19	2.57	8.53	21.72
Aug	49.94	22.3		13.86	2.57	14.61	28.47
Sep	30.17	14.0		13.13	2.49	0.05	13.18

3.8 Existing River EWRs in the Hex Catchment

There are three EWR sites on the Hex River but only the most downstream site, EWR site 3 was used in calibrating flows. Summary information for this site is provided below.

3.8.1 A2 Hex River - EWR3 (Hex)

Site	IUA	River	PES	EIS	REC
EWR 3 (Hex)	A2	Hex	C	MOD	C

The critical sources and actions required to maintain the PES in a C category, together with the degree of difficulty associated with addressing each of these are summarised in the following table.

Table 3.105 Summary of sources and actions to maintain PES at Hex River EWR site 3

Sources	Action	Degree of difficulty
Flow- related • Agriculture & upstream dams (fluctuating flows)	• Provide the Reserve.	• Reasonable*
Non-flow related • Agriculture (Nutrient enrichment) • Alien vegetation • Alien fish • Channel manipulation	• Better agricultural practices • Put in buffer zones • Working for Water • Limit stocking • Land use management	• Difficult • Reasonable • Reasonable • Reasonable • Very difficult

*Considered reasonable because the poorly distributed (fluctuating) flows are mainly the result of the influence of the dams in the Sandrifkloof River. Therefore, sufficient flow and flow variability (including floods) are still available from the Hex River upstream as well as the Amandels River. Requirement will probably be a change in operation to prevent the negative impacts of fluctuations.

Considering that only a reasonable degree of difficulty is associated with addressing most of the sources, an REC of category C was deemed attainable and was therefore the target condition at this EWR site (Table 3.106). The flood requirements and summary of seasonal high and low flows are provided in Table 3.107 and Table 3.108 respectively.

Table 3.106 Summary of PES and REC – Hex River EWR 3

EWR site	Discipline	Ecological category
EWR 3_Hex	Water quality	B
	Geomorphology	C
	Riparian vegetation	E
	Fish	C
	Aquatic macroinvertebrates	C
	PES	C
	EIS	Moderate
	REC	C

Table 3.107 Flood requirements Hex River EWR 3 - C

	FLOOD	NATURAL (m^3/s)	CURRENT (m^3/s) Category C	NUMBER OF EVENTS	DISTRIBUTION*
INTRA-ANNUAL FLOODS	Class I	8.5	4.9	2	10-4
	Class II	11.3	9	2	5-6
	Class III	22.5	19	2	8-10
	Class IV	45.0	39	1	6-9
> 1 YEAR FLOODS	1:2	60	53		

Table 3.108 Summary table for Hex River EWR 3 - C

EWR 3: Hex River (Category C) ASSURANCE OF MAINTENANCE LOW FLOWS: 50 % (summer) and 50 % (winter) nMAR: 116.66 (million m^3) pMAR: 93.72 (million m^3)										
MONTHS	**MAINTENANCE LOW FLOWS**			**HIGH FLOWS**				**DROUGHT LOW FLOWS**		
	DEPTH[4]	**FLOW**	**VOLUME**	**DEPTH**	**FLOW**	**DURATION**	**VOLUME[1]**	**DEPTH[4]**	**FLOW**	**VOLUME**
	(m)	**(m^3 s^{-1})**	**(10^6 m^3)**	**(m)**	**M^3 s^{-1} Daily average**	**(days)**	**(10^6 m^3)**	**(m)**	**(m^3 s^{-1})**	**(10^6 m^3)**
OCT	0.59	1.27	3.403	0.89	4.9	2	0.439	0.42	0.32	0.857
NOV	0.58	1.16	3.007	0.89	4.9	2	0.448	0.42	0.3	0.778
DEC	0.53	0.8	2.143					0.37	0.18	0.482
JAN	0.47	0.5	1.339					0.32	0.1	0.268
FEB	0.47	0.5	1.210					0.30	0.08	0.194
MAR[2]	0.45	0.4	1.071					0.28	0.06	0.161
APR	0.47	0.5	1.296					0.29	0.65	0.168
MAY	0.51	0.7	1.875	1.08	9	3	1.291	0.32	0.15	0.402
JUN	0.56	0.99	2.566	1.08	9	3	1.246	0.40	0.25	0.648
JUL	0.59	1.3	3.482	1.81	39	5	7.72	0.43	0.33	0.884
AUG[3]	0.61	1.5	4.018	1.39	19	4	3.175	0.45	0.40	1.071
SEP	0.61	1.46	3.784	1.39	19	4	3.182	0.44	0.39	1.011
TOTAL			29.194				17.50			6.924
		% OF nMAR	25.02				14.68			5.94
3.8.1.1 Long term % OF nMAR: 42% (48 million m^3)										
1	The volume represents the daily average less the low flows									
2	March was the month identified by the specialists to determine the dry season flows.									
3	August was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Depths are taken from cross-section C									

Flows for alternate categories B and D category were also calculated (Table 3.109, Table 3.110, Table 3.111). In order to generate the flow regime for a B Category, the specialists decided to increase the number of flood events (Table 8.6), rather than concentrate on the lowflows. Lowflows were increased by 10% on the basis that for the other Breede River sites (BRBS) there was a *c.* 10% difference in percentage MAR between a Category B and Category C ERC for a river.

Table 3.109 Flood events for alternate categories Hex River EWR 3 – B, C and D

INTRA-ANNUAL FLOOD CLASS	B (from BRBS)	B (EWR Site 3 – Hex)	C (from BRBS)	D (from BRBS)	Distribution*
Class 1	3	4	2	2	10 - 4
Class 2	2	2	2	1	5-6
Class 3	2	3	2	1	8-10
Class 4	1	1	1	1	6-9

Table 3.110 Summary table for Hex River EWR 3 - B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLEWR												
(m^3/s)	1.270	1.200	0.880	0.550	0.550	0.440	0.550	0.770	2.000	1.400	1.700	1.700
(million m^3/a)	3.402	3.110	2.357	1.473	1.331	1.178	1.426	2.062	5.184	3.750	4.553	4.406
(%MAR)	2.92	2.67	2.02	1.26	1.14	1.01	1.22	1.77	4.44	3.21	3.90	3.78
DLEWR												
(m^3/s)	0.320	0.300	0.180	0.100	0.080	0.060	0.065	0.150	0.250	0.330	0.400	0.390
(million m^3/a)	0.857	0.778	0.482	0.268	0.194	0.161	0.168	0.402	0.648	0.884	1.071	1.011
(%MAR)	0.73	0.67	0.41	0.23	0.17	0.14	0.14	0.34	0.56	0.76	0.92	0.87
MHEWR												
(m^3/s)	3.630	3.700	0.000	4.400	0.000	4.500	4.400	8.300	8.000	37.700	27.079	17.500
(million m^3/a)	0.439	0.448	0.000	0.532	0.000	0.544	0.532	1.291	1.244	7.720	6.200	3.175
(%MAR)	0.38	0.38	0.00	0.46	0.00	0.47	0.46	1.11	1.07	6.62	5.31	2.72
(Days)	2	2	0	2	0	2	2	3	3	5	6	4

Annual Totals

	MLEWR	DLEWR	MHEWR	Maint.	Drought
million m^3/a	34.233	6.923	22.125	56.359	6.923
% nMAR	29.35	5.93	18.97	48.31	5.93

Table 3.111 Summary table for Hex River EWR 3 - D

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLEWR												
(m^3/s)	0.630	0.550	0.320	0.170	0.140	0.110	0.160	0.270	0.460	0.620	0.760	0.740
(million m^3/a)	1.687	1.426	0.857	0.455	0.339	0.295	0.414	0.723	1.192	1.661	2.036	1.918
(%MAR)	1.45	1.22	0.73	0.39	0.29	0.25	0.36	0.62	1.02	1.42	1.74	1.64
DLEWR												
(m^3/s)	0.320	0.300	0.180	0.100	0.080	0.060	0.065	0.150	0.250	0.330	0.400	0.390
(million m^3/a)	0.857	0.778	0.482	0.268	0.194	0.161	0.168	0.402	0.648	0.884	1.071	1.011
(%MAR)	0.73	0.67	0.41	0.23	0.17	0.14	0.14	0.34	0.56	0.76	0.92	0.87
MHEWR												
(m^3/s)	4.270	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.540	38.380	18.240	0.000
(million m^3/a)	0.516	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.328	7.859	3.309	0.000
(%MAR)	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	6.74	2.84	0.00
(Days)	2	0	0	0	0	0	0	0	3	5	4	0

Annual Totals

	MLEWR	DLEWR	MHEWR	Maint.	Drought
million m^3/a	13.003	6.923	13.013	26.016	6.923
% Nat. MAR	11.15	5.93	11.16	22.30	5.93

3.9 Additional EWR Sites in the Overberg area (G40 and G50)

There were no previously identified Reserve sites or EWR determinations in the Overberg area (G40 and G50). Rapid III level EWR determinations were recommended for three rivers in order to provide input into catchment-wide assessment of EWRs for the Rivers in secondary catchments G40 and G50, the Overberg region.

The Resource Unit Prioritisation tool (DWAF 2011) was used to assess the relative importance of the rivers on which nodes had been delineated following the Classification procedures (Dollar et al. 2006) in secondary catchments G40 and G50. The top five rivers in order of priority were the Palmiet, the Kars, the Klein and the Bot, and the Heuningnes Rivers. There were already four EWR river sites along the Palmiet River so this river was not considered further. The Klein and Bot Rivers were considered to be similar enough to one another that EWRs calculated for one could be extrapolated to the other and the both flow into large and important coastal estuaries. The Kars River is quite different in that it is situated in the drier Renosterveld region of the Overberg with different vegetation to the other rivers situated closer to the coast. The Heuningnes River (called the Nuwejaars in the vicinity of Elim upstream of Soetendalsvlei) too is important as it supports a number of temporary wetlands and also flows through Soetendalsvlei, a large permanent wetland in the Agulhas National park, before entering the large Heuningnes estuary.

There was more than one node on each of these river systems. The rivers of the Overberg are intensively farmed with cattle, sheep and lucerne so many of the floodplains and associated wetlands have been drained or infilled. For these reasons, the nodes where a naturally shaped river channel still remained independently of lateral wetlands were selected as the EWR sites in the three river systems:

- Nv24 on the Kars River
- Nv23 on the Klein River
- Ni4 on the Nuwejaars River, u/s of Soetendalsvlei

3.9.1 New EWR Site Kar1: Kars River

The location of the EWR site Kar1 is shown in Figure 3.2.

Figure 3.2 EWR site Kar1, u/s of node Nv24 and gauge G5H003, situated d/s of R319 at -34 29 22.85, 20 07 04.38

Kar1 was in an extremely good condition, a BC category, with an overall PES score of 81.2%. The EIS was moderate but the specialists felt that this type of river was regionally important as a river type. That being said improved flow should improve water quality and have knock-on improvements to aquatic biota since the river channel at the EWR site is generally well protected in a deep channel from the surrounding farming activities. The most sensible course of action would be to set the REC at a B with a slightly higher condition score to accommodate this improvement.

Table 3.112 Present ecological status, ecological importance and sensitivity, and recommended ecological category

EWR site	Discipline	Component score	Ecological condition
Kar1	Water quality	70	C
	Geomorphology	85.5	B
	Riparian vegetation	82.5	B
	Aquatic macroinvertebrates	81.2	B
	Fish	36	E
	Median PES	81.20	BC
	EIS	1.67	MODERATE
	REC		B

The specialists felt that the EIS tool underscored the importance of the EWR site Kar1 as it does not consider river type *per se* in its ranking of importance, rather being focussed at biota and conservation importance of plant and animal species. Scores for the Ecological importance and sensitivity are summarised below in Table 3.113.

Table 3.113 Ecological importance and sensitivity

EWR site	Category	Component score	Reasoning
Kar1	Biota (riparian and aquatic)		
	Rare and endangered	1.33	1.33
	Unique (endemic)	1.00	1.33
	Intolerant (flow and water quality)	1.33	1.33
	Species richness	2.33	1.33
	Habitat (riparian and aquatic)	(0-4)	
	Diversity of types	1.33	2.00
	Refugia	3.00	2.00
	Sensitivity to flow changes	1.67	2.00
	Sensitivity to flow related water quality changes	1.67	1.67
	Migration corridors	2.67	1.67
	Conservation importance	1.67	2.00
	Median of scores	1.67	
	EIS	MODERATE	

Reasons for the present day conditions are summarised per discipline and EWR site in Table 3.114.

Table 3.114 Causes and sources of present day condition and projected trends

EWR site	Discipline	Causes and sources	Trend
Kar1	Water quality	Probably elevated salinities resulting from natural geology and agricultural runoff.	The catchment has been cultivated for a long time with similar crops and unless this change the long term trend will be stable, with a seasonal trend of poorer water quality in the dry summer months and improved water quality during the wet winter months.
	Geomorphology	Cultivation on hillslopes. Limited impacts.	Stable, provided farming intensity remains constant.
	Riparian vegetation	Animal husbandry of beef and sheep, lucerne farming.	Stable, provided exotic woody plants are cleared regularly.
	Aquatic macroinvertebrates	Water quality impairment from diffuse runoff of nutrients and pesticides/insecticides from an intensely cultivated catchment. There is some loss of habitat due to grazing of riparian vegetation along channel margins and the loss of fast flowing habitats in the summer due to abstraction during the low flow season.	Intensification of land use activities may exacerbate water quality deterioration in the future although intensification is unlikely.
	Fish	• Hydrological alteration (reduction in low flows, increase in zero flows) • Introduction of alien invasive fish species • Sedimentation	Stable.

The flow measured at Kar1 on the 26th June 2017 was 0.003 m^3/s, indicative of the severe drought at the time. This is lower than the average natural monthly discharge for the month of June (Table 3.115).

Table 3.115 Simulated naturalised and present day hydrology at Kar1 on the Kars River

Month	Mean (million m^3/a)			Discharge
	nMAR	pMAR	% natural	Natural median Q (m^3/s)
October	1.759	1.911	92.0	0.310
November	1.246	1.390	89.7	0.228
December	0.485	0.558	86.8	0.116
January	0.323	0.373	86.5	0.082
February	0.350	0.406	86.3	0.079
March	0.533	0.609	87.4	0.075
April	1.419	1.588	89.4	0.116
May	1.319	1.479	89.2	0.194
June	1.731	1.902	91.0	0.270
July	1.501	1.667	90.1	0.366
August	1.919	2.113	90.8	0.497
September	1.303	1.437	90.7	0.409

Table 3.116 Hydrological summary table for B category at Kar1 site on the Kars River

Desktop Version 2, Generated on 30/12/2016
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
Total Runoff : nv24
Annual Flows (million m^3 or index values):
MAR = 15.433
S.Dev. = 12.430
CV = 0.805
Q75 = 0.240
Q75/MMF = 0.187
BFI Index = 0.403
CV(JJA+JFM) Index = 3.846
Ecological Category = B
Total EWR = 4.674 (30.29 %MAR)
Maint. Lowflow = 2.607 (16.89 %MAR)
Drought Lowflow = 0.644 (4.17 %MAR)
Maint. Highflow = 2.067 (13.40 %MAR)
Monthly Distributions (million m^3)
Distribution Type : W.Cape(wet)

Month	Natural Flows			Modified Flows (EWR)			
				Low		High	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.911	4.130	2.161	0.322	0.079	0.301	0.623
Nov	1.390	1.950	1.403	0.282	0.070	0.157	0.440
Dec	0.558	0.696	1.245	0.168	0.044	0.000	0.168
Jan	0.373	0.528	1.414	0.121	0.034	0.000	0.121
Feb	0.406	0.916	2.256	0.109	0.031	0.000	0.109
Mar	0.609	1.946	3.195	0.119	0.033	0.000	0.119
Apr	1.588	4.472	2.816	0.191	0.030	0.000	0.191
May	1.479	2.508	1.696	0.204	0.050	0.268	0.472
Jun	1.902	4.129	2.171	0.250	0.063	0.349	0.600
Jul	1.667	1.898	1.139	0.255	0.064	0.170	0.425
Aug	2.113	2.878	1.362	0.304	0.075	0.651	0.956
Sep	1.437	1.338	0.931	0.283	0.070	0.170	0.453

3.9.2 New EWR Site Kle1: Klein River

The location of the EWR site Kle1 is shown in Figure 3.3.

Figure 3.3 EWR site Kle1, situated u/s of the gauge G5H006 and d/s of node Nv23 at -34 24 22.32, 19 35 57.08

Kle1 was in a CD category with a PES score of 60%. The EIS was moderate and management toward an improved condition may be attempted through the clearing of exotic woody vegetation that allows indigenous riparian plants to re-establish. This is likely to result in an improved category designation on its own raising the percentage score to a C. Similarly, since the river is channelized there is little room to reclaim lateral aquatic habitat or floodplain from the surrounding farmed fields. Since the river has good potential for improvement the most sensible course of action was to set the REC to improve the current condition of the river to the ecological category C.

Table 3.117 Present ecological status, ecological importance and sensitivity, and recommended ecological category

EWR site	Discipline	Component score	Ecological condition
Kle1	Water quality	60	C
	Geomorphology	63.7	C
	Riparian vegetation	45	D
	Aquatic macroinvertebrates	69	C
	Fish	25	E
	Median PES	60.00	CD
	EIS	2.00	MODERATE
	REC		C

The specialists felt that the EIS tool underscored the importance of the EWR site Kle1 as it does not consider river type *per se* in its ranking of importance, rather being focussed at biota and conservation importance of plant and animal species.

Table 3.118 Ecological importance and sensitivity

EWR site	Category	Component score	Reasoning
Kle1	Biota (riparian and aquatic)		
	Rare and endangered	0.83	1.33
	Unique (endemic)	0.67	1.33
	Intolerant (flow and water quality)	1.67	1.33
	Species richness	1.17	1.33
	Habitat (riparian and aquatic)	(0-4)	
	Diversity of types	2.33	2.00
	Refugia	2.67	2.00
	Sensitivity to flow changes	3.67	2.00
	Sensitivity to flow related water quality changes	3.33	2.00
	Migration corridors	2.67	2.00
	Conservation importance	1.33	2.33
	Median of scores	2.00	
	EIS	MODERATE	

Reasons for the present day conditions are summarised per discipline and EWR site in Table 3.114.

Table 3.119 Causes and sources of present day condition and projected trends

EWR site	Discipline	Causes and sources	Trend
Kle1	Water quality	Largely agricultural impacts.	There is a long term increasing trend in salinity superimposed onto the seasonal trend of poorer water quality in the dry summer months and improved water quality during the wet winter months. This is expected to continue and may include increases in potassium, sodium, chloride, nitrate & nitrite, phosphate, pH and total alkalinity.
	Geomorphology	Upstream dams, surrounding cultivation and livestock impacts. There has been morphological change to the channel.	Stable, provided farming intensity remains constant.
	Riparian vegetation	Animal husbandry of dairy cows, wine grape farming.	Stable, provided exotic woody plants are cleared regularly.
	Aquatic macroinvertebrates	Loss of dry season flows (summer flows) and eutrophication are the key cause of poor water quality	The system is likely to deteriorate further with the current level of abstraction and nutrient inputs.
	Fish	• Hydrological alteration (reduction in low flows, increase in zero flows) • Loss of connectivity • Introduction of alien invasive fish species • Poor water quality • Sedimentation • Habitat degradation (loss of cover)	Declining.

The flow measured at Kle1 on the 28th June 2017 was 0.015 m^3/s. This is lower than the average natural monthly discharge for the month of June (Table 3.120), indicative of the drought at the time.

Table 3.120 Simulated naturalised and present day hydrology at Kle1 on the Klein River

Month	Mean (million m^3/a)			Discharge
	nMAR	pMAR	% natural	Natural Mean Q (m^3/s)
October	3.381	3.931	86.0	1.005
November	2.016	2.555	78.9	0.562
December	0.857	1.161	73.8	0.224
January	0.350	0.464	75.6	0.076
February	0.386	0.485	79.5	0.042
March	0.498	0.616	80.9	0.027
April	1.794	2.078	86.4	0.090
May	2.919	3.335	87.5	0.288
June	4.529	5.004	90.5	0.673
July	6.319	6.866	92.0	1.229
August	9.362	10.040	93.2	2.356
September	5.967	6.476	92.1	1.679

Table 3.121 Hydrological summary table for C category at Kle1 site on the Klein River

Desktop Version 2, Generated on 30/12/2016
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
Total Runoff : nv23

Annual Flows (million m^3/a or index values):
MAR = 43.010
S.Dev. = 34.553
CV = 0.803
Q75 = 0.234
Q75/MMF = 0.065
BFI Index = 0.327
CV(JJA+JFM) Index = 4.986

Ecological Category = C

Total EWR = 8.291 (19.28 %MAR)
Maint. Lowflow = 3.414 (7.94 %MAR)
Drought Lowflow = 1.259 (2.93 %MAR)
Maint. Highflow = 4.877 (11.34 %MAR)

Monthly Distributions (million m^3.)
Distribution Type : W.Cape(wet)

Month	Natural Flows			Modified Flows (EWR)			
				Low		High	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	3.931	3.795	0.965	0.465	0.175	0.398	0.863
Nov	2.555	3.147	1.232	0.358	0.136	0.179	0.537
Dec	1.161	2.407	2.073	0.199	0.077	0.000	0.199
Jan	0.464	1.150	2.480	0.091	0.037	0.000	0.091
Feb	0.485	1.986	4.096	0.065	0.027	0.000	0.065
Mar	0.616	2.765	4.489	0.064	0.027	0.000	0.064
Apr	2.078	6.573	3.163	0.126	0.030	0.000	0.126
May	3.335	6.540	1.961	0.196	0.051	0.516	0.712
Jun	5.004	7.316	1.462	0.293	0.112	0.767	1.060
Jul	6.866	8.695	1.266	0.413	0.156	0.502	0.915
Aug	10.040	11.699	1.165	0.603	0.227	2.013	2.616
Sep	6.476	7.199	1.112	0.541	0.204	0.502	1.043

3.9.3 New EWR Site Nuw1: Nuwejaars River

The location of the EWR site Nuw1 is shown in Figure 3.4**Error! Reference source not found.**.

Figure 3.4 EWR site Nuw1, situated u/s of Soetendalsvlei and d/s node Ni4 at -34 38 00.33, 19 51 51.65

Nuw1 was in a D category with a PES score of 46.7%. The EIS was moderate and the REC was set to maintain the current condition of the river in a D category. The river is channelized and flow and longitudinal connectivity are interrupted during the dry season and there is little room to reclaim lateral aquatic habitat or floodplain. Some improvement in overall condition could be made by clearing exotic woody and non-woody plants from the riparian area but this is unlikely to increase the condition out of its current D category.

Table 3.122 Present ecological status, ecological importance and sensitivity, and recommended ecological category

EWR site	Discipline	Component score	Ecological condition
Nuw1	Water quality	50	D
	Geomorphology	55.9	D
	Riparian vegetation	35	E
	Aquatic macroinvertebrates	46.7	D
	Fish	27	E
	Median PES	46.70	D
	EIS	1.83	MODERATE
	REC		D

The ecological importance and sensitivity (EIS) are summarised in Table 3.123.

Table 3.123 Ecological importance and sensitivity

EWR site	Category	Component score	Reasoning
Nuw1	Biota (riparian and aquatic)		
	Rare and endangered	1.33	1.33
	Unique (endemic)	1.00	1.33
	Intolerant (flow and water quality)	0.33	1.33
	Species richness	1.50	1.33
	Habitat (riparian and aquatic)	(0-4)	
	Diversity of types	1.67	2.00

EWR site	Category	Component score	Reasoning
	Refugia	3.67	2.00
	Sensitivity to flow changes	2.50	2.00
	Sensitivity to flow related water quality changes	2.67	1.67
	Migration corridors	3.00	1.67
	Conservation importance	2.00	2.00
	Median of scores	1.83	
	EIS	MODERATE	

Reasons for the present day conditions are summarised per discipline and EWR site in Table 3.114.

Table 3.124 Causes and sources of present day condition and projected trends

EWR site	Discipline	Causes and sources	Trend
Nuw1	Water quality	Probably elevated salinities resulting from natural geology and agricultural runoff.	The catchment has been cultivated for a long time with similar crops and unless this change the long term trend will be stable, with a seasonal trend of poorer water quality in the dry summer months and improved water quality during the wet winter months.
	Geomorphology	Cultivation, overgrazing and livestock trampling on the channel banks. Small farm dams, channels and furrows. Significant morphological change, in particular to the banks and flood zone.	Stable, provided farming intensity remains constant.
	Riparian vegetation	Animal husbandry of beef and sheep, wine grape farming.	Stable, provided exotic woody plants are cleared regularly.
	Aquatic macroinvertebrates	Loss of habitat through sedimentation of cobble substratum, grazing and trampling of riparian vegetation, abstraction and thus the loss of flowing habitats (particularly runs and riffles) during the dry summer season. Also, water quality impairment due to cattle within the channel and intense transformation of the catchment to accommodate farming practices.	Only hardy taxa remain in the system and thus it is unlikely to deteriorate further in terms of the macroinvertebrate community.
	Fish	• Hydrological alteration (reduction in low flows, increase in zero flows) • Loss of connectivity • Introduction of alien invasive fish species • Poor water quality • Sedimentation • Channelisation of the river • Habitat degradation (loss of cover)	Declining.

The flow measured at Nuw1 on the 27th June 2017 was 0.076 m^3/s. This is lower than the average natural monthly discharge for the month of June (Table 3.125).

Table 3.125 Simulated naturalised and present day hydrology at Nuw1 on the Nuwejaars River

Month	Mean (million m^3/a)			Discharge
	nMAR	pMAR	% natural	Natural Mean Q (m^3/s)
October	0.633	1.216	52.1	0.239
November	0.353	0.812	43.4	0.150
December	0.112	0.319	35.1	0.075
January	0.091	0.262	34.8	0.056
February	0.138	0.349	39.4	0.050
March	0.096	0.275	34.7	0.045
April	0.470	0.952	49.3	0.077
May	0.469	1.053	44.5	0.157
June	0.900	1.810	49.7	0.270
July	1.011	1.901	53.2	0.347
August	1.178	2.170	54.3	0.385
September	0.744	1.354	55.0	0.316

Table 3.126 Hydrological summary table for D category at Nuw1 site on the Nuwejaars River

Desktop Version 2, Generated on 17/01/2017
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
Total Runoff : ni4

Annual Flows (million m^3 or index values):
MAR = 12.473
S.Dev. = 14.086
CV = 1.129
Q75 = 0.160
Q75/MMF = 0.154
BFI Index = 0.381
CV(JJA+JFM) Index = 4.150

Ecological Category = D

Total EWR = 1.626 (13.03 %MAR)
Maint. Lowflow = 0.490 (3.93 %MAR)
Drought Lowflow = 0.210 (1.68 %MAR)
Maint. Highflow = 1.136 (9.11 %MAR)

Monthly Distributions (million m^3)
Distribution Type : W.Cape(wet)

Month	Natural Flows			Modified Flows (EWR)			
				Low		High	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.216	2.168	1.783	0.055	0.020	0.115	0.170
Nov	0.812	1.132	1.394	0.046	0.010	0.052	0.098
Dec	0.319	0.355	1.112	0.030	0.010	0.000	0.030
Jan	0.262	0.489	1.863	0.022	0.010	0.000	0.022
Feb	0.349	1.058	3.030	0.022	0.010	0.000	0.022
Mar	0.275	0.475	1.727	0.020	0.010	0.000	0.020
Apr	0.952	3.536	3.713	0.030	0.020	0.000	0.030
May	1.053	1.880	1.786	0.035	0.030	0.129	0.163
Jun	1.810	3.792	2.095	0.049	0.030	0.232	0.281
Jul	1.901	3.664	1.927	0.056	0.020	0.108	0.164
Aug	2.170	3.924	1.809	0.065	0.020	0.393	0.459
Sep	1.354	1.769	1.307	0.059	0.020	0.108	0.167

3.10 Preliminary Ecological Water Requirements for River Nodes

3.10.1 Updated hydrological information for Biophysical Nodes

3.10.1.1 Incorporating biophysical nodes into existing hydrological models

The original WR2012 configurations of the Pitman model were structured around Quaternary catchment delineations, but with all bulk infrastructure and demands located at the correct points inside the respective catchments. These configurations were now further sub-divided to reflect the biophysical and allocation river nodes identified by the river ecology team. In total, 148 river nodes were introduced for the Gouritz sub-area and 114 river nodes for the Breede-Overberg sub-area. As described above EWRs were only determined for a sub section of these nodes, but natural and present day flows were generated for all nodes.

3.10.1.2 Proportioning of incremental flows at biophysical nodes

Because the locations of the biophysical and allocation river nodes frequently did not coincide with locations of existing modelling nodes in the Pitman configurations, streamflows at each such river node had to be derived by proportioning of the incremental streamflows at the immediately downstream existing modelling node on the basis of the Mean annual precipitation (MAP) and area of the incremental catchment of the river node and the well-established WR90 MAP-MAR (in mm) regionalised curves. The incremental MAPs of river node catchments were derived from the WR2012 gridded MAP coverage of the whole country through Geographical Information System (GIS) applications.

Estuaries of major rivers usually represent the outflow point of the most downstream quaternary catchment, whereas the catchments of minor estuaries sometimes comprise only a portion of a Quaternary. For a number of minor estuaries a similar proportioning exercise to that described above for river nodes was conducted.

3.10.1.3 Improvement of existing WR2012 model configurations

In the course of incorporation of the biophysical and allocation river nodes into the existing WR2012 Pitman model configurations, a number of incorrect aspects of these configurations were noticed and corrected. These aspects include occasionally incorrect items relating to bulk infrastructure details, demands, irrigation areas, model routes and sub-catchment interlinkages. The WR2012 configurations were improved by correcting all the above aspects.

3.10.1.4 Generating of monthly flow series for EWRs

The simulated natural and present-day monthly streamflow series for hydrological years 1920 to 2009 for all biophysical and allocation river nodes, as well as for inflows to all estuaries, were developed for use in determining the EWR requirements for different ecological categories at all nodes in the study area.

Natural monthly streamflow series for hydrological years 1920 to 2009 were simulated for all biophysical and allocation river nodes, as well as for inflows to all estuaries by excluding all human impacts from the configurations.

Present-day monthly streamflow series for hydrological years 1920 to 2009 were simulated for all biophysical and allocation river nodes, as well as for inflows to all estuaries, for the entire study area by including all human impacts in the configurations, i.e. all bulk water resources infrastructure, demands, clusters of farm dams, run-or-river abstractions, afforestation, invasive alien plants, return flows from irrigated areas and treated effluent return flows.

3.10.2 Provisional Ecological Water Requirements for rivers

To facilitate routing of flows through the river catchments and to meet estuary requirements an initial set of EWRs have been generated for 66 Gouritz River catchment and Outeniqua region nodes (Table 3.127) and 76 Breede River basin and Overberg region nodes (Table 3.128). The following information is provided:

- the nMAR (in million m^3/a) is provided per node
- flows required to maintain the Baseline 2014 Ecological Condition is provided per node, as a percentage of the nMAR and the annual total EWR (million m^3/a)
- where the EC is an E-category, flows are provided for the minimum allowed D-category
- nodes calibrated using the same EWR data are shaded in the same colour to indicate that the flow requirements of the EWR site were used to calibrate flows at the node in question.

In Table 3.127 the EWRs for the Breede River and Overberg region, preliminary rapid II EWRs have been calculated for the Overberg rivers in the interim, prior to the analysis of scenarios. This is because river EWRs tend to request lower percentages of the nMAR than estuarine EWRs. Since one of the objectives of the Classification process is to route flows in a downstream direction (through the rivers) to supply and meet the EWRs requested at the estuaries, these preliminary river EWRs of the Overberg rivers are going to be over ridden by the requests at the estuaries.

This means, in practical terms, the flows routed through the rivers will be the same percentages of the mean annual runoff requested at the estuary, but scaled to the nMAR at each river node in question respectively. In most cases, there are few nodes upstream of the small coastal rivers, which leaves little scope for manipulating flows higher or lower than those requested by the estuaries.

Table 3.127 Nodes at which EWRs have been calculated in the Gouritz River catchment and Outeniqua region. EWR sites are indicated in red text

EWR site for calibration	IUA	#	SQ code	CODE	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EIS	nMAR	1999EC	2014EC	EWR %	EWR MAR
WK	E8	4	J12D-08735	giv28	Touws	20.2714	-33.4567	J12D	SFM	3	UF	H	16.4	C	D	11.3	1.8
WK	E8	8	J12H-08834	giv27	Touws	20.9021	-33.6208	J12H	SFM	3	UF	M	26.4	C	B	26.8	7.1
EK	E8	10	J12K-08887	giv26	Brak	20.9042	-33.6280	J12K	SFM	3	UF	H	2.9	C	C	17.7	0.5
G7 (EK)	**E8**	**11**	**J12L-08985**	**gviii1**	**Doring - EWR 7_Go - C/D**	**20.9274**	**33.7904**	**J12L**	**SFM**	**3**	**UF**	**L**	**2.9**	**C**	**CD**	**12.0**	**0.4**
G3 (EK)	**E8**	**12**	**J12M-08904**	**gv5**	**Touws - EWR 3_Go - C**	**21.0896**	**-33.6779**	**J12M**	**SFM**	**3**	**UF**	**H**	**33.5**	**C**	**BC**	**17.8**	**6.0**
EK	C6	16	J11C-08151	giv34	Buffels	20.8783	-33.0691	J11C	GK	3	UF	H	13.1	C	B	26.5	3.5
EK	C6	19	J11F-08427	gv25	Buffels	20.9646	-33.2511	J11F	SFM	3	UF	H	24.2	C	C	17.8	4.3
G5 (EK)	**E8**	**22**	**J11J-08686**	**gv4**	**Buffels - EWR5_Go - C**	**20.9852**	**-33.4657**	**J11J**	**SFM**	**3**	**UF**	**M**	**27.4**	**D**	**C**	**17.9**	**4.9**
G5 (EK)	E8	24	J11K-08860	giv32	Groot	21.1842	-33.7316	J11K	SFM	3	UF	H	30.5	C	D	17.9	5.5
G3 (EK)	E8	25	J13B-08923	gv7	Groot	21.4334	-33.7421	J13B	SFM	3	UF	H	72.7	C	C	18.0	13.1
G3 (EK)	E8	28	J13C-09099	gii3	Groot	21.6543	-33.8861	J13C	SFM	3	UF	H	78.1	C	B	27.0	21.1
EK	C6	33	J21D-07700	giv3	Gamka	22.0363	-32.7307	J21D	GK	3	LF	H	31.9	C	B	27.1	8.7
EK	C6	40	J22F-07805	giv1	Koekemoer	21.9763	-32.7606	J22F	GK	3	LF	VH	7.4	C	C	17.9	1.3
EK	C6	44	J22K-07655	giv2	Leeu	21.9798	-32.7559	J22K	GK	3	LF	VH	17.1	C	C	17.9	3.1
EK	C6	47	J23F-08268	gv17	Gamka	21.93780	-33.0868	J23F	GK	3	LF	H	58.1	C	B	27	15.7
EK	C6	52	J23J-08497	gv27	Gamka	21.6679	-33.2840	J23J	SFM	3	LF	H	69.6	C	C	18.3	12.7
EK	C6	56	J24E-08292	gv14	Dwyka	21.6083	-33.1444	J24E	GK	3	LF	H	4.0	C	A	39.1	1.6
G4 (EK)	**D7**	**57**	**J25A-08567**	**giv20**	**Gamka EWR4_Go - C/D**	**21.6243**	**-33.4941**	**J25A**	**SFM**	**3**	**LF**	**H**	**79.8**	**C**	**CD**	**14.9**	**11.4**
G4 (EK)	D7	63	J25E-08884	gii2	Gamka	21.7142	-33.6784	J25E	SFM	3	LF	H	111.8	D	C	15.2	17.0
G9 (EK)	**D7**	**67**	**J31D-08592**	**giii2**	**Olifants - EWR9_Go - C**	**23.2932**	**-33.4469**	**J31C**	**SFM**	**2**	**LF**	**M**	**11.8**	**C**	**BC**	**17.8**	**2.1**
EK	D7	72	J32E-08545	giv15	Traka	23.0952	-33.4392	J32E	SFM	3	LF	H	2.7	C	C	17.9	0.5
G9 (EK)	D7	74	J33B-08714	gv33	Olifants	22.6869	-33.5082	J33B	SFM	3	LF	H	25.0	D	D	11.9	3.0
SK	D7	77	J33D-08571	gv21	Meirings	22.5447	-33.4810	J33E	SFM	2	UF	VH	21.4	D	C	19.1	4.0
SK	D7	79	J33F-08772	giv11	Olifants	22.2434	-33.6147	J33F	SFM	2	LF	H	80.0	D	E	12.4	9.9
G10 (SK)	**D7**	**82**	**J34C-08869**	**gv36**	**Kammanassie - EWR10_Go - CD**	**22.6969**	**-33.7319**	**J34D**	**SFM**	**2**	**LF**	**L**	**41.2**	**D**	**CD**	**15.3**	**6.3**
SK	D7	85	J34F-08848	giv10	Leeu	22.2404	-33.6241	J34F	SFM	2	LF	VH	59.2	D	E	12.1	7.1
SK	D7	94	J35E-08764	gv19	Olifants	22.0332	-33.6143	J35E	SFM	2	LF	H	224.5	D	E	12.9	29.0
SK	D7	96	J35F-08739	giv17	Olifants	21.7226	-33.6805	J35F	SFM	2	LF	H	253.4	D	D	12.9	32.6
G6 (EK)	**D7**	**99**	**J40B-09106**	**gi4**	**Gouritz - EWR6_Go - C**	**21.6539**	**-33.9786**	**J40B**	**SCB**	**2**	**LF**	**M**	**489.1**	**C**	**C**	**14.8**	**72.5**
G6 (EK)	F13	102	J40E-09284	gv9	Gouritz	21.7388	-34.1564	J40E	SCB	2	L	H	571.8	C	C	14.8	84.8
G1 (SCW)	F12	104	H80C-09208	giii5	Duiwenhoks	20.9314	-34.0163	H80B	SCB	1	LF	VH	62.5	C	E	20.1	13.1
G1 (SCW	**F12**	**106**	**H80E-09314**	**giii8**	**Duiwenhoks - EWR1_Go - D**	**20.9902**	**-34.2475**	**H80D**	**SCB**	**1**	**LF**	**L**	**83.2**	**C**	**D**	**20.9**	**17.4**
SCW	F12	108	H90B-09155	giii6	Korinte	21.2330	-34.0346	H90C	SCB	1	UF	H	34.1	C	D	14.5	5.0
G2 (SCW)	**F12**	**109**	**H90C-09229**	**giii7**	**Goukou - EWR2_Go - C/D**	**21.3386**	**-34.0732**	**H90C**	**SCB**	**1**	**UF**	**M**	**50.9**	**C**	**CD**	**24.2**	**12.3**
G2 (SCW)	I18	111	H90E-09343	gv41	Goukou	21.3395	-34.3107	H90E	SCB	1	LF	H	105.0	C	C	28.2	29.6
GB1	C6	114	K10D-09163	giv25	Brandwag	22.1163	-34.0632	K10D	SCB	1	LF	H	17.9	C	D	9.9	1.8
GB1	C6	116	K20A-09083	gvii7	Groot-Brak	22.2227	-34.0292	K20A	SCB	1	UF	VH	27.0	C	BC	26.5	7.2
GB1	**C6**	**117**	**K20A-09083**	**gviii2**	**Groot-Brak EWR GB1 - BC**	**22.1932**	**-33.9781**	**K20A**	**SCB**	**1**	**UF**	**VH**	**15.3**	**C**	**BC**	**26.5**	**4.1**
Var2	**C6**	**118**	**U**	**gviii3**	**Varing EWR Var3 - CD**	**22.2320**	**-33.9973**	**K20A**	**SCB**	**1**	**U**	**H**	**8.4**	**C**	**D**	**20.9**	**1.8**
Var2	**C6**	**149**	**U**	**gviii12**	**Varing EWR Var2 - CD**	**22.2412**	**-33.96**	**K20A**	**SCB**	**1**	**U**	**H**	**6.0**	**C**	**CD**	**20.9**	**1.3**
Mal1	G15	119	K30A-09087	gviii4	Maalgate	22.3320	-33.9883	K30A	SCB	1	UF	VH	15.3	C	B	46.0	7.0
Mal1	**G15**	**120**	**K30A-09087**	**gvii8**	**Maalgate - EWR Maa2 - D**	**22.3512**	**-34.0077**	**K30A**	**SCB**	**1**	**UF**	**H**	**30.1**	**C**	**D**	**16.4**	**4.9**
Mal1	**G15**	**122**	**K30B-09082**	**gvii9**	**Malgas - EWR Mal1 - C**	**22.4210**	**-33.9529**	**K30B**	**SECB**	**1**	**UF**	**VH**	**17.3**	**C**	**C**	**31.6**	**5.5**

EWR site for calibration	IUA	#	SQ code	CODE	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EIS	nMAR	1999EC	2014EC	EWR %	EWR MAR
Mal1	**G15**	**124**	**K30B-09151**	**gviii6**	**Gwaiing – EWR Gwa1 - D**	**22.418**	**-33.9889**	**K30B**	**SCB**	**1**	**UF**	**H**	**34.1**	**C**	**E**	**16.4**	**5.6**
Ka1	**G15**	**125**	**K30C-09093**	**gviii7**	**Swart – EWR Sw1 - D**	**22.5217**	**-33.9675**	**K30C**	**SECB**	**1**	**UF**	**H**	**16.1**	**B**	**D**	**14.5**	**2.4**
Ka1	**G15**	**126**	**K30C-09065**	**gvii11**	**Kaaimans - EWR Ka1 - B**	**22.5472**	**-33.9714**	**K30C**	**SECB**	**1**	**UF**	**H**	**18.6**	**B**	**B**	**50.2**	**9.4**
Ka1	**G15**	**127**	**U**	**gviii8**	**Silver- EWR Si1 - B**	**22.5561**	**-33.9767**	**K30C**	**SECB**	**1**	**T**	**VH**	**14.9**	**B**	**B**	**50.2**	**7.5**
Die1	G15	128	K30D-09042	gvii12	Touws	22.6128	-33.9459	K30D	SECB	1	UF	VH	16.7	B	B	30.3	5.1
Die1	G15	129	K30D-09108	gx8	Klein Keurbooms	22.6543	-33.9757	K30D	SECB	1	MH	VH	2.5	B	D	14.1	0.4
Die1	**G15**	**130**	**K40A-09027**	**giii10**	**Diep - EWR 2 Diep - B**	**22.7089**	**-33.9338**	**K40A**	**SECB**	**1**	**UF**	**VH**	**12.4**	**B**	**B**	**30.3**	**3.8**
Die1	G15	131	K40B-09022	giii13	Hoekraal	22.8007	-33.9784	K40B	SECB	1	LF	VH	27.9	B	B	30.3	8.5
Kar1	**G15**	**132**	**K40C-09036**	**gvii13**	**Karatara - EWR 4 Karatara - AB**	**22.8383**	**-33.8830**	**K40C**	**SECB**	**1**	**UF**	**VH**	**11.2**	**B**	**AB**	**40.2**	**4.5**
Kar1	G15	133	K40C-09140	giii11	Karatara	22.8271	-33.9977	K40C	SECB	1	UF	VH	33.8	B	AB	40.2	13.6
Gouk1	**G15**	**134**	**K40E-09016**	**gviii9**	**Goukamma - EWR Gou1 - BC**	**22.9192**	**-33.9477**	**K40E**	**SECB**	**1**	**UF**	**VH**	**30.4**	**B**	**BC**	**38.5**	**11.7**
Kny1	**G15**	**135**	**K50A-09069**	**gvii14**	**Knysna - EWR 1 - B**	**23.0308**	**-33.8935**	**K50A**	**SECB**	**1**	**UF**	**H**	**26.5**	**B**	**B**	**32.1**	**8.5**
Kny1	**G15**	**136**	**K50B-09111**	**giii12**	**Knysna – B**	**23.0016**	**-33.9872**	**K50A**	**SECB**	**1**	**UF**	**U**	**46.6**	**B**	**B**	**32.1**	**15.0**
Goun1	**G15**	**137**	**K50B-09117**	**gviii11**	**Gouna EWR 2 - AB**	**23.0346**	**-33.9862**	**K50B**	**SECB**	**1**	**UF**	**VH**	**27.6**	**B**	**AB**	**53.4**	**14.8**
Goun1	**G15**	**138**	**K60G-09180**	**gviii10**	**Noetsie – EWR Noe1 - AB**	**23.1376**	**-34.0663**	**K60G**	**SECB**	**1**	**U**	**VH**	**4.8**	**B**	**B**	**63.4**	**3.0**
SCW	G15	139	K60G-09200	gx3	Piesang	23.3314	-34.0651	K60G	SECB	1	UF	VH	7.3	B	D	28.5	2.07
SCW	G15	140	K60F-09092	giv4	Bitou	23.3847	-34.0069	K60F	SECB	1	LF	VH	23.6	B	C	22.8	5.4
G8	**G15**	**143**	**K60C-08992**	**giv6**	**Keurbooms - EWR8 - C**	**23.3618**	**-33.9271**	**K60C**	**SECB**	**1**	**UF**	**VH**	**46.1**	**B**	**C**	**34.9**	**16.1**
SCW	G15	144	K60D-08996	giv5	Palmiet	23.3720	-33.9253	K60D	SECB	1	UF	VH	42.1	B	A	48.3	20.3
G8	G15	145	K60E-09097	gx9	Keurbooms	23.4018	-33.9573	K60E	SECB	1	LF	VH	91.3	B	C	34.9	31.9
SCW	G15	146	K70A-09110	gx4	Buffels	23.4636	-33.9858	K70A	SECB	1	U	VH	1.8	B	B	34.3	0.6
SCW	G15	147	K70A-09086	gx5	Sout	23.5189	-33.9731	K70A	SECB	1	U	VH	3.8	B	B	34.3	1.3
SCW	G15	148	K70B-09055	gvii15	Bloukrans	23.64061	-33.9546	K70B	SECB	1	UF	VH	31.2	B	B	33.9	10.6

Where EWR = Ecological Water Requirement: G1-10 = Gouritz EWR site, SK = Southern Karoo, SCW = Southern Cape Wet; IUA = Integrated Unit of Analysis; SQ = Sub-quat; Long = Longitude, Lati = latitude; ER = Ecoregion: SFM = Southern Fold Mountains, GK = Great Karoo, SCB = Southern Coastal Belt, SECB = South-eastern Coastal Belt; HI = Hydrological Index; GZ = Geozone; EIS = Ecological Importance and Sensitivity; nMAR = natural Mean Annual Runoff (million m3/a); 1999EC = Ecological Condition 1999; 2014EC = Ecological Condition 2014.

In the table above, reading from left to right, the IUA in which the node is located if listed first, followed by the node number and the sub-quaternary code that relates to the biophysical data gathered during the PES/EIS updates. Then the EWR column states what EWR site has been used to extrapolate the EWRs, followed by a descriptive comment about the site and then the river name, the coordinates are given next and this is followed by the quaternary code, a code for the Ecoregion Level 1, Hydrological Index and Geozone, and then the Ecological Importance and Sensitivity. This is followed finally by the Mean annual runoff, the Ecological category from the 1999 PES data and that of the updated data used as the baseline in this study, either that from the PES/EIS 2014 or updated during this study in 2017, and finally the % of the mean annual runoff assigned as the EWR and the mean annual runoff volume for this.

Table 3.128 Nodes at which DRAFT EWRs have been calculated in the Breede River catchment and Overberg region. EWR sites are indicated in red text.

EWR site for calibration	IUA	#	SQ code	NODE	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EIS	nMAR	1999EC	2014EC	EWR %	EWR MAR
WCW	A1	2	H10C-08644	Niv2	Dwars	19.3006	-33.3544	H10C	WFM	1	LF	H	74.9	D	C	22.0	16.5
WCW	A1	3	H10C-08560	Niv1	Koekedou	19.2983	-33.35961	H10C	WFM	1	UF	VH	18.8	D	D	14.2	2.7
WCW	A1	5	H10B-08700	Niv3	Titus	19.3236	-33.3798	H10C	WFM	1	LF	VH	26.2	C	C	22.0	5.8
WCW	A1	7	H10D-08755	Niv4	Witels	19.2924	-33.4174	H10D	WFM	1	T	VH	84.3	C	A	43.3	36.6
B1	A1	8	H10F-08730	Nvi3	Breede	19.2684	-33.4214	H10D	WFM	1	UF	H	252.8	C	C	31.7	80.1
WCW	A1	9	H10E-08836	Nvii16	Witte	19.1081	-33.4214	H10E	WFM	1	UF	VH	42.6	A	A	46.6	19.8
WCW	A1	11	H10E-08836	Niv5	Witte	19.1994	-33.5357	H10F	WFM	1	LF	VH	141.7	D	A	47.2	66.9
WCW	A1	12	H10F-08804	Niv6	Wabooms	19.2062	-33.5382	H10F	WFM	1	UF	H	7.4	D	D	14.4	1.1
B1	**A1**	**13**	**H10G-08837**	**Nviii1**	**Breede – EWR 1 –D**	**19.2073**	**-33.5398**	**H10F**	**WFM**	**1**	**LF**	**H**	**434.9**	**D**	**DE**	**31.7**	**137.9**
WCW	A2	14	H10G-08889	Niv7	Slanghoek	19.2402	-33.5766	H10G	WFM	1	UF	H	32.6	D	D	14.5	4.7
B1	A2	15	H10G-08844	Niii1	Breede	19.3491	-33.6536	H10G	WFM	1	LR	H	497.6	C	D	25.4	126.2
B2	A1	16	H10J-09038	Niv40	Elands	19.1157	-33.7338	H10J	WFM	1	T	VH	58.1	C	B	50.8	29.5
B2	A1	17	H10J-09000	Niv41	Krom	19.1123	-33.7301	H10J	WFM	1	T	VH	9.0	C	B	50.8	4.6
B2	**A1**	**18**	**H10J-08990**	**Nvii2**	**Molenaars – EWR 2 – B**	**19.1709**	**-33.7239**	**H10J**	**WFM**	**1**	**UF**	**VH**	**105.6**	**C**	**B**	**35**	**36.9**
B2	A2	19	H10L-08968	Niv42	Smalblaar	19.3159	-33.6899	H10J	WFM	1	UF	H	191.2	C	E	17.4	33.2
WCW	A2	20	H10H-08826	Niv8	Jan du Toit/Bothaspruit	19.3634	-33.6471	H10H	WFM	1	LF	VH	17.9	C	D	14.4	2.6
WCW	A2	21	H10H-08850	Nvii6	Hartbees	19.4359	-33.5589	H10H	WFM	1	MH	VH	4.0	C	D	14.4	0.6
WCW	A2	22	H10H-08850	Niv9	Hartbees	19.3747	-33.6519	H10H	WFM	1	T	VH	10.2	C	D	14.4	1.5
B2	A2	23	H10K-08972	Niv12	Holsloot	19.3251	-33.6940	H10K	WFM	1	LF	H	119.5	C	C	35	41.8
B1	A2	24	J10H-08895	Nv3	Breede	19.4510	-33.6928	H10L	WFM	1	LR	H	850.9	C	C	31.7	269.7
H3	**A2**	**31**	**H20H-08839**	**Nvii7**	**Hex – EWR 3 - C**	**19.5033**	**-33.5784**	**H20G**	**WFM**	**1**	**UF**	**M**	**102.8**	**D**	**C**	**22.3**	**22.9**
H3	A2	32	H20H-08839	Niv10	Hex	19.4565	-33.6941	H20H	WFM	1	LF	H	107.1	D	D	22.3	23.9
B3	A2	33	H40C-08935	Nii1	Breede	19.4638	-33.7037	H40C	WFM	2	LR	M	958.0	C	C	33.7	332.0
WCD	A2	35	H40B-08890	Nvii5	Koo	19.7629	-33.5973	H40B	SFM	2	UF	H	0.9	C	D	13.1	0.2
WCW	A2	37	H40C-08999	Niv11	Nuy	19.4813	-33.7180	H40C	WFM	2	LF	H	29.4	C	E	13.2	3.9
WCW	A3	38	H40D-09051	Niv13	Doring	19.5158	-33.7690	H40D	WFM	1	LF	H	47.4	C	E	12.9	6.1
B3	**A3**	**39**	**H40F-09026**	**Nvii8**	**Breede – EWR 3 - CD**	**19.6947**	**-33.8187**	**H40F**	**SFM**	**1**	**LR**	**M**	**1042.8**	**D**	**CD**	**45.5**	**474.7**
WCW	A3	41	H40G-09126	Nvii11	Poesnels	19.7240	-33.8666	H40G	SFM	2	LF	H	16.1	D	D	12.8	2.1
WCW	A3	42	H40H-09039	Niv15	Vink	19.7975	-33.8241	H40H	SFM	2	UF	VH	15.6	D	D	12.4	1.9
WCW	A3	43	H40J-09007	Nviii2	Willem Nels	19.8640	-33.8163	H40J	SFM	1	UF	H	5.2	D	D	12.4	0.65
B3	A3	44	H40J-09072	Nvii19	Breede	19.8905	-33.8472	H40J	SFM	1	LF	H	1082.0	D	B	45.5	492.6
WCW	A3	46	H40K-09118	Niv14	Keisers	19.8899	-33.8503	H40K	SFM	2	LF	VH	12.6	D	D	12.5	1.6
WCW	A1	49	H30C-08991	Niv20	Pietersfontein	20.1083	-33.7419	H30C	SFM	2	UF	M	17.3	C	D	12.0	2.1
WCD	A1	50	H30D-09015	Nvii9	Keisie	20.1068	-33.7928	H30D	SFM	2	LR	H	21.5	C	D	11.9	2.5
WCD	A1	52	H30B-08978	Niv18	Kingna	20.1160	-33.7928	H30B	SFM	2	LF	H	27.1	C	D	12.3	3.3
WCD	A3	53	H30E-09032	Nii2	Kogmanskloof	20.0032	-33.8704	H30E	SFM	1	LF	VH	52.0	D	D	18.9	9.8
B4	A3	55	H50B-09129	Ni2	Breede	20.2866	-'34.0686	H50B	SCB	1	LF	H	1170.1	C	D	17.3	202.2
B2	B4	57	H60B-09162	Nvii10	Du Toits	19.1539	-33.9795	H60B	SFM	1	UF	VH	43.9	C	B	50.8	22.3
B5	B4	59	H60D-09239	Nv7	Riviersonderend	19.4633	-34.0636	H60D	SCB	1	LF	VH	370.2	C	C	30.1	111.5
B6	**B4**	**60**	**H60E-09127**	**Niv28**	**Baviaans – EWR 6 - B**	**19.5567**	**-34.0633**	**H60E**	**SCB**	**1**	**UF**	**H**	**7.9**	**C**	**B**	**70.9**	**5.6**
B6	B4	61	H60E-09302	Niv29	Sersants	19.5591	-34.0660	H60E	SCB	1	UF	H	4.6	C	D	29.9	1.4
B6	B4	63	H60F-09248	Niv30	Gobos	19.6091	-34.0705	H60F	SCB	1	UF	VH	12.4	C	C	48.1	6.0
B5	**B4**	**64**	**H60F-09277**	**Nv9**	**Riviersonderend – EWR 5 - D**	**19.7049**	**-34.1178**	**H60F**	**SCB**	**1**	**LF**	**H**	**413.7**	**C**	**D**	**24.5**	**101.5**

EWR site for calibration	IUA	#	SQ code	NODE	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EIS	nMAR	1999EC	2014EC	EWR %	EWR MAR
WCW	F9	65	H60G-09321	Niv31	Kwartel	19.703	-34.1202	H60G	SCB	1	LF	H	10.7	C	D	13.4	1.4
B6	F9	66	H60H-09275	Niv33	Soetmelksvlei	19.7563	-34.1185	H60H	SCB	1	UF	VH	4.0	C	D	29.9	1.2
B6	F9	67	H60H-09280	Niv34	Slang	19.8113	-34.1277	H60H	SCB	1	UF	VH	2.1	C	C	29.9	0.6
B5	F9	68	H60H-09288	Nv10	Riviersonderend	19.8562	-34.1265	H60H	SCB	1	LF	VH	442.9	D	D	24.5	108.6
WCW	F9	70	H60K-09297	Niv35	Kwassadie	20.1414	-34.0853	H60K	SCB	1	LR	VH	5.9	D	E	17.3	1.0
B5	F9	72	H60L-09270	Ni3	Riviersonderend	20.2851	-34.0703	H60L	SCB	1	LF	H	483.8	D	D	24.5	118.6
WCW	F11	73	H50B-09129	Niv24	Leeu	20.3186	-34.0859	H70A	SCB	1	UF	VH	5.8	C	E	12.6	0.7
B4	A3	75	H70B-09251	Nv2	Breede	20.5172	-34.0656	H70B	SCB	1	LR	H	1701.4	C	C	26.4	449.8
WCW	F11	77	H70D-09157	Nii3	Tradouw	20.7077	-33.9413	H70D	SCB	2	UF	VH	19.4	C	B	29.9	5.8
WCW	F11	80	H70F-09226	Niv25	Buffeljags	20.5188	-34.0960	H70F	SCB	1	LF	H	119.4	C	E	14.1	16.9
B4	**F11**	**81**	**H70G-09345**	**Niii4**	**Breede – EWR 4 - BC**	**20.5146**	**-34.2337**	**H70G**	**SCB**	**1**	**L**	**VH**	**1832.7**	**C**	**C**	**40.1**	**735.5**
WCD	F11	83	H70J-09358	Niv26	Slang	20.7149	-34.3573	H70J	SCB	1	LF	H	10.0	C	E	14.2	1.4
P1	**B5**	**86**	**G40C-09305**	**Piii1**	**Palmiet – EWR 1 - B**	**19.05545**	**-34.1143**	**G40C**	**SFM**	**1**	**UF**	**H**	**39.9**	**D**	**C**	**19.1**	**7.6**
P1	B5	87	U	Piv10	Witklippieskloof	19.03684	-34.1463	G40C	SFM	1	U	H	15.1	D	D	21.5	3.2
P1	B5	88	G40C-09305	Piv9	Palmiet	19.02777	-34.1488	G40C	SFM	1	LF	H	78.8	D	D	21.5	16.9
P1	B5	89	U	Piv8	Klipdrif	19.02679	-34.1487	G40C	SFM	1	U	H	13.6	D	D	21.5	2.9
P3	B5	91	U	Piv4	Klein-Palmiet	18.98786	-34.2458	G40D	SFM	1	U	H	13.7	C	D	21.5	3.0
P3	B5	93	G40D-09333	Piv7	Krom/Ribbok	19.04561	-34.2483	G40D	SFM	1	LF	VH	27.5	C	D	21.5	5.9
P3	**B5**	**94**	**G40D-09369**	**Piii2**	**Palmiet – EWR 3 BC**	**18.98457**	**-34.2857**	**G40D**	**SFM**	**1**	**LF**	**VH**	**206.6**	**C**	**C**	**31.2**	**64.5**
100%	B5	95	U	Piv12	Dwars/Louws	18.93654	-34.2916	G40D	SFM	1	LF	VH	25.2	C	C	100	25.2
P4	**B5**	**96**	**G40D-09369**	**Piii3**	**Palmiet – EWR 4 - B**	**18.99073**	**-34.3305**	**G40D**	**SFM**	**1**	**LF**	**VH**	**250.4**	**C**	**D**	**34.5**	**86.3**
Nxi6 – Bot estuary	H16	98	G40G-09370	Niii5	Bot	19.2008	-34.2635	G40G	SFM	1	L	VH	31.9	D	C	21.3	6.8
WCW	H16	100	G40H-09398	Nx6	Onrus	19.2511	-34.3599	G40H	SFM	1	UF	H	5.1	C	E	13.4	0.7
Nxi6 – Bot estuary	F10	101	G40F-09365	Niv43	Swart	19.2192	-34.2589	G40F	SFM	1	LF	H	42.1	D	E	13.3	5.6
Kle1	F10	103	G40K-09349	Niv45	Steenbok	19.5357	-34.3275	G40K	SCB	2	LF	VH	10.8	C	E	12.2	1.3
Kle1	F10	104	G40J-09395	Nii4	Hartbees	19.5337	-34.3923	G40J	SCB	1	LF	VH	18.4	C	D	12.5	2.3
Kle1	**F10**	**105**	**G40L-09411**	**Nv23**	**Klein**	**19.6022**	**-34.4058**	**G40K**	**SCB**	**2**	**LF**	**M**	**43.0**	**C**	**CD**	**19.3**	**8.3**
WCD	F10	107	G50G-09352	Nii6	Sout	20.0238	-34.2921	G50H	SCB	2	LF	U	4.2	D	D	12.6	0.5
WCD	F10	108	G50H-09406	Nii7	De Hoop Vlei	20.3117	-34.4051	G50H	SCB	2	L	H	27.1	D	B	30.0	8.1
Nxi5 – Uilkraals estuary	F10	109	G40M-09414	Nx8	Uilkraals	19.6926	-34.4601	G40M	SFM	1	T	VH	2.4	C	C	19.2	0.5
Nuw1	**F10**	**110**	**G50B-09418**	**Ni4**	**Nuwejaar**	**19.8317**	**-34.6301**	**G50B**	**SCB**	**1**	**L**	**M**	**12.5**	**C**	**D**	**13.0**	**1.6**
Nuw1	F10	111	G50C-09432	Nvii15	Heuningnes	19.9575	-34.7214	G50C	SCB	2	LF	U	17.8	C	D	13.1	2.3
Nuw1	F10	112	G50C-09432	Niv44	Heuningnes	20.1020	-34.6575	G50C	SCB	2	LF	VH	18.8	C	D	13.1	2.5
Kar1	**F10**	**113**	**G50E-09404**	**Nv24**	**Kars**	**20.1275**	**-34.4996**	**G50E**	**SCB**	**1**	**L**	**M**	**15.4**	**C**	**BC**	**30.3**	**4.7**
Kar1	F10	114	G50E-09427	Nii5	Kars	20.0141	-34.6722	G50C	SCB	2	LF	VH	21.6	C	E	20.4	4.4

Where EWR = Ecological Water Requirement: B1-6 = Breede EWR site, H3 = Hex River EWR site 3, P1-4 = Palmiet River EWR site, WCW = Western Cape Wet, WCD = Western Cape Dry; IUA = Integrated Unit of Analysis; SQ = Sub-quat; Long = Longitude, Lati = latitude; ER = Ecoregion: WFM = Western Fold Mountains, SFM = Southern Fold Mountains, SCB = Southern Coastal Belt; HI = Hydrological Index; GZ = Geozone; EIS = Ecological Importance and Sensitivity; nMAR = natural Mean Annual Runoff (million m3/a); 1999EC = Ecological Condition 1999; 2014EC = Ecological Condition 2014.

In the table above, reading from left to right, the IUA in which the node is located if listed first, followed by the node number and the sub-quaternary code that relates to the biophysical data gathered during the PES/EIS updates. Then the EWR column states what EWR site has been used to extrapolate the EWRs, followed by a descriptive comment about the site and then the river name, the coordinates are given next and this is followed by the quaternary code, a code for the Ecoregion Level 1, Hydrological Index and Geozone, and then the Ecological Importance and Sensitivity. This is followed finally by the Mean annual runoff, the Ecological category from the 1999 PES data and that of the updated data used as the baseline in this study, either that from the PES/EIS 2014 or updated during this study in 2017, and finally the % of the mean annual runoff assigned as the EWR and the mean annual runoff volume for this.

3.11 Ecological water requirements for estuaries

3.11.1 Conceptual framework

Ecological water requirements for estuaries are described in terms of the quantity and quality of flows required to meet defined health thresholds. The way in which estuary health is determined is described below, followed by an explanation of what determines how sensitive estuaries are to freshwater inflows, and our conceptual understanding of the mathematical relationships we can expect between inflows and health.

3.11.1.1 Ecological condition of estuaries

Various approaches have been used in the past to assess the health of estuaries in South Africa. The first broad scale assessment of estuary health in South Africa was attempted by Heydorn & Tinley who reviewed the condition of the estuaries of the former Cape Province (from the Orange to the Great Kei). This was followed by a national assessment of the condition of South African estuaries (Heydorn 1986). Various other attempts have been made since this including the work by Ramm (1988, 1990), Cooper *et al.* (1994), CERM (1996), Coetzee *et al.* (1997), Van Driel (1998), Whitfield (2000), and Harrison & Whitfield (2004). The above attempts all ultimately paved the way towards the formulation of a robust health index that is now routinely used in Reserve processes for estuaries – the Estuary Health Index (EHI). The first version of the EHI was developed in 1999 after a series of workshops with members of the Consortium for Estuary Research and Management (Turpie 1999) as a component of the methodology for determining the freshwater Reserve for estuaries (DWAF 1999). Since then this method has been applied in Reserve studies of a large number of estuaries in South Africa, during which time the various aspects of the methods have been fine-tuned. After a second round of workshops and review, a second version of the method was developed in 2004 (officially published in 2008), while a third round of review and workshops by the Consortium for Estuary Research and Management led to the version of the method that is currently in use – the Estuary Health Index or EHI (Turpie *et al*. 2012).

Essentially, this assesses the Present Ecological Status (PES) of an estuary using a simple scale of A to F (Table 3.129). The index has three tiers, with the basic measures grouped, using weighted means or minima, into four abiotic and five biotic measures, the weighted averages of which form overall abiotic and biotic scores. These are then equally weighted to compute the overall Estuary Health Score (Figure 3.5). The computation of the first tier scores is summarized in Table 3.130. In all cases the scoring is based on available data (including data that might have been collected specifically for the study) for describing present day, and historical data (if available), models or expert opinion to describe the estimated reference condition.

The Reference Condition of an estuary refers to the ecological status that it would have had:

- before any anthropogenic changes to freshwater inputs
- before any human development in the catchment or within the estuary, and
- before any mouth manipulation practices (e.g. artificial breaching)

Once the Reference condition has been described for all the abiotic and biotic components, the Estuary Health Index is applied, which entails estimating the degree to which features of the Present State (e.g. inflows, fish species richness etc.) resemble those under the Reference Condition. To account for cyclical variability, the mean conditions during pristine conditions are compared with the mean conditions at present. All scores involve a min-mean scoring system in which the weighted mean of the scores is combined with the minimum score. Scores are done quantitatively as far as possible, and using a similarity index wherever appropriate, in order to maximise comparability and standardise the procedure as far as possible.

Table 3.129 The six categories for indicating the Present Ecological Status of an estuary using the Estuarine Health Index (EHI). Categories A to D are within the acceptable range, whereas E and F are not (Kleynhans 1996, MacKay 1999).

EC	DESCRIPTION
A	**Unmodified, or approximates natural condition**; *the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodifed natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used.*
B	**Largely natural with few modifications**. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. *Only a small risk of modifyng the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.*
C	**Moderately modified**. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. *A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well being and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.*
D	**Largely modified**. A large loss of natural habitat, biota and basic ecosystem functions has occurred. *Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota depending on (the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.*
E	**Seriously modified**. The loss of natural habitat, biota and basic ecosystem functions is extensive
F	**Critically modified**. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible

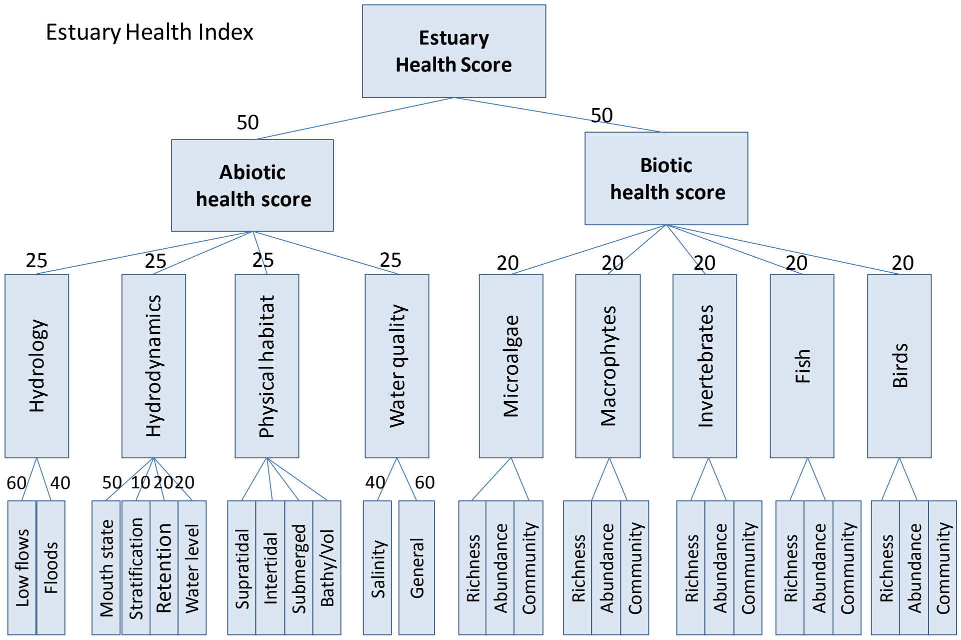

Figure 3.5 Structure of the Estuary Health Index (Source: Turpie et al. 2012). Weightings are equal unless otherwise shown.

Table 3.130 Summary description of the measures used in scoring the 1st tier variables that make up the 2nd and 3rd tier scores

2nd Tier	1st Tier	Measures used in scoring
Hydrology	Low flows	Similarity in the amount of flow during a defined low flow period or simply % natural MAR (data poor).
	Floods	Similarity in the magnitude and frequency of floods. Usually summarized as the average volume of the highest 2% of average monthly flows, based on the simulated monthly flows described above.
Hydrodynamics	Abiotic/mouth states	Similarity in terms of proportion of time the estuary is in different states. e.g closed, open freshwater dominated.
	Stratification	Similarity in the degree of mixing or stratification in the water column
	Retention	Similarity in the duration of water retention in different parts of the estuary
	Water level	Similarity in average water levels
Physical habitat	Supratidal area	Similarity in supratidal physical habitat
	Intertidal area	Similarity in intertidal extent and sediment characteristics
	Subtidal/ submerged area	Similarity in subtidal extent and sediment characteristics
	Bathymetry/volume	Similarity in channel morphology and estuary volume
Water quality	Salinity	Similarity in axial salinity gradient and vertical salinity stratification, based on the amount of time in which different zones of the estuary are within different salinity ranges, or at worst (data poor) considering just average salinity.
	General	Similarity among different variables (N & P, suspended solids, dissolved oxygen, toxins), based on a scoring guideline (Unmodified = 100; largely natural = 80; moderately modified = 60; largely modified = 40; seriously modified = 20; completely modified = 0).
Microalgae, macrophytes, invertebrates, fish and birds	Richness, abundance and community composition	Similarity in estimated average instantaneous species richness, total abundance (biomass or numbers), and community composition, with the latter being based on the estimated abundance of defined subgroups of the biotic component (e.g. waterfowl, waders etc).

The prevalent or average level of confidence is also described for each of the abiotic and biotic components of the study, for the present and reference state. Confidence categories are usually translated to % certainty using values listed in Table 3.131.

Overall confidence is provided for each component of the Estuary Health Index, and weighted in the same way to obtain overall confidence. The overall confidence level is then converted back to a category (High, medium etc.).

Table 3.131 Guidelines for describing levels of confidence

Degree of confidence	Explanation	Score (~ % certainty)	Range
Very Low	If no data were available for the estuary or similar estuaries (i.e. < 40% certain)	30	≤40
Low	Limited data were available, and estimates could be out by 60% (40%-60 certain of estimate)	50	41 – 60
Medium	If reasonable data were available for the estuary and estimates could be out by 20-60% (i.e. 60% – 80% certain of estimate)	70	61 – 80
High	If good data were available for the estuary and estimates are probably not more than 20% out (i.e. > 80% certain of estimate)	90	81 - 100

3.11.1.2 Sensitivity of estuaries to river inflows

All estuaries are sensitive to reductions and changes in river inflow. However, there are certain parameters (primarily physical parameters) that indicate whether an estuary is particularly sensitive to modifications in this regard. Based on current understanding of estuaries, the following are important indicators that could be used towards establishing the extent to which estuaries would be sensitive to modification in inflows:

Frequency of mouth closure (mostly applicable to temporarily open/closed systems). The sensitivity of an estuary mouth to closure can roughly be correlated to the river inflow, particularly during low flow periods, required to keep the mouth open. For many estuaries, especially the smaller ones, the most important factor in keeping the mouth open is river flow, and particularly base flows. In addition to river flow there are also other factors and/or a combination of thereof, that may contribute to an estuary's sensitivity to mouth closure such as:

- ***Size of the estuary***. In general, larger estuaries are less sensitive to mouth closure than smaller estuaries, because of greater tidal flows through the mouth, e.g. Berg. At breaching, larger estuaries also tend to scour deeper mouths due to higher outflows, which generally take longer to close, e.g. Diep. However, when the mouth of a large estuary closes, a substantial amount of water is required to first fill up the estuary before breaching can occur and as a result more river flow is needed to ensure breaching in large estuaries compared to smaller estuaries. Small estuaries are very sensitive to flow reduction as this is the main force keeping the mouth open, once flow decrease below a certain volume the system will close, and remain closed, until such time as flow increase enough to cause a mouth breaching.
- ***Availability of sediment***. In general, the larger the amount of sediment available in the adjacent marine environment, the greater the sensitivity to mouth closure, e.g. Zandvlei. In estuaries where there is not a large amount of sediment available, for example on a rocky coastline or where longshore transport is further offshore, e.g. Steenbras, the system would be less sensitive to flow reductions.
- ***Wave action in the mouth***. Wave action is the most important contributing cause of mouth closure in estuaries. In general, the stronger the wave action in the mouth the greater the sensitivity to mouth closure. Wave conditions in the mouth are influenced by the degree of protection of the mouth, e.g. by a headland, and beach slope. A steep beach slope normally means that high-energy wave action occurs on the beach at the mouth, resulting in higher suspended sediment load. This type of beach slope is characteristic of the KwaZulu-Natal coastline. The beach slope can also vary from winter to summer due to winter storms. Generally the steeper the slope of a beach, the higher the suspended sediment load in the mouth area, therefore the greater the sensitivity to mouth closure. A mild beach slope means that less energetic wave action occurs at the mouth and a mild beach slope therefore provides a special type of protection against wave action.

Taking the above into account, the degree of sensitivity of a temporarily open/closed estuaries mouth to reduction in flow can broadly be categorized as follows:

Sensitivity	River inflows
High sensitivity to closure	< 2 -10 m^3/s are likely to result in closure
Medium sensitivity to closure	0.5 m^3/s - 2.0 m^3/s are likely to result in closure
Low sensitivity to closure	< 0.5 m^3/s are likely to result in closure

Although mouth closure is normally only factored in during the analyses of temporarily open/closed estuaries, it should be noted that even some permanently open estuaries can close relatively easily if the flows are reduced.

Volume of mean annual runoff (MAR). As a first estimate, the volume of the natural MAR that an estuary receives is probably the most important parameter in judging overall sensitivity to reduced river inflows. It is, however, important to realize that it is not only the amount of river inflow that is important, but also the variability of flows. In general (although there are many exceptions), it can be assumed that the larger the natural MAR of an estuary, the less sensitive it might be to reduced river inflow. Care should be taken in applying this guideline as the local bathymetry of an estuary can cause exceptions. Sensitivity to reduced river flows versus natural MAR volumes can roughly be categorized as follows:

Sensitivity to reduced river flows	**Natural mar**
Low sensitivity	> 100 Mm^3/a (large estuaries)
Medium sensitivity	50 Mm^3/a < MAR > 100 Mm^3/a (medium - small estuaries)
Higher sensitivity	< 50 Mm^3/a (smaller estuaries).

Extent of Saline intrusion (especially relevant to permanently open systems). If an estuary is permanently open to the sea, the most important effect of reduced seasonal base flows or extended duration of low flows is an increase in the upstream intrusion of saline water. The variation in salinity distribution gradients in estuaries and the sensitivity to estuaries in this regard, is very difficult to quantify. In general if an estuary is permanently open, its sensitivity to reduction in seasonal base flows during the low flow period is assumed to be very high and, therefore a reduction in river inflow during the low flow period should not be considered. Permanently open estuaries are often less sensitive to reductions in higher flows, e.g. >50 – 100m^3/s.

NOTE:

It is important to note, that although the above-mentioned parameters are mainly influenced by seasonal base flows, floods play an important role in the long-term equilibrium of an estuary. Floods are therefore needed for the scouring of accumulated marine and catchment sediment from the system, deepening the mouth and the resetting of the salinity regime in estuaries.

3.11.1.3 Relationship between freshwater inflows and estuary health

The relationship between freshwater inflows as a percentage of natural Mean Annual Runoff (%MAR) and estuary health is expected to be a logarithmic function in which ecosystem health initially falls off fairly slowly in relation to falling %MAR, but then falls off more rapidly as %MAR tends towards zero (Figure 3.6). This has been borne out by empirical analysis of the health scores used in Reserve determination workshops. With flow = 100% of MAR, the EHI (EHI_{100}) is expected to be below 100, because EHI is also influenced by anthropogenic factors other than changes in flow volume, such as changes in nutrient inputs, habitat reclamation and fishing. Thus in most cases, restoring flows to 100% of natural would not be sufficient to restore estuary condition to natural.

In addition, it is expected that the slope of the curve will be steeper (i.e. health will deteriorate more rapidly in response to decreasing flows) for some kinds of estuaries than for others. Thus the slope of the curve reflects sensitivity to freshwater inflows.

In Figure 3.7, it is possible to read off the threshold %MAR above which a hypothetical estuary would be in a D, C, B or A category. In this example, the non-flow influences on estuary health are significant, and for all else equal, it would not be possible to achieve a B or A condition for the estuary by restoring the quantity of inflows alone.

Setting environmental flows requires consideration of both quantity and quality of flows. If anthropogenic impacts on water quality are reduced, then EHI goes up. Thus one can achieve an improvement in EHI through increase in flows, reduced pollution or a combination of both. Figure 3.7 extends the initial conceptual model to show the hypothetical relationship that could be derived if anthropogenic polluting inputs were removed. The EHI for each %MAR would be expected to be higher, but again, the graph would not achieve an EHI of 100 at 100% of flow unless there were no other anthropogenic pressures on the system. The difference between the health at EHI for natural water quality and 100 reflects the degree of non flow-related pressures on the system, and the sensitivity of the system to those pressures.

Comparison of the threshold values shows that the flow thresholds (%MAR) for each EC would vary depending on the degree to which catchment management measures are put in place to reduce pollution. It is important to note that higher ECs are also possible when water pollution issues are eliminated. In this example, the system that could not achieve higher than C category with quantity of flows alone, could reach an A category when both quantity and quality of flows are addressed.

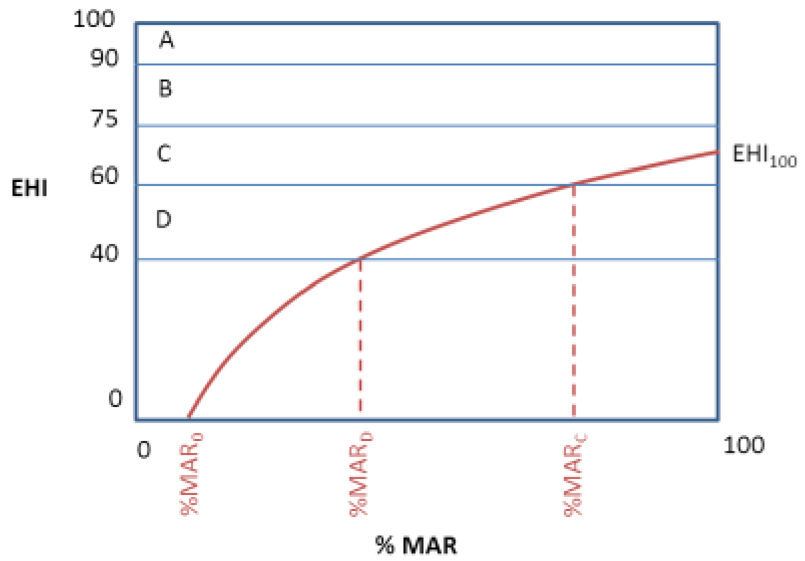

Figure 3.6 Hypothetical relationships between %MAR and estuary health (EHI) for the (typical) situation where flows are reduced compared to natural (Turpie in prep)

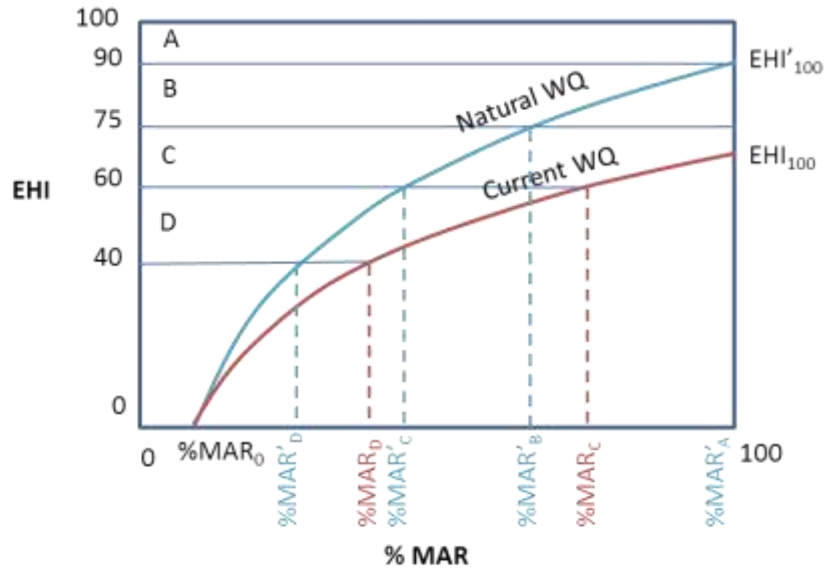

Figure 3.7 Hypothetical relationships between %MAR and estuary health (EHI) for the (typical) situation where flows are reduced compared to natural, (a) under current non-flow pressures and (b) when anthropogenic impacts on water quality are removed (Turpie in prep)

The means with which a class threshold should be achieved is essentially an economic problem, depending on the relative costs of fixing pollution problems and those of meeting water supply requirements from alternative sources.

Another dimension which is not depicted here is the temporal distribution of the flows. We recognise that the manner in which MAR is disaggregated into a seasonal flow pattern for a particular estuary can have a profound impact on the health of the system depending on how this is done (i.e. the extent to which dry season and wet season flows have been reduced relative to natural) and also on the type of estuary in question (the seasonal distribution of flow is generally less important for estuarine lake than a permanently open or temporally open-closed system). An examination of monthly flow data for the Present State for estuaries in the Breede-Gouritz WMA (and indeed national, Turpie *et al*. in prep.) shows very cleary that the percentage reduction in flows during the dry season is almost without exception greater than that in the wet season. This intuitively makes sense as it is generally during the dry season when additional water is required for irrigation which is one of the major uses for water in a catchment. (Note that this is not always the case for rivers, owing to the fact that river channels are often used as conduits to convey water from a major impoundment upstream to areas downstream where it is required for irrigation.) Again, while we recognise that the precise extent to which flow in each season for a particular system is impacted in any particular particular scenario should be assessed in an expert workshop for each estuary, we know that this is not practically possible given the number of estuaries and scenarios that need to be evaluated in this study. As such, and for the purposes of this study, we have used the measured (or estimated) reduction in flow for each month under Present day conditions to disaggregate MARs for all of the class thresholds into seasonally disaggregated flows for each estuary. While this method may have its shortcomings, we belive that it is an effective way of generating seasonally disaggregated estimates of MAR for a large number of estuaries at the full suite of class thresholds from A-B to D-E for all of the estuaries in Breede-Gouritz WMA

3.11.2 Data and methods

EWRs of estuaries are determined using scenarios. In most estuary EWR studies, operational scenarios are provided by DWS, together with a description of the hydrology associated with each. These usually represent real planning options. Depending on the range of the operational scenarios provided by DWS, additional scenarios are then designed to expand the range of scenarios in order to fine-tune the understanding between flows and estuary health enough to identify thresholds between different categories of health (A, B, C, D and E). The additional scenarios, termed the Ecological Reserve Scenarios (or Ecological Water Requirement Scenarios), are hypothetical, and may or may not be feasible. They could take the form of a series of hypothetical runoff scenarios with a range of % natural MAR (e.g. 75%, 50% and 25% of natural MAR). However, the number of scenarios analysed is usually subject to a budget constraint, and since the results are unknown until the scenario is analysed, the outcomes often do not cover the full range of health categories.

Reserve studies have been carried out for 19 of the 26 significant estuaries in the Breede-Gouritz WMA, plus for two of the micro-estuaries, including the Onrus and Rooiels Reserve studies undertaken as part of this study (see Appendices 1 and 2), and the Heuningnes Reserve determination by Anchor Environmental Consultants for BGCMA and CapeNature, which is currently underway. There are estimates of % MAR and present ecological status (PES) for all but two of the estuaries in the study area (i.e. all the estuaries included in the 2012 National Biodiversity Assessment).

In most cases the scenarios do not cross all of the class thresholds from A/B to D/E. To get around this problem, a set of models was developed using scenario results of EWR studies, based on the conceptual model described above. This allowed us to interpolate and extrapolate the results of previous studies in order to identify EWRs at EC thresholds.

Table 3.132 Summary of Reserve data available for estuaries in the Breede-Gouritz WMA

Estuary	Type	Area (ha) incl. floodplain	Channel area	Catchment size (km^2)	Present day MAR Mm^3	Reserve (Scenarios)	PES	REC
Rooiels	Closed	16.03	1.9	21	9.44	Yes 4	B	B
Buffels (Oos)	Micro	4.73	1.3	23	12.70	-	B	B
Palmiet	Closed	28.53	26	470	177.94	Yes 7	C	B
Bot/Kleinmond	Lake	2 039.01	1229.2	887	77.67	Yes 3	C	B
Onrus	Closed	15.13	3.5	58	4.74	Yes 5	E	D
Klein	Lake	1 802.33	113.6	896	51.21	Yes 7	C	B
Uilkraals	Closed	702.31	55.7	377	6.82	Yes 4	D	C
Ratel	Micro	8.63	1.5	95	3.42	-	C	C
Heuningnes	Open	13 125.81	1451.5	3578	29.53	In Prog 5	C	A
Klipdriftsfontein	Micro	2.23	0.8	27	0.75	-	A	A
Breede	Open	2 079.43	1147.6	12 496	1140.69	Yes 5	B	B
Duiwenhoks	Open	419.33	108.3	1207	81.62	Yes 5	B	A
Goukou	Open	372.33	122.4	1438	89.94	Yes 5	C	B
Gouritz	Open	1 049.41	319	45 544	397.85	Yes 5	C	B
Blinde	Micro	4.13	2.1	28	1.01	-	B	B
Tweekuilen	Micro	9.82	1.6	35	1.25	-	D	D
Gericke	Micro	3.62	0.9	12	0.39	-	D	D
Hartenbos	Closed	236.93	30.5	169	3.74	-	D	C
Klein Brak	Closed	976.93	89.4	556	35.54	Yes 5	C	C
Groot Brak	Closed	205.13	65.6	162	0.92	Yes 10	D	C
Maalgate	Closed	22.23	17	185	35.72	-	B	B
Gwaiing	Closed	10.63	4.2	121	51.16	Yes 5	B	C
Kaaimans	Open	20.63	9	132	26.88	-	B	B
Wilderness	Lake	1 091.73	501.8	173	29.01	Yes 5	B	A
Swartvlei	Lake	2 037.9[1]	114.5	419	92.49	Yes 8	B	B
Goukamma	Closed	213.13	45.3	252	46.25	Yes 8	B	A
Knysna	Bay	2 284.11	1691.7	419	84.32	Yes 10	B	B
Noetsie	Closed	14.83	8	39	5.11	-	B	A
Piesang	Closed	59.53	4.9	48	6.41	-	C	B
Keurbooms	Open	1 523.41	398.2	1123	104.2	Yes 5	A	A
Matjies	Micro	2.53	0.5	25	3.22	Yes 5	B	B
Sout (Oos)	Micro	13.83	1.7	33	3.45	Yes 5	A	A
Groot (Wes)	Closed	64.43	30.2	82	10.88	-	B	A
Bloukrans	River mouth	4.21	2.3	88	31.38	-	A	A

Note: Tweekuilen and Gericke have not been formally assessed. The PES and REC were estimated in this study based on expert opinion

The results from all the Reserve studies were analysed in order to develop a set of models from which to estimate the flows corresponding to estuary class thresholds. In nearly all cases, scenarios involved changes in flow, whereas very few included changes in water quality. The latter were too scarce to allow statistical analysis and were excluded from the analysis of flows.

The relationship between %MAR and both abiotic health score (AHS) and the overall estuary health score (EHI) was generally logarithmic as expected, but the shape of the function beyond the scenarios evaluated could not be reliably predicted from these functions alone. In order to extend the relationships to the full extent, we solved for $\%MAR_0$, the %MAR where AHS = 0 and for AHS where %MAR = 100 to maximize fit (R^2). The relationship between overall EHI and %MAR was then derived using the $\%MAR_0$ derived from AHS and solving for EHI_{100} (EHI where %MAR = 100) to maximize fit. In nearly all cases, EHI_{100} was lower than AHS_{100}. This is to be expected, since the biotic components are subject to a wider range of anthropogenic pressures than the abiotic components.

It should be noted that this effectively extends the analysis to a range beyond the data, with the extent of this varying between estuaries depending on the data. Thus the models are not entirely empirical. Nevertheless, the consistency with which the same approach fitted all the data sets suggests that the model is fairly reliable. The difference between this approach and the DRIFT method used to assess the ecological flow requirements for rivers is that in the latter, specialist scientists model responses to flows across the full range of possibilities. The scenario-based approach used in most estuary studies falls short in this regard. For this reason, it is necessary to extrapolate beyond existing estimates. The models developed here involved two experienced estuarine ecologists, rather than a full team of specialists, but they are anchored in the estimates of a full team. Given the way in which the estuary EWRs have been determined (a scenario based approach as opposed to DRIFT or similar modelling) the only alternative to identifying the minimum flow requirement (for a D) would be to have a workshop and create new scenarios for each estuary. This is not feasible where large numbers of estuaries are involved, necessitating a modelling approach. However, it should be recognised that there could be a significant error margin around the EWR estimates in cases where they extend well beyond the range of the data.

Finally, a new relationship was derived to simulate the potential thresholds in the absence of existing anthropogenic impacts on water quality. This was done by imputing a new EHI100 based on the difference between the AHS100 and EHI100, as $EHI'_{100} = EHI_{100}-(AHS_{100}-EHI_{100})$. This theoretically captures the difference due to pollution versus other anthropogenic impacts. However, following the precautionary principle, and especially in light of the error margins of the estimates as discussed above, the EWRs applied should only be those using data corresponding to the current water quality, irrespective of requirements for improving water quality.

3.11.3 Ecological Water Requirements for Estuaries

These relationships described above were used to determine threshold flow requirements for each EC for each of the Breede-Gouritz estuaries, based on current WQ (the default minimum requirement) and based on a situation where pollution is entirely eliminated (Table 3.133). The final threshold value will be determined in each case based on assessment of the feasible and likely degree to which pollution problems can be reduced relative to the present-day situation. This %MAR will then be translated into flow pattern for use in the water supply model using the patterns of the relevant Reserve studies used the approach described in Section 3.11.2 above.

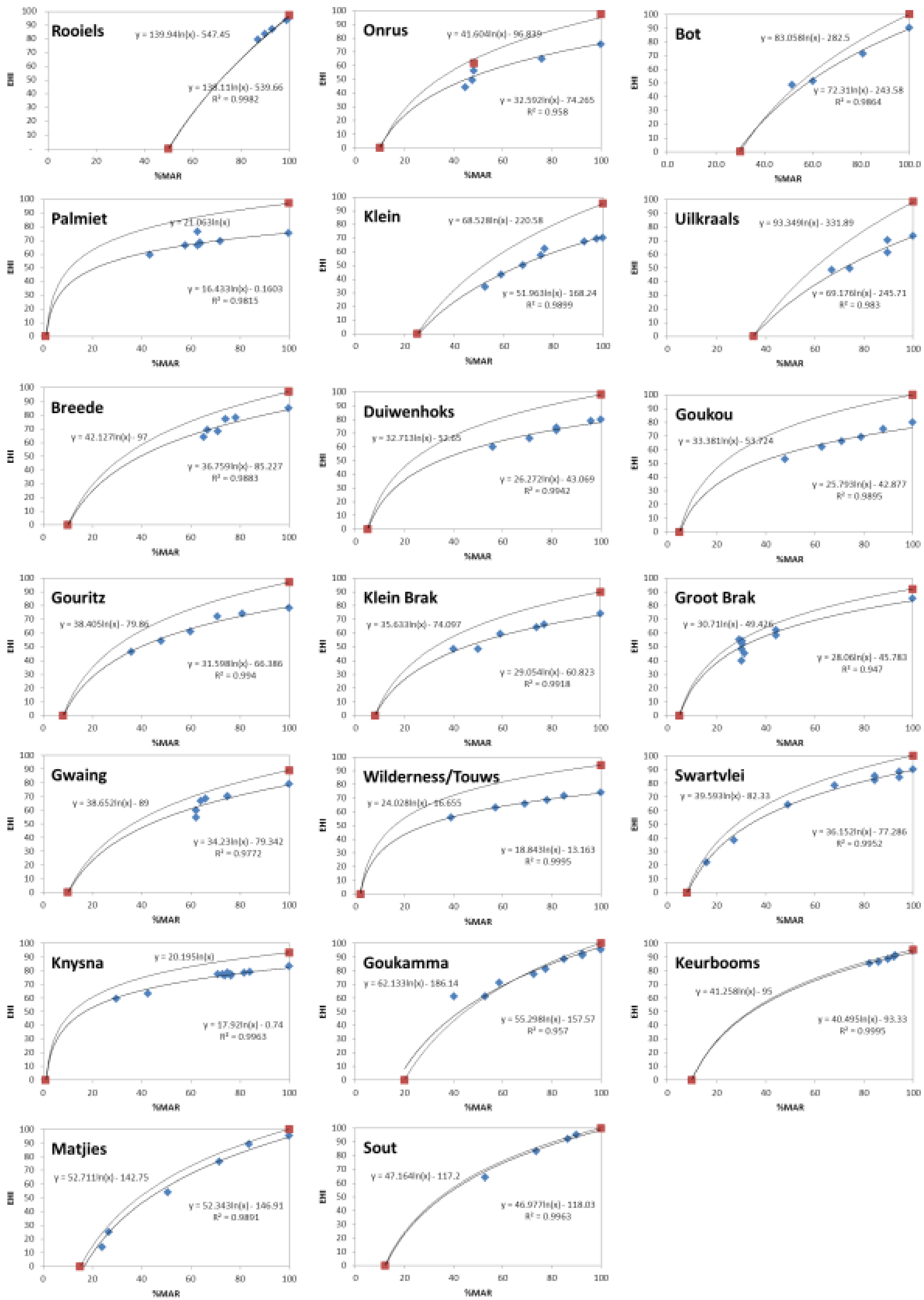

Figure 3.8 Relationships between %MAR and estuary health (EHI) for 20 estuaries of the Breede-Gouritz WMA (a) under current non-flow pressures – lower line, and (b) when anthropogenic impacts on water quality are removed – upper line.

Table 3.133 Ranges of threshold flow requirements (%MAR) for each Ecological Category for each of the Breede River catchment and Overberg region estuaries, based on current WQ (the default minimum requirement) and based on a situation where pollution is entirely eliminated. *imputed from similar systems

IUA	%MAR thresholds	E/D threshold		D/C threshold		C/B threshold		B/A threshold	
		Fixed WQ	Current WQ	Fixed WQ	Current WQ	Fixed WQ	Current WQ	Fixed WQ	Current WQ
H16	Rooiels	66	67	77	77	85	86	95	95
	Buffels (Oos)*	66	67	77	77	85	86	95	95
	Palmiet	7	12	17	39	35	97	72	n/a
	Bot / Kleinmond	49	50	62	67	74	82	89	n/a
	Onrus	26	35	42	65	59	n/a	85	n/a
H17	Klein	45	55	60	81	75	n/a	93	n/a
	Uikraals	54	62	67	83	78	n/a	92	n/a
	Ratel*	54	62	67	83	78	n/a	92	n/a
	Heuningnes	67	66	77	77	85	86	95	95
	Klipdrifsfontein*	54	62	67	83	78	n/a	92	n/a
F11	Breë	26	30	42	52	59	78	85	n/a

Table 3.134 Ranges of threshold flow requirements (%MAR) for each Ecological Category for each of the Gouritz River catchment and Outeniqua region estuaries, based on current WQ (the default minimum requirement) and based on a situation where pollution is entirely eliminated. *imputed from similar systems

IUA	%MAR thresholds	E/D threshold		D/C threshold		C/B threshold		B/A threshold	
		Fixed WQ	Current WQ	Fixed WQ	Current WQ	Fixed WQ	Current WQ	Fixed WQ	Current WQ
F12	Duiwenhoks	17	24	31	51	50	89	78	n/a
I18	Goukou (Kaffirkuils)	17	25	30	54	47	97	74	n/a
F13	Gouritz	23	29	38	55	56	88	83	n/a
G14	Blinde*	26	35	42	65	59	n/a	85	n/a
	Tweekuilen*	26	35	42	65	59	n/a	85	n/a
	Gericke*	26	35	42	65	59	n/a	85	n/a
	Hartenbos	25	32	43	64	66	n/a	n/a	n/a
	Klein Brak	25	32	43	64	66	n/a	n/a	n/a
	Groot Brak	18	21	35	43	57	74	94	n/a
G15	Maalgate*	28	33	47	59	70	91	n/a	n/a
	Gwaing	28	33	47	59	70	91	n/a	n/a
	Kaaimans*	28	33	47	59	70	91	n/a	n/a
	Wilderness/ Touw	11	17	24	49	45	n/a	85	n/a
	Swartvlei	22	26	36	45	53	68	78	n/a
	Goukamma	36	36	51	51	67	67	88	88

IUA	%MAR thresholds	E/D threshold		D/C threshold		C/B threshold		B/A threshold	
		Fixed WQ	Current WQ	Fixed WQ	Current WQ	Fixed WQ	Current WQ	Fixed WQ	Current WQ
	Knysna	7	10	20	30	41	68	86	n/a
	Noetsie*	32	36	47	52	62	69	83	92
	Piesang*	25	32	43	64	66	n/a	n/a	n/a
	Keurbooms	26	27	43	44	62	64	89	93
	Matjies	32	36	47	52	62	69	83	92
	Sout (Oos)	28	29	43	44	59	61	81	84
	Groot (Wes)*	36	36	51	51	67	67	88	88
	Bloukrans*	28	29	43	44	59	61	81	84

3.12 EcoClassification of Nodes

The ecological condition of rivers in the Gouritz and Breede River catchments were collated and synthesized during the PES/EIS project (DWS 2014) along with empirical data about river condition, riparian vegetation and aquatic macroinvertebrates. The PES/EIS project (DWS 2014) also calculated provisional RECs for all sub-quaternary rivers in these areas. These, along with the PES and REC calculated for each river Reserve study site are listed below in Table 3.135 and Table 3.136, as are those for the estuaries.

It can be seen that in most cases, the provisional RECs for the rivers surpass the present ecological condition and in most cases will be unachievable due to limited additional water availability and mostly due to the ecological condition also being driven by non-flow related factors, such as poor water quality, the presence of exotic woody vegetation, alien fish and poor habitat conditions from physical disturbances related to agricultural and urban influences of various sorts. This is not a problem for the construction of the REC scenario as the scenario will be constructed to achieve the REC at each EWR site as a starting point, and this will then require adjusting the nodes up and downstream of these EWR site (nodes) in order to balance flows to achieve these. This means, in practical terms, that these desktop RECs at all nodes, other than the EWR sites, will be over-ridden by what is practically and realistically achievable, taking current day flows, water quality and non-flow related factors into account on a node by node basis.

Table 3.135 Ecological condition (PES 2014) and desktop REC (DWS 2014) for all nodes in the Gouritz River catchment and Outeniqua region (red text denotes EWR sites), blue highlight indicates estuaries

Secondary Catchment	CODE	Sub-quaternary code	RIVER	QUAT	PES	REC
J1	giv28	J12D-08735	Touws	J12D	D	B
	giv27	J12H-08834	Touws	J12H	B	C
	giv26	J12K-08887	Brak	J12K	C	B
	gviii1	J12L-08985	Doring	J12L	CD	CD
	gv5	J12M-08904	Touws	J12M	BC	BC
	giv34	J11C-08151	Buffels	J11C	B	B
	gv25	J11F-08427	Buffels	J11F	C	B
	gv4	J11J-08686	Buffels	J11J	C	C
	giv32	J11K-08860	Groot	J11K	D	B
	gv7	J13B-08923	Groot	J13B	C	B
	gii3	J13C-09099	Groot	J13C	B	B

Secondary Catchment	CODE	Sub-quaternary code	RIVER	QUAT	PES	REC
J2	giv3	J21D-07700	Gamka	J21D	B	A
	giv1	J22F-07805	Koekemoers	J22F	C	A
	giv2	J22K-07655	Leeu	J22K	C	A
	gv17	J23F-08268	Gamka	J23F	B	B
	gv27	J23J-08497	Gamka	J23J	C	B
	gv14	J24E-08292	Dwyka	J24E	A	B
	giv20	J25A-08567	Gamka	J25A	CD	C
	gii2	J25E-08884	Gamka	J25E	C	B
J3	giii2	J31D-08592	Olifants	J31C	C	C
	giv15	J32E-08545	Traka	J32E	C	C
	gv33	J33B-08714	Olifants	J33B	D	B
	gv21	J33D-08571	Meirings	J33E	C	A
	giv11	J33F-08772	Olifants	J33F	E	B
	gv36	J34C-08869	Kammanassie	J34D	CD	CD
	giv10	J34F-08848	Leeu	J34F	E	A
	gv19	J35E-08764	Olifants	J35E	E	B
	giv17	J35F-08739	Olifants	J35F	D	B
J4	gi4	J40B-09106	Gouritz	J40B	C	C
	gv9	J40E-09284	Gouritz	J40E	C	B
	gxi1	J40E	Gouritz Estuary	J40E	C	B
H8	giii5	H80C-09208	Duiwenhoks	H80B	E	A
	giii8	H80E-09314	Duiwenhoks	H80D	D	D
	gxi2	H80E	Duiwenhoks Estuary	H80E	B	A
H9	giii6	H90B-09155	Korinte	H90C	D	B
	giii7	H90C-09229	Goukou	H90C	CD	CD
	gv41	H90E-09343	Goukou	H90E	C	B
	gxi3	H90E	Goukou Estuary	H90E	C	B
K1	gxi19	K10A	Blinde Estuary	K10A	B	B
	gxi20	K10A	Tweekuilen Estuary	K10A	-	-
	gxi21	K10A	Gericke Estuary	K10A	-	-
	gxi22	K10B	Hartenbos Estuary	K10B	D	C
	giv25	K10D-09163	Brandwag	K10D	D	B
	gxi4	K20A	Klein Brak Estuary	K10F	C	C
K2	gvii7	K20A-09083	Groot-Brak	K20A	BC	A
	gviii2	K20A-09083	Groot-Brak	K20A	BC	BC
	gviii3	K20A	Varing	K20A	D	CD
	Gviii12	K20A	Varing	K20A	D	CD
	gxi5	K20A	Groot Brak Estuary	K20A	D	C
K3	gviii4	K30A-09087	Maalgate	K30A	B	A
	gvii8	K30A-09087	Maalgate	K30A	B	D
	gxi6	K30A	Malgat Estuary	K30A	B	B
	gvii9	K30B-09082	Malgas	K30B	C	C
	gviii6	K30B-09151	Gwaing	K30B	E	D
	gxi7	K30B	Gwaing Estuary	K30B	B	C
	gviii7	K30C-09093	Swart	K30C	D	D
	gvii11	K30C-09065	Kaaimans	K30C	B	B
	gxi8	K30C	Kaaimans Estuary	K30C	B	B
	gviii8	K30C	Silver	K30C	B	B
	gvii12	K30D-09042	Touws	K30D	B	A
	gx8	K30D-09108	Klein Keurbooms	K30D	D	B
	gxi9	K30D	Wilderness Estuary	K30D	B	A

Secondary Catchment	CODE	Sub-quaternary code	RIVER	QUAT	PES	REC
K4	giii10	K40A-09027	Diep	K40A	B	B
	giii13	K40B-09022	Hoekraal	K40B	B	A
	gxi10	K40B	Swartvlei Estuary	K40B	B	B
	gvii13	K40C-09036	Karatara	K40C	B	AB
	giii11	K40C-09140	Karatara	K40C	AB	A
	gviii9	K40E-09016	Goukamma	K40E	BC	BC
	gxi11	K40E	Goukamma Estuary	K40E	B	A
K5	gvii14	K50A-09069	Knysna	K50A	B	B
	giii12	K50B-09111	Knysna	K50A	B	B
	gviii11	K50B-09117	Gouna	K50B	AB	AB
	gxi12	K50B	Knysna Estuary	K50B	B	B
K6	gvii10	K60G-09180	Noetzie	K60G	B	AB
	gx3	K60G-09200	Piesang	K60G	D	A
	giv4	K60F-09092	Bitou	K60F	C	A
	giv6	K60C-08992	Keurbooms	K60C	C	BC
	giv5	K60D-08996	Palmiet	K60D	A	A
	gxi13	K60G	Noetsie Estuary	K60G	B	A
	gxi14	K60G	Piesang Estuary	K60G	C	B
	gxi15	K60G	Keurbooms Estuary	K60G	A	A
	gx9	K60E-09097	Keurbooms	K60E	C	A
K7	gx4	K70A-09110	Buffels	K70A	B	A
	gx5	K70A-09086	Sout	K70A	B	A
	gxi16	K70A	Matjies Estuary	K70A	B	B
	gxi23	K70A	Groot (Wes) Estuary	K70A	B	A
	gxi17	K70A	Sout (Oos) Estuary	K70A	A	A
	gvii15	K70B-09055	Bloukrans	K70B	B	A
	gxi18	K70B	Bloukrans Estuary	K70B	B	B

Where EWR = Ecological Water Requirement: PES = Present Ecological Status, REC = Recommended Ecological Category, QUAT = Quaternary Catchment

Table 3.136 Ecological condition (PES 2014) and desktop REC (DWS 2014) for all nodes in the Breede River catchment and Overberg region (red text denotes EWR sites)

Secondary Catchment	NODE	Sub-quaternary code	RIVER	QUAT	PES	REC
H1	Niv2	H10C-08644	Dwars	H10C	C	B
	Niv1	H10C-08560	Koekedou	H10C	D	A
	Niv3	H10B-08700	Titus	H10C	C	A
	Niv4	H10D-08755	Witels	H10D	A	A
	Nvi3	H10F-08730	Breede	H10D	C	B
	Nvii16	H10E-08836	Witte	H10E	A	A
	Niv5	H10E-08836	Witte	H10F	A	A
	Niv6	H10F-08804	Wabooms	H10F	D	B
	Nviii1	H10G-08837	Breede	H10F	DE	D
	Niv7	H10G-08889	Slanghoek	H10G	D	B
	Niii1	H10G-08844	Breede	H10G	D	B
	Niv40	H10J-09038	Elands	H10J	B	A
	Niv41	H10J-09000	Krom	H10J	B	A
	Nvii2	H10J-08990	Molenaars	H10J	C	B
	Niv42	H10L-08968	Smalblaar	H10J	E	B

Secondary Catchment	NODE	Sub-quaternary code	RIVER	QUAT	PES	REC
	Niv8	H10H-08826	Jan du Toit	H10H	D	A
	Nvii6	H10H-08850	Hartbees	H10H	D	A
	Niv9	H10H-08850	Hartbees	H10H	D	A
	Niv12	H10K-08972	Holsloot	H10K	C	B
	Nv3	10HJ-08895	Breede	H10L	C	B
H2	Nvii7	H20H-08839	Hex	H20G	C	C
	Niv10	H20H-08839	Hex	H20H	D	B
H4	Nii1	H40C-08935	Breede	H40C	C	C
	Nvii5	H40B-08890	Koo	H40B	D	B
	Niv11	H40C-08999	Nuy	H40C	E	B
	Niv13	H40D-09051	Doring	H40D	E	B
	Nvii8	H40F-09026	Breede	H40F	CD	CD
	Nvii11	H40G-09126	Poesnels	H40G	D	B
	Niv15	H40H-09039	Vink	H40H	D	A
	Nviii2	H40J-09007	Willem Nels	H40J	D	B
	Nvii19	H40J-09072	Breede	H40J	B	B
	Niv14	H40K-09118	Keisers	H40K	D	A
H3	Niv20	H30C-08991	Pietersfontein	H30C	D	C
	Nvii9	H30D-09015	Keisie	H30D	D	B
	Niv18	H30B-08978	Kingna	H30B	D	B
	Nii2	H30E-09032	Kogmanskloof	H30E	D	A
H5	Ni2	H50B-09129	Breede	H50B	D	B
H6	Nvii10	H60B-09162	Du Toits	H60B	B	A
	Nv7	H60D-09239	Riviersonderend	H60D	C	A
	Niv28	H60E-09127	Baviaans	H60E	B	B
	Niv29	H60E-09302	Sersants	H60E	D	B
	Niv30	H60F-09248	Gobos	H60F	C	A
	Nv9	H60F-09277	Riviersonderend	H60G	D	D
	Niv31	H60G-09321	Kwartel	H60G	D	B
	Niv33	H60H-09275	Soetmelksvlei	H60H	D	A
	Niv34	H60H-09280	Slang	H60H	D	A
	Nv10	H60H-09288	Riviersonderend	H60H	D	A
	Niv35	H60K-09297	Kwassadie	H60K	E	A
	Ni3	H60L-09270	Riviersonderend	H60L	D	B
H7	Niv24	H70A-9186	Leeu	H70A	E	A
	Nv2	H70B-09251	Breede	H70B	C	B
	Nii3	H70D-09157	Tradouw	H70D	B	A
	Niv25	H70F-09226	Buffeljags	H70F	E	B
	Niii4	H70G-09345	Breede	H70G	C	BC
	Niv26	H70J-09358	Slang	H70J	E	B
	Nxi2	H70K	Breede Estuary	H70K	B	B
G4	Nxi9	G40B	Rooiels Estuary	G40B	B	B
	Nxi10	G40B	Buffels Oos Estuary	G40B	B	B
	Piii1	G40C-09305	Palmiet	G40C	B	B
	Piv10	G40C	Witklippieskloof	G40C	D	D
	Piv9	G40C-09305	Palmiet	G40C	D	B
	Piv8	G40C	Klipdrif	G40C	D	D
	Piv4	G40D	Klein-Palmiet	G40D	D	D
	Piv7	G40D-09333	Krom/Ribbok	G40D	D	A

Secondary Catchment	NODE	Sub-quaternary code	RIVER	QUAT	PES	REC
	Piii2	G40D-09369	Palmiet	G40D	C	BC
	Piv12	G40D	Dwars/Louws	G40D	C	C
	Piii3	G40D-09369	Palmiet	G40D	C	B
	Pxi1	G40D	Palmiet Estuary	G40D	C	B
	Niii5	G40G-09370	Bot	G40G	C	A
	Nxi6	G40G	Bot/Kleinmond Estuary	G40G	C	B
	Nx6	G40H-09398	Onrus	G40H	E	B
	Nxi8	G50H	Onrus Estuary	G40H	E	D
	Niv43	G40F-09365	Swart	G40F	E	B
	Niv45	G40K-09349	Steenbok	G40K	E	A
	Nii4	G40J-09395	Hartbees	G40J	D	B
	Nv23	G40L-09411	Klein	G40K	D	C
	Nxi7	G40L	Klein Estuary	G40L	C	B
	Nx8	G40M-09414	Uilkraal	G40M	C	A
	Nxi5	G40M	Uilkraals Estuary	G40M	D	C
G5	Nii6	G50H-09406	Sout	G50H	D	B
	Nxi11	G50K	Klipdrifsontein Estuary	G50K	A	A
	Nii7	G50G-09352	DeHoopVlei	G50G	B	B
	Nxi3	G50A	Ratel Estuary	G50A	C	C
	Nxi1	G50F	Heuningnes Estuary	G50F	C	A*
	Ni4	G50B-09418	Nuwejaar	G50B	D	D
	Nvii15	G50C-09432	Heuningnes	G50C	D	B
	Niv44	G50C-09432	Heuningnes	G50C	D	B
	Nv24	G50E-09404	Kars	G50E	C	B
	Nii5	G50E-09427	Kars	G50C	E	B

Where EWR = Ecological Water Requirement: PES = Present Ecological Status; REC = Recommended Ecological Category, QUAT = Quaternary Catchment, *Best Attainable State as determined by specialists due to occurrence within protected area

3.13 Wetlands link to Nodes and EWRs

The Status Quo report (DWS, 2016b) defined the wetlands within the study area according to the spatial framework of Ecoregions to define wetland resource units (considered to be wetland "regions"). The associated hydro geomorphic (HGM) unit characteristics for each wetland resource unit was also described. According to the "Classification system for wetlands" (Ollis et al., 2013), whilst the HGM unit is influenced by the source of water and how it moves into, through and out of an Inland System, the hydrological regime describes the behaviour of water within the system and in the underlying soil. This level of assessment is an important consideration for the development of scenarios as the hydrological regime relates to the EWRs for surface flow.

In terms of hydrological regime, rivers may be described as either perennial (flows continually throughout the year) or non-perennial (does not flow continually throughout the year). Wetlands should be classified according to the period of inundation (Level 5A) and saturation (Level 5B), together with inundation depth class (Level 5C) for permanently inundated open water bodies. Although classification in this regard may be relatively straightforward for rivers, the classification of the hydrological regime for wetlands is more complicated due the non-uniformity of wetness across a wetland. There is also lack of quantitative date for most wetlands according to hydrology. An additional constraint for this study is the lack of baseline data for wetlands in the study area in terms of hydro period. The National Freshwater Ecosystem Priority Areas (NFEPA) dataset classifies wetlands up to the HGM unit (Level 4) scale of classification, whilst the fine scale planning (FSP) dataset classifies wetlands up to the hydrological regime (Level 5), but does not extend over the entire study area.

Wetlands are transitional between aquatic and terrestrial systems, and are generally classified by saturated soils and hydrophytic vegetation. The HGM approach (using hydrological and geomorphological characteristics) to wetland classification may distinguish the primary wetland unit, but a finer scale assessment is required for quantification of EWRs for wetland systems. An overview of the classification of wetlands (Ollis et al., 2013) is provided to determine the level of information necessary for this report.

- **Level 1: Systems**

  Wetlands include all aquatic ecosystems and can be divided at the broadest level into Marine, Estuarine and Inland systems. For the purpose of this study only inland systems were described. Inland systems may include all rivers plus any other inland areas that are permanently or periodically inundated or saturated.

  - Inland systems are ecosystems that
    - Are permanently or periodically inundated or saturated
    - Have no existing connection to the ocean
    - Are characterised by absence of marine exchange or tidal influence

- **Level 2: Regional Setting**

  Identification of the regional setting allows for an understanding of the broad ecological context within which an aquatic ecosystem occurs. The DWA ecoregions were described in the Status Quo report, which indicated a coarse scale wetland regional setting. The NFEPA wetland dataset also provides a coarse scale regional setting for priority wetlands.

- **Level 3: Landscape Setting**

  The use of these units recognises that the hydrological and hydrodynamic processes acting within Inland Systems are likely to be strongly influenced by their topographical processes that have brought about and drive these topographical contexts. Four landscape units are defined according to landscape setting, these are as follows:

  - Valley floor, the base of a valley, situated between two distinct valley side-slopes, where alluvial or fluvial processes typically dominate.

- Slope, an inclined stretch of ground typically located on the side of a mountain, hill or valley floor.
- Plain, an extensive area of low relief.
- Bench, a relatively discrete area of mostly level or nearly level high ground, including hilltops, saddles and shelves.

- **Level 4: Hydro geomorphic Unit**

  HGM units are distinguished primarily on the basis of:

  - Landform, which defines the shape and localised setting of the aquatic ecosystem.
  - Hydrological characteristics, which describe the nature of water movement into, through and out of the aquatic ecosystem.
  - Hydrodynamics, which describe the direction and strength of flow through the aquatic ecosystem.

  There are six HGM types for wetland inland systems at Level 4A:

  - Valley-bottom wetlands (Channelled and Unchannelled), a mostly flat wetland area located along a valley floor, often connected to an upstream or adjoining river channel.
  - Floodplain wetland,
  - Depression, a wetland or aquatic ecosystem with closed (or near closed) elevation contours, which increases in depth from the perimeter to a central area of greatest depth and within which water typically accumulates.
  - Seep, a wetland area located on gently to steeply sloping land and dominated by colluvial, unidirectional movement of water and material downslope.
  - Wetland flat, a level or near level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. Closed elevation contours are not evident around the edge of wetland.

- **Level 5: Hydrological regime**

  The hydrological regime describes the behaviour of water within the system and, for wetlands, in the underlying soil. For wetlands and inland water bodies the hydrological regime may be classified according to the period of inundation and saturation, as well as inundation depth class for permanently inundated waterbodies.

- **Level 6: Descriptors**

  Certain descriptors for the structural/chemical/biological characterisation of inland systems may be used depending on relevance.

It is clear that the HGM approach to wetland classification provides a starting point for assessment of the EWRs for wetlands, but that further assessment of additional information related to the use of wetlands is required to determine the value and ecological condition of priority wetlands. This assessment will be provided for during the determination of Resource Quality Objectives for the study area.

This study is associated with flow related non-consumptive use and has been assessed as such. Wetlands in the study area were identified according to Hydro geomorphic unit, Hydro period, PES, EIS and REC (where this information is available). The source of data was also referenced. Wetlands are either driven by channel flow (i.e. river associated) or interflow (i.e. groundwater driven), therefore the assessment of wetlands can be associated with river and estuary nodes and groundwater resource units in terms of EWRs.

The wetland units associated with river nodes are as follows:

- Valley bottom
- Floodplain

- Depression linked to a channel

The wetland units associated with groundwater resource units are as follows (although the wetlands associated with river nodes may also have groundwater linkages i.e. valley bottom and floodplain wetlands as described above):

- Seep
- Isolated depression

Within the Breede River catchment and Overberg region there are 76 river nodes and 11 estuary nodes. The wetlands which are surface water driven are related to these nodes (Table 3.137). Within the Gouritz River catchment and Outeniqua region there are 65 river nodes and 34 estuary nodes. The wetlands which are surface water driven are related to these nodes (Table 3.138).

Table 3.137 The surface water driven wetlands associated with nodes in the Breede River catchment and Overberg region with estuary nodes highlighted in blue

<table>
<tr><th>IUA</th><th>Node</th><th>Quat</th><th>Description</th><th>Associated wetlands</th><th>HGM</th><th>Hydro-period</th><th>PES</th><th>EIS</th><th>REC</th><th>Source</th></tr>
<tr><td rowspan="5">A1</td><td>Niv2</td><td>H10C</td><td></td><td>De Vlakte*</td><td rowspan="2">Channelled valley-bottom</td><td rowspan="2">Unknown</td><td rowspan="2">AB</td><td rowspan="2">Mod</td><td rowspan="2">(AB)</td><td rowspan="2">EGI</td></tr>
<tr><td>Nvii16</td><td>H10E</td><td></td><td></td></tr>
<tr><td>Niv5</td><td>H10F</td><td></td><td></td><td>Channelled valley-bottom</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td>Niv41</td><td>H10J</td><td></td><td></td><td>Flat</td><td>Unknown</td><td>AB</td><td>-</td><td>(AB)</td><td>EGI</td></tr>
<tr><td>Nvii2</td><td>H10J</td><td></td><td></td><td>Channelled valley-bottom</td><td>Unknown</td><td>AB</td><td>-</td><td>(AB)</td><td>EGI</td></tr>
<tr><td rowspan="16">A2</td><td rowspan="2">Niv7</td><td rowspan="2">H10G</td><td rowspan="2"></td><td rowspan="2"></td><td>Channelled valley-bottom</td><td>Unknown</td><td>AB</td><td>-</td><td>(AB)</td><td>EGI</td></tr>
<tr><td>Unchannelled valley-bottom</td><td>Unknown</td><td>AB</td><td>-</td><td>(AB)</td><td>EGI</td></tr>
<tr><td rowspan="3">Niii1</td><td rowspan="3">H10G</td><td rowspan="3"></td><td>Bree River wetland*</td><td>Floodplain</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td rowspan="2"></td><td>Flat</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td>Channelled valley-bottom</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td>Niv8</td><td>H10H</td><td></td><td></td><td>Floodplain</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td rowspan="5">Niv9</td><td rowspan="5">H10H</td><td rowspan="5"></td><td rowspan="3"></td><td>Channelled valley-bottom</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td>Flat</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td>Floodplain</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td rowspan="2">Papenkuils Wetland*</td><td>Floodplain</td><td>EWR</td><td>C</td><td>High</td><td>C</td><td>EWR</td></tr>
<tr><td>Floodplain</td><td>EWR</td><td>CD</td><td>High</td><td>CD</td><td>EWR</td></tr>
<tr><td>Nvii7</td><td>H20G</td><td></td><td></td><td>Channelled valley-bottom</td><td>Unknown</td><td>AB</td><td>-</td><td>(AB)</td><td>EGI</td></tr>
<tr><td>Nv3</td><td>H10L</td><td></td><td>Breede River</td><td>Floodplain</td><td>Unknown</td><td>AB</td><td>-</td><td>(AB)</td><td>EGI</td></tr>
<tr><td>Niv10</td><td>H20H</td><td></td><td></td><td>Channelled valley-bottom</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>EGI</td></tr>
<tr><td>Nvii9</td><td>H30D</td><td></td><td></td><td>Floodplain</td><td>Unknown</td><td>C</td><td>-</td><td>(C)</td><td>NFEPA</td></tr>
<tr><td>Niv13</td><td>H40D</td><td></td><td>Bree River vlei*</td><td>Floodplain flat</td><td>Perennial</td><td>AB</td><td>-</td><td>(AB)</td><td>FSP</td></tr>
</table>

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydro-period	PES	EIS	REC	Source
	Nv7	H60D		Elandskloof wetlands*	Floodplain	Non-perennial	-			FSP
	Nv9	H60F		Kwarte wetlands*	Floodplain	Perennial	-			FSP
	Niv25	H70F		Potberg pan*	Floodplain	Non-perennial	-			FSP
H16			Rooiels Estuary		Channelled valley bottom	Unknown	AB	-	(AB)	NFEPA
			Buffels Oos Estuary		Channelled valley bottom	Unknown	C	-	(C)	NFEPA
					Unchannelled Valley-bottom	Unknown	C	-	(C)	NFEPA
					Unchannelled Valley-bottom	Unknown	AB	-	(AB)	NFEPA
			Bot/Kleimond Estuary		Channelled valley bottom	Unknown	C	-	(C)	NFEPA
H17		G40L	Klein Estuary		Channelled valley bottom	Unknown	AB	-	(AB)	NFEPA
					Unchannelled Valley-bottom	Unknown	AB	-	(AB)	NFEPA
		G40M	Uitkraals Estuary		Channelled valley bottom	Unknown	C	-	(C)	NFEPA
				Upper Boesmans Wetlands	Channelled valley bottom		C	V High	C	WfW
					Seep		C	V High	C	WfW
		G50A	Ratel Estuary	Ratel River#	Floodplain	Unknown	C	-	(C)	NFEPA
					Flat	Unknown	C	-	(C)	NFEPA
					Unchannelled Valley-bottom	Unknown	C	-	(C)	NFEPA
		G50F	Heuninnes Estuary		Floodplain	Unknown	C	-	(C)	NFEPA
					Flat	Unknown	C	-	(C)	NFEPA
					Unchannelled Valley-bottom	Unknown	C	-	(C)	NFEPA
					Seep		C	High	C	WfW
	Ni4	G50B		Moddervlei* within Algulhas-Heuningnes IBA	Floodplain	Non-perennial	-	-		FSP
				Pietersielieskloof	Channelled valley bottom	unknown	E	V High	D	WfW
	Nvii15	G50C		Algulhas# wetlands within Algulhas-Heuningnes IBA	Seep	Unknown	C/D	V High	C/D	WfW
B5		G40D	Palmiet Estuary		Channelled valley bottom	Unknown	AB	-	(AB)	NFEPA

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydro-period	PES	EIS	REC	Source
					Unchannelled Valley-bottom	Unknown	C	-	(C)	NFEPA

Where IUA = Integrated Unit of Analysis, Quat = Quaternary; * Western Cape Wetlands Directory, # = Working for Wetlands wetland, EGI = Electrical Grid Infrastructure Data; EWR = Reserve for Papenkuils, refer to Appendix for data; IBA = Important Bird Area, NFEPA = National Freshwater Ecosystem Priority Area, FSP = Fine Scale Planning, HGM = Hydro geomorphic Unit, PES = Present Ecological Status, (NFEPA: Z1 = wetland overlap with artificial inland water body, Z2 = majority wetland artificial, Z3 = percentage natural land cover <25%) WfW: Working for Wetlands Data

Table 3.138 The surface water driven wetlands associated with nodes in the Gouritz River catchment and Outeniqua region with estuary nodes highlighted in blue

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydroperiod	PES	EIS	REC	Source
E8	giv28	J12D	U/s confluence Touws Kragga	Bokke River Vlei*	Channelled Valley Bottom	No information	AB	-	(AB)	EGI
				Verkeerdevlei*	Channelled Valley Bottom	No information	AB	-	(AB)	EGI
	giv26	J12K	U/s confluence Touws Brak	Wetland within Eyerpoort Nature Reserve	Channelled Valley Bottom	No information	AB	Mod+	(AB)	NFEPA
					Channelled Valley Bottom	No information	C	Mod+	(C)	NFEPA
					Floodplain	No information	C	Mod+	(C)	NFEPA
	gviii1	J12L			Channelled Valley Bottom	No information	C	Mod+	(C)	NFEPA
	gv5	J12M	U/s confluence Touws Doring		Channelled Valley Bottom	No information	C	-	(C)	NFEPA
	gv4	J11J		Within Swartberg Mountains IBA	Channelled Valley Bottom	No information	AB	-	(AB)	NFEPA
					Unchannelled Valley Bottom	No information	AB	-	(AB)	NFEPA
C6	giv34	J11C	U/s confluence Buffels Meintjiesplaas		Channelled Valley Bottom	No information	AB	-	(AB)	NFEPA
	giv2	J22H	U/s confluence Leeu Koekemoers	Karoo National Park IBA	Channelled Valley Bottom	No information	AB	-	(AB)	NFEPA
				Karoo National Park IBA	Channelled Valley Bottom	No information	AB	-	(AB)	NFEPA
	gv14	J24A	D/s Dwyka Jakkals/Vlakkraal	Dwyka River vlei*	Channelled Valley Bottom	No information	Z3	-		NFEPA
				Plaatdoorns vlei*	Floodplain	No information	AB	-	AB	NFEPA

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydroperiod	PES	EIS	REC	Source
				Yuk River vlei*	Floodplain	No information	AB	-	(AB)	NFEPA
				Spitskop vlei*	Floodplain	No information	AB	-	(AB)	NFEPA
		J24B		Buffels Valley vlei*	Floodplain	No information	AB	-	(AB)	NFEPA
	gi4	J40B	Quaternary outlet J40B	Small wetlands on channel	Channelled Valley Bottom	No information	AB	Low+	(AB)	NFEPA
					Floodplain	Permanent	AB	High+	(AB)	FSP
					Channelled Valley Bottom	Permanent	AB	High+	(AB)	FSP
	gxi1	J40E	Gouritz Estuary		Floodplain	Permanent	AB	High+	(AB)	FSP
					Channelled valley bottom	Permanent	AB	High+	(AB)	FSP
F12	giii5	H80B		Noukrans River vlei*	Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
				Grootvadersbosch vlei*	Floodplain	Permanent	Z	Mod+		FSP
				Duiwenhoks#	Floodplain	Permanent	Z	Mod+		FSP
				Duiwenhoks#	Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	giii8	H80D			Floodplain	Permanent	AB	Mod+	(AB)	FSP
	gxi2	H80E	Duiwenhoks Estuary		Floodplain	Permanent	AB	Mod+	(AB)	FSP
					Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	giii6	H90B			Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	giii7	H90A		Klein Kruisrivier#	Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
				Upper Gaffie#		Unknown	D	Mod	D	WfW
				Lower Tierk#		Unknown	D	Mod	D	WfW
				Grootbosberg#	Unchannelled valley bottom	Unknown	A	Mod	A	WfW
I18	gv41	H90E			Floodplain	Permanent	AB	Mod+	(AB)	FSP
					Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gxi3	H90E	Goukou Estuary		Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
G14	gxi19	K10A	Blinde Estuary	Rietvalley vlei*	Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gxi20	K10A	Tweekuilen Estuary		Floodplain					
					Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gxi21	K10A	Gericke Estuary		Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydroperiod	PES	EIS	REC	Source
					Unchannelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gxi22	K10B	Hartenbos Estuary		Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gv39	K10F			Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	giv25	K10D		Brandwag River vlei*	Floodplain flat	Permanent	AB	Mod+	(AB)	FSP
					Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gxi4	K10F	Klein Brak Estuary		Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gviii12	K20A		Wetlands within Outeniqua IBA	Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gviii3	K20A			Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gviii2	K20A		Wetlands within Outeniqua IBA	Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gvii7	K20A			Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
	gxi5	K20A	Groot Brak Estuary		Channelled valley bottom	Permanent	AB	Mod+	(AB)	FSP
G15	gviii4	K30A		Small wetlands	Channelled valley bottom	Unknown	C	High+	(C)	NFEPA
	gvii8	K30A		Small wetlands	Channelled valley bottom	Unknown	C	High+	(C)	NFEPA
	gxi6	K30A	Maalgat Estuary		Channelled valley bottom	Unknown	AB	High+	AB)	NFEPA
	gviii6	K30B			Channelled valley bottom	Unknown	C	High+	(C)	NFEPA
	gxi7	K30B	Gwaing Estuary		Channelled valley bottom	Unknown	C	High+	(B)	NFEPA
	gxi8	K30C	Kaaimans Estuary		Channelled valley bottom	Unknown	C	Mod+	(C)	NFEPA
	gxi9	K30D	Wilderness Estuary		Channelled valley bottom	Unknown	AB	Very High+	(AB)	NFEPA
					Unchannelled valley bottom	Unknown	AB	Very High+	(AB)	NFEPA
					Floodplain	Unknown	C	Very High+	(C)	NFEPA
					Floodplain	Unknown	AB	Very High+	(AB)	NFEPA
	giii13	K40B			Floodplain	Unknown	C	Mod+	(C)	NFEPA
	gxi10	K40B	Swartvlei Estuary		Floodplain	Unknown	AB	Mod+	(AB)	NFEPA

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydroperiod	PES	EIS	REC	Source
					Unchannelled valley bottom	Unknown	AB	Mod+	(AB)	NFEPA
	gxi12	K50B	Knysna Estuary		Floodplain	Unknown	C	Mod+	©	NFEPA

Where IUA = Integrated Unit of Analysis: Quat = Quaternary; * = Western Cape Wetlands Directory, # = Working for Wetlands wetland, + = DWS 2015, EGI = Electrical Grid Infrastructure Data, IBA = Important Bird Area, NFEPA = National Freshwater Ecosystem Priority, FSP = Fine Scale Planning, HGM = Hydro geomorphic Unit, PES = Present Ecological Status (NFEPA: Z1 = wetland overlap with artificial inland water body, Z2 = majority wetland artificial, Z3 = percentage natural land cover <25%), WfW: Working for Wetlands data.

Each river node was assessed for GWBF, compared to EWR for ecological category, as an indication of the relative reliance of ecology on GWBF. Certain nodes have GWBF above 75%, this is considered to be a significant contribution from groundwater. The wetlands which are groundwater water driven are related to the river and estuary nodes, with consideration of the significance of groundwater contribution to each node (Table 3.139; Table 3.140).

Table 3.139 The groundwater driven wetlands associated with nodes in the Breede River catchment and Overberg region with estuary nodes highlighted in blue and nodes with significant contribution to groundwater highlighted in green

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydro-period	PES	EIS	REC	Source
	Nvii16	H10E			Seep	Unknown	AB	-	(AB)	EGI
	Niv5	H10F			Seep	Unknown	C	-	(C)	EGI
	Niv6	H10F			Seep	Unknown	C	-	(C)	EGI
A2	Niv7	H10G			Seep	Unknown	C	-	(C)	EGI
	Niii1	H10G			Seep	Unknown	C	-	(C)	EGI
	Niv8	H10H			Seep	Unknown	C	-	(C)	EGI
	Niv9	H10H			Seep	Unknown	C	-	(C)	EGI
	Nvii7	H20G			Seep	Unknown	AB	-	(AB)	EGI
	Niv13	H40D			Seep	Unknown	C	-	(C)	NFEPA
	Nvii8	H40F			Seep	Unknown	C	-	(C)	NFEPA
	Nii2	H30E			Seep	Unknown	C	-	(C)	NFEPA
	Ni2	H50B			Seep	Unknown	AB	-	(AB)	NFEPA
B4	Nv7	H60D			Seep	Unknown	C	-	(C)	NFEPA
	Niv28	H60E			Seep	Unknown	C	-	(C)	NFEPA
	Niv29	H60E			Seep	Unknown	C	-	(C)	NFEPA
	Niv30	H60F			Seep	Unknown	C	-	(C)	NFEPA
					Valley head Seep	Unknown	C	-	(C)	NFEPA
	Nv9	H60F			Seep	Unknown	C	-	(C)	NFEPA
F9	Niv31	H60G			Seep	Unknown	C	-	(C)	NFEPA
	Niv33	H60H			Seep	Unknown	C	-	(C)	NFEPA
	Niv34	H60H			Seep	Unknown	C	-	(C)	NFEPA
	Nv10	H60J			Seep	Unknown	C	-	(C)	NFEPA
	Niv35	H60H			Seep	Unknown	C	-	(C)	NFEPA
	Ni3	H60L			Seep	Unknown	C	-	(C)	NFEPA
F11	Niv25	H70F			Depression	Unknown	AB	-	(AB)	NFEPA
	Nv2	H70F			Seep	Unknown	C	-	(C)	NFEPA
	Nii3	H70B			Seep	Unknown	AB	-	(AB)	NFEPA
H16		G40B	Buffels Oos Estuary		Seep	Unknown	AB	-	(AB)	NFEPA
					Valley head Seep	Unknown	C	-	(C)	NFEPA

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydro-period	PES	EIS	REC	Source
	Nxi6	G40G	Bot/Kleinmond Estuary		Valley head Seep	Unknown	C	-	(C)	NFEPA
	Nxi8	G40H	Onrus Estuary		Seep	Unknown	C	-	(C)	NFEPA
	Nx8	G40M			Seep	Unknown	C	-	(C)	NFEPA
	Nxi5	G40M	Uilkraals Estuary		Seep	Unknown	AB	-	(AB)	NFEPA
		G50A	Ratel Estuary	Ratel River#	Valley head Seep	Unknown	C	-	(C)	NFEPA
					Depression	Unknown	AB	-	(AB)	NFEPA
	Nxi1	G50F	Heuningnes Estuary		Valley head Seep	Unknown	C	-	(C)	NFEPA
					Depression	Unknown	C	-	(C)	NFEPA
					Seep	Unknown	C	-	(C)	NFEPA
	Ni4	G50B		Moddervlei* within Agulhas-Heuningnes IBA	Valley head Seep	Unknown	C	-	(C)	NFEPA
					Depression	Unknown	C	-	(C)	NFEPA
					Seep	Unknown	C	-	(C)	NFEPA
	Nvii15	G50C		Agulhas# wetlands within Agulhas-Heuningnes IBA	Depression	Unknown	C	-	(C)	NFEPA
	Nv24	G50E		Within Overberg Wheatbelt IBA	Seep	Unknown	C	-	(C)	NFEPA
	Nii5	G50C		Agulhas# wetlands within Algulhas-Heuningnes IBA	Valley head Seep	Unknown	C	-	(C)	NFEPA
	Piv4	G40D			Seep	Unknown	AB	-	(AB)	NFEPA

Where IUA = Integrated Unit of Analysis, Quat = Quaternary; * Western Cape Wetlands Directory, # = Working for Wetlands wetland, EGI = Electrical Grid Infrastructure Data, IBA = Important Bird Area, NFEPA = National Freshwater Ecosystem Priority Area, FSP = Fine Scale Planning, HGM = Hydro geomorphic Unit, PES = Present Ecological Status (NFEPA: Z1 = wetland overlap with artificial inland water body, Z2 = majority wetland artificial, Z3 = percentage natural land cover <25%)..

Table 3.140 The groundwater driven wetlands associated with nodes in the Gouritz River catchment and Outeniqua region with estuary nodes highlighted in blue and nodes with significant contribution to groundwater highlighted in green

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydro period	PES	EIS	REC	Source
	giv27	J12G	U/s confluence Touws Brak		Seep	Unknown	AB	-	(AB)	NFEPA
	giv26	J12K	U/s confluence Touws Brak		Valley head Seep	Unknown	Z1	Mod+		NFEPA
					Seep	Unknown	AB	Mod+	(AB)	NFEPA
					Depression	Unknown	AB	Mod+	(AB)	NFEPA
	gviii1	J12L			Seep	Unknown	C	Mod+	(C)	NFEPA
	gv32	J11K	U/s confluence Groot Touws		Seep	Unknown	Z3	Mod+		NFEPA
	gv25	J11F	Placed u/s of Floriskraal reservoir		Depression	Unknown	Z3	Mod+		NFEPA
	giv3	J21D			Depression	Unknown	AB	-	(AB)	NFEPA
	giv1	J22F	U/s confluence Koekemoer Leeu		Depression	Unknown	C	-	(C)	NFEPA
	giv2	J22H	U/s confluence Leeu Koekemoer	Karoo National Park IBA	Depression	Unknown	AB	-	(AB)	NFEPA
	gv17	J23F	D/s confluence Gamka	Small wetlands	Seep	Unknown	AB	-	(AB)	NFEPA

IUA	Node	Quat	Description	Associated wetlands	HGM	Hydro period	PES	EIS	REC	Source
			Gedenksteen se leegte							
	gv14	J24E	D/s Dwyka Jakkals/Vlakkraal	Small wetlands	Seep	Unknown	AB	-	(AB)	NFEPA
F13	gv9	J40E			Hillslope seep	Unknown	AB	-	(AB)	FSP
	gxi1	J40E	Gouritz Estuary		Hillslope seep	Unknown	AB	High+	(AB)	FSP
F12	giii5	H80B			Hillslope seep	Unknown	AB	Low+	(AB)	FSP
	giii8	H80D			Hillslope seep	Unknown	AB	Low+	(AB)	FSP
	giii6	H90B			Hillslope seep	Unknown	AB	-	(AB)	FSP
	giii7	H90A			Hillslope seep	Unknown	AB	-	(AB)	FSP
I18	gv41	H90E			Hillslope seep	Unknown	AB	-	(AB)	FSP
	gxi3	H90E	Goukou Estuary		Hillslope seep	Unknown	AB	-	(AB)	FSP
G14		K10A	Blinde Estuary	Rietvalley vlei*	Hillslope seep	Non-permanent	AB	Mod+	(AB)	FSP
		K10A	Tweekuilen Estuary		Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
		K10A	Gericke Estuary		Hillslope seep	Permanent	Z	Mod+		FSP
					Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
	gv39	K10F			Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
	giv25	K10D			Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
	gxi4	K20A	Klein Brak Estuary		Basin seep	Permanent	AB	Mod+	(AB)	FSP
					Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
	gviii12	K20A		Wetlands within Outeniqua IBA	Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
	gvii7	K20A			Hillslope seep	Permanent	AB	Mod+	(AB)	FSP
G15	gviii4	K30A		Small wetlands	Seep	Unknown	Z	High+		NFEPA
	gviii6	K30B			Depression	Unknown	Z3	High+		NFEPA
		K30B	Gwaiing Estuary		Seep	Unknown	Z	High+		NFEPA

Where IUA = Integrated Unit of Analysis: Quat = Quaternary; * = Western Cape Wetlands Directory, # = Working for Wetlands wetland, + = DWS 2015, EGI = Electrical Grid Infrastructure Data, IBA = Important Bird Area, NFEPA = National Freshwater Ecosystem Priority, FSP = Fine Scale Planning, HGM = Hydro geomorphic Unit, PES = Present Ecological Status, (NFEPA: Z1 = wetland overlap with artificial inland water body, Z2 = majority wetland artificial, Z3 = percentage natural land cover <25%).

3.14 Water Quality link to Nodes and EWRs

In preparation for the scenario analyses, water quality monitoring points and flow gauging stations associated with the IUAs and nodes were identified (Table 3.141, Table 3.142). They will be used to examine the relationships between key water quality constituents and flow during the next phases of the study, namely Ecological Base Configuration Scenarios, and Evaluation of Classification Scenarios, to determine the water quality consequences of different flow and development scenarios.

Table 3.141 Water quality sampling points associated with nodes in the Breede Overberg WMA

WQ point is the registered number in WMS and n is the number of samples in the water quality data record.

IUA	NODE	QUAT	WQ Point	Registered DWS Monitoring Point Name	Type	n	Flow gauge
A1	Niv2	H10C	1000009594	CMNT-Ceres-DW800A1-After Runoff from Cfp Irri Area on Mazoe	Rivers	140	n/a
	Niv1	H10C	102024	Koekedou River at Ceres/Persephone (NCWQ)	Rivers	527	H1H013

IUA	NODE	QUAT	WQ Point	Registered DWS Monitoring Point Name	Type	n	Flow gauge
	Niv3	H10C	1000009677	CMNT-Ceres-TR800A-Low Water Bridge on Lorraine Farm	Rivers	73	n/a
	Niv4	H10D					
	Nvi3	H10D	102020	Bree River at Ceres Commonage/Witbrug (NCWQ)	Rivers	1242	H1H006
	Nvii16	H10E	102021	Wit River at Drosterskloof (NCWQ)	Rivers	1275	H1H007
	Niv5	H10F	102021	Wit River at Drosterskloof (NCWQ)	Rivers	1275	H1H007
	Niv6	H10F					
	Nviii1	H10F					
	Niv40	H10J	102028	At Hawequas Forest Reserve on Elandsrivier	Rivers	699	H1H017
	Niv41	H10J					
	Nvii2	H10J	102029	Molenaars River at Hawequas Forest Reserve (NCWQ)	Rivers	1336	H1H018
A2	Niv7	H10G					
	Niii1	H10G					
	Niv42	H10J					
	Niv8	H10H					
	Nvii6	H10H	102031	At Brandwachtsberg on Hartbeesrivier	Rivers	32	H1H020
	Niv9	H10H					
	Niv12	H10K	102023	Holsloot River at Daschbosch Rivier (NCWQ)	Rivers	329	H1H012
	Nv3	H10L					
	Nvii7	H20G	102043	Hex River at Glen Heatlie (NCWQ)	Rivers	1211	H2H006
	Niv10	H20H	102047	Hex River at Worcester/Drie Riviere (Bridge) (ncwq NCMP)	Rivers	1152	H2H010
	Nii1	H40C	102070	Bree River at Onder Brandvlei/le Chasseur	Rivers	702	H4H006
	Nvii5	H40B	102072	Koo River at Dwars in Die Weg	Rivers	171	H4H008
	Niv11	H40C	102084	Nuy River at Doornrivier (ncwq NCMP)	Rivers	1075	H4H020
	Niv20	H30C					
	Nvii9	H30D					
	Niv18	H30B					
A3	Niv13	H40D					
	Nvii8	H40F	102081	Bree River at la Chasseur (ncwq NCMP)	Rivers	1323	H4H017
	Nvii11	H40G	102082	Poesnels River at la Chasseur (NCWQ)	Rivers	1385	H4H018
	Niv15	H40H	102083	Vink River at de Goree (NCWQ)	Rivers	1332	H4H019
	Nviii2	H40J					
	Nvii19	H40J					
	Niv14	H40K	102075	Keisers River at Uitnood	Rivers	281	H4H011
	Nii2	H30E	102063	Kogmanskloof River at Goudmyn (ncwq NCMP)	Rivers	1302	H3H011
	Ni2	H50B	102099	Bree River at Wagenboomsheuvel/Drew (ncwq NCMP)	Rivers	1398	H5H005
	Nv2	H70B	102119	At Swellendam on Bree River (ncwq NCMP GEMS)	Rivers	989	H7H006
B4	Nvii10	H60B	102105	Du Toits River at Purgatory Outspan	Rivers	375	H6H007
	Nv7	H60D	102110	Riviersonderend at Dwarstrek (NCWQ)	Rivers	641	H6H012
	Niv28	H60E	102103	At Genadendal Mission Station on Baviaansrivier (NCWQ)	Rivers	528	H6H005
	Niv29	H60E					
	Niv30	H60F					
	Nv9	H60F	102110	Riviersonderend at Dwarstrek (NCWQ)	Rivers	641	H6H012

IUA	NODE	QUAT	WQ Point	Registered DWS Monitoring Point Name	Type	n	Flow gauge
B5	Piii1	G40C	102010	Klein Wessels Gat 287 - Eikenhof Dam on Palmiet Rivier: near Dam Wall (NCWQ) Q01	Dam / Barrage	302	G4R002
	Piv10	G40C					
	Piv9	G40C	102010	Klein Wessels Gat 287 - Eikenhof Dam on Palmiet Rivier: near Dam Wall (NCWQ) Q01	Dam / Barrage	302	G4R002
	Piv8	G40C	188128	Kleine Wesselsgat 287 Grabouw at Worcester Street Bridge on Klipdrif Rivier (nmmp)	Rivers	511	n/a
	Piv4	G40D	102014	Farm 792 - Kogelberg Dam on Palmiet Rivier: near Dam Wall Q01	Dam / Barrage	50	G4R006
	Piv7	G40D					
	Piii2	G40D	101998	Palmiet River at Farm 562-Welgemoed/Kleinmond (ncwq NCMP)	Rivers	1325	G4H007
	Piv12	G40D	101998	Palmiet River at Farm 562-Welgemoed/Kleinmond (ncwq NCMP)	Rivers	1325	G4H007
	Piii3	G40D	101998	Palmiet River at Farm 562-Welgemoed/Kleinmond (ncwq NCMP)	Rivers	1325	G4H007
F09	Niv31	H60G					
	Niv33	H60H					
	Niv34	H60H					
	Nv10	H60H	102107	Riviersonderend at Reenen (ncwq NCMP)	Rivers	1041	H6H009
	Niv35	H60K					
	Ni3	H60L	102107	Riviersonderend at Reenen (ncwq NCMP)	Rivers	1041	H6H009
F10	Niv43	G40F	1000011043	CMNT-Bot+palmiet-SW400A-Swart River at Low Water Bridge	Rivers	96	n/a
	Niv45	G40K					
	Nii4	G40J					
	Nv23	G40K	101997	Klein River at Can Q5-8/Wagenboomsdrift (ncwq NCMP)	Rivers	427	G4H006
	Nii6	G50H					
	Nii7	G50H	102018	Sout River at Farm 74 de Hoop Nature Reserve (ncwq NCMP) Q01	Wetland	266	G5R001
F11	Niv24	H70A					
	Nii3	H70D	102117	Huis River at Barrydale (NCWQ)	Rivers	502	H7H004
	Niv25	H70F	102121	Buffeljags Dam on Buffeljags Rivier D/S Weir (NCWQ)	Rivers	222	H7H013
	Niii4	H70G					
	Niv26	H70J					
H16	Niii5	G40G	102002	At Roode Heuvel on Botrivier (NCWQ)	Rivers	837	G4H014
	Nx6	G40H					
H17	Nx8	G40M					
	Ni4	G50B					
	Nvii15	G50C					
	Niv44	G50C					
	Nv24	G50E	102015	At Nagt Wagt on Kars River	Rivers	16	G5H005
	Nii5	G50C	102015	At Nagt Wagt on Kars River	Rivers	16	G5H005

Where Cmnt = catchment; NCWQ = National Chemical Water Quality Network; NCMP = National Chemical Monitoring Programme; GEMS = Global Environment Monitoring System; NMMP = National Microbial Monitoring Programme

Table 3.142 Water quality sampling points associated with nodes in the Gouritz WMA

WQ point is the registered number in WMS and n is the number of samples in the water quality data record.

IUA	Node	QUAT	WQ	Registered DWS Monitoring Point Name	Type	n	Flow gauge
C6	giv25	K10D	102206	At Brandwacht on Brandwag River (ncwq NCMP)	Rivers	614	K1H004
	gv39	K10F	102240	Klipheuwel Dam: near Dam Wall (NCWQ) Q01	Dam / Barrage	232	K1R002
	gvii7	K20A	102241	At Wolwedans on Groot-Brak River (ncwq NCMP)	Rivers	990	K2H002
	gviii2	K20A					
	gviii3	K20A					
	gviii12	K20A					
D7	giv20	J25A	102168	Gamka River at Huisrivier (ncwq NCMP)	Rivers	778	J2H010
	gii2	J25E					
	giii2	J31C					
	giv15	J32E	102181	Olifants River at Pardekloof/Barandas/Kromlaagte	Rivers	139	J3H004
	gv33	J33B	102190	Wynands River at Koetzers Kraal (NCWQ)	Rivers	415	J3H018
	gv21	J33E	102184	At de Rust on Grootrivier (ncwq)	Rivers	395	J3H012
	giv11	J33F	190529	Onverwacht 143 Directly After Oudtshoorn WWTW Discharge Point on Olifants (NMMP)	Rivers	111	n/a
	gv36	J34D					
	giv10	J34F					
	gv19	J35E					
	giv17	J35F	102183	Olifants River at Warm Water (ncwq NCMP)	Rivers	1094	J3H011
	gi4	J40B	102201	Gouritz River at Zeekoedrift/Die Poort (ncwq NCMP GEMS)	Rivers	656	J4H002
E8	gv4	J11J	102140	Buffels River at Slang Gat	Rivers	11	J1H011
	giv32	J11K	102141	At Baviaans Krans on Grootrivier	Rivers	188	J1H012
	giv28	J12D					
	giv27	J12H					
	giv26	J12K					
	gviii1	J12L					
	gv5	J12M	102147	Touws River at Okkerskraal (ncwq NCMP)	Rivers	244	J1H018
	gv7	J13B	102148	At Buffelsfontein van Wyksdorp on Groot River (ncwq NCMP)	Rivers	762	J1H019
	gii3	J13C	102201	Gouritz River at Zeekoedrift/Die Poort (ncwq NCMP GEMS)	Rivers	656	J4H002
F12	giii5	H80B	102124	Duiwenhoks River at Broken Hill	Rivers	336	H8H002
	giii8	H80D	102123	Duiwenhoks River at Dassies Klip (ncwq NCMP)	Rivers	946	H8H001
	giii6	H90C	102127	At the Camp on Vetrivier (NCWQ)	Rivers	344	H9H002
	giii7	H90C	102130	At Farm 216 Swq 4A-11 on Goukou River (ncwq NCMP)	Rivers	557	H9H005
F13	gv9	J40E					
G14	giv34	J11C					
	gv25	J11F	102152	Floriskraal Dam on Buffels River: downstream Weir (ncwq NCMP)	Rivers	339	J1H028
	giv3	J21D					
	giv1	J22F					
	giv2	J22K	102178	Baviaans Kloof 136 - Ou Kloof Dam on Cordiers River: near Dam Wall (NCWQ) Q01	Dam / Barrage	332	J2R003
	gv17	J23F					

IUA	Node	QUAT	WQ	Registered DWS Monitoring Point Name	Type	n	Flow gauge
	gv27	J23J	102180	Dwuka River 199 - Gamkapoort Dam on Gamka Rivier: near Dam Wall (NCWQ) Q01	Dam / Barrage	395	J2R006
	gv14	J24E	102180	Dwuka River 199 - Gamkapoort Dam on Gamka Rivier: near Dam Wall (NCWQ) Q01	Dam / Barrage	395	J2R006
G15	gviii4	K30A					
	gvii8	K30A	102250	Maalgate River at Knoetze Kama/Buffelsdrift (ncwq NCMP)	Rivers	559	K3H003
	gvii9	K30B	102251	Malgas River at Blanco (NCWQ)	Rivers	584	K3H004
	gviii6	K30B					
	gviii7	K30C	102257	George - Garden Route Dam on Swartrivier: near Dam Wall (NCWQ) Q01	Dam / Barrage	330	K3R002
	gvii11	K30C	102248	Kaaimans River at Upper Barbiers Kraal (ncwq NCMP)	Rivers	601	K3H001
	gviii8	K30C					
	gvii12	K30D	102252	Touws River at Farm 162/Geo.F.12-8 (NCWQ)	Rivers	581	K3H005
	gx8	K30D	102255	Duiwe River at Klein Krantz (NCWQ)	Rivers	258	K3H011
	giii10	K40A	102277	Diep River at Woodville Forest Reserve (NCWQ)	Rivers	532	K4H003
	giii13	K40B	102275	Hoekraal River at Eastbrook (ncwq NCMP)	Rivers	574	K4H001
	gvii13	K40C	102276	Karatara River at Karatara Forest Reserve (NCWQ)	Rivers	780	K4H002
	giii11	K40C	190524	Eastbrook 183 at Road Bridge on Karatara Rivier (NMMP)	Rivers	86	n/a
	gviii9	K40E	102278	At Buffels Vermaak Goukamma on Goukamma	Rivers	23	K4H004
	gvii14	K50A	102293	Knysna River at Millwood Forest Reserve/Laer Streepbos (ncwq NCMP)	Rivers	594	K5H002
	giii12	K50A					
	gviii11	K50B	102292	at Gouna Commonage Concordia Plantation on Gouna River	Rivers	207	K5H001
	giv6	K60C	102296	At Newlands on Keurbooms Rivier (NCWQ)	Rivers	328	K6H002
	giv5	K60D	102296	At Newlands on Keurbooms Rivier (NCWQ)	Rivers	328	K6H002
	gx9	K60E	102312	Bloukrans River at Lottering Forest Res/Blaauwkrans (ncwq NCMP)	Rivers	842	K7H001
	giv4	K60F	102304	At Hangklip Old Bridge on Bietourivier	Rivers	21	K6H012
	gviii10	K60G					
	gx3	K60G					
	gx4	K70A					
	gx5	K70A					
	gvii15	K70B	102312	Bloukrans River at Lottering Forest Res/Blaauwkrans (ncwq NCMP)	Rivers	842	K7H001
I18	gv41	H90E					

Where Cmnt = catchment; NCWQ = National Chemical Water Quality Network; NCMP = National Chemical Monitoring Programme; GEMS = Global Environment Monitoring System; NMMP = National Microbial Monitoring Programme

4 GROUNDWATER BALANCE AND PRESENT STATUS

4.1 Groundwater's Role in Classification

Groundwater's role in classification studies, and in the associated Reserve and RQO studies, and the resulting methodology, has varied over time (Parsons, 1995; Parsons and Wentzel, 2007; Dennis et al., 2013) and varies between the studies that have been completed to date. The following points summarise the theory underlying the approach applied here to the water resources classification system for groundwater:

- **There is no separate water resource class for groundwater** (a departure from the early guidelines of Parsons (1995), applied by Conrad et al. (1999), and earlier studies such as Classification in the Olifants-Doorn, DWA (2012a) and DWA (2012b)). The primary emphasis of a water resource class is protection of water resources. A water resource class is established for an IUA (only), based on the percentage of biophysical nodes within that IUA that fall into a particular EC (Dollar et al, 2006). Groundwater has a role in supporting this water resource class through its contribution to baseflow, and hence towards part of the EWRs, and hence the EC. As such, a ***separate*** water resource class for groundwater ***is not gazetted*** from this study. This approach is in alignment with DWA (2013), in which it was deemed that gazetting a class would limit groundwater development, and with Riemann (2013).
- **The present status is established for groundwater** largely related to the alteration of the groundwater system from natural state. Various indicators can be used to inform the present status, but it is predominantly linked to the level of use (Dennis et al, 2013), which can be assumed to influence current groundwater contribution to baseflow, and hence to river flow at particular nodes, and hence to the PES.
- **A recommended category can be established for groundwater, however this is related to the recommended EC and hence water resource class.** Via analysis of development driven scenarios, a groundwater yield required for abstraction may be specified. This in turn has implications for groundwater contribution to baseflow, and hence to the ability to meet various EWRs, and hence to the EC and resulting water resource class.
- **An established water resource class dictates the REC, and hence dictates the REC for Groundwater.** Via analysis of conservation driven scenarios, a water resource class may be established based on a required EC, which has EWRs. This in turn dictates the amount of groundwater contribution to baseflow required to be maintained in the river, and hence the groundwater use that is permissible under the water resource class.

Although the above theory may well be widely accepted, the simplifying assumptions required to implement the theory, and the associated scale, data availability and modelling challenges, mean that methods still vary greatly between studies. The method applied also varies between studies naturally based on the location of the study. In some cases, only a present status is calculated (based on use / recharge), and the link between the water resource class and groundwater availability is not considered, hence groundwater availability not specifically calculated (DWA, 2015). This may be an acceptable simplification in areas where groundwater-surface water interaction is minimal, and as such the impact of groundwater's use (and changing abstraction rates) on ecology (and meeting the EWR) is minimal, greatly simplifying the connection between groundwater use and the resulting water resource class.

In other cases, groundwater is recognised as playing an important role in maintaining low flows, and as such, it is assumed that the groundwater contribution to baseflow should be maintained (when setting the Reserve &/ RQOs), in order to ensure groundwater's role to meeting the EWR is met (DWA, 2013). This is also a simplification to some degree, as the low flow may be met in part by interflow (or even return flows from WWTW in altered systems), and EWR may be less than groundwater contribution to baseflow. As such, there may not be the need to maintain all of groundwater's contribution to baseflow (Riemann, 2013).

Also, the above theoretical connection aside, whether the recommended category for groundwater is determined in addition to the REC, per water resource class, and whether the recommended category for groundwater is gazetted along with the water resource class, is often questioned. DWA (2013) did not establish RECs for groundwater, based on the motivation that "there is no guideline and current recommendations are not aimed at maintaining the ecological requirements in the receiving surface water bodies" (DWA 2013, op cit. pg35/206). DWA (2013) therefore consider the primary role of the water resource class to be protection of water resources, and groundwater's primary role in that is maintaining low flows. As such, RQOs are linked directly to maintaining groundwater contribution to baseflow, without specification of a related REC (the related groundwater availability or use / recharge).

The Breede-Gouritz WMA includes areas where groundwater contribution to baseflow makes up a significant portion of runoff (on average 14%, and up to 40% using GRAII data (DWAF 2006), and up to 90% using data the WR2000 Pitman model with Sami GW utility, (i.e. the hydrology model updated and used within this study). It also includes areas where further surface water availability is limited and groundwater development is proposed as a means to meet future demand, and as such any measures that inappropriately limit groundwater availability are to be avoided.

Therefore, in this study, attempts were made to fully accommodate groundwater's potential role in classification, thus requiring that in addition to determination of the PS, the relationship between groundwater status (associated to groundwater use), and groundwater contribution to baseflow be established, in order that a water resource class can be related to the reference condition for groundwater (and hence groundwater use and availability). A groundwater balance model is developed, in which the relationship between availability and groundwater contribution to baseflow is established (albeit highly simplified) and data from which is used to inform the present status. Where various limitations (scale, and associated data) have prevented fully accommodating groundwater's theoretical role in classification, at least the intended analysis is described, along with the necessary simplifications applied.

4.2 Groundwater Balance Approaches and the Capture Principle

In all (known) WRCS studies (Reserve Determinations, Classification, RQOs) the present status has generally been defined in terms of groundwater stress: the level of groundwater use (within a quaternary catchment, see section 4.4.3, compared to recharge within the same area (Dennis et al., 2013). The underlying assumptions in this calculation are:

i) that recharge is comparable to or an indicator of groundwater availability, and
ii) that the proportion of this recharge/ availability being used, is a direct indicator of the acceptability of groundwater use (at least at regional scale).

These underlying assumptions are in line with those of groundwater balance approaches, in which groundwater availability is set to some portion of recharge. The basis for the water balance approach (recently discussed in Seyler et al. (2016) and summarised here), is that an aquifer, as a contained unit, is in a natural balance over the long term or in steady state: recharge enters the aquifer, and water leaves the aquifer via discharge. Applying thinking consistent with the Law of Conservation of Matter, it is seemingly logical to think then that if an aquifer is pumped more than it is recharged, it will one day run out of water (Delvin and Sophocleous, 2005). Water budget (or balance) type approaches therefore generally compare groundwater use against recharge, and sometimes include the groundwater contribution to baseflow, or to the (ecological) Reserve (Dennis et al., 2013). There is an assumption in the approach that abstraction should not exceed the recharge rate if it is to be considered sustainable. Aquifers with high use compared to recharge are generally identified as “stressed” or “over-utilised”.

This abstraction/recharge approach to groundwater availability can be useful for broad scale resource planning. For potentially under-utilized aquifers it could provide a rapid indication of an aquifer with very low use compared to recharge, suggesting further groundwater development may be feasible. However Seyler et al. (2016) provide examples in which the results of this approach have limited groundwater development in cases where there is high groundwater use compared to recharge, and perhaps incorrectly so as various authors have shown a number of ways in which water balance type calculations are incorrect, inaccurate and are an inappropriate approach for groundwater management. Application of the water balance approach implicitly means application of the assumption that the recharge rate does not change from the original or natural rate, due to pumping (Delvin and Sophocleous, 2005). This assumption is false as there are a number of mechanisms, each widely accepted and dictated by fundamental groundwater flow theory, by which pumping can affect recharge.

Application of the water balance approach also implicitly means application of the assumption that the change in discharge from original or natural under a pumped regime is equal to the pumped yield (related to equation 1, and Delvin and Sophocleous, 2005). Given that the recharge does not remain constant under pumping, the pumped yield cannot only be equated to the change in discharge. The water balance approach also implicitly assumes that the aquifer is a closed system or a fixed directional flow system in which water only enters through prescribed pathways and only leaves through different prescribed pathways. Aquifers may behave as fixed directional systems under some conditions, but they can change when those conditions change, and saline intrusion is an example of this. The water balance approach also considers only the long term or steady state of an aquifer and does not consider the dynamic nature of aquifer behaviour, and does not allow for the use or management of water stored in the aquifer. It is essentially equivalent to managing a surface water dam at a constant storage/water level only.

A theoretically accurate and appropriate to the assessment of groundwater availability is the Capture Principle Approach, recently discussed in Seyler et al (2016) and summarised here. Under natural conditions an aquifer is in a state of dynamic equilibrium: wet and dry years balance out, aquifer discharge equals recharge, and the groundwater levels (equivalent to the stored volume) are constant over the long-term. When an aquifer is pumped this equilibrium is disturbed, and “water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes” (Theis,1940).

On pumping, water levels will therefore decline, natural discharge may decline, and recharge may increase. Over time (and with the same rate of pumping), a new dynamic equilibrium will be reached in response to the changed fluxes (i.e. new discharge mechanisms to abstraction, reduced discharge and or enhanced recharge). Once the new dynamic equilibrium is reached, there is no further loss from storage i.e. groundwater levels no longer decline in response to abstraction. The initial, and the final, reduction in discharge is therefore not directly proportional to the abstracted yield.

The time taken to reach this new dynamic equilibrium (the “response time”) can vary from relatively short to hundreds of years, depending on the aquifer parameters (hydraulic diffusivity) and the distance between abstraction and hydraulic boundaries (rivers, streams, faults) (Sophocleous 2000; Bredehoeft and Durbin, 2009). The magnitude of storage depletion (water level change before new equilibrium is met), is also dependent on the aquifer parameters and location of abstraction.

If the abstraction can be met by changes in the aquifer fluxes (reduced discharge, enhanced recharge) and a new equilibrium can be established (halting water level decline), then the abstraction can be considered maintainable (note, not sustainable) (Delvin and Sophocleous, 2005; Seyler et al., 2016). The maintainable yield therefore depends on the abstraction location within the aquifer, and one value for an aquifer is inappropriate: one value for a combination of wellfields in optimal locations best describes aquifer maintainable yield. Water balance approaches by comparison provide one value for the area assessed.

If "sustainable groundwater use" is defined as groundwater use that is socially, environmentally (ecologically), and economically acceptable, then abstraction of a maintainable yield is not necessarily sustainable. A critical step from quantification of a maintainable aquifer yield to quantification of sustainable groundwater use, is to determine the volume contribution from each source under the new dynamic equilibrium (projected reduced discharge, enhanced recharge, impact on storage / groundwater levels), and then take a socio-economic-environmental decision as to whether this is acceptable (Sophocleous, 2000; Alley and Leake, 2004; Seyler et al., 2016).

Not all abstraction can be maintained. Abstraction from groundwater without an active flow regime (fossil groundwater) simply harvests stored groundwater and groundwater levels continue to fall. "Runaway" drawdown, in which the rate of decline of groundwater level increases over time, is an indication that the abstraction rate cannot be met by changes in the aquifer fluxes (it is not maintainable).

The groundwater theory outlined above dictates that groundwater use/ abstraction will reduce discharge, at some time (dependent on distance and hydraulic diffusivity), but not necessarily by an amount directionally proportional to use. Groundwater use is hence connected to ecological integrity in surface waters (where aquifers discharge to surface water). As the groundwater present status or recommended category is generally defined based on groundwater use, it is related to groundwater contribution to baseflow, and as such, impacts the surface flow and hence relates to the ecological category and hence water resource class. Projection of the impact of pumping on storage / water levels can be completed (for simple situations) with analytical models that derive a characteristic water level decline over time when pumped ("pump curves", Kruseman and de Ridder, 1991). Determination of the impact of groundwater use on natural discharge or enhanced recharge generally requires a numerical model to be setup for the aquifer in question to simulate the abstraction and impacts on flow regime.

Recommendations have been made for DWS to manage all major aquifers / regions with numerical groundwater models such that this relationship between abstraction and reduced discharge can be quantified (DWAF, 2008, Seyler et al., 2016). Calibration of numerical model (or models) for the Breede-Gouritz area is technically possible, using existing data, information and understanding, and some large regional models exist for part of the area already (such as the Breede Valley Alluvial Aquifer, (DWAF, 2008), and the greater Outdshoorn area, (Wilmot, 2008 and DWS, 2015)). However, it was not possible to accommodate new model development within the groundwater portion of the budget available on this project. As such, with acknowledgement of the inaccuracies and limitations of the water balance approach, a water balance model is established to support the groundwater assessments required for the WRCS, with full description of the implicit assumptions, limitations, and inaccuracies. Adjustments to the water balance to account for lateral recharge (across boundaries used in the water balance), and indirect recharge (where indirect recharge significantly impacts availability) will be carried out in priority areas.

4.3 Groundwater Balance Model

4.3.1 Groundwater Balance Equations

The groundwater balance approach is underpinned by the hypothesis that recharge is equivalent to groundwater availability, and that if availability is reduced (recharge is used) by an amount up to GWBF, then discharge will continue and surface water is not affected. This can be illustrated by the following equations, typically applied in desktop scale groundwater availability assessments and Reserve determinations (specifically equation 3):

Total Groundwater Availability = recharge **(equation 1)**

Groundwater availability (whilst "maintaining" groundwater's contribution to the ecological integrity of surface water, and maintaining ecological integrity in its natural state)

= recharge – natural GWBF **(equation 2)**

Remaining Groundwater availability (whilst "maintaining" groundwater's contribution to the ecological integrity of surface water, and maintaining ecological integrity in its present state)

= recharge – current use – current GWBF **(equation 3)**

The following assumptions underlie these equations:

- The aquifer has reached dynamic equilibrium in response to abstraction, where groundwater recharge is equivalent to discharge. As such, contribution to groundwater availability from storage are not considered.
- Contribution from enhanced recharge is not accommodated (i.e. recharge is constant under abstraction).
- Abstraction is therefore met by reduced discharge (at some time). As discharge is equivalent to recharge (when at dynamic equilibrium), recharge can be used as a proxy for groundwater availability.
- The aquifer is a closed system or a fixed directional flow system.
- If the portion of discharge that is known to support surface water (GWBF) is removed from the availability equation, it is not impacted. I.e., if abstraction is at or set below recharge minus use minus GWBF, then the quantity of GWBF will not be affected.
- Abstraction occurs sufficiently distant from locations of groundwater discharge to surface water, such that abstraction can harness recharge minus use minus GWBF, before reducing GWBF. Said in other words, it is assumed that abstraction is sufficiently distant from surface water such that the portion of recharge discharging to surface waters, is unaffected by the abstraction.

*For the remainder of this section **remaining groundwater availability** implies "maintaining" groundwater's contribution to the ecological integrity of surface waters.* The assumption that abstraction occurs sufficiently distant from locations of groundwater discharge to surface water is a significant one, and if not met, equation 3 would **overestimate** remaining groundwater availability. It is not possible to overcome this potential overestimate within a water balance approach, which provides one result for the area over which the equation is applied, independent of abstraction location. The results generated with this approach therefore come with the proviso that the resulting groundwater abstraction is a potential yield if abstraction is optimally located and far enough from the river (the exact distance is aquifer specific).

The assumption of dynamic equilibrium in response to pumping is also a significant assumption. If the aquifer response time (related to hydraulic diffusivity and distance to discharge point is so great that reduction in discharge will not be recognised within a realistic planning timeframe (or 100s years), then "maintaining" GWBF may not be necessary. This is potentially the case in large parts of the Karoo in the Gouritz area, where diffusivity is low and surface water discharge points are more distant. In this case, equation 3 **underestimates** groundwater availability, and groundwater availability could be set simply to recharge minus use (Table 4.1). This is also appropriate in areas where the relative contribution from groundwater to flow is negligible such that maintaining GWBF has insignificant contribution to meeting EWR. The dependence of surface water on groundwater contribution and degree to which the GWBF can meet EWR, was assessed through comparison of GWBF to EWR and MAR (Table 4.8). The analysis also shows that where GWBF is a low portion of EWR (<11%), GWBF/MAR is also very low (generally <1%), indicative of low surface water – groundwater interactions, low dependence of the surface water system, and hence surface water ecology, on GWBF. Hence where the criteria of GWBF/MAR ≤1% (in the final quaternary scale dataset) was met, the equation recharge minus use was applied (Table 4.1).

Where the response time is short, and groundwater abstraction does within the planning horizon reduce discharge to surface water, then a decision is required as to how much (what %) of recharge (equivalent to natural discharge) is considered available. Equation 3 assumes that it is unacceptable to reduce groundwater contribution to baseflow at all. However, if GWBF encompasses all discharge to surface water in a defined area, then recharge minus use, minus GWBF (equation 3), simply equates to unquantified discharge. This discharge may include oceanic discharge, evapotranspiration where water tables are near surface, or lateral recharge to other aquifers beyond the area of assessment (where it may then support groundwater contribution to baseflow in other areas). These other forms of discharge are not necessarily any more or less available to use than GWBF – depending on the acceptability of reducing the natural discharge. Nevertheless, if groundwater's primary role in classification is to support / ensure its portion of EWR for a specified EC is maintained, then where EWR is less than GWBF, GWBF in equation 3 is better replaced by EWR to avoid underestimation of groundwater availability (Table 4.1).

Table 4.1 Various surface water – groundwater interaction conditions in the WMA, and the corresponding applied groundwater balance equations

Conditions in order of hierarchy	Groundwater balance equation	Comments / motivation	Applicability
Quaternary catchments with GW-fed wetlands ***Quaternary catchments with estuaries***	*Balance = Recharge – use - GWBF*	*Maintain all of GWBF to protect areas where quantitative EWRs are not always established*	*166/210 quaternary's (79%).*
Where ERW > GWBF ***(or GWBF/MAR>1%)***	*Balance = Recharge – use - GWBF*	*Maintain GWBF to protect groundwater's role in meeting EWRs*	
Where EWR < GWBF	*Balance = Recharge – use – EWR*	*If EWR < GWBF do not necessarily need to maintain all of GWBF to protect groundwater's role in meeting a specific EC* *Avoids inappropriately limiting groundwater availability*	*2/210 quaternary's (1%).*
Where GWBF/MAR<1%	*Balance = Recharge – use*	*Limited SW-GW interactions* *Very long response time* *GWBF plays insignificant role in meeting EWRs, do not necessarily have to maintain GWBF.*	*42/210 quaternary's (20%).* *35 of these have zero baseflow*

Equation 3 would **underestimate** groundwater availability if:

- Only direct recharge is considered under "recharge", and direct recharge is not the only source of recharge (i.e. indirect natural recharge from surface water losses, or lateral recharge from a unit beyond the boundary considered in the water balance calculation)
- Recharge is enhanced under abstraction (enhanced recharge may increase groundwater availability, and whether the available groundwater yield is considered 'sustainable' depends on an assessment of the acceptability of the impact of abstraction, including the induced recharge, Seyler et al. 2016)

It is not possible to overcome the potential underestimate of neglecting enhanced recharge within a water balance approach, as the hydraulic response to abstraction, and hydraulic connection to surface water, is not considered. It is not possible to account for indirect recharge (losses from surface water) without significant effort to analyse gauge data and model surface water use and evaporation on a small scale in the area of interest. Lateral recharge from a unit beyond the boundary considered in the water balance calculation is related to the spatial scale of the assessment.

4.3.2 Impacts of Spatial and Temporal Scale on data and approach

An assessment of groundwater availability or assessment of impact of groundwater use on discharge (and hence relationship to EWR), whether based on water balance equations or numerical modelling, is appropriately conducted over an area defined by aquifer boundaries. It is this area for which the equations outlined in Section 4.3.1 and Table 4.1 apply, as recharge and discharge within these aquifer boundaries can be considered to balance (over the long-term, and if in dynamic equilibrium). The defined groundwater resource units (GRUs) attempt to follow hydraulic boundaries (aquifer boundaries, flow divides within an aquifer). However, DWS manages surface and groundwater resources based on surface water quaternary catchments, and there is a specific requirement for groundwater information for the study to be presented at quaternary catchment scale. A quaternary catchment often contains several aquifers, and the boundaries do not generally coincide with aquifer boundaries. An aquifer may therefore extend beyond the quaternary boundary the primary implication of which is that recharge within one quaternary flows laterally to another, and may discharge in yet another. This is especially true in areas with significant fractured and confined aquifers (Riemann, 2013), as is the case in the Breede-Gouritz study area.

Previous studies have attempted to overcome this disconnect between groundwater boundaries and the need to work at quaternary scale by disaggregating groundwater data (recharge, GWBF, use, remaining groundwater availability) to major aquifers within quaternary catchments (a relatively simple exercise based on outcrop area, DWAF, 2008). The results however is also not ideal. At least shallow groundwater in the quaternary catchment will largely mimic topography and within one quaternary shallow groundwater is likely to be in hydraulic connection between aquifers. For example shallow groundwater in the Table Mountain Group Aquifer in valley slopes will be in connection with the alluvial aquifer lower down the slopes. Reporting the two aquifer balance separately can be misleading when they are in connection and use of one aquifer is supported by lateral recharge in another aquifer within the same quaternary. For example, quaternary catchments H10G (BB-3, Breede River Alluvium), H10L (BB-5, Holsloot alluvial fan), H20B, H20E, (both in BB-2, Hex River valley alluvium), and H20G (in BB-5, Hex River alluvial fan) are reported as having negative groundwater availability for intergranular aquifers, yet the groundwater availability in the Peninsula &/ Nardouw aquifers is in positive balance, as is the net quaternary balance. It is likely that abstraction from the intergranular aquifers is being supported by lateral flow from the Table Mountain Group. This kind of hydraulic interaction is common across the Breede-Gouritz, and as such, disaggregation of information to per aquifer per quaternary is not seen as necessary.

In an attempt to meet the need to present data on a quaternary scale, yet address the key simplification of application of surface water boundaries (or at least minimise its impact on results), key major lateral flows across quaternary catchments were identified and taken into account in the establishment of GRU boundaries. As such, the groundwater balance information is presented per GRU and per quaternary catchment. Detailed information on lateral flows will be provided for prioritised resource units as part of RQO development (report 10).

In terms of temporal scale, data for current GWBF and current MAR were used in the groundwater balance, assuming that aquifers are in dynamic equilibrium in response to current groundwater use, to provide estimates of current remaining availability. EWR is however established based on nMAR, which may have been supported by higher GWBF, since reduced by groundwater use. Where maintaining EWR requires additional water, groundwater use may (theoretically) have to reduce, up to the difference between natural and current GWBF. The maximum that groundwater could support EWR is natural GWBF, and will be considered in scenario analysis.

4.4 Groundwater Balance and Contribution to Baseflow

4.4.1 Data selection

Various data including recharge, groundwater use, and groundwater contribution to baseflow were presented and described in the Status Quo report (DWS, 2016b), per GRU. Due to the numerous sources of data available, which are often widely conflicting, measures were taken to analyse the datasets and select the most appropriate data for the groundwater balance calculations.

4.4.2 Recharge

Recharge data was taken from the GRAII database (DWAF, 2006). The dataset provides several estimates of recharge, and the mean annual potential recharge was selected. A review of the recharge dataset is provided by DWA (2009), and although the review highlight uncertainties in the data, use of it is in line with other regional and national projects, and it underlies the national estimates of groundwater availability (DWA, 2010, DWS, 2016d).

4.4.3 Use

Registered groundwater use was acquired from the Water Authorisation Registration and Management System (WARMS) database, at project commencement (refer to Information and Data Gaps Report).

Significant manual effort was applied to correct erroneous coordinates in the WARMS dataset, through comparison of the registered address with cadastral data (referred to as WARMS 2016 in Table 4.2). The total sum of groundwater use per quaternary catchment however differs significantly from the estimated groundwater use in the GRAII data with a correlation (R^2) at quaternary catchment level of only 0.48.

In line with the approach of other similar studies (DWAF 2008, DWS 2015), preference was given to WARMS data for groundwater use. Where registered groundwater use is greater than actual use the groundwater balance results will be conservative. Some further adjustments to individual allocations were made based on observations with a second WARMS dataset and in consultation with GRAII database.

Table 4.2 Comparison of water use estimates for Breede-Gouritz WMA

Data Source	Sum (million m^3/a)	Maximum registration per quaternary catchment (million m^3/a)	Number of catchments with sum of abstraction as zero
WARMS (2016)	215.33	26.30	33
GRAII (DWAF, 2006)	173.57	28.07	68
Final groundwater use dataset used	194.86	20.06	33

4.4.4 Groundwater Contribution to Baseflow

Data for GWBF (along with total baseflow) is available to the study from the GRAII database (DWAF 2006), per quaternary catchment. Data for GWBF (along with total baseflow and interflow) is also a component of the WR2000 Pitman model with Sami GW utility, used in the surface water component of the study, available per quaternary catchment. A comparison of these two datasets (in terms of sum per quaternary catchment) reveals a lack of correlation (an R^2 of 0.02 for current GWBF, and 0.06 for natural GWBF).

In line with previous studies (DWAF 2008), a preference was placed on GRAII, for the following reasons:

- The GRAII data has greater internal consistency: in all cases GWBF is less than recharge, whereas the WR2000 Pitman data is greater than recharge in four quaternary catchments. Although this is not feasible impossible (recharge from a neighbouring quaternary may contribute to groundwater discharging to baseflow in a neighbouring quaternary where recharge is relatively low), these four catchments did not correspond with those in which significant lateral recharge / indirect recharge is considered likely.

- Quaternary catchments with a large difference between natural and current GWBF in the GRAII database correlate with those where groundwater use is high. The same is not true for data in the WR2012 Pitman model.

However, in a large number of catchments the GRAII baseflow is zero, especially in catchments of the Karoo region. Whilst in certain catchments (i.e. Karoo) this is acceptable, several quaternary catchments in wetter regions also have zero GWBF in the GRAII datasets, where recharge is higher, and where total baseflow is also non-zero. As such, for the final dataset:

- GRAII data was used in catchments where the estimate was non-zero;
- in catchments where GRAII GWBF is zero, yet based on the catchment setting (geology, recharge, total baseflow in GRAII and WR2012 Pitman) some GWBF was deemed likely, then GWBF was established by assigning the most reasonable out of:
  - the WR2012 Pitman GWBF data
  - calculating GWBF by the median portion of total baseflow from surrounding catchments

The sum of GWBF in the final dataset is therefore slightly higher than the GRAII data (Table 4.3), which represents a cautious approach to the groundwater balance.

Table 4.3 Statistics comparing various estimates of Groundwater Contribution to Baseflow per quaternary catchment

Parameter	GWBF (million m^3/a)		
	WR2012 Pitman + Sami	GRAII	Final used
Mean	0.55	1.94	1.97
Median	0.35	0.91	0.98
Max	4.16	14.45	14.45
Min	0.00	0.00	0.00
St dev	0.63	2.65	2.62
Count quaternary with zero	4	78	44
Sum (all quaternaries)	116.24	407.39	413.83

4.4.5 Groundwater Balance

The results of the groundwater balance are contained in Table 4.6 and Table 4.7. The results show that:

- 97 catchments (47%) have a groundwater balance in excess of 3 million m^3/a, reaching 51 million m^3/a in H10J.
- 93 catchments (44%) have a groundwater balance of 0 to 3 million m^3/a.
- 20 catchments (10%) have a negative groundwater balance, 18 of which are between 0 to -2 million m^3/a.
- No GRUs have negative groundwater balance based on the current estimated use.

The sum of remaining groundwater availability calculated at catchment scale is over 1000 million m^3/a. Instances of negative groundwater balance do not necessarily mean groundwater mining is occurring: but simply illustrate that *registered* use within the quaternary catchment, minus GWBF, is greater than recharge within the same catchment. There is great uncertainty in each parameter: registered use over-estimate actual use, recharge data used is potential direct recharge only and significant lateral or indirect recharge may occur, and the GRAII GWBF estimates are known to be of low confidence (DWA, 2009).

For example, the highest negative balance is calculated in H10L (BB-5, Rawsonville) where registered use is ~13.5 million m^3/a, GWBF is zero, and recharge is relatively low (2.33 million m^3/a). DWA (2008) also calculate a negative balance in H10L using similar data (lower WARMS use, which is acceptable given the ~10 years between WARMS databases used). Abstraction in H10L is known to be supported by lateral and indirect recharge from catchments to the south (H10J and H10K). High recharge in the Table Mountain Group (TMG) aquifers, where not entering deep flow systems, will laterally recharge alluvium where the two units are in contact (see maps in appendix B of Status Quo Report). High recharge in the TMG aquifers, where not entering deep flow systems, will also decant to the Holsloot and Molenaars rivers (in H10J and H10K), both of which will then lose water to/ indirectly recharge the alluvial fans as these rivers enter the valley in H10L (behaviour described in a numerical groundwater model DWAF, 2008). The quaternary catchments related to H10L via lateral recharge are incorporated in the same GRU (BB-3), and over which scale the groundwater balance is positive. This GRU scale will however fail to identify "hot spots" of high groundwater abstraction, where impacts may require management.

Negative balances occur in other catchments with high groundwater use and a similar hydrogeological setting to H10L (such as H20A, H20B, H20F, H20H, H10C), but also in areas where use is almost absent to moderate, but recharge is very low (i.e. the Karoo areas).

Where the datasets are at least regionally representative of the real situation, a negative groundwater balance still does not necessarily indicate unsustainable groundwater use, if sustainability is considered as groundwater use that is economically socially and environmentally acceptable. In these areas the groundwater use may not impact on meeting the EWR, especially if the GWBF is a very small portion of EWR, and if the surface water flow is sufficient to meet EWR (hence groundwater use can still be ecologically acceptable). However (acknowledging the assumptions and shortcomings of a water balance model), the negative balance may indicate groundwater mining (i.e. use of storage that will not be replenished). This also not necessarily a problem. The abstraction will not be maintainable in the very long term, but the response time may be so long that use of storage can occur for hundreds of years. Each case of negative groundwater balance requires further investigation, and comparison with groundwater level data. This investigation is recommended for prioritised GRUs, as part of establishing RQOs.

4.5 Present Status Assessment

The present status of groundwater is formally defined in relation to the alteration from pre-development condition. It is a function of groundwater use, and the impacts of that use (Dennis et al, 2013), as summarised in Table 4.4. However, current guidelines (Dennis et al, 2013) then link the present status directly and only to groundwater use as a portion of recharge, as per Table 4.5. Perhaps the reason for this is that use/recharge provides a readily applicable quantitative assessment, and the impacts of use listed in Table 4.4 are rarely quantifiable or represented in regional datasets. To attribute changes in river flow to groundwater use would require long term monitoring (pre abstraction, and current) in >3 piezometers close to a river, at regular distances in river reaches where groundwater is thought to discharge to surface. Alternatively it would require high confidence surface water modelling in which all other factors (runoff, return flow, surface water use, interflow) are well known such that the change in GWBF can be accurately determined. The stress categories in Table 4.5 can also be used as spatial compliance categories; i.e. of 20-65% of the quantified units (i.e. quaternary's) in an area (i.e. IUAs) are moderately used, then the groundwater present status for the IUA can be considered II moderately used (Dennis et al, 2013).

Limitations from definition of present status based on aquifer stress include:

- Aquifer stress (if defined as Use/Recharge) usually does not take into account groundwater's role in meeting the EWR (i.e. GWBF). An aquifer with significant contribution to the ecological Reserve (high GWBF/EWR) could be over-exploited with a low aquifer stress index, whilst the reverse is true for an aquifer that doesn't contribute significantly to GWBF and therefore EWR (Riemann 2013)
- As with most water balance approaches the calculation of aquifer stress uses mean annual recharge, and when used to make decisions on groundwater availability, could lead to over-

abstraction for aquifers in arid climates with episodic recharge, and under development of aquifers with high storage capacity and long response time (Riemann, 2013).

- Related to the challenges of water balance approaches (section 4.3.2), there is no spatial consideration: an abstraction close to a river, in an aquifer with low stress, could significantly impact the ability to meet groundwater's contribution to EWR. Likewise, a particular wellfield may be causing negative impacts locally (reduced discharge to a nearby spring), whereas the aquifer (or quaternary) as a whole may have minimal use
- There is an implicit assumption that a heavily used aquifer (high use/recharge based Table 4.5) has negative impacts (those listed in Table 4.4), and that alteration or impact is directly proportional to use/recharge. However, the volume abstracted does not directly relate to the same reduction in discharge (this depends on flow regime, distance to river, access to storage).
- To 'ground truth' the results from a stress index, and determine alteration from pre-development state would ideally require indicators for aquifer storage depletion, discharge depletion, and recharge enhancement (rarely available). Comparison with water level data alone will only indicate storage reduction, which is a certainty in response to pumping, hence is not necessarily an indication of "stress" or level of alteration.

Acknowledging the limitations, in line with other studies, (DWA, 2012b, DWS, 2015) and current guidelines, (Dennis et al, 2013), the Use/Recharge (stress) is calculated per quaternary catchment, and the present status assigned accordingly. For comparison, the stress and present status is also calculated per GRU.

Table 4.4 Definition of present Status (from Dennis et al, 2013)

Present Status	Generic Description	Affected Environment
Minimally used (I)	The water resource is minimally altered from its pre-development condition	No sign of significant impacts observed
Moderately used (II)	Localised low level impacts, but no negative effects apparent	Temporal, but not long-term significant impact to: -spring flow -river flow -vegetation -land subsidence -sinkhole formation -groundwater quality
Heavily used (III)	The water resource is significantly altered from its pre-development condition	Moderate to significant impacts to: -spring flow -river flow -vegetation -land subsidence -sinkhole formation -groundwater quality

Table 4.5 Recharge/Use as an Indicator for present Status (from Dennis *et al*, 2013)

Present Status	Description	Use/ Recharge (Stress)
I	Minimally used	≤20%
II	Moderately used	20-65%
III	Heavily used	>65%

The results of the present status assessment are contained in Table 4.6 and Figure 4.1 (catchment scale), and in Table 4.7 and Figure 4.2 (GRU scale). The results show:

- 149 catchments (71%) have a groundwater stress of <20%, and present status I
- 35 catchments (17%) have a groundwater stress of 20-65%, and present status II
- 26 catchments (12%) have a groundwater stress of >65%, and present status III

At the GRU scale, similarly 63% of GRUs (20/32) have a groundwater stress of <20%, and present status I. However the frequency of high stress / present status III is reduced due to consideration of larger areas reducing the impact of more localised high groundwater use areas. Only 1 GRU has a groundwater stress >65% and present status III (BB-1, Ceres region).Based on the limitations of a water balance approach, and the limitations of the Present Status definition, it is noted that high stress / present status of III does not necessarily equate to an area where abstraction is not maintainable, or has unacceptable impacts.

Table 4.6 Results of groundwater balance model at quaternary catchment scale showing groundwater balance, 'stress' and present Status

Quaternary	Recharge (million m^3/a)	Use (million m^3/a)	GWBF (million m^3/a)	Balance (million m^3/a)	Stress (Use/ Recharge)	Present Status
G40A	13.06	0.00	3.17	9.89	0%	I
G40B	19.19	0.00	5.33	13.85	0%	I
G40C	45.16	0.40	6.25	38.51	1%	I
G40D	59.72	0.53	14.45	44.74	1%	I
G40E	13.19	1.15	4.41	7.63	9%	I
G40F	11.28	2.72	2.12	6.44	24%	II
G40G	16.02	2.16	3.72	10.14	13%	I
G40H	6.53	3.43	1.58	1.53	52%	II
G40J	6.92	0.49	2.53	3.91	7%	I
G40K	9.13	0.19	4.67	4.27	2%	I
G40L	13.96	2.68	1.63	9.65	19%	I
G40M	10.57	2.23	5.17	3.17	21%	II
G50A	7.37	0.10	2.61	4.66	1%	I
G50B	6.59	1.24	3.47	1.89	19%	I
G50C	8.56	0.07	2.05	6.44	1%	I
G50D	5.39	0.13	2.55	3.16	2%	I
G50E	4.92	1.23	1.37	2.32	25%	II
G50F	6.64	0.41	1.27	4.96	6%	I
G50G	2.40	0.39	1.43	1.51	16%	I
G50H	5.75	0.00	3.28	2.47	0%	I
G50J	6.07	0.00	1.90	4.17	0%	I
G50K	2.72	0.00	0.76	1.95	0%	I
H10A	13.15	3.58	0.76	8.82	27%	II
H10B	12.20	8.86	0.48	2.86	73%	III
H10C	21.28	26.30	2.00	-7.03	124%	III
H10D	14.89	0.13	2.05	12.72	1%	I
H10E	20.35	0.00	3.20	17.15	0%	I
H10F	25.24	5.19	1.39	18.66	21%	II
H10G	31.82	9.22	0.44	22.15	29%	II
H10H	28.48	7.45	2.80	18.23	26%	II
H10J	61.45	2.40	7.94	51.12	4%	I
H10K	43.17	0.35	7.40	35.42	1%	I
H10L	2.76	13.56	0.00	-10.81	492%	III
H20A	2.42	2.72	0.47	-0.77	112%	III
H20B	5.37	6.87	0.17	-1.66	128%	III
H20C	2.84	1.63	0.05	1.16	57%	II

Quaternary	Recharge (million m^3/a)	Use (million m^3/a)	GWBF (million m^3/a)	Balance (million m^3/a)	Stress (Use/ Recharge)	Present Status
H20D	8.74	0.34	2.11	6.29	4%	I
H20E	14.68	2.09	2.01	10.58	14%	I
H20F	8.65	8.19	0.32	0.14	95%	III
H20G	4.83	1.56	0.47	2.80	32%	II
H20H	1.56	1.62	0.07	-0.14	104%	III
H30A	5.17	1.87	0.33	2.96	36%	II
H30B	6.04	5.06	0.16	0.82	84%	III
H30C	10.59	2.58	0.07	8.01	24%	II
H30D	3.18	2.07	0.06	1.05	65%	II
H30E	2.95	1.15	0.31	1.49	39%	II
H40A	3.74	0.12	0.87	2.75	3%	I
H40B	12.26	1.90	0.87	9.49	15%	I
H40C	4.90	2.34	0.86	1.70	48%	II
H40D	4.18	0.24	1.85	2.09	6%	I
H40E	10.91	1.34	0.20	9.37	12%	I
H40F	1.07	0.00	0.58	0.49	0%	I
H40G	3.22	1.76	0.23	1.23	55%	II
H40H	4.71	0.34	0.13	4.37	7%	I
H40J	4.44	1.37	0.18	2.88	31%	II
H40K	2.99	1.13	0.24	1.63	38%	II
H40L	2.47	0.09	0.42	1.97	4%	I
H50A	1.42	0.65	0.26	0.51	45%	II
H50B	5.04	0.83	0.78	3.43	17%	I
H60A	30.87	0.32	2.49	28.07	1%	I
H60B	42.43	0.63	7.28	34.52	1%	I
H60C	30.89	1.49	1.64	27.76	5%	I
H60D	14.76	0.00	0.95	13.82	0%	I
H60E	9.73	0.29	0.71	8.73	3%	I
H60F	7.65	0.00	0.66	6.98	0%	I
H60G	4.11	0.23	0.64	3.24	6%	I
H60H	7.49	0.44	1.14	5.91	6%	I
H60J	8.17	0.00	1.31	6.86	0%	I
H60K	3.59	0.17	1.04	2.38	5%	I
H60L	2.88	0.06	0.87	1.94	2%	I
H70A	5.55	0.00	1.47	4.08	0%	I
H70B	22.83	0.27	4.17	18.39	1%	I
H70C	3.99	1.97	0.23	1.79	49%	II
H70D	20.70	0.10	5.53	15.06	0%	I
H70E	26.55	0.06	5.16	21.33	0%	I
H70F	15.50	0.27	2.31	12.92	2%	I
H70G	3.92	0.00	1.26	2.66	0%	I
H70H	2.80	0.07	1.89	0.84	3%	I
H70J	3.95	0.00	1.43	2.52	0%	I
H70K	3.03	0.05	1.21	1.77	2%	I
H80A	16.34	0.17	7.21	8.96	1%	I
H80B	24.01	0.00	6.45	17.56	0%	I
H80C	5.75	0.78	0.61	4.35	14%	I
H80D	2.57	0.32	1.23	1.03	13%	I
H80E	7.66	0.02	2.11	5.53	0%	I
H80F	5.96	0.52	2.72	2.71	9%	I
H90A	19.62	0.12	9.04	10.45	1%	I
H90B	12.96	0.10	6.02	6.84	1%	I
H90C	5.51	1.14	1.93	2.44	21%	II

Quaternary	Recharge (million m^3/a)	Use (million m^3/a)	GWBF (million m^3/a)	Balance (million m^3/a)	Stress (Use/ Recharge)	Present Status
H90D	10.38	0.08	3.29	7.00	1%	I
H90E	9.70	4.47	4.88	0.35	46%	II
J11A	2.98	0.00	0.00	2.98	0%	I
J11B	3.11	0.09	0.00	3.02	3%	I
J11C	0.22	0.00	0.00	0.22	0%	I
J11D	3.74	0.15	0.00	3.59	4%	I
J11E	1.40	2.19	0.00	-0.79	156%	III
J11F	0.43	0.50	0.00	-0.08	118%	III
J11G	0.12	0.15	0.00	-0.03	126%	III
J11H	4.01	0.85	0.00	3.16	21%	II
J11J	6.02	1.67	0.00	4.35	28%	II
J11K	2.52	1.70	0.00	0.81	68%	III
J12A	3.15	0.01	0.02	3.14	0%	I
J12B	1.55	0.03	0.00	1.52	2%	I
J12C	1.59	1.99	0.01	-0.40	125%	III
J12D	6.32	2.22	0.02	4.07	35%	II
J12E	1.93	0.50	0.02	1.41	26%	II
J12F	6.15	0.42	0.03	5.70	7%	I
J12G	5.66	0.00	0.01	5.64	0%	I
J12H	4.53	0.38	0.02	4.12	8%	I
J12J	4.59	0.56	0.01	4.03	12%	I
J12K	2.44	0.00	0.01	2.43	0%	I
J12L	6.59	0.59	0.05	5.95	9%	I
J12M	3.04	0.38	0.06	2.60	12%	I
J13A	4.10	0.63	0.02	3.45	15%	I
J13B	2.86	0.38	0.03	2.45	13%	I
J13C	2.91	0.11	0.03	2.77	4%	I
J21A	4.28	5.15	0.00	-0.87	120%	III
J21B	0.56	0.97	0.00	-0.41	174%	III
J21C	0.12	0.20	0.00	-0.08	163%	III
J21D	0.24	0.17	0.00	0.07	70%	III
J21E	0.26	0.68	0.00	-0.42	264%	III
J22A	3.04	0.00	0.00	3.04	0%	I
J22B	1.12	0.00	0.00	1.12	0%	I
J22C	1.27	0.04	0.00	1.23	3%	I
J22D	1.22	0.02	0.00	1.20	2%	I
J22E	1.31	0.01	0.00	1.30	0%	I
J22F	0.12	0.06	0.00	0.05	53%	II
J22G	2.92	0.00	0.00	2.92	0%	I
J22H	4.19	0.01	0.00	4.17	0%	I
J22J	0.90	0.00	0.00	0.90	0%	I
J22K	0.35	0.00	0.00	0.35	0%	I
J23A	0.28	2.29	0.00	-2.01	820%	III
J23B	0.50	0.06	0.00	0.44	12%	I
J23C	0.25	0.14	0.00	0.11	57%	II
J23D	0.70	0.05	0.00	0.66	6%	I
J23E	2.03	1.15	0.18	0.71	56%	II
J23F	1.33	0.88	0.00	0.45	66%	III
J23G	0.00	0.00	0.00	0.00	0%	I
J23H	1.11	0.00	0.00	1.11	0%	I
J23J	1.82	0.17	0.97	0.68	10%	I
J24A	2.58	0.07	0.00	2.50	3%	I
J24B	0.51	0.28	0.00	0.23	55%	II

Quaternary	Recharge (million m^3/a)	Use (million m^3/a)	GWBF (million m^3/a)	Balance (million m^3/a)	Stress (Use/ Recharge)	Present Status
J24C	0.21	0.03	0.00	0.17	16%	I
J24D	0.08	0.15	0.00	-0.07	184%	III
J24E	0.39	0.58	0.00	-0.20	151%	III
J24F	1.37	0.05	0.00	1.32	4%	I
J25A	2.42	0.00	1.02	1.39	0%	I
J25B	4.45	0.50	1.23	2.72	11%	I
J25C	1.04	0.00	0.02	1.01	0%	I
J25D	2.94	0.01	0.61	2.32	0%	I
J25E	1.12	0.07	0.04	1.01	6%	I
J31A	7.88	0.23	1.13	6.52	3%	I
J31B	1.57	0.00	0.48	1.09	0%	I
J31C	1.87	0.16	0.35	1.35	9%	I
J31D	2.07	0.14	0.38	1.54	7%	I
J32A	0.08	0.41	0.00	-0.33	501%	III
J32B	0.01	0.12	0.00	-0.12	2434%	III
J32C	0.01	0.19	0.00	-0.17	1336%	III
J32D	0.00	0.00	0.00	0.00	0%	I
J32E	1.76	0.46	0.00	1.30	26%	II
J33A	4.81	0.50	1.44	2.87	10%	I
J33B	8.98	0.55	1.47	6.95	6%	I
J33C	2.83	0.28	0.01	2.55	10%	I
J33D	3.82	0.00	1.24	2.58	0%	I
J33E	8.22	1.68	1.98	4.56	20%	II
J33F	4.50	0.24	2.19	2.07	5%	I
J34A	3.08	0.97	1.48	0.63	31%	II
J34B	6.44	1.06	2.85	2.53	17%	I
J34C	9.60	0.36	3.51	5.73	4%	I
J34D	4.06	0.05	1.80	2.21	1%	I
J34E	2.29	0.52	1.13	0.64	23%	II
J34F	3.44	0.50	0.47	2.47	14%	I
J35A	8.47	1.08	1.20	6.20	13%	I
J35B	8.12	1.59	1.24	5.29	20%	I
J35C	1.98	0.25	0.88	0.85	13%	I
J35D	9.82	1.24	3.65	4.92	13%	I
J35E	1.33	1.23	0.21	-0.11	92%	III
J35F	6.67	0.04	2.02	4.62	1%	I
J40A	9.73	0.06	5.03	4.64	1%	I
J40B	5.45	0.03	2.71	2.71	0%	I
J40C	15.81	0.33	6.58	8.90	2%	I
J40D	10.21	1.66	4.20	4.36	16%	I
J40E	7.48	0.55	3.45	3.48	7%	I
K10A	2.34	0.91	1.16	0.28	39%	II
K10B	1.96	0.11	1.20	0.65	6%	I
K10C	4.43	0.00	2.33	2.09	0%	I
K10D	2.53	0.35	1.10	1.08	14%	I
K10E	13.70	0.06	4.30	9.33	0%	I
K10F	2.82	0.06	0.99	1.78	2%	I
K20A	19.85	0.14	6.15	13.56	1%	I
K30A	28.06	0.26	7.15	20.65	1%	I
K30B	21.52	0.97	5.03	15.52	5%	I
K30C	27.80	0.59	7.83	19.38	2%	I
K30D	18.44	0.20	7.43	10.81	1%	I
K40A	8.99	0.00	3.79	5.20	0%	I

Quaternary	Recharge (million m^3/a)	Use (million m^3/a)	GWBF (million m^3/a)	Balance (million m^3/a)	Stress (Use/ Recharge)	Present Status
K40B	13.52	0.01	4.85	8.65	0%	I
K40C	17.00	0.00	4.32	12.67	0%	I
K40D	17.74	0.96	3.71	13.06	5%	I
K40E	26.56	0.19	10.61	15.76	1%	I
K50A	27.43	0.05	10.09	17.29	0%	I
K50B	24.71	2.34	8.58	13.79	9%	I
K60A	6.43	0.21	4.20	2.02	3%	I
K60B	8.43	0.00	5.70	2.73	0%	I
K60C	10.95	0.15	6.60	4.20	1%	I
K60D	23.54	0.00	12.43	11.11	0%	I
K60E	6.39	0.38	3.95	2.06	6%	I
K60F	14.35	0.20	9.35	4.80	1%	I
K60G	11.31	0.80	5.02	5.50	7%	I
K70A	14.30	0.05	6.84	7.41	0%	I
K70B	20.46	0.00	4.46	16.01	0%	I

Table 4.7 Results of groundwater balance model at GRU scale showing groundwater balance, 'stress' and present Status

GRU	Recharge (million m^3/a)	Use (million m^3/a)	GWBF (million m^3/a)	Balance (million m^3/a)	Stress (Use/ Recharge)	Present Status
BB-1	51.60	38.79	4.03	8.78	75%	III
BB-2	46.87	22.58	5.23	19.06	48%	II
BB-3	200.28	30.58	21.67	148.04	15%	I
BB-4	16.92	1.79	1.73	13.40	11%	I
BB-5	38.25	12.72	4.13	21.40	33%	II
BB-6	41.69	14.17	2.76	24.75	34%	II
BB-7	38.42	8.89	5.19	24.33	23%	II
BB-8	98.56	0.77	23.28	74.51	1%	I
BO-1	123.48	0.94	28.17	94.38	1%	I
BO-2	55.99	11.55	14.90	29.54	21%	II
BO-3	64.26	5.80	25.10	33.36	9%	I
BR-1	153.10	3.70	19.12	130.29	2%	I
BR-2	43.79	1.20	6.35	36.24	3%	I
GC-1	136.10	2.63	39.06	94.40	2%	I
GC-2	177.50	4.70	68.59	104.21	3%	I
GC-3	72.66	0.43	33.12	39.11	1%	I
GGa-1	3.62	1.12	0.00	2.50	31%	II
GGa-2a, 2b and 2c	22.66	9.66	0.00	13.00	43%	II
GGa-3	13.50	0.63	2.92	9.95	5%	I
GGa-4	6.98	2.37	1.13	3.49	34%	II
GGa-5	16.05	0.09	8.23	7.74	1%	I
GGo-1	34.82	3.54	15.95	15.32	10%	I
GGo-2a and 2b	114.52	7.73	40.83	65.96	7%	I
GGr-1	11.38	4.74	0.05	6.60	42%	II
GGr-2	16.89	0.81	0.06	16.02	5%	I
GGr-3	11.44	3.08	0.00	8.36	27%	II
GGr-4	11.90	4.23	0.00	7.67	36%	II
GGr-5	31.84	2.10	5.63	24.11	7%	I
GO-1	7.47	1.13	1.17	5.16	15%	I
GO-2	26.97	1.93	5.13	19.91	7%	I
GO-3	21.69	2.60	10.75	8.33	12%	I
GO-4	61.82	8.40	19.51	33.91	14%	I

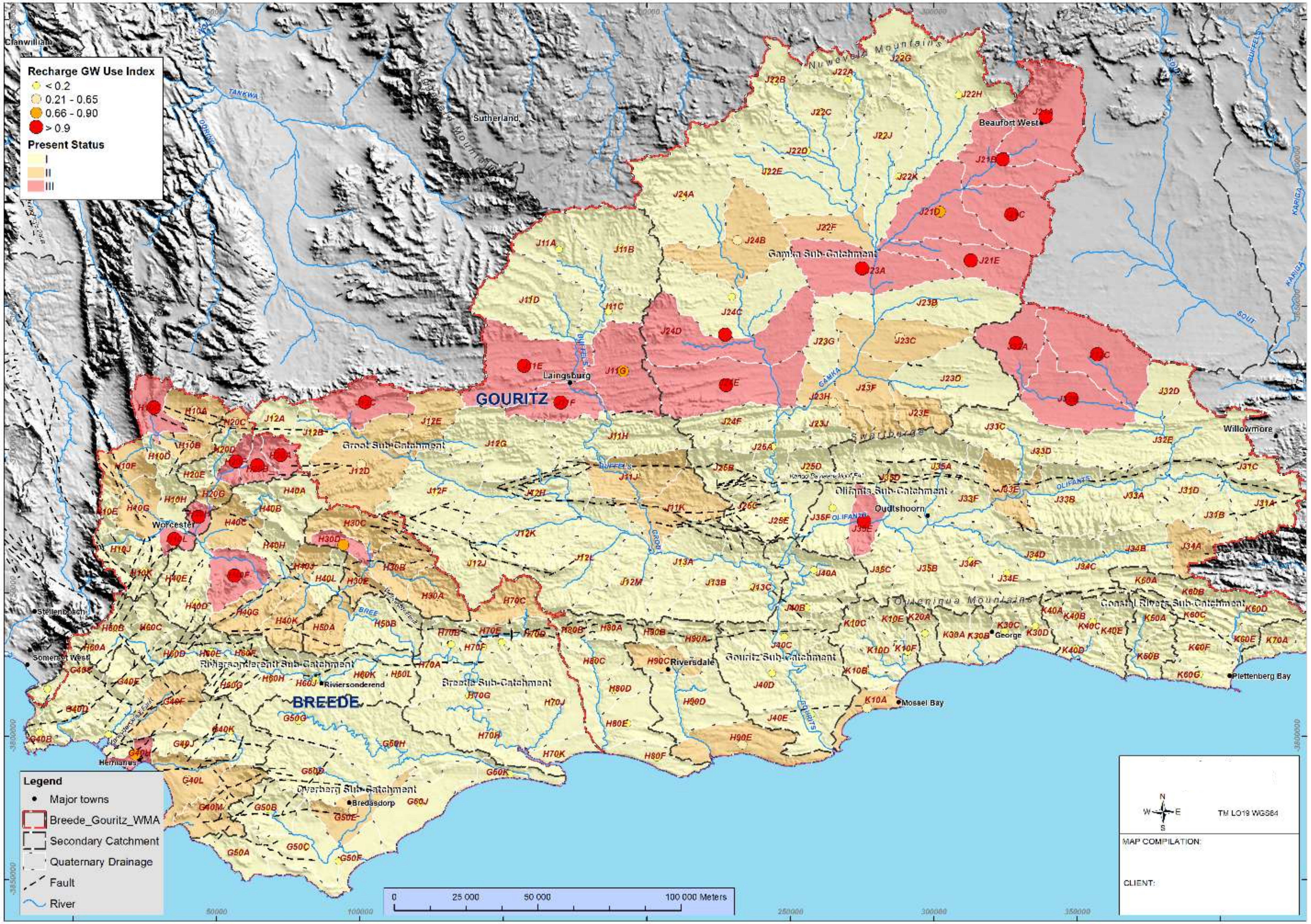

Figure 4.1 **Map showing Use/Recharge and resulting present status per quaternary catchment**

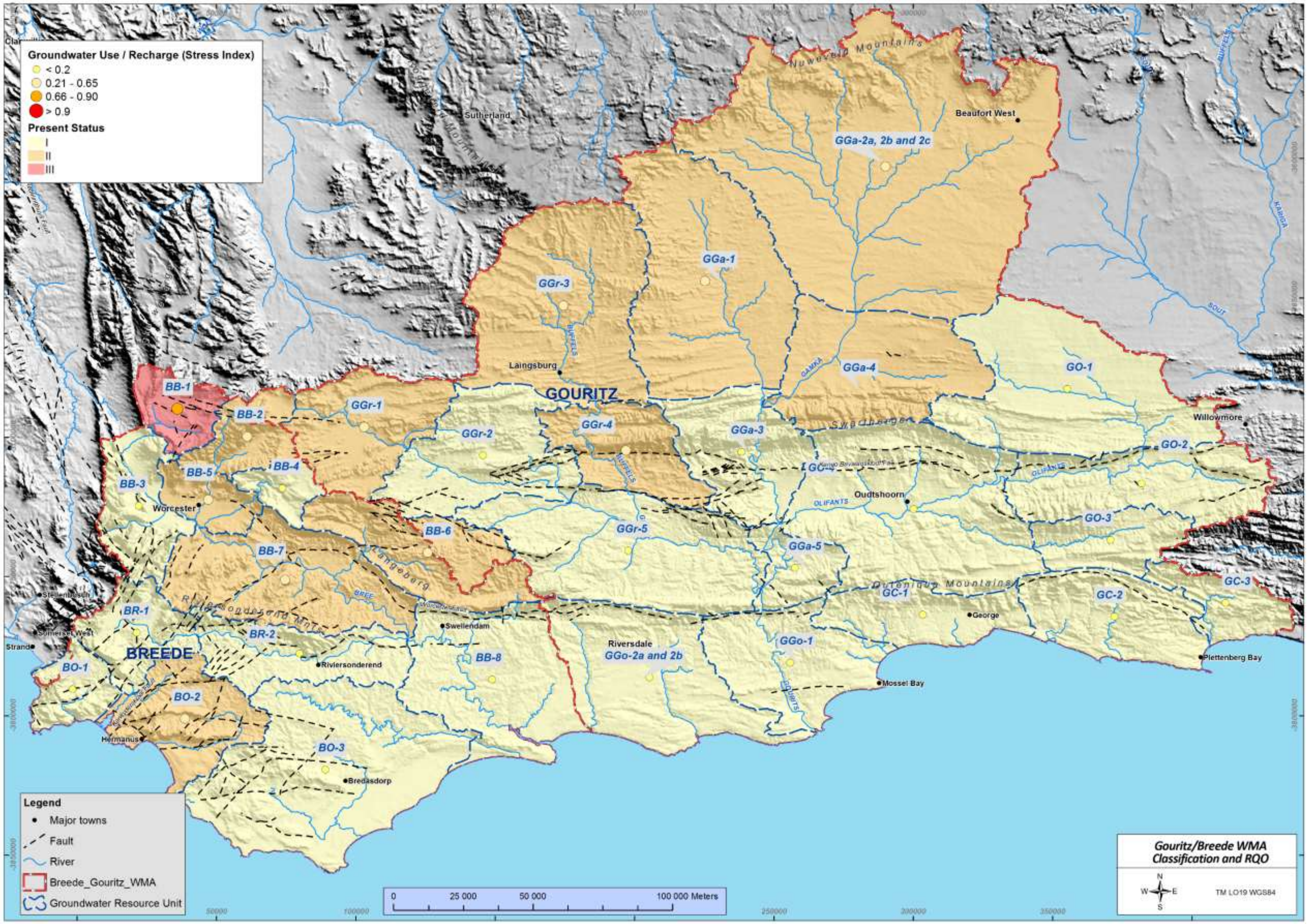

Figure 4.2 Map showing Use/Recharge and resulting present status per GRU

4.6 Future Groundwater Assessment

The results of the water balance model will be used to evaluate the impact of various development/conservation scenarios on groundwater, and determine a recommended category for groundwater in relation to the selected water resource class. The limitations of the groundwater balance model are outlined within this section. The groundwater balance data and present status analysis will be used, with other information, in the prioritisation of resource units for RQO development. In prioritised areas, the following more detailed assessments may be necessary to 'ground truth' the water balance model results:

- Baseflow separation may be carried out from gauge data, for improving knowledge of GWBF
- Lateral / indirect flow may be quantified to adjust water balance
- Point data (water level and water quality) may be used to ground truth the groundwater balance.

4.7 Groundwater link to Nodes and EWRs

Some portion of the flow (to maintain a particular EC for river, wetland or estuary) is derived from surface water (runoff), and some from groundwater via GWBF. Use of groundwater can reduce GWBF hence impact the flow (and EC), and surface water use clearly impacts runoff hence flow (and EC). A groundwater balance model has been established to support scenario evaluation (step 5). However prior to establishing the groundwater balance model, information is required on *the degree to which EWR can be met by GWBF,* for two purposes:

1. The role of GWBF in meeting EWR shapes the approach to the groundwater balance model.
2. The information will assist in prioritisation of resource units and the development of RQOs, such that GWBF can be protected, supporting groundwater's role in maintaining ecological integrity.

In this study EWRs are defined at biophysical nodes. However, groundwater discharge to surface water can occur over large distributed areas which may extend beyond quaternary boundaries (i.e. an alluvial aquifer surrounding a river), along specific river reaches, or at points related to spring discharge, and is not homogenously distributed across the catchment or aquifer (Riemann, 2013). Data for GWBF is available to the study per quaternary catchment from the GRAII database (DWAF 2006). GWBF is also a component of the WR2000 Pitman model with Sami GW utility, used in the surface water component of the study, and available per quaternary catchment. Using these two datasets, a final GWBF dataset was established for the project (section 4.4.4). The groundwater balance information is required per GRU and per quaternary catchment (section 4.1), and as such it was necessary to establish a representative EWR per quaternary catchment, for comparison to catchment-scale GWBF. The following procedures were applied in the establishment of a representative node (and associated EWR) per quaternary catchment:

- Where quaternary catchments do not have biophysical nodes, no comparison of GWBF to EWR within that catchment is made or necessary to determine the role GWBF has in meeting EWR.
- Where only one node is available in a quaternary catchment it was used.
- Where multiple nodes exist per quaternary catchment, priority was given to:
  - the node at the downstream quaternary catchment boundary, if present, in order to be most comparable to GWBF values,
  - the node with the highest EWR was prioritised to avoid selecting a node with ERW<GWBF where this may not be the case at all nodes in the catchment. The measure was to ensure 'protection' of GWBF in the groundwater balance equation, but results the ratio GWBF/EWR being minimised.
- If the node selected is not located at the downstream quaternary catchment boundary, the GWBF data was disaggregated to the node based on the proportion of the area of the quaternary catchment upstream of a particular node.

The GWBF values are not considered cumulatively along a river course. The GWBF per catchment reflects the GWBF contribution to surface water across a particular quaternary catchment: but flow in that catchment will be contributed to by GWBF from upstream catchments. This approach has the potential to underestimate groundwater availability (by 'maintaining' all GWBF contributed per quaternary catchment in groundwater balance equations), given that some GWBF at a particular node may be contributed to the river farther upstream, not 'used' from the river, hence still available to provide for GWBFs role in meeting the EWR downstream. Nevertheless it can be seen as conservative.

Also, the spatial disaggregation of GWBF alters an already low- confidence dataset away from the boundaries over which it was intended for use. Furthermore, the prioritisation of nodes with high EWR minimises the GWBF/EWR ratio. These challenges arise due to the differing scale and physical processes that the two datasets represent (section 4.1). It is therefore stressed that this activity was completed as an indicator, alongside GWBF/MAR, for groundwater's role in meeting EWRs, but that the results should only be taken as indicative of the ***relative*** importance of groundwater to support meeting EWRs, rather than quantitative values.

The GWBF/EWR proportion and GWBF/MAR are expressed as a percent in Table 4.8, and show that:

- The median GWBF/EWR is 11%;
- GWBF/EWR is low (<11%) at 63 quaternary's (57%), and in these cases GWBF/nMAR is also low, generally <1%
- GWBF/EWR is moderate (11-75%) at 36 quaternary's (32%),
- GWBF/EWR is high (>75%) at 12 quaternary's (11%), and GWBF/nMAR is high (>20%) at 12 quaternary's (not necessarily the same quaternary's)
- EWR is < GWBF at 6 quaternary's (5%), where GWBF alone is sufficient to meet EWR.

Table 4.8 (Current) Groundwater Contribution to Baseflow (GWBF) compared to the EWR and nMAR at a biophysical node selected as representative of the quaternary catchment

Node	Quaternary	EWR (Mm^3/a)	nMAR (Mm^3/a)	GWBF (Mm^3/a)	GWBF/EWR	GWBF/nMAR
Piv9	G40C	16.9	78.8	5.69	34%	7%
Piii3	G40D	86.3	250.4	14.45	17%	6%
Niv43	G40F	5.6	42.1	2.12	38%	5%
Nx6	G40H	0.7	5.1	0.60	86%	12%
Nii4	G40J	2.3	18.4	2.53	110%	14%
Nv23	G40K	8.3	43.0	4.67	56%	11%
Nx8	G40M	0.5	2.4	0.79	158%	33%
Ni4	G50B	1.6	12.5	3.47	217%	28%
Niv44	G50C	2.5	18.8	2.05	82%	11%
Nv24	G50D	2.1	15.4	2.55	121%	17%
Nii5	G50E	4.4	21.6	1.37	31%	6%
Nii6	G50G	0.5	4.2	1.43	287%	34%
Nii7	G50H	8.1	27.1	3.02	37%	11%
Niv3	H10B	5.8	26.2	0.48	8%	2%
Niv2	H10C	16.5	74.9	1.18	7%	2%
Nvi3	H10D	96.0	252.8	2.05	2%	1%
Nvii16	H10E	19.8	42.6	1.08	5%	3%
Nviii1	H10F	136.0	434.9	1.39	1%	0%

Node	Quaternary	EWR (Mm^3/a)	nMAR (Mm^3/a)	GWBF (Mm^3/a)	GWBF/EWR	GWBF/nMAR
Niii1	H10G	189.0	497.6	0.44	0%	0%
Niv8	H10H	2.6	17.9	1.29	50%	7%
Niv42	H10J	35.5	191.2	7.94	22%	4%
Niv12	H10K	165.1	474.5	7.40	4%	2%
Nv3	H10L	266.1	850.9	0.00	0%	0%
Nvii7	H20G	23.5	102.8	0.30	1%	0%
Niv10	H20H	24.5	107.1	0.07	0%	0%
Niv18	H30B	3.3	27.1	0.16	5%	1%
Niv20	H30C	2.1	17.3	0.07	3%	0%
Nvii9	H30D	2.5	21.5	0.06	3%	0%
Nii2	H30E	9.8	52.0	0.31	3%	1%
Niv11	H40C	3.9	29.4	0.86	22%	3%
Niv13	H40D	6.1	47.4	1.85	30%	4%
Nvii8	H40F	474.7	1042.8	0.58	0%	0%
Nvii11	H40G	2.1	16.1	0.21	10%	1%
Niv15	H40H	1.9	15.6	0.13	7%	1%
Nvii19	H40J	492.6	1082.0	0.18	0%	0%
Niv14	H40K	1.6	12.6	0.24	15%	2%
Ni2	H50B	202.2	1170.1	0.78	0%	0%
Nvii10	H60B	41.5	87.8	2.00	5%	2%
Nv7	H60D	111.1	370.2	0.95	1%	0%
Niv28	H60E	5.6	7.9	0.71	13%	9%
Niv30	H60F	6.0	12.4	0.43	7%	3%
Niv31	H60G	1.4	10.7	0.64	45%	6%
Nv10	H60H	108.5	442.9	1.14	1%	0%
Niv35	H60K	1.0	5.9	0.54	54%	9%
Ni3	H60L	118.5	483.8	0.87	1%	0%
Niv24	H70A	0.7	5.8	0.69	99%	12%
Nv2	H70B	449.8	1701.4	4.17	1%	0%
Nii3	H70C	5.8	19.4	0.23	4%	1%
Niv25	H70F	16.9	119.4	2.31	14%	2%
Niii4	H70G	735.5	1832.7	1.26	0%	0%
Niv26	H70J	1.4	10.0	1.43	102%	14%
giii5	H80B	16.7	62.5	6.45	39%	10%
gv11	H80C	15.7	75.1	0.61	4%	1%
giii8	H80D	33.6	83.2	1.23	4%	1%
gv10	H90C	18.0	93.0	1.93	11%	2%
giv34	J11C	3.5	13.1	0.00	0%	0%
gv25	J11F	5.6	24.2	0.00	0%	0%
gv4	J11H	3.1	27.4	0.00	0%	0%
gv6	J11J	4.8	29.7	0.00	0%	0%
giv32	J11K	3.5	30.5	0.00	0%	0%
giv31	J12B	0.8	6.9	0.00	1%	0%
giv30	J12C	0.3	2.8	0.01	3%	0%

Node	Quaternary	EWR (Mm³/a)	nMAR (Mm³/a)	GWBF (Mm³/a)	GWBF/EWR	GWBF/nMAR
giv28	J12D	1.8	16.4	0.02	1%	0%
giv27	J12H	7.0	26.4	0.02	0%	0%
giv26	J12K	0.5	2.9	0.01	2%	0%
gv5	J12L	3.8	33.5	0.05	1%	0%
gv7	J13A	12.0	72.7	0.02	0%	0%
gii3	J13C	17.6	78.1	0.03	0%	0%
Gv18	J21A	7.2	26.7	0.00	0%	0%
giv3	J21D	8.7	31.9	0.00	0%	0%
giv1	J22F	1.3	7.4	0.00	0%	0%
giv2	J22K	3.1	17.1	0.00	0%	0%
gv17	J23C	13.1	58.1	0.00	0%	0%
giv21	J23F	18.6	68.0	0.00	0%	0%
gv27	J23J	12.7	69.6	0.97	8%	1%
gv14	J24D	1.6	4.0	0.00	0%	0%
giv20	J25A	14.7	79.8	1.02	7%	1%
giv18	J25D	1.3	11.0	0.61	47%	6%
gii2	J25E	13.5	111.8	0.04	0%	0%
giii2	J31C	1.7	11.8	0.04	2%	0%
giv15	J32E	0.4	2.7	0.00	0%	0%
gv33	J33B	3.0	25.0	1.47	49%	6%
gv21	J33D	2.6	21.4	1.24	48%	6%
giv11	J33F	9.9	80.0	2.19	22%	3%
gv36	J34C	9.5	41.2	3.51	37%	9%
giv10	J34F	9.0	59.2	0.47	5%	1%
gv19	J35D	36.5	224.5	3.65	10%	2%
giv17	J35F	41.1	253.4	2.02	5%	1%
giv16	J40A	58.6	395.0	5.03	9%	1%
gi4	J40B	72.5	489.1	2.71	4%	1%
gv28	J40C	57.7	520.7	6.58	11%	1%
gv9	J40D	84.9	571.8	4.20	5%	1%
giv25	K10D	1.8	17.9	1.10	61%	6%
gvii7	K20A	6.9	27.0	5.54	80%	21%
gvii8	K30A	14.3	30.1	5.08	36%	17%
gviii6	K30B	12.2	34.1	3.17	26%	9%
gviii8	K30C	7.5	14.9	4.62	62%	31%
gvii12	K30D	5.1	16.7	3.72	73%	22%
giii10	K40A	3.9	12.4	3.79	97%	31%
giii13	K40B	8.5	27.9	4.85	57%	17%
giii11	K40C	13.6	33.8	4.32	32%	13%
gviii9	K40E	11.7	30.4	6.05	52%	20%
gvii14	K50A	8.5	26.5	5.75	68%	22%
gviii11	K50B	14.8	27.6	4.98	34%	18%
giv6	K60C	16.1	46.1	6.60	41%	14%
giv5	K60D	20.3	42.1	12.43	61%	30%

Node	Quaternary	EWR (Mm^3/a)	nMAR (Mm^3/a)	GWBF (Mm^3/a)	GWBF/EWR	GWBF/nMAR
gx9	K60E	31.9	91.3	1.23	4%	1%
giv4	K60F	12.9	23.6	9.35	72%	40%
gvii10	K60G	2.5	4.8	0.60	24%	13%
gx5	K70A	1.3	3.8	1.03	79%	27%
gvii15	K70B	10.6	31.2	2.85	27%	9%

5 EVALUATING CHANGES IN ECOLOGICAL GOODS, SERVICES AND ATTRIBUTES

5.1 Overview

The objective of Step 3c is to *quantify the changes in relevant ecosystem components, functions and attributes for each category for each node* to help evaluate the socio-economic and ecological implications of different catchment configuration scenarios in later steps of the classification procedure (DWAF, 2007).

The ecosystem changes at different ecological categories allow for the consideration of ecological and socioeconomic information at different scales and enables the evaluation of various ecological catchment configurations. Thus in terms of the socio-economic evaluation of scenarios it is important to understand what the EGSAs for the IUAs are, the nodes at which the changes can be provided and the changes that occur based on different characteristics within the water resource.

As per the WRCS guidelines the required information on changes in ecosystem components can be related to hydrological characteristics, biological components and processes, physical components and processes, structure and organisation of aquatic ecosystems and water quality characteristics.

This section details the EGSAs information required for socio-economic evaluation and the ecosystem changes that relate to these EGSAs considered for the study area. The EGSAs aspects considered were assessed based on a change in ecological category. The significance of the change is described in terms of the socio-economic assessment. In many instances the ecosystem changes will be quantified in the assessment of the scenarios (catchment configurations).

5.2 EGSAs Considered for the Study Area

The sectors dependent on aquatic ecosystem services could either shrink or expand as a result of moving to a lower or higher ecological category, respectively. The availability and quality of water in rivers, wetlands and estuaries and the overall condition of these natural systems influences their capacity to deliver aquatic ecosystem services. These, in turn, will influence the value of final goods and services generated by activities that depend on them.

In this study, the main sectoral impacts considered are tourism, property and inshore fisheries. These sectors and their linkages to the aquatic ecosystem services in the study area are explained in more detail in the *Status Quo report* (DWS, 2016b).

In addition, we also consider the impact of changes in ecosystem condition on people's wellbeing. This requires estimating the relationships between ecosystem condition and the capacity to supply natural resources, as well as amenity values such as recreation and spiritual fulfilment.

5.3 Relationship between Ecosystem Condition and EGSAs

The value of ecosystem services resides in the contributions that they make to human well-being. Of particular relevance is determining how changes in the supply of ecosystem services affect human well-being, and to understand this, it is necessary to understand the underlying links between ecosystem structure and function and the supply of ecosystem services as well as their demand.

The condition of the aquatic ecosystems in the WMA will vary under each of the Classification Scenarios. This will be expected to have an impact on their attributes that are valued by society as well as their capacity to deliver goods and services.

The main types of ecosystem services considered are summarised below, along with the flow-related characteristics that are likely to be the main drivers of these values. These variables are all assessed in the scoring of estuaries using the EHI.

Table 5.1 Main ecosystem services provided by rivers, wetlands and estuaries of the study area, and the main flow-related variables that can be derived from Reserve studies to estimate changes in the capacity to deliver these services

Category of service	Types of values	Description of EGSA	Independent variables related to estuary condition
Goods (Provisioning services)	Subsistence fishing	Invertebrates and fish collected on a subsistence basis for consumption or bait	Invertebrate abundance Freshwater fish abundance Estuary line- and net fish abundance
Services (Regulating services)	Nursery value	Contribution to marine fish catches due to the nursery habitat provided by estuaries	Abundance of estuary-dependent marine fish
Attributes (Cultural services)	Tourism value & property value	A river, wetland or estuary's contribution to recreation/tourism appeal of a location	Overall health Line fish abundance Water quality

In order to inform this analysis, the relationships between abiotic and biotic scores and the overall health score for estuaries were explored. In general, it was found that the component scores were strongly correlated with the overall health scores, with all having a slope close to unity. Variation was highest for birds, which are influenced by non-flow disturbance factors, fish, which are influenced by fishing, and macrophytes, which are influenced by habitat loss through development. Nevertheless, it suggests that the overall relationships are generally consistent with health score.

The above relationships were used as a guide for the assumptions in this study. The relevant relationships and assumptions are described in more detail below.

5.3.1 Sustainable yield of stocks used by subsistence fishers

Rivers, wetlands and estuaries provide numerous resources which can be harvested, including raw materials such as reeds, fish, invertebrates, and food and medicinal plants. The delivery of these ecosystem goods is a function of the productivity of the system. The value of this service depends on the extent to which it is demanded, which can be influenced by regulation, as in the case of protected areas.

The aquatic ecosystems of the Breede-Gouritz are not as well endowed with resources as some of those further east in the country, which include extensive marshes, swamp forests and mangrove forests, but they are used for the subsistence harvesting of fish and invertebrates. Nevertheless subsistence fishers in the study area harvest a wide range of macro-invertebrates as food (e.g. mussels) and bait (e.g. mud prawns) from estuaries, as well as several species of fish that can be targeted using rods, set lines, hand lines, cast nets and gill nets. Net fishing is illegal in estuaries, and thus only line fish species are of relevance here. Fish are also harvested on a subsistence basis from rivers and dams in the study area.

For this study, changes in the capacity to deliver this service were approximately estimated by changes in the fish score that result from a change in Ecological Category. Because Classification is done on the basis of Ecological Category and does not have the resolution of scores, the following rules were devised (Table 5.2), based on the relationship between fish score and EHI at the midpoint of each category ().
Fish are also harvested on a subsistence basis from rivers and dams in the study area.

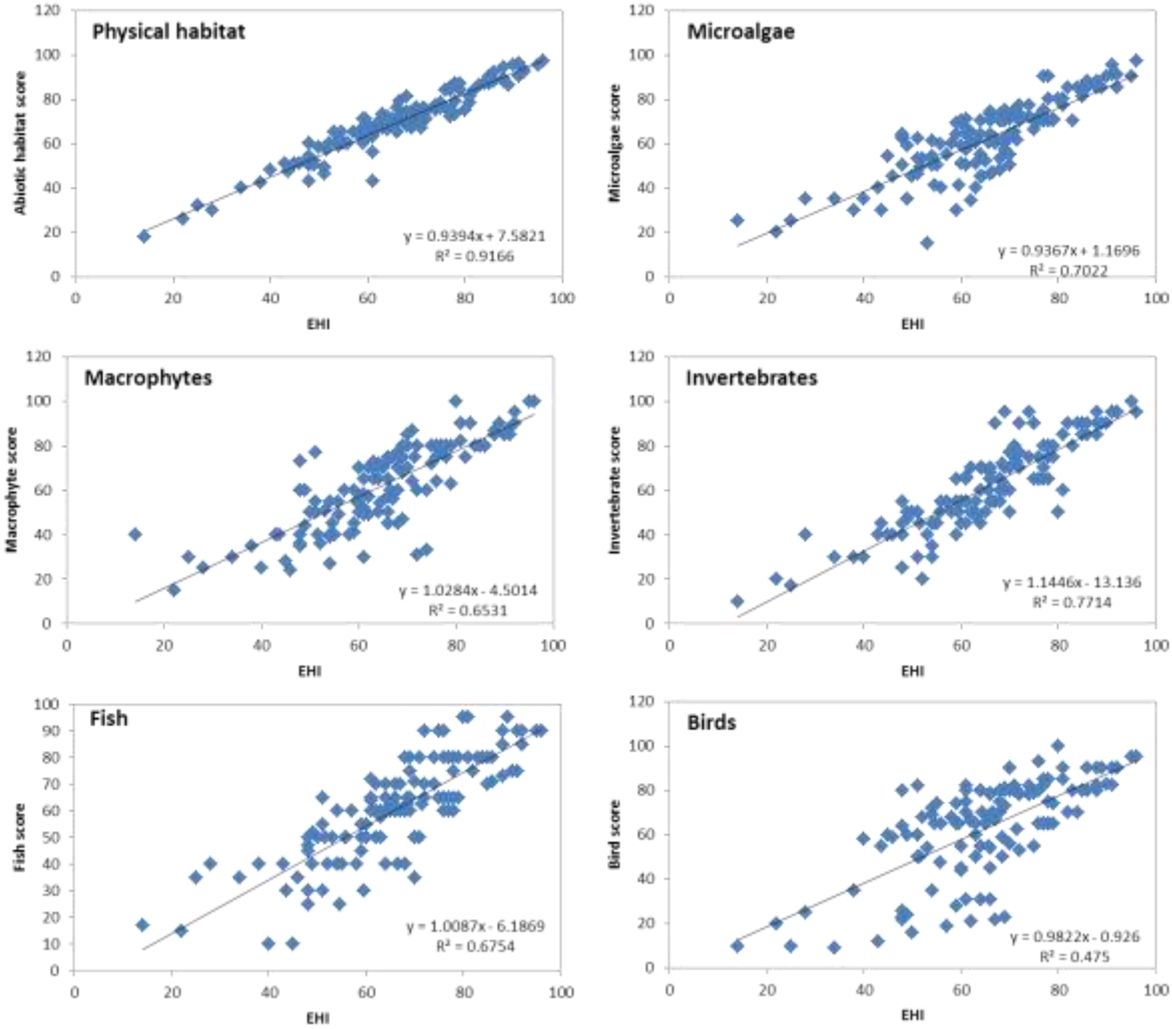

Figure 5.1 Relationship of overall abiotic health score, microalgae, macrophyte, invertebrate, fish and bird health scores to the overall Estuary Health Score, for a total of 131 scored scenarios across 29 estuaries of the Breede-Gouritz WMA

Table 5.2 Factors to estimate changes in sustainable yield relative to present-day

		Assigned Ecological Category			
		A	B	C	D
PES	A	1.0	0.9	0.7	0.5
	B	1.2	1.0	0.8	0.6
	C	1.4	1.2	1.0	0.7
	D	2.0	1.7	1.4	1.0
	E	3.7	3.2	2.6	1.8
	F	23.0	19.8	15.9	11.3

5.3.2 Nursery function

Numerous species use estuaries as nursery areas and many of these are important in marine line fisheries. Most estuary-dependent fish species enter the estuary as larvae or post larvae and once the estuary dependent phase is complete, they leave the estuary for the marine environment where they become available to marine fisheries, and upon maturity contribute to the spawning stock.

The contribution of estuaries in terms of their outputs of these fish depends on their suitability as a nursery area, which, in turn is determined by the size and quality of the habitat and the amount of connection to the marine environment. These factors are taken into consideration when estimating changes in the populations of estuary-depending fish for the evaluation of estuary health. Estuary dependent fish form a significant component of estuary fish populations, and for this reason, it is acceptable to use the overall fish health score to estimate changes in estuary capacity to perform this service.

Currently it is estimated that the degradation of estuaries in the Western Cape (largely due to freshwater starvation, but also due to illegal fishing) has already led to the reduction of nursery function to approximately 27% of the original capacity, which amounts to losses to the value of some R675 million (Turpie et al. 2014). This is because some of the most important nursery areas that account for much of the overall capacity have been severely degraded.

A similar approach was used in this study, in which capacity for nursery function was related to fish abundance score. However, this is simplified to a class level analysis, using the same multipliers as in Table 5.4.

5.3.3 Aesthetic/recreational appeal

Rivers, wetlands and estuaries may contribute to the tourism appeal of areas, and thus it can be expected that a change in their condition may affect tourism demand and values. In particular, estuaries are a dominant feature of many coastal resort areas in the study area, and have been investigated in some detail for this analysis. The approach derived here will be used for all aquatic systems.

These attractions, combined with other attractions, provide the amenity values that drive people to visit or even invest in property to remain in these areas. The tourism and property values of all the estuaries in the study area have been estimated in the Status Quo assessment. However, the Classification Process also requires an understanding of how these values might change as a result of changes in the characteristics of the systems. Very little research has been carried out on this, and previous classification studies have avoided this issue altogether.

Turpie & Clark (2007), in their assessment of how values would change with or without conservation measures, assumed that the relationship between amenity values and estuary health was logarithmic in form, with people being largely insensitive to decreasing health until a relatively low state of health is reached, after which value would drop off rapidly. In order to inform the development of a rule based model for this study, we investigated the relationship between our estimates of current value and the health of the estuaries for the Berg and Breede-Gouritz WMAs.

Tourism value

The tourism value estimated for each of the estuaries in this study was analysed in relation to nine different variables, using an ordinary least squares (OLS) regression using R Project for Statistical Computing (ver. 3.2.0) (Table 5.3). A total of 49 estuaries were included in the analysis. A semi-log model was specified as follows:

$$Ln\,TV_e = \beta_0 + \beta_1 S_e + \beta_2 E_e + \beta_3 P_e + \varepsilon_e$$

where the dependent variable ($Ln\,TV_e$) is the natural logarithm of the tourism value for each estuary. S_e represents the size of the estuary, E_e the measure of environmental and health characteristics and P_e represents the physical and social variables of interest. Similarly $\beta_0, \beta_1, \beta_2, \beta_3$ represent the corresponding parameters to be estimated, whereas ε_{pt} captures the stochastic error term. The model was improved by disregarding collinear variables and non-significant variables through a stepwise approach.

The water quality score, fish score and overall health score were all correlated and a result, through a stepwise approach, only the variable contributing the most to the overall fit of the model was retained. The distance to Cape Town variable was removed early on in the analysis as it was insignificant and did not contribute to the overall model fit.

Table 5.3 Definitions of variables used in the tourism value model

Independent variables	Unit	Description
Size	Ha	Size of the estuary in hectares
Overall Health	Score	Overall health score of estuary based on abiotic and biotic components
Scenic beauty	Score	Score out of 10 given to each estuary by a panel (Turpie & Clark 2007)
Water quality	Score	Water quality health score given to each estuary
Fish	Score	Fish health score given to each estuary
Distance to CT	Km	Distance along national roads from each estuary to Cape Town
Non-estuary tourism drawcards	Score	Score out of 10 based on the availability of shops, restaurants and bars, recreational activities, golf courses and access to coastline and a swimming beach. The scores for these were weighted (40% beach and coast, 30% hospitality, 20% terrestrial activities, 10% golf) and summed to generate a score out of ten.
Population size	Categorical	The size of the surrounding population was given as low, medium or high

The final model included estuary size, overall health score, non-estuary tourism drawcards, population and scenic beauty (Table 5.3). However, only two of these variables were significant and contributed to the overall model fit. Through a stepwise approach overall health score, population and scenic beauty were dropped from the model. Estuary size and non-estuary tourism drawcards were found to be the two most important variables influencing the tourism value associated with estuaries. The adjusted R^2 (0.46) indicates only a reasonable model fit of the data into the specified model and the two variables retained in the model were statistically significant at the 1% level.

Table 5.4 Results of the regression estimates from the tourism value model

Variable	Co-efficient	Standard error	t-value	Pr (>F)	
(Intercept)	13.9500	0.5124	27.24	< 2.2e-16	***
Estuary size	0.0005	0.0002	2.29	0.000168	***
Non-estuary drawcard score	0.8703	0.1854	4.69	0.000025	***
Sample size				49	
R-squared				0.46	

Non-estuary tourism drawcards include access and quality of coastline and swimming beaches, access to restaurants, bars and shops, access to golf courses and the availability of terrestrial nature based activities in the surrounding area. Estuaries with the highest non-estuary tourism drawcards score include Knysna, Swartvlei, Hartenbos, and Keurbooms. The coastal towns associated with these estuaries are all popular tourist destinations offering a wide variety of attractions and activities and it is not surprising that this variable has a significant influence on tourism value.

The fact that the scenic beauty score was not significant and dropped was not entirely surprising given that a number of the most scenic estuaries are remote and not easily accessible, and as a result have a lower tourism value. However, one would expect that tourists would be affected by estuary health to some degree. This result may be largely an artefact of history, in that the resort towns that continue to attract people would have developed when the estuaries were in a good condition. The towns themselves are now a major part of the attraction and continue to draw visitors despite some changes in estuary condition. It is also possible that people only become sensitive to deterioration in estuary health beyond some threshold when the changes are significant and noticeable.

This is certainly suggested by the relationship between estuary health and average tourism value (Figure 5.2, Figure 5.3). There are many estuaries in the Breede-Gouritz WMA that have relatively high health scores, but which are fairly inaccessible and have low tourism values. However, while the actual tourism value per estuary are highly variable, the upper limit, and therefore also the average value, increases with increasing health. The pattern of average value is also suggestive of a threshold level of health below which potential value drops of rapidly.

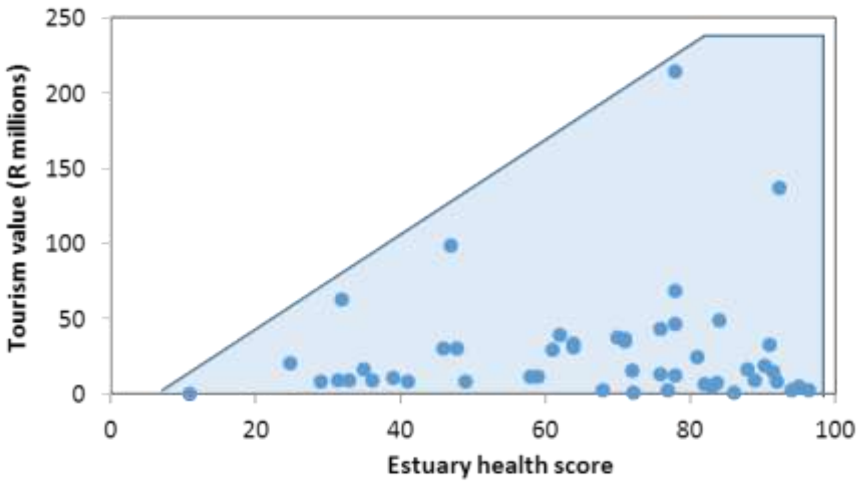

Figure 5.2 The relationship between tourism value and estuary health score

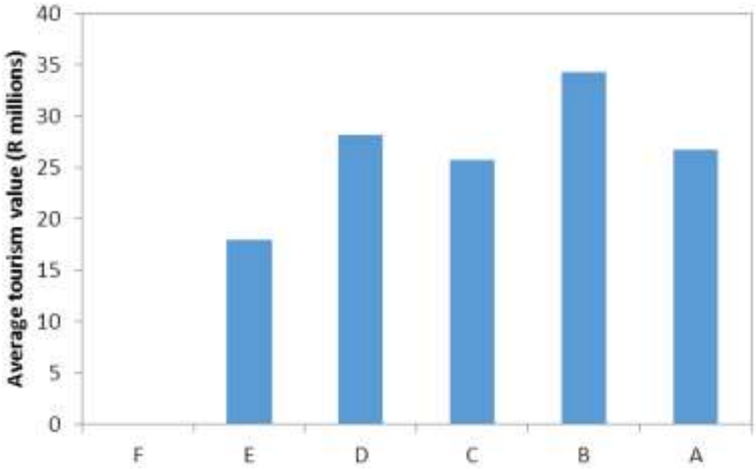

Figure 5.3 The relationship between average tourism value and estuary ecological health category

Based on the above relationship, a rule curve was derived with which to estimate the potential changes in tourism value as a result of changes in estuary health. This was used to develop a set of factors with which to adjust tourism value for changes from PES to alternative Ecological Categories in the scenario analysis (Table 5.5).

Table 5.5 Factors to estimate changes in property value attributed to estuaries, relative to present-day

		Assigned Ecological Category			
		A	**B**	**C**	**D**
PES	**A**	1.0	1.0	0.9	0.8
	B	1.1	1.0	0.9	0.8
	C	1.1	1.1	1.0	0.9
	D	1.3	1.2	1.1	1.0
	E	2.0	1.9	1.8	1.6

Property value

An analysis of our property value estimates yielded similar results to those for tourism value. The estimated property value associated with estuaries was weakly related to EHI. However the pattern suggests that potential for high property values is highest for estuaries of moderate to good health, and decreases with decreasing and increasing health. This makes sense, because estuaries of low health are not attractive for recreational use, and estuaries that are of very high health are usually protected and/or relatively inaccessible. In fact high levels of property development around an estuary would seldom allow an estuary to retain a very high level of health.

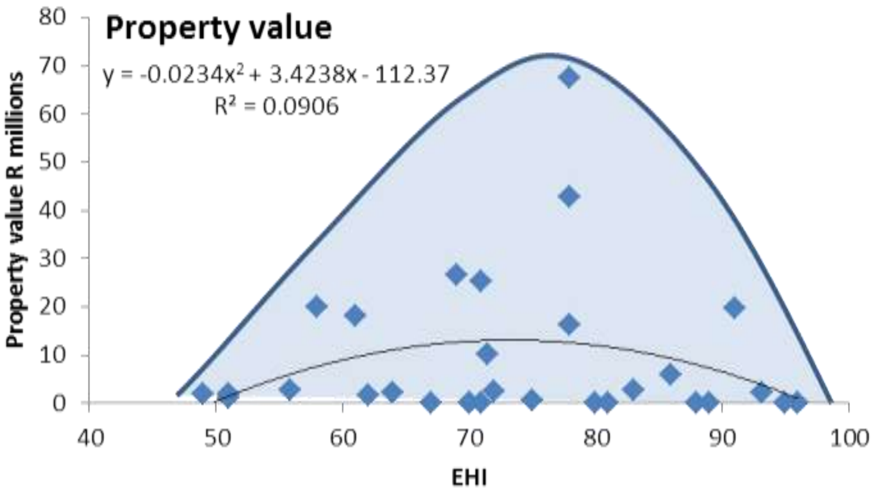

Figure 5.4 The relationship between property value and estuary health score

However, for all else equal, if an estuary increases in health, property values would be expected to be unchanged or to increase, whereas a decrease in health would be expected to lead to a loss of property value. The factors to estimate changes in property value as a result of changed estuary health were estimated based on the average property value per estuary in each Ecological Category, but with the assumption that increases in condition from a B to an A class, for all else equal, would lead to a slight increase in property value (Table 5.6).

Table 5.6 Factors to estimate changes in property value attributed to estuaries, relative to present-day

		Assigned Ecological Category			
		A	**B**	**C**	**D**
PES	**A**	1.0	1.0	1.0	0.7
	B	1.0	1.0	1.0	0.7
	C	1.1	1.0	1.0	0.7
	D	1.5	1.5	1.4	1.0
	E	2.8	2.7	2.6	1.8

6 THE WAY FORWARD

The data on EWRs and changes in the non-water quality EGSAs will be used to determine the flow requirements at individual nodes based on the recommended ecological category as well as determining the impact of alternative development scenario on the ecological condition of individual nodes. The associated impact in terms of changes in EGSAs will then be used to evaluate the impacts of alternative scenarios.

The general approach to the scenario analysis has been described in the Linking the Value Report and will be further developed as part of the base line scenarios report. The development of current and future development scenarios and the analysis of the potential impact of these scenarios is the next step.

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Appendix A. Additional River EWR studies (Rapid Level III)

Appendix B. Breede River catchment EWRs

Appendix C. Papenkuils wetland

Appendix D. Palmiet River catchment EWRs

Appendix E. Hex River catchment EWRs

Appendix F. Gouritz River EWRs – revised desktop

Appendix G. Gouritz EWRs – EWR edit settings

Appendix H. Outeniqua region EWRs

Appendix I. Estuary Reserves – Rooiels Estuary

Appendix J. Estuary Reserves – Onrus Estuary