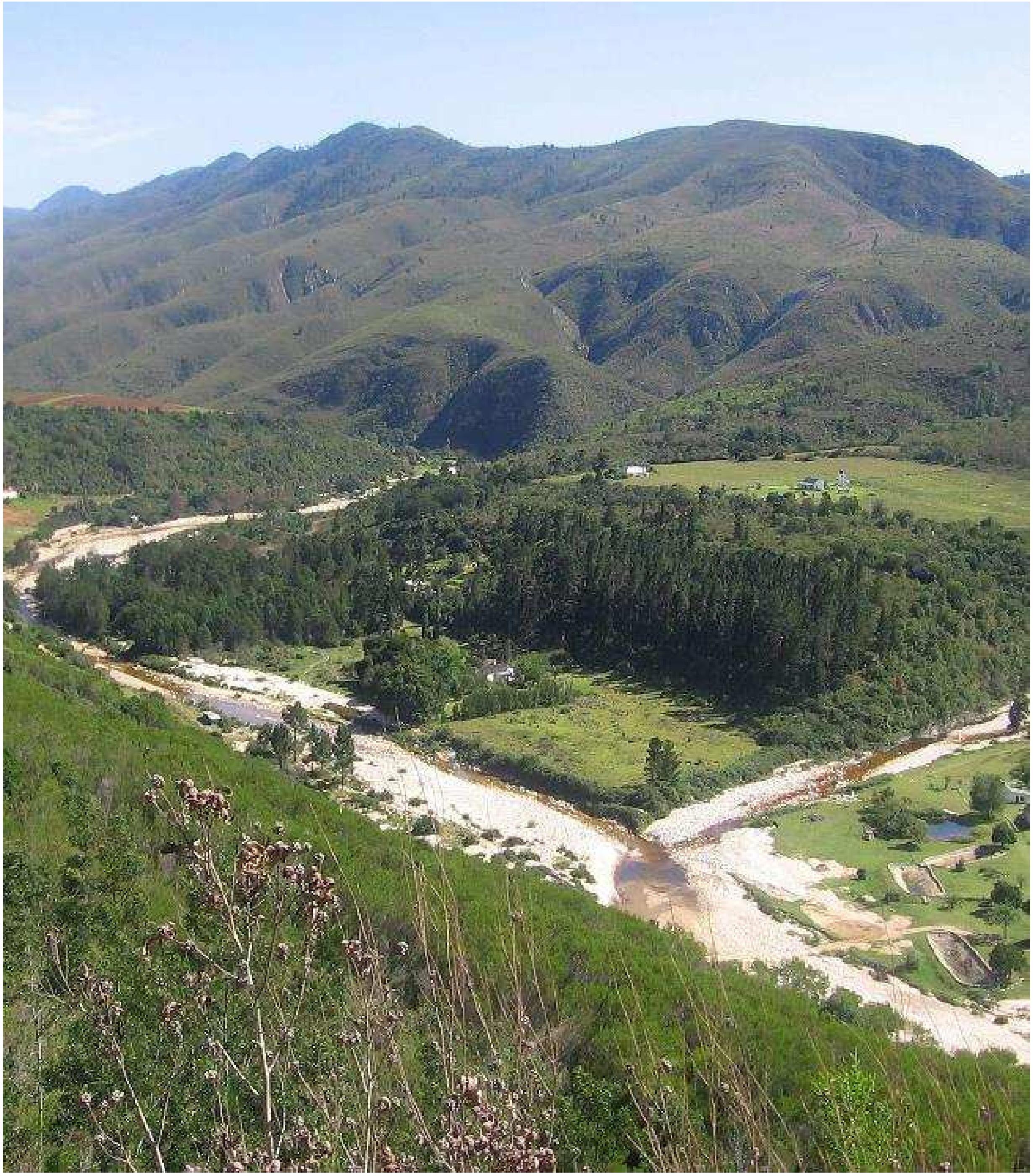

Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz WMA

December 2017

Revision: Final

Ecological Base Configuration Scenario Report

No: RDM/WMA8/00/CON/CLA/0317

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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: *Ecological Base Configuration Scenario Report*

Author: *Dr Alison Joubert, Dr Karl Reinecke, Prof André Görgens, Helen Seyler, Louise Lodenkemper, Dr Jane Turpie,*

Project Name: *Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz Water Management Area*

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Chief Directorate: Water Ecosystems

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Chief Director: Water Ecosystems

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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	Baseline Ecological Condition 2014
BF	Baseflow
BGCMA	Breede-Gouritz Catchment Management Agency
CD: WE	Chief Directorate: Water Ecosystems
CMS	Catchment management strategy
Co	Coastal
DAFF	Department of Agriculture, Forestry and Fisheries
DWA	(Previous) Department of Water Affairs
DWAF	(Previous) Department of Water Affairs
DWS	Department of Water and Sanitation
EC	Ecological Category
EGSA	Ecological goods, services and attributes
EIS	Ecological importance and sensitivity
ER	Ecoregion
ES	Ecological Sensitivity
ESBC	Ecologically sustainable base configuration scenario
EWR	Ecological water requirements
FBC	Flow-based category
GK	Great Karoo
GRU	Groundwater resource unit
GWBF	Groundwater contribution to baseflow
GZ	Geozone
HGM	Hydrogeomorphic Unit
HI	Hydrological Index
IUA	Integrated Unit of Analysis
Lati	Latitude
Long	Longitude
MAR	Mean annual runoff
NFEPA	National Freshwater Ecosystem Priority Areas
nMAR	natural Mean Annual Runoff
NWA	National Water Act
NWRCS	National Water Resources Classification System
OER	Overberg East Renosterveld
PES	Present Ecological Status
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RI	Recurrence Interval
RQOs	Resource Quality Objectives
SCB	Southern Coastal Belt
SCW	Southern Cape Wet
SECB	South-eastern Coastal Belt
SFM	Southern Fold Mountains
SK	Southern Karoo,
SQ	Sub-quat
TMG	Table Mountain Group
U	unclassified
WARMS	Water Authorisation Registration and Management System
WC/WDM	Water conservation and water demand management
WRCS	Water Resource Classification System

WR2012	Water Resources of South Africa 2012
WMA	Water Management Area
WRU	Wetland resource unit

Executive Summary

INTRODUCTION

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

In terms of the deliverables required for the water resource class determination task of this study, the following separate (but linked) reports will be required, of which this is the third:

1. Linking the Value and Condition of the Resource report
2. Quantification of the Ecological Water Requirements and changes in Ecological Goods, Services and Attributes (EGSA) report
3. Ecologically sustainable base configuration scenario (ESBC) report (this report)
4. Evaluation of Classification Scenarios report

This report is a sub-set (Step 4a) of the fourth step of the classification procedure as outlined by the DWS (DWAF, 2007a). The objective of Step 4a is to set up the Ecologically Sustainable Base Configuration (ESBC) scenario in preparation for the analysis of proposed alternative classification scenarios. A critical component of this is setting up the necessary tools used to establish the other configuration scenarios. . The setting up of the other scenarios that form part of sub-Steps 4b and 4c are also outlined in this report but their analysis and evaluation are executed during Step 5 of the 7-step WRCS procedure.

This includes a pre-yield model analysis tool called the **basin configuration tool** which is described in this report and is used to determine the necessary flows at different locations in the catchment in order to meet the required ecological category at critical, or priority nodes which will be used to determine the overall impact (social, economic and environmental) of the different scenarios. The ESBC scenario is the minimum flow scenario that sustains the lowest acceptable D-conditions for water resources basin-wide.

The proposed scenarios framework, including the ESBC scenario, was first described in the Linking Value and Condition of Water Resource report and has been refined as shown in Table E1.

Table E1. Description of configuration scenarios

#	Scenario	Abbreviation	Description
1	Maintain Present Ecological Status ("Baseline")	PES	River, wetland and estuary systems are maintained in their present condition, or where currently in an E or F, improved to a D as far as possible. The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario
2	Ecologically Sustainable Base Configuration (ESBC) Scenario (also called the "Bottom-line" Scenario)	ESBC	The maximum volume of water is made available for abstraction from the system for economic activities, with the provision that all water resources are just maintained in a D category (the ecological "bottom line"). The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario

#	Scenario	Abbreviation	Description
3	Recommended Ecological Categories (RECs)	REC	The RECs determined for rivers, wetlands and estuaries based on present health and conservation importance (but without any consideration of socio-economic effects) are applied in this scenario. The implications for water supply are tested under both (a) the current level of economic development and (b) projected demands under a high growth scenario
4	High future demands	High Dev	This development-focussed scenario presents the situation where the water demand for the future level of economic development (assuming high growth in future water demands) are met. The resulting ecological categories are not constrained and may result in ECs of worse than a D category.
6	Climate change	CC(10)	The shifts that climate change might cause to the ecological conditions of nodes across the Study Area was assessed by modelling catchment streamflow changes relative to current day for the 10th percentile case selected from the "drying" side of the spectrum of outcomes of a wide range of climate change impact models for different emission scenarios (Cullis *et al*, 2015) covering the whole of Southern Africa. For every node the proportional mean monthly streamflow changes under the CC(10) scenario were super-imposed on the current day mean monthly streamflow values at that node. These changed nodal mean monthly streamflow values were then input to the basin configuration tool.

Establishing the Ecologically Sustainable Base Configuration scenario aims to route flows through the network of biophysical and allocation nodes such that the minimum ecological conditions (i.e. D-condition EWRs) are met in the rivers basin-wide and at the estuaries. This is achieved by first putting the estuary requirements in place (i.e. D-condition), and then working in an upstream direction from the estuary through the node network, setting flows in place to ensure that the necessary flows are routed down the system to maintain the estuary condition. The bottom line condition of each node is then established as either a D or whichever higher category is required to maintain all the downstream nodes in at least a D (Figure E1).

USE OF BASIN CONFIGURATION TOOL TO SET THE ESBC

In order to set up the ESBC and other scenarios a "**basin configuration tool**" was developed in Excel. Average monthly flows for Natural, Current and each of the ecological categories were used and flows are routed from one node to the next in a downstream direction. This was set up so that if a particular ecological category was chosen for a node, the monthly flows associated with that category were selected and routed to the next node (and so on down the system), in order to assess whether those flows would provide what was required for chosen ecological categories at downstream nodes.

The tool reports "surpluses" and "deficits" at each node for the category specified annually, monthly, and for wet and dry seasons, relative to current. If a chosen category upstream does not provide the required flows at a downstream node, the deficit or surplus can be reported and / or the category can be changed until the requirement is met. In the subsequent scenario analysis, the yield model, and groundwater models will be used to assess how the deficits could be remedied, and the concomitant socio-economic effects of the outcome thereof. In the case of surpluses, once verified in the yield model, the potential benefits of the water thus available for abstractive uses can be assessed. This is done as part of the scenarios evaluation phase and in some cases involves additional analysis of potential impacts on yield.

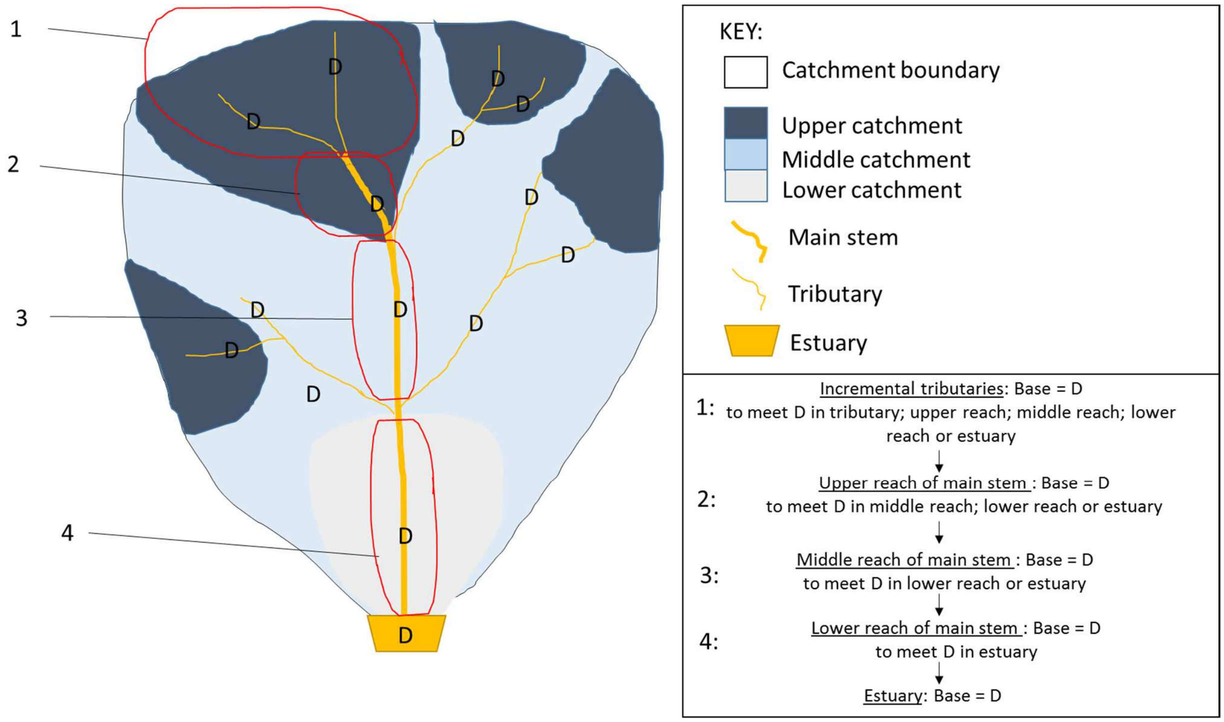

Figure E1. Schematic illustrating a downstream dependence on upstream condition for a hypothetical, simplified catchment (adapted from DWAF, 2007b)

COMPARING THE ESBC TO CURRENT DAY FLOWS

The volumes resulting from the ESBC are reported as surpluses or deficits relative to current day at each node according to groups of Integrated Units of Analysis (IUAs). The IUAs of the Breede River basin and the Overberg area and those of the Gouritz River basin and the Outeniqua area are reported separately.

PREPARATION OF OTHER DATA FOR SCENARIO ANALYSIS

In the work leading up to the *Evaluation of Scenarios* Report, the surface water yield model will be adjusted in an attempt to meet the deficits reported for the Ecologically Sustainable Base Configuration and also to meet the Reserve requirements of the other scenarios. So too, will the outcomes of the scenario analyses be evaluated in terms of their impacts on river ecological condition, water quality, availability of groundwater, impacts on wetlands and socio-economic outcomes of these. A short background to preparation of these other data is provided.

THE WAY FORWARD

After completing the ESBC scenario, the balancing tool will be used to set up the necessary ecological category requirements at all nodes in order to achieve the target objectives of the alternative proposed classification scenarios including the Present Ecological Scenario (PES), the Recommended Ecological Category (REC) scenario, as well as the high development and future climate change scenarios. The scenarios analysis will then consider the associated social, economic and environmental impacts of these alternative configuration scenarios in order to assess the overall impact and to agree with stakeholders on the final recommended classification scenario for each resource unit and the individual IUAs in the WMA.

The results of this analysis will be presented in the next report produced as part of this study.

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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 Regulation 810, dated 17 September 2010.

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 class in accordance with the prescribed classification system; and
- Resource quality objectives based on the class determined in terms of paragraph (a).

In accordance with the above section of the NWA, the Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned a study to determine Water Resource Classes and associated Resource Quality Objectives (RQOs) for all significant water resources in the Breede-Gouritz Water Management Area (WMA). The Study Area covers all significant water resources of the Breede-Gouritz WMA (see Figure 1.1 on page 2).

The Breede River basin comprises the Breede River, its main tributary, the Riviersonderend River, and other smaller coastal rivers in the Overberg region, including the Palmiet, Rooi-Els, Onrus, Klein, Bot, Uilkraals, Ratel, Heuningnes, Klipdriftsfontein, Duiwenhoks, Hartenbos and Sout Rivers. The Gouritz River basin comprises the Gouritz River, formed from the junctions of the Buffels, Touws, Groot, Gamka and Olifants Rivers, along with other smaller coastal rivers in the Outeniqua region, such as the Goukou, Klein Brak, Groot Brak, Kaaimans, Touws, Karatara, Goukamma, Swart, Maalgate, Gwaing, Noetsie, Knysna, Piesang and Keurbooms Rivers.

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 in the Breede-Gouritz Water Management Area (WMA).
- Determine RQOs using the DWS Procedures to Determine and Implement RQOs for all significant water resources in the Breede-Gouritz WMA.

This report presents the Ecological Sustainable Base Configuration (ESBC) for the Study Area and is part of a series of reports that will be prepared as part of the determining the water resource classes:

1. Linking the Value and Condition of the Resource report
2. Quantification of the Ecological Water Requirements and changes in Ecological Goods, Services and Attributes (EGSA) report
3. **Ecologically sustainable base configuration scenario (ESBC) report (this report)**
4. Evaluation of Classification Scenarios report

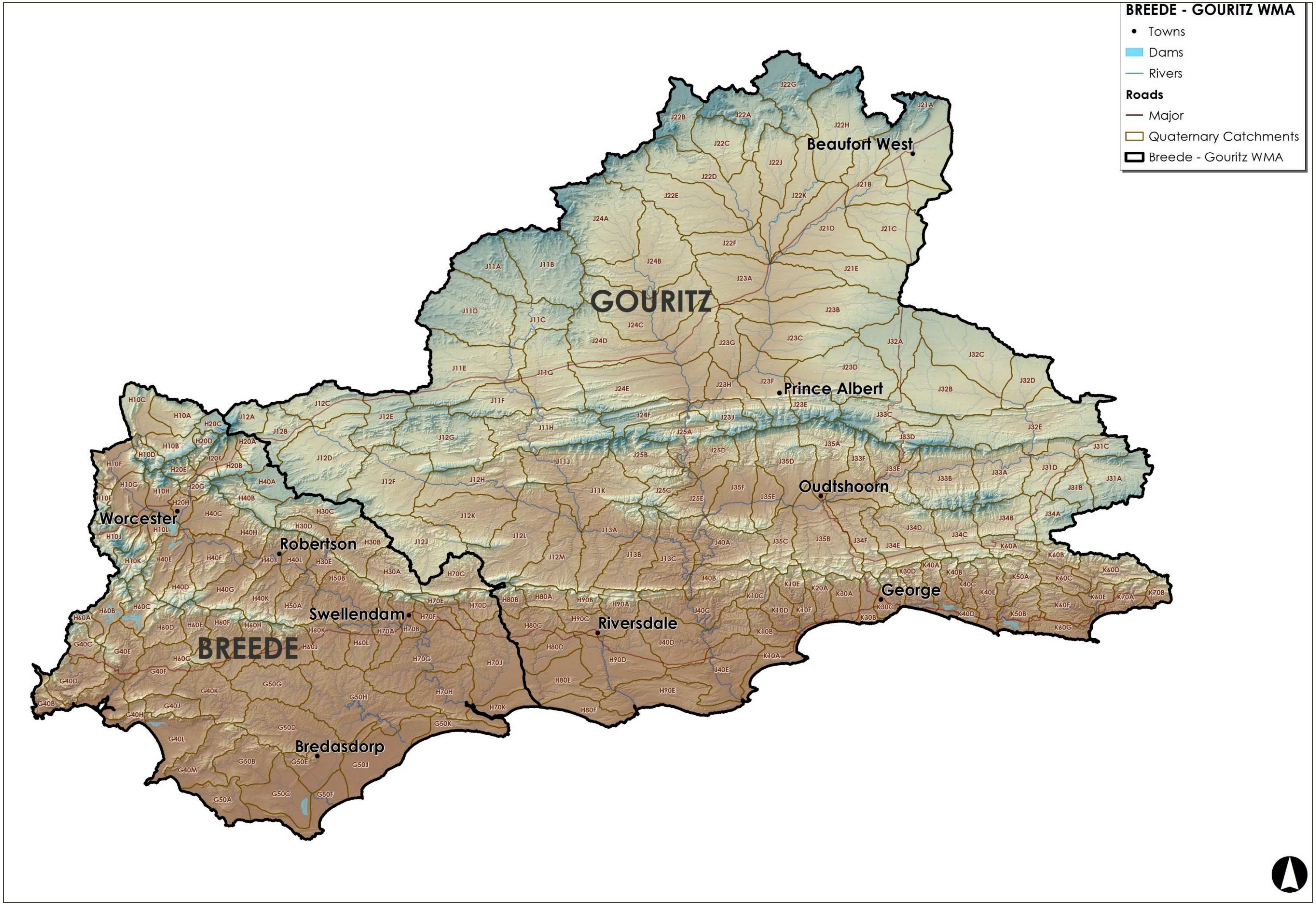

Figure 1.1 Map of the study area

1.3 Purpose of this report

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

This report primarily covers the sub-Step 4a of the fourth step of the classification procedure as outlined by the DWS (DWAF, 2007a). The objective of Step 4a is to set up the Ecologically Sustainable Base Configuration (ESBC) scenario in preparation for the analysis of proposed alternative classification scenarios. A critical component of this is setting up the necessary tools used to establish the other configuration scenarios. The setting up of the other scenarios that form part of sub-Steps 4b and 4c are also outlined in this report but their analysis and evaluation are executed during Step 5 of the 7-step WRCS procedure.

STEP 1: Delineate the units of analysis and describe the status quo of the water resources.
STEP 2: Link the value and condition of the water resource.
STEP 3: Quantify the Ecological Water Requirements and changes in non-water quality Ecosystem Goods, Services and Attributes.
STEP 4: Determine an Ecologically Sustainable Base Configuration scenario and establish the starter configuration scenarios.
STEP 5: Evaluate scenarios within the Integrated Water Resource Management (IWRM) process.
STEP 6: Evaluate the scenarios with stakeholders.
STEP 7: Gazette the class configuration.

Figure 1.2 7-Step Procedure to determine Water Resource Classes

The ESBC is the minimum environmental flow scenario that sustains the lowest acceptable D-conditions for water resources basin-wide. In this report (and in the project from here on) it is suggested that the suffix *bottom line* is attached to the ESBC when describing this scenario, to avoid confusion between this and the baseline scenario that maintains PES (baseline 2014) *viz.* ESBC (bottom line).

The ESBC and the other scenarios were first described in the *Linking Value and Condition of Water Resource* Report (DWS, 2017a) and have been refined in this report as described in Table 1.1:

Table 1.1 Description of configuration scenarios

#	Scenario	Abbreviation	Description
1	Maintain Present Ecological Status ("Baseline")	PES	River, wetland and estuary systems are maintained in their present condition, or where currently in an E or F, improved to a D as far as possible. The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario

#	Scenario	Abbreviation	Description
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3	Recommended Ecological Categories (RECs)	REC	The RECs determined for rivers, wetlands and estuaries based on present health and conservation importance (but without any consideration of socio-economic effects) are applied in this scenario. The implications for water supply are tested under both (a) the current level of economic development and (b) projected demands under a high growth scenario
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6	Climate change	CC(10)	The shifts that climate change might cause to the ecological conditions of nodes across the Study Area was assessed by modelling catchment streamflow changes relative to current day for the 10th percentile case selected from the "drying" side of the spectrum of outcomes of a wide range of climate change impact models for different emission scenarios (Cullis *et al*, 2015) covering the whole of Southern Africa. For every node the proportional mean monthly streamflow changes under the CC(10) scenario were super-imposed on the current day mean monthly streamflow values at that node. These changed nodal mean monthly streamflow values were then input to the basin configuration tool.

In order to determine the configuration of ecological water requirements (EWRs) and all nodes, a pre-yield screening model (called the **basin configuration tool** in this report) was set up to assess whether the present day flows are sufficient to meet these EWRs. This is described in more detail in Section 3 of this Report.

Establishing the ESBC scenario aims to route flows (and their associated ecological conditions per node, see Section 2 of this Report) through the network of biophysical and allocation nodes, such that minimum D-condition flows are met in the rivers basin-wide and finally at the estuaries which represent the outlet of each catchment (Figure 1.3). Normally, even though flows are finally routed in a downstream direction, establishing this bottom-line configuration is approached first by putting the estuary requirements in place (D-condition), and then working in an upstream direction from the estuary through the node network setting flows in place to maintain this. The bottom line condition of each node is then established as either a D or whichever higher category is required to maintain all downstream nodes in at least a D condition.

Since EWRs are calculated from natural flows, the EWRs for the targeted ecological category (EC) often exceed flows of the present day, reduced relative to natural by water demands basin-wide. This is especially the case in the Western Cape where water use is high during the peak growing season that coincides with the low flow periods during the dry season. That being the case, it is necessary to check that these bottom line EWRs can be met by flows of the present day. Inevitably deficits result where the EWRs exceed present day flows, normally during the dry season. In these cases it may be possible to increase flow supplied to a node in deficit (*viz.* with negative cumulative flow) to balance out the deficit.

The flows required to meet the ecological conditions of the bottom line scenario (EBSC) are compared to that of the present day using the pre-yield model (basin configuration tool) in Section 4 of this Report. The results of this analysis will show deficits and surpluses of flow (water volumes) between the EWRs for the ESBC and present day flows. A deficit results when EWRs for the targeted ecological category (EC) exceed flows of the present day, a surplus occurs when present day flows exceed the EWRs for the target EC.

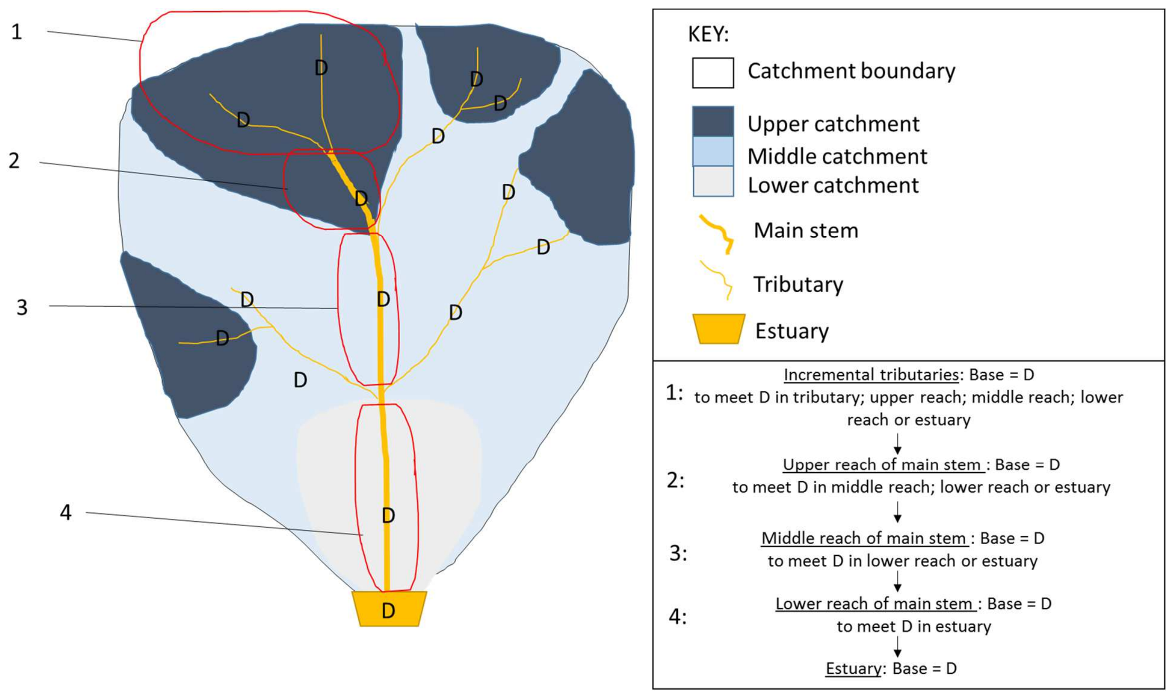

Figure 1.3 Schematic illustrating a downstream dependence on upstream condition for a hypothetical, simplified catchment (adapted from DWAF, 2007b)

In the Scenario analysis report, the surface water yield model will be adjusted in an attempt to surpass the deficits reported for the ESBC and also to meet the EWR requirements of the target ecological categories for the other scenarios. So too, will the outcomes of the scenario analyses be evaluated in terms of their impacts on river ecological condition, water quality, availability of groundwater, impacts on wetlands and socio-economic outcomes of these.

A short background to preparation of these other data is provided in Section 5 of this Report.

2 Integrated Units of Analysis (IUAs) and location of nodes for analysis

2.1 Delineation of Integrated Units of Analysis

A total of 18 Integrated Units of Analysis (IUAs) have been delineated in the Breede-Gouritz WMA. The IUAs approximate socio-economic boundaries, delineated to facilitate the integration of ecological and socio-economic aspects required for the evaluation of scenarios in the next report, *Evaluation of Scenarios*. The delineation of these IUAs are described in the Delineation Report (DWS 2016a) and are summarised in Table 2.1.

Table 2.1 IUAs delineated in the Breede-Gouritz WMA

IUA Code	IUA Name	Quaternary Catchments
A1	Upper Breede Tributaries	H10A H10B H10C H10D H10E H10F H10J H10K H20C H20D H20E
A2	Breede Working Tributaries	H10G H10H H10L H20A, H20B H20F H20G H20H H30A H30B H30C H30D H40A H40B H40C H40H H40J H80D
A3	Middle Breede Renosterveld	H30E H40D H40E H40F H40L H40G H40K H50A H50B
B4	Riviersonderend Theewaters	H60A H60B H60C H60D H60E H60F
F9	Lower Riviersonderend	H60G H60H H60J H60K H60L
F11	Lower Breede Renosterveld	H70A H70B H70C H70D 70E H70F H70G H70H H70J H70K
H16	Overberg West Coastal	G40B G40H G40G
B5	Overberg West	G40C G40D G40E
F10	Overberg East Renosterveld	G40F G40J G40K G50D G50H G50G
H17	Overberg East Fynbos	G40L G40M G50A G50B G50C G50E G50F G50J G50K
F12	Duiwenhoks	H80A H80B H80C H80D H80E H90A H90B H90C H90D
I18	Hessequa	H80F H90E
E8	Touws	J11H J11J J11K J12A J12B J12C J12D J12E J12F J12G J12H J12J J12L J12K J12M J13A J13B J13C
C6	Gamka-Buffels	J11A J11B J11C J11D J11E J11F J11G J21A J21B J21C J21E J22A J22B J21D J22C J22D J22E J22F J22G J22H J22J J22K J23A J23B J24A J24B J24C J24D J24E J32A J23C J23D J23G J23F**J23H**
D7	Gouritz-Olifants	J23E J23F** J23H** 23J J24F 25A J25D J25E J25B J25C J31A J31B J31C J31D J32B J32C J32D J32E J33A J33B J33C J33D J33E J33F J34A J34B J34C J34D J34F J35A J35B J35D J35F J35E J35C J34E J40A J40B
F13	Lower Gouritz	J40C J40D J40E
G14	Groot Brak	K10A K10B K10C K10D K10E K10F K20A
G15	Coastal	K30A K30B K30C K30D K40A K40B K40C K40D K40E K50A K50B K60A K60B K60C K60D K60E K60F K60G K70A K70B

***: J23F and J23H shared between Gamka-Buffels and Gouritz-Olifants IUAs*

2.2 Location of River and Estuary Nodes

A total of 145 river and estuary nodes have been identified in the Breede-Gouritz WMA. There are 67 nodes in the Breede River basin and Overberg region (Table 2.2), and 78 in the Gouritz River basin and Outeniqua region (Table 2.3). The process for identification of these nodes is described in the Delineation and EWRs Report (DWS 2016a). The locations of the nodes are shown in Figure 2.1 and Figure 2.2. It should be noted that in these maps each river system has a unique EWR site numbering sequence starting at EWR1. This numbering system relates to the original numbering system for the study. In the table below the name of the associated river appears before the EWR site number. There are 13 EWR sites in the Breede River basin and Overberg region, and 26 in the Gouritz basin and Outeniqua region.

The nodes indicated by a star are the nodes for which Reserve determination studies have been undertaken in order to determine the Ecological Water Requirements (EWRs) for different ecological categories. These EWR nodes are indicated in **red** and named with associated EWR site in the tables.

Table 2.2 Nodes in the Breede River basin and Overberg region

IUA	SQ code	NODE	RIVER	LONG	LATI	QUAT	2014EC
A1	H10C-08644	Niv2	Dwars	19.3006	-33.3544	H10C	C
A1	H10C-08560	Niv1	Koekedou	19.2983	-33.35961	H10C	D
A1	H10B-08700	Niv3	Titus	19.3236	-33.3798	H10C	C
A1	H10D-08755	Niv4	Witels	19.2924	-33.4174	H10D	A
A1	H10F-08730	Nvi3	Breede	19.2684	-33.4214	H10D	C
A1	H10E-08836	Nvii16	Witte	19.1081	-33.4214	H10E	A
A1	H10E-08836	Niv5	Witte	19.1994	-33.5357	H10F	A
A1	H10F-08804	Niv6	Wabooms	19.2062	-33.5382	H10F	D
A1	**H10G-08837**	**Nviii1**	**Breede EWR 1-D**	**19.2073**	**-33.5398**	**H10F**	**D**
A2	H10G-08889	Niv7	Slanghoek	19.2402	-33.5766	H10G	D
A2	H10G-08844	Niii1	Breede	19.3491	-33.6536	H10G	D
A1	H10J-09038	Niv40	Elands	19.1157	-33.7338	H10J	B
A1	H10J-09000	Niv41	Krom	19.1123	-33.7301	H10J	B
A1	**H10J-08990**	**Nvii2**	**Molenaars EWR 2-B**	**19.1709**	**-33.7239**	**H10J**	**B**
A2	H10L-08968	Niv42	Smalblaar	19.3159	-33.6899	H10J	E
A2	H10H-08826	Niv8	Jan du Toit/Bothaspruit	19.3634	-33.6471	H10H	D
A2	H10H-08850	Nvii6	Hartbees	19.4359	-33.5589	H10H	D
A2	H10H-08850	Niv9	Hartbees	19.3747	-33.6519	H10H	D
A2	H10K-08972	Niv12	Holsloot	19.3251	-33.6940	H10K	C
A2	J10H-08895	Nv3	Breede	19.4510	-33.6928	H10L	C
A2	**H20H-08839**	**Nvii7**	**Hex EWR 3-C**	**19.5033**	**-33.5784**	**H20G**	**C**
A2	H20H-08839	Niv10	Hex	19.4565	-33.6941	H20H	D
A2	H40C-08935	Nii1	Breede	19.4638	-33.7037	H40C	C
A2	H40B-08890	Nvii5	Koo	19.7629	-33.5973	H40B	D
A2	H40C-08999	Niv11	Nuy	19.4813	-33.7180	H40C	E
A3	H40D-09051	Niv13	Doring	19.5158	-33.7690	H40D	E
A3	**H40F-09026**	**Nvii8**	**Breede EWR 3-CD**	**19.6947**	**-33.8187**	**H40F**	**CD**
A3	H40G-09126	Nvii11	Poesnels	19.7240	-33.8666	H40G	D
A3	H40H-09039	Niv15	Vink	19.7975	-33.8241	H40H	D
A3	H40J-09007	Nviii2	Willem Nels	19.8640	-33.8163	H40J	D
A3	H40J-09072	Nvii19	Breede	19.8905	-33.8472	H40J	B
A3	H40K-09118	Niv14	Keisers	19.8899	-33.8503	H40K	D
A2	H30C-08991	Niv20	Pietersfontein	20.1083	-33.7419	H30C	D
A2	H30D-09015	Nvii9	Keisie	20.1068	-33.7928	H30D	D
A2	H30B-08978	Niv18	Kingna	20.1160	-33.7928	H30B	D
A3	H30E-09032	Nii2	Kogmanskloof	20.0032	-33.8704	H30E	D

IUA	SQ code	NODE	RIVER	LONG	LATI	QUAT	2014EC
A3	H50B-09129	Ni2	Breede	20.2866	-'34.0686	H50B	D
B4	H60B-09162	Nvii10	Du Toits	19.1539	-33.9795	H60B	B
B4	H60D-09239	Nv7	Riviersonderend	19.4633	-34.0636	H60D	C
B4	**H60E-09127**	**Niv28**	**Baviaans EWR 6-B**	**19.5567**	**-34.0633**	**H60E**	**C**
B4	H60E-09302	Niv29	Sersants	19.5591	-34.0660	H60E	D
B4	H60F-09248	Niv30	Gobos	19.6091	-34.0705	H60F	C
B4	**H60F-09277**	**Nv9**	**Riviersonderend EWR 5-D**	**19.7049**	**-34.1178**	**H60F**	**D**
F9	H60G-09321	Niv31	Kwartel	19.703	-34.1202	H60G	D
F9	H60H-09275	Niv33	Soetmelksvlei	19.7563	-34.1185	H60H	D
F9	H60H-09280	Niv34	Slang	19.8113	-34.1277	H60H	C
F9	H60H-09288	Nv10	Riviersonderend	19.8562	-34.1265	H60H	D
F9	H60K-09297	Niv35	Kwassadie	20.1414	-34.0853	H60K	E
F9	H60L-09270	Ni3	Riviersonderend	20.2851	-34.0703	H60L	D
F11	H50B-09129	Niv24	Leeu	20.3186	-34.0859	H70A	E
A3	H70B-09251	Nv2	Breede	20.5172	-34.0656	H70B	C
F11	H70D-09157	Nii3	Tradouw	20.7077	-33.9413	H70D	B
F11	H70F-09226	Niv25	Buffeljags	20.5188	-34.0960	H70F	E
F11	**H70G-09345**	**Niii4**	**Breede EWR 4-BC**	**20.5146**	**-34.2337**	**H70G**	**C**
F11	H70J-09358	Niv26	Slang	20.7149	-34.3573	H70J	E
B5	**G40C-09305**	**Piii1**	**Palmiet EWR 1-B**	**19.05545**	**-34.1143**	**G40C**	**C**
B5	U	Piv10	Witklippieskloof	19.03684	-34.1463	G40C	D
B5	G40C-09305	Piv9	Palmiet	19.02777	-34.1488	G40C	D
B5	U	Piv8	Klipdrif	19.02679	-34.1487	G40C	D
B5	U	Piv4	Klein-Palmiet	18.98786	-34.2458	G40D	D
B5	G40D-09333	Piv7	Krom/Ribbok	19.04561	-34.2483	G40D	D
B5	**G40D-09369**	**Piii2**	**Palmiet EWR 3-BC**	**18.98457**	**-34.2857**	**G40D**	**C**
B5	U	Piv12	Dwars/Louws	18.93654	-34.2916	G40D	C
B5	**G40D-09369**	**Piii3**	**Palmiet EWR 4-B**	**18.99073**	**-34.3305**	**G40D**	**B**
H16	G40G-09370	Niii5	Bot	19.2008	-34.2635	G40G	C
H16	G40H-09398	Nx6	Onrus	19.2511	-34.3599	G40H	E
F10	G40F-09365	Niv43	Swart	19.2192	-34.2589	G40F	E
F10	G40K-09349	Niv45	Steenbok	19.5357	-34.3275	G40K	E
F10	G40J-09395	Nii4	Hartbees	19.5337	-34.3923	G40J	D
F10	**G40L-09411**	**Nv23**	**Klein EWR Kle1-C**	**19.6022**	**-34.4058**	**G40K**	**C**
F10	G50G-09352	Nii6	Sout	20.0238	-34.2921	G50H	D
F10	G50H-09406	Nii7	DeHoopVlei	20.3117	-34.4051	G50H	B
H17	G40M-09414	Nx8	Uilkraal	19.6926	-34.4601	G40M	C
H17	**G50B-09418**	**Ni4**	**Nuwejaar EWR Nuw1-D**	**19.8317**	**-34.6301**	**G50B**	**D**
H17	G50C-09432	Nvii15	Heuningnes	19.9575	-34.7214	G50C	D
H17	G50C-09432	Niv44	Heuningnes	20.1020	-34.6575	G50C	D
H17	**G50E-09404**	**Nv24**	**Kars EWR Kar1-B**	**20.1275**	**-34.4996**	**G50E**	**B**
H17	G50E-09427	Nii5	Kars	20.0141	-34.6722	G50C	E

Where IUA = Integrated Unit of Analysis: U = unclassified; SQ = Sub-quat; Long = Longitude, Lati = latitude; 2014EC = Baseline Ecological Condition 2014.

Table 2.3 Nodes in the Gouritz River basin and Outeniqua region

IUA	SQ code	CODE	RIVER	LONG	LATI	QUAT	2014EC
E8	J12D-08735	giv28	Touws	20.2714	-33.4567	J12D	D
E8	J12H-08834	giv27	Touws	20.9021	-33.6208	J12H	B
E8	J12K-08887	giv26	Brak	20.9042	-33.6280	J12K	C
E8	**J12L-08985**	**gviii1**	**Doring EWR 7-CD**	**20.9274**	**33.7904**	**J12L**	**CD**
E8	**J12M-08904**	**gv5**	**Touws EWR 3-BC**	**21.0896**	**-33.6779**	**J12M**	**BC**
C6	J11C-08151	giv34	Buffels	20.8783	-33.0691	J11C	B
C6	J11F-08427	gv25	Buffels	20.9646	-33.2511	J11F	C
E8	**J11J-08686**	**gv4**	**Buffels EWR 5-C**	**20.9852**	**-33.4657**	**J11J**	**D**
E8	J11K-08860	giv32	Groot	21.1842	-33.7316	J11K	D
E8	J13B-08923	gv7	Groot	21.4334	-33.7421	J13B	C
E8	J13C-09099	gii3	Groot	21.6543	-33.8861	J13C	B
C6	J21D-07700	giv3	Gamka	22.0363	-32.7307	J21D	B
C6	J22F-07805	giv1	Koekemoers	21.9763	-32.7606	J22F	C
C6	J22K-07655	giv2	Leeu	21.9798	-32.7559	J22K	C
C6	J23F-08268	gv17	Gamka	21.93780	-33.0868	J23F	B
C6	J23J-08497	gv27	Gamka	21.6679	-33.2840	J23J	C
C6	J24E-08292	gv14	Dwyka	21.6083	-33.1444	J24E	A
D7	**J25A-08567**	**giv20**	**Gamka EWR 4-CD**	**21.6243**	**-33.4941**	**J25A**	**C**
D7	J25E-08884	gii2	Gamka	21.7142	-33.6784	J25E	C
D7	**J31D-08592**	**giii2**	**Olifants EWR-9 C**	**23.2932**	**-33.4469**	**J31C**	**C**
D7	J32E-08545	giv15	Traka	23.0952	-33.4392	J32E	C
D7	J33B-08714	gv33	Olifants	22.6869	-33.5082	J33B	D
D7	J33D-08571	gv21	Meirings	22.5447	-33.4810	J33E	C
D7	J33F-08772	giv11	Olifants	22.2434	-33.6147	J33F	E
D7	**J34C-08869**	**gv36**	**Kammanassie EWR 10-CD**	**22.6969**	**-33.7319**	**J34D**	**CD**
D7	J34F-08848	giv10	Leeu	22.2404	-33.6241	J34F	E
D7	J35E-08764	gv19	Olifants	22.0332	-33.6143	J35E	E
D7	J35F-08739	giv17	Olifants	21.7226	-33.6805	J35F	D
D7	**J40B-09106**	**gi4**	**Gouritz EWR 6-C**	**21.6539**	**-33.9786**	**J40B**	**C**
F13	J40E-09284	gv9	Gouritz	21.7388	-34.1564	J40E	C
F12	H80C-09208	giii5	Duiwenhoks	20.9314	-34.0163	H80B	E
F12	**H80E-09314**	**giii8**	**Duiwenhoks EWR-1D**	**20.9902**	**-34.2475**	**H80D**	**D**
F12	H90B-09155	giii6	Korinte	21.2330	-34.0346	H90C	D
F12	**H90C-09229**	**giii7**	**Goukou EWR 2-CD**	**21.3386**	**-34.0732**	**H90C**	**CD**
I18	H90E-09343	gv41	Goukou	21.3395	-34.3107	H90E	C
G14	K10D-09163	giv25	Brandwag	22.1163	-34.0632	K10D	D
G14	**K10F-09139**	**gv39**	**Moordkuil EWR Moo1-BC**	**22.1276**	**-33.9928**	**K10F**	**D**
G14	K20A-09083	gvii7	Groot Brak	22.2227	-34.0292	K20A	BC
G14	**K20A-09083**	**gviii2**	**Groot Brak EWR GB1-BC**	**22.1932**	**-33.9781**	**K20A**	**BC**
G14	**U**	**gviii3**	**Varing EWR Var-3CD**	**22.2320**	**-33.9973**	**K20A**	**D**
G14	**U**	**gviii12**	**Varing EWR Var-2CD**	**22.2412**	**-33.96**	**K20A**	**CD**
G15	K30A-09087	gviii4	Maalgate	22.3320	-33.9883	K30A	B
G15	**K30A-09087**	**gvii8**	**Maalgate EWR Maa-2D**	**22.3512**	**-34.0077**	**K30A**	**D**
G15	**K30B-09082**	**gvii9**	**Malgas EWR Mal1-C**	**22.4210**	**-33.9529**	**K30B**	**C**

IUA	SQ code	CODE	RIVER	LONG	LATI	QUAT	2014EC
G15	**K30B-09151**	**gviii6**	**Gwaing EWR Gwa1-D**	**22.418**	**-33.9889**	**K30B**	**E**
G15	**K30C-09093**	**gviii7**	**Swart EWR Swa1-D**	**22.5217**	**-33.9675**	**K30C**	**D**
G15	**K30C-09065**	**gvii11**	**Kaaimans EWR Ka1-B**	**22.5472**	**-33.9714**	**K30C**	**B**
G15	**U**	**gviii8**	**Silver EWR Si1-B**	**22.5561**	**-33.9767**	**K30C**	**B**
G15	K30D-09042	gvii12	Touws	22.6128	-33.9459	K30D	B
G15	K30D-09108	gx8	Klein Keurbooms	22.6543	-33.9757	K30D	D
G15	**K40A-09027**	**giii10**	**Diep EWR 2-B**	**22.7089**	**-33.9338**	**K40A**	**B**
G15	K40B-09022	giii13	Hoekraal	22.8007	-33.9784	K40B	B
G15	**K40C-09036**	**gvii13**	**Karatara EWR 4-AB**	**22.8383**	**-33.8830**	**K40C**	**B**
G15	K40C-09140	giii11	Karatara	22.8271	-33.9977	K40C	AB
G15	**K40E-09016**	**gviii9**	**Goukamma EWR Gou1-BC**	**22.9192**	**-33.9477**	**K40E**	**BC**
G15	**K50A-09069**	**gvii14**	**Knysna EWR 1-B**	**23.0308**	**-33.8935**	**K50A**	**B**
G15	K50B-09111	giii12	Knysna	23.0016	-33.9872	K50A	B
G15	**K50B-09117**	**gviii11**	**Gouna EWR 2-AB**	**23.0346**	**-33.9862**	**K50B**	**AB**
G15	**K60G-09180**	**gviii10**	**Noetzie EWR Noe1-AB**	**23.1376**	**-34.0663**	**K60G**	**B**
G15	K60G-09200	gx3	Piesang	23.3314	-34.0651	K60G	D
G15	K60F-09092	giv4	Bitou	23.3847	-34.0069	K60F	C
G15	**K60C-08992**	**giv6**	**Keurbooms EWR 8-B**	**23.3618**	**-33.9271**	**K60C**	**C**
G15	K60D-08996	giv5	Palmiet	23.3720	-33.9253	K60D	A
G15	K60E-09097	gx9	Keurbooms	23.4018	-33.9573	K60E	C
G15	K70A-09110	gx4	Buffels	23.4636	-33.9858	K70A	B
G15	K70A-09086	gx5	Sout	23.5189	-33.9731	K70A	B
G15	K70B-09055	gvii15	Bloukrans	23.64061	-33.9546	K70B	B

Where EWR = Ecological Water Requirement; IUA = Integrated Unit of Analysis: SQ = Sub-quat; U = unclassified; Long = Longitude, Lati = latitude; 2014EC = Baseline Ecological Condition 2014.

In addition to the existing Reserve determination studies for the identified EWR river nodes, Reserve determination studies have been carried out for 19 of the 26 significant estuaries in the Breede-Gouritz WMA plus two of the micro-estuaries (Table 2.4). The Onrus, Rooiels and Heuningnes Reserve studies were undertaken as part of this study (see Appendices of the *Quantification of the Environmental Water Requirements and changes in Ecosystems Goods, Services and Attributes* Report (DWS, 2017)).

Figure 2.1 Location of biophysical and allocation nodes in the Breede River basin and Overberg region

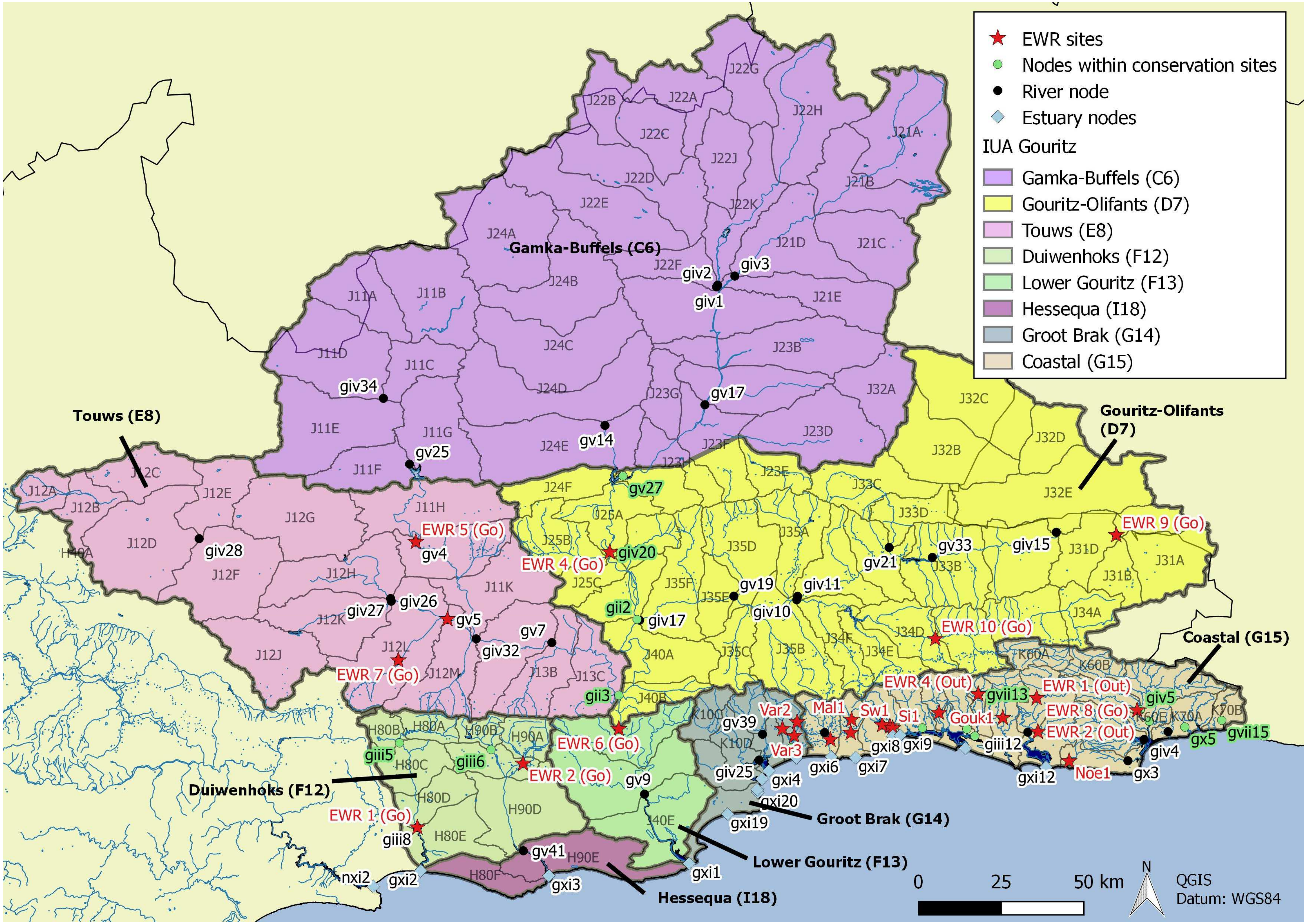

Figure 2.2 Locations of biophysical and allocation nodes in the Gouritz River basin and Outeniqua region

The 2012 National Biodiversity Assessment provides estimates of % MAR and PES for most estuaries in the study area. Both health assessments, from the National Biodiversity Assessment 2012, and Reserve studies involve scoring the present day situation using the Estuary Health Index (EHI), while Reserve studies also include a number of flow scenarios for estuaries that are also scored using the EHI.

Table 2.4 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 (million m^3)	Reserve (Scenarios)	PES	REC
Rooiels	Closed	16.03	1.9			Yes 4	B	B
Buffels (Oos)	Micro	4.73	1.3			-	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			-	C	C
Heuningnes[1]	Open	13 125.81	1451.5	3578	29.53	In Prog 5	C	A
Klipdrifsfontein	Micro	2.23	0.8			-	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			-	B	B
Tweekuilen	Micro	9.82	1.6			-	D	D
Gericke	Micro	3.62	0.9			-	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
Gwaing	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			Yes 5	B	B
Sout (Oos)	Micro	13.83	1.7			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

[1] Any estuary in a protected area or in a proposed or desired protected area must have a REC of "A" or "Best Attainable State". The BAS for an estuary is determined by experts as part of the RDM process. The Heuningnes estuary is located in the De Mond Nature Reserve and hence should have a REC of A of BAS. The BAS for the Heuningnes estuary was determined as an "A" category during the preliminary reserve determination process that was undertaken for this system. Thus, although the PES for this system is a C a REC of A is considered entirely achievable for this system.

3 Basin Configuration Scenario Tool

3.1 Introduction

In order to set up the ESBC and other scenarios a "**basin configuration tool**" was developed in Excel. Average monthly flows for Natural, Current, Future High-Growth and for each of the ecological categories were used and flows are routed from one node to the next in a downstream direction. This was set up so that if a particular ecological category was chosen for a node, the monthly flows associated with that category were selected and routed to the next node (and so on down the system), in order to assess whether those flows would provide what was required for chosen ecological categories at downstream nodes. Figure 3.1 depicts a schematic that illustrates downstream dependence on upstream conditions for a hypothetical, simplified catchment.

The tool reports "surpluses" and "deficits" at each node for the category specified annually, monthly, and for wet and dry seasons, relative to current. If a chosen category upstream does not provide the required flows at a downstream node, the deficit or surplus can be reported and / or the category can be changed until the requirement is met. In the subsequent scenario analysis, the yield model, and groundwater models will be used to assess how the deficits could be remedied, and the concomitant socio-economic effects of the outcome thereof. In the case of surpluses, once verified in the yield model, the potential benefits of the water thus available for abstractive uses can be assessed. This is done as part of the scenarios evaluation phase and in some cases involves additional analysis of potential impacts on yield.

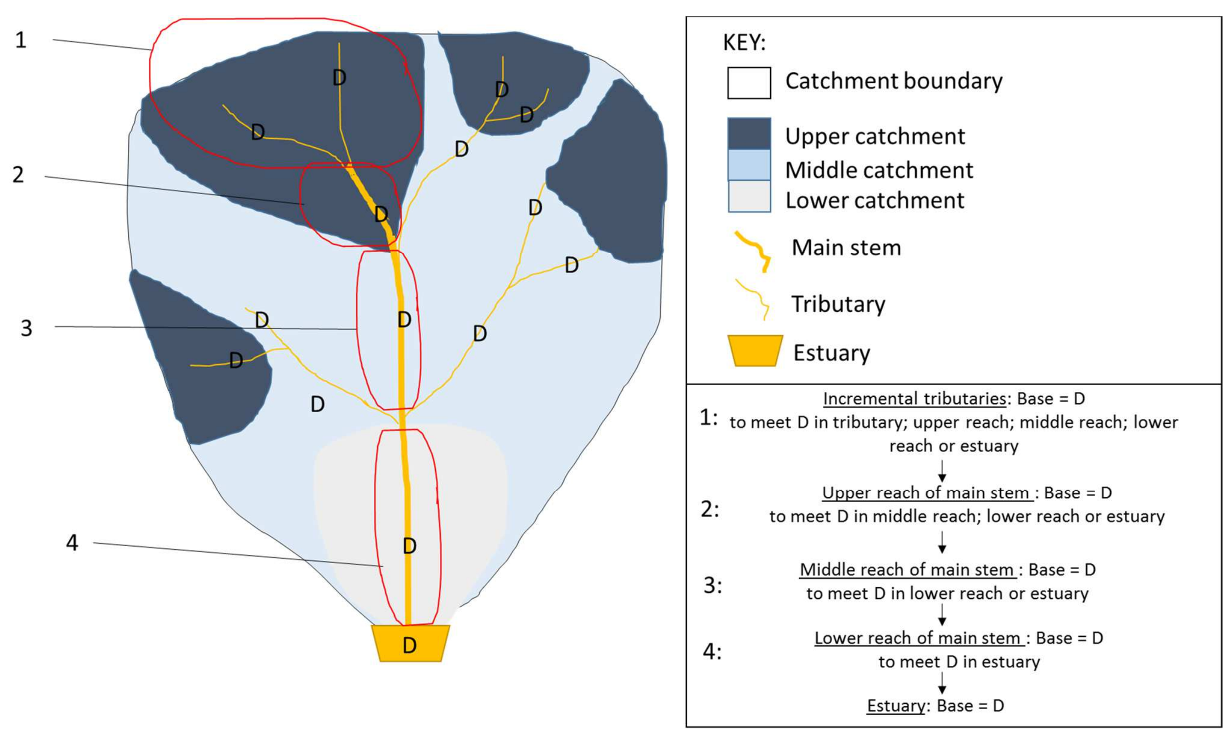

Figure 3.1 Schematic illustrating a downstream dependence on upstream condition for a hypothetical, simplified catchment (adapted from DWAF, 2007b)

3.2 The "Basin configuration tool"

The basin configuration tool (hereafter called the **tool**) is an EXCEL based model that was programmed to route flows through the river nodes to the estuaries; nodes represent various points of interest in the study area. As such the tool is a hydrological model that was created to model how changes in flow affect the ecological condition of rivers and estuaries, the two primary water resources where data from past Reserve studies are readily available. To achieve this, the tool calculates the ecological condition of rivers and estuaries (at the nodes) as the flows are increased or decreased, relative to flows of the current day.

It is important to note that Reserves (in terms of ecological water requirements) for rivers and estuaries were calculated based on percentage change from natural flows, *viz.* NOT relative to current day.

There are various inputs into the tool, some of which are related to the background programming and are not discussed here. The following description deals with the main inputs included in the basin configuration tool and used to construct the ecological scenarios (at each node):

- The location of each node geographically in the study area relative to the other nodes, up- and downstream respectively
- The ecological condition of each node (river and estuary)
- Naturalized hydrological monthly time series' (cumulative and incremental flows), calculated as volumes in Million Cubic Meters
- Current day hydrological monthly time series' (cumulative and incremental flows), calculated as volumes in Million Cubic Meters
- Hydrological monthly Reserve time series' (cumulative and incremental flows), calculated as volumes in Million Cubic Meters for a range of ecological categories

The location of each node, relative to the others, is important in the tool as flows are linked together in a downstream direction toward their receiving estuary. In some cases, there are a large number of nodes that are linked together in a network of tributaries and river channels of various orders, such as the Breede and Gouritz Rivers. In other cases, there are few, sometimes one, river node upstream of the estuary on one river channel, for example the Onrus and Bot Rivers in the Overberg; there are variations in between these two extremes. Whatever the case, for each receiving estuary, the different flows (listed above) associated with each node, the location of the node in the river network and its ecological condition are loaded into the tool (EXCEL spreadsheet).

The nodes are listed in a downstream direction with the distal nodes listed first. The tool calculates the cumulative flows in a downstream direction for each node by taking into account nodes that deliver flow from upstream. In short, for each node, the tool calculates and reports what the cumulative current day flows are. This is the primary data source against which all other flow calculations are made. The next main source of data for the flow calculations are the Reserve flows; provided for a range of ecological categories where rivers and estuaries in better condition maintain higher levels of flow.

3.3 Routing of flow requirements for each scenario

The Reserve flows were calculated using naturalized hydrological time series' at each node in the Desktop Model that calibrates Reserve flows based on flow sequences from Reserve studies, or the use of regional specific settings. The model only calculates intra-annual flows, *viz.* flows that include the small intra-annual floods (that occur every year) and excludes the larger inter-annual floods (1:2, 1:5, 1:10 etc.). Therefore, in order to compare various Reserve flows to the naturalized and current hydrological time series', which are TOTAL flows (inclusive of all floods), it was necessary to first put back the inter-annual floods into the Reserve hydrological time series' prior to any comparative calculations.

The starting point for calculations that compare the hydrological outcome of setting Reserve flows at a location or interest (node) therefore are naturalized, current day and Reserve TOTAL flow time series.

The other important data source in the tool, and necessary for scenario evaluation, is the present ecological status of each node. This is the baseline ecological condition of each (river and estuary) node, taken from the 2014 PES EIS data base (DWS 2014a), in the Western Cape these data were derived from field based studies, or the relevant Reserve study. The PES EIS data for the Gouritz River and Outeniqua region were reviewed and updated by the Gouritz River reserve team (DWS 2014b).

3.4 Linking flow requirements to ecological condition

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

- Ecological conditions were ranked into groups designated different ecological categories (Kleynhans and Louw 2007, Table 3.1)
- Current day and Reserve flows were ranked into groups designated different flow categories, based on their % differences to naturalized flow
- Changes in flow were linked to changes in ecological condition in a non-linear manner such that rivers/estuaries in good ecological condition were more responsive to changes in flow, whereas rivers/estuaries in poor ecological condition were less responsive to changes in flow
    - the premise being that poor ecological conditions often result from a combination of impacts, not just flow alone, and where this is the case an improved ecological condition requires multiple interventions, not flow manipulation alone

3.5 User interface and scenario analysis

The interface of the tool is:

- a list of nodes, associated with
    - incremental nodes that contribute flow at that point
    - river names
    - their location per quaternary and integrated unit of analyses
    - the present ecological status (baseline ecological condition)
    - the recommended ecological category at river and estuary Reserve study sites
- a program button per node that allows the user to change flow routed at each node from
    - current day, or
    - Reserve flows for different ecological categories

The user works from the various estuaries in an upstream direction, loading different flow volumes at each node and while doing so, the tool calculates how the cumulative flows at each node downstream changes, relative to current day flow, and calculates whether this relative change is sufficient, when compared to the flow sustaining the baseline ecological condition (current day), to improve the ecological condition of the water resource at that node, if flows are increased relative to current day, or degrade in response to decreases in flow.

As flow, and resulting ecological conditions change, the results calculated to per node include:

- Current ecological condition
- Annual scenario ecological condition
- Current day annual flow volume as a percentage of mean annual runoff
- Scenario annual flow volume as a percentage of mean annual runoff
- Cumulative current day annual flow volume in Million Cubic Meters (MCM)

- Scenario cumulative annual flow volume in MCM
- Surplus/deficit annual flow volume relative to current day
- Current day wet season average monthly flow volume as a percentage of mean annual runoff
- Current day dry season average monthly flow volume as a percentage of mean annual runoff

Table 3.1 Ecological categories and associated PES scores (Kleynhans et al., 2008)

Ecological Category	PES % Score	Description of the habitat
A	92-100	Still in a Reference Condition.
A/B	87-92	
B	82-87	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
B/C	77-82	
C	62-77	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.
C/D	57-62	
D	42-57	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
D/E	37-42	
E	22-37	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
E/F	17-2	
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 the tables of results from the tool, colouring is used to guide description and highlight changes. The ecological condition classes are coloured in the standard fashion, blue for better conditions, and red for poorer conditions, and green and orange in between. Other shading is used for the percentages of flow relative to natural mean annual runoff (nMAR) in the tables that follow). Here, light pink indicates a small change from natural, light orange a greater change, then darker orange and finally red to indicate a large degree of change in flow, relative to natural. Lastly, the surplus or deficit volumes per node, are also colour coded where light pink indicates a deficit and light blue indicates a surplus. Very small changes from natural or current day respectively, are not colour coded. Nodes in bold text are estuary nodes.

Illustration of the distribution of Ecological Categories on a continuum.

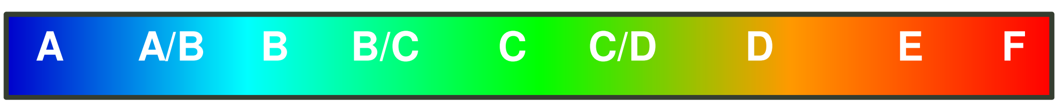

Illustration of the distribution of percentages of flow relative to mean annual runoff on a continuum.

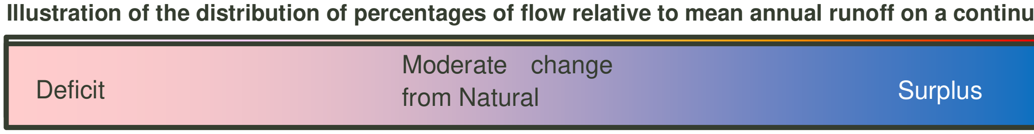

Illustration of the distribution of deficit or surplus flows on a continuum.

4 Results of the ESBC scenario

4.1 Introduction

The volumes resulting from the ESBC are reported as surpluses or deficits relative to current day at each node according to groups of Integrated Units of Analysis (IUAs). The IUAs of the Breede River basin and the Overberg area and those of the Gouritz River basin and the Outeniqua area are reported separately.

The results are reported in terms of groupings of IUAs, rather than individual IUAs noting that many of the IUAs are strongly linked hydrologically and hence the balancing of water requirements in order to meet a specified ecological condition, particularly for the downstream estuaries, needs to be done across the entire basin, which in many cases involves nodes in different IUAs. This is because the IUAs were delineated taking into account socio-economic considerations and not just streamflows.

Table 4.1 IUAs grouped for presentation of ESBC

IUA Code	IUA Name	Group
A1	Upper Breede Tributaries	1
A2	Breede Working Tributaries	
A3	Middle Breede Renosterveld	
B4	Riviersonderend Theewaters	2
F9	Lower Riviersonderend	
F11	Lower Breede Renosterveld	3
H16	Overberg West Coastal	4
B5	Overberg West	
F10	Overberg East Renosterveld	5
H17	Overberg East Fynbos	
F12	Duiwenhoks	6
I18	Hessequa	
E8	Touws	7
C6	Gamka-Buffels	8
D7	Gouritz-Olifants	9
F13	Lower Gouritz	
G14	Groot Brak	
G15	Coastal	

For each grouping of IUAs, the results from the basin configuration tool for the ESBC configuration are presented, indicating the potential surplus and deficit water availability at each node. The descriptions focus on changes in streamflows and the resulting changes in river and estuary ecological condition, relative to that of the current day for each scenario. In some instances and at certain IUAs, consideration was also given to wetlands, conservation areas of importance and certain worthy socio-economic factors, as appropriate. The reference year for current day conditions is 2014, because that year is reasonably representative of the different EWR determinations across the WMA.

4.2 Breede River basin and the Overberg area

4.2.1 Upper Breede (A1), Breede Working Tributaries (A2) and Middle Breede Renosterveld (A3)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.2 and Figure 4.1. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at Niv42 the Smalblaar River and Niv11 the Nuy River, where increasing flow did not improve the ecological conditions up from an E; current day flows were chosen at these nodes,
- results in no deficits in flow volume at any of the nodes and at the last node in this tier of nodes, and creates a surplus leaving the lower most quaternary H50B,
- current day flows were kept at a number of nodes either because routing Reserve flows through these nodes reduced their ecological condition or that of nodes downstream, or due to the node being selected as a water source area that requires maintaining 100% of natural flow, such as that done for the Witels River,
- in this example, Reserve flows were routed down the Witte, Elands, Krom and Molenaars River to reduce their ecological conditions from an A and B to C's respectively, despite these rivers being located in nature reserves,this reduced the average annual monthly flow percentages of the Witte River to a third of their current day flow and that of the Elands, Krom and Molenaars River to approximately half their natural flow, both annually and seasonally,
- similarly, Reserve flows were routed through two lower Breede River nodes Ni1 and Nvii19, both currently in a B ecological condition, which sustains their B condition and does not dramatically change the average annual flow percentage, when compared to natural, butin contrast to the results of Reserve flows described for the Witte, Elands, Krom and Molenaars Rivers, changes the seasonal distribution of flow by making more water available in the dry season than currently is available.

Table 4.2 Ecologically sustainable base configuration scenario for Group 1: Upper Breede (A1), Breede Working (A2) and Middle Breede Renosterveld (A3)

River	NODE	QUAT	Results based on annual %				Annual flow (MCM)			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Titus	Niv3	H10C	C	C	52.1	52.1	21.5	21.5	0.0	Kept current day
Koekedou	Niv1	H10C	D	D	73.2	52.0	18.1	10.5	7.6	
Dwars	Niv2	H10C	C	D	59.6	30.7	46.8	28.3	18.5	
Breede	nvi4	H10C	C	D	55.9	37.9	89.4	62.9	26.5	

River	NODE	QUAT	Results based on annual %				Annual flow (MCM)			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Witels	Niv4	H10D	A	A	100.0	100.0	84.3	84.3	0.0	Kept current day
Breede	Nvi3	H10D	C	C	56.4	58.5	189.8	164.9	24.9	
Witte	Nvii16	H10E	A	C	91.7	25.2	39.1	14.3	24.8	
Witte	Niv5	H10F	A	C	83.1	26.0	125.3	48.3	77.0	
Wabooms	Niv6	H10F	D	D	36.7	31.4	4.7	2.8	1.9	
Breede	Nviii1	H10F	D	D	55.2	45.5	335.7	229.5	106.2	
Slanghoek	Niv7	H10G	D	D	47.9	41.4	23.1	15.6	7.6	
Breede	Niii1	H10G	D	D	54.8	44.5	386.7	257.4	129.2	
Elands	Niv40	H10J	B	C	89.9	41.6	53.6	26.6	27.0	
Krom	Niv41	H10J	B	C	89.9	40.9	8.3	4.1	4.1	
Molenaars	Nvii2	H10J	B	C	89.9	43.1	97.3	52.1	45.2	
Smalblaar	Niv42	H10J	E	E	89.9	64.1	176.3	131.0	45.2	Kept current day
Jan du Toit	Niv8	H10H	D	D	55.7	40.8	14.6	8.5	6.1	
Hartbees	Nvii6	H10H	D	D	50.8	43.5	3.1	2.0	1.2	
Hartbees	Niv9	H10H	D	D	53.8	50.9	8.2	7.1	1.2	Kept current day
Holsloot	Niv12	H10K	C	D	60.4	37.7	97.6	46.2	51.4	
Breede	Nv3	H10L	C	C	72.1	47.8	609.2	456.1	153.1	
Hex	Nv18	H20F	D	D	41.2	41.2	5.5	5.5	0.0	Kept current day
Hex	Nvii7	H20G	C	C/D	79.4	45.7	83.0	54.9	28.1	
Hex	Niv10	H20H	D	D	46.5	45.3	62.9	56.8	6.1	
Breede	Nii1	H40C	C	C	72.1	47.7	685.2	512.8	172.4	
Koo	Nvii5	H40B	D	D	56.2	40.2	0.6	0.4	0.2	
Nuy	Niv11	H40C	E	E	22.5	22.0	8.7	8.5	0.2	Kept current day
Breede	Nvii8	H40F	C/D	D	72.1	47.5	745.8	561.3	184.5	
Breede	Ni1	H40F	B	B	72.1	47.5	746.1	561.5	184.6	
Poesjenels	Nvii11	H40G	D	D	47.1	42.2	8.2	7.0	1.1	
Vink	Niv15	H40H	D	D	71.9	71.9	13.1	13.1	0.0	Kept current day
Willem Nels	Nviii2	H40J	D	D	84.3	84.3	4.4	4.4	0.0	Kept current day
Breede	Nvii19	H40J	B	B	68.6	48.0	742.2	586.7	155.5	
Keisers	Nvii12	H40K	D	D	50.7	42.7	4.0	3.3	0.6	
Keisers	Niv14	H40K	D	D	48.5	40.4	6.8	5.6	1.2	
Kingna	Niv18	H30B	D	D	53.3	40.6	15.7	11.6	4.1	
Pietersfontein	Niv20	H30C	D	D	78.9	78.9	14.5	14.5	0.0	Kept current day
Keisie	Nvii9	H30D	D	D	80.0	68.7	17.9	15.4	2.4	
Breede	Nvi1	H40L	D	D	65.0	48.2	711.8	597.6	114.2	
Kogmanskloof	Nii2	H30E	D	D	64.1	56.8	36.1	31.0	5.2	
Breede	Niii3	H50A	D	D	49.1	49.0	704.5	630.0	74.5	
Breede	Ni2	H50B	D	D	49.1	50.1	713.9	646.7	67.2	

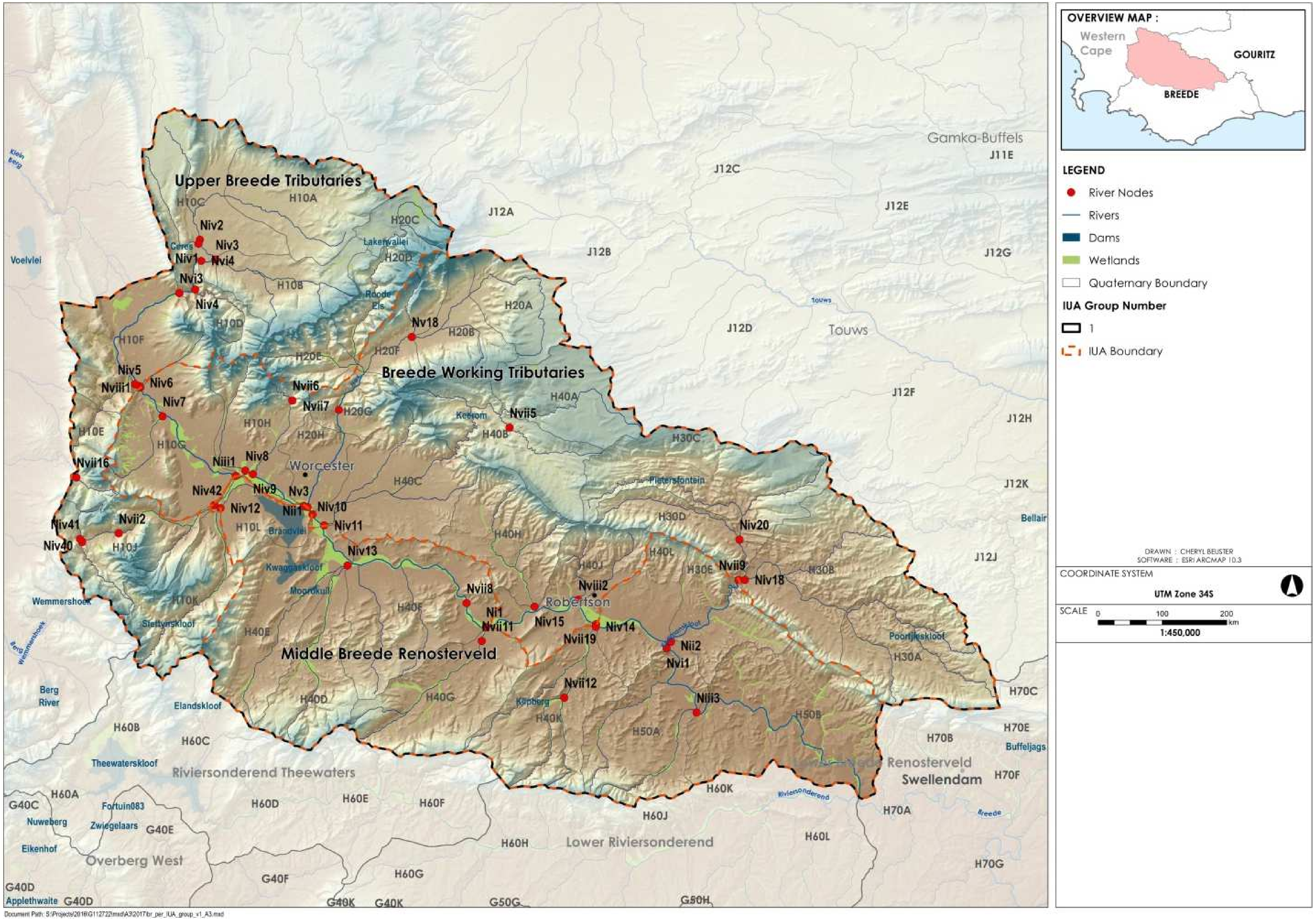

Figure 4.1 The nodes and significant water resources for the Upper Breede Tributaries, Breede Working Tributaries and Middle Breede Renosterveld IUAs

4.2.2 Riversonderend Theewaters (B4) and Lower Riviersondered (F9)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.3 and Figure 4.2. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at Niv35 the Kwassadie River, where increasing flow did not improve the ecological conditions up from an E; Reserve flows were routed down this river to improve the seasonal distribution and increase flow during the dry season,
- results in no deficits in flow volume at any of the nodes and at the last node in this tier of nodes, and creates a surplus leaving the lower most quaternary H50B,
- Reserve flows were selected at all nodes,
- there Du Toits River is the only one of conservation interest, where Reserve flows were selected that sustain the current B condition but make water available,
- here, the current day flows are higher than the Reserve flows required to sustain the D conditions of most of the tributaries and the Riviersonderend River.

Table 4.3 Ecologically sustainable base configuration scenario for Riversonderend Theewaters and Lower Riviersonderend

River	NODE	QUAT	Results based on annual %				Annual flow (MCM)		
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current
Du Toits	Nvii10	H60B	B	B	90.1	74.6	39.9	35.9	4.0
Riviersonderend	Nv7	H60D	C	C	53.6	51.8	183.2	179.2	4.0
Baviaans	Niv28	H60E	C	C/D	85.0	48.4	7.0	4.1	2.9
Sersants	Niv29	H60E	D	D	85.0	50.0	4.0	2.5	1.6
Gobos	Niv30	H60F	C	C/D	80.2	49.1	10.9	6.5	4.3
Riviersonderend	Nv9	H60F	D	D	56.7	50.9	221.6	203.3	18.3
Kwartel	Niv31	H60G	D	D	87.2	50.9	9.7	5.7	4.0
Soetmelksvlei	Niv33	H60H	D	D	59.5	49.1	2.7	2.1	0.6
Slang	Niv34	H60H	D	D	59.5	45.7	1.4	1.0	0.4
Riviersonderend	Nv10	H60H	D	D	55.9	49.9	243.6	217.6	26.0
Riviersonderend	Nv11	H60J	D	D	56.7	48.6	260.9	226.2	34.8
Kwassadie	Niv35	H60K	E	E	77.4	52.7	5.0	3.4	1.6
Riviersonderend	Nv12	H60K	D	D	56.4	48.2	269.6	231.4	38.1
Riviersonderend	Ni3	H60L	D	D	52.7	47.5	271.5	234.8	36.6

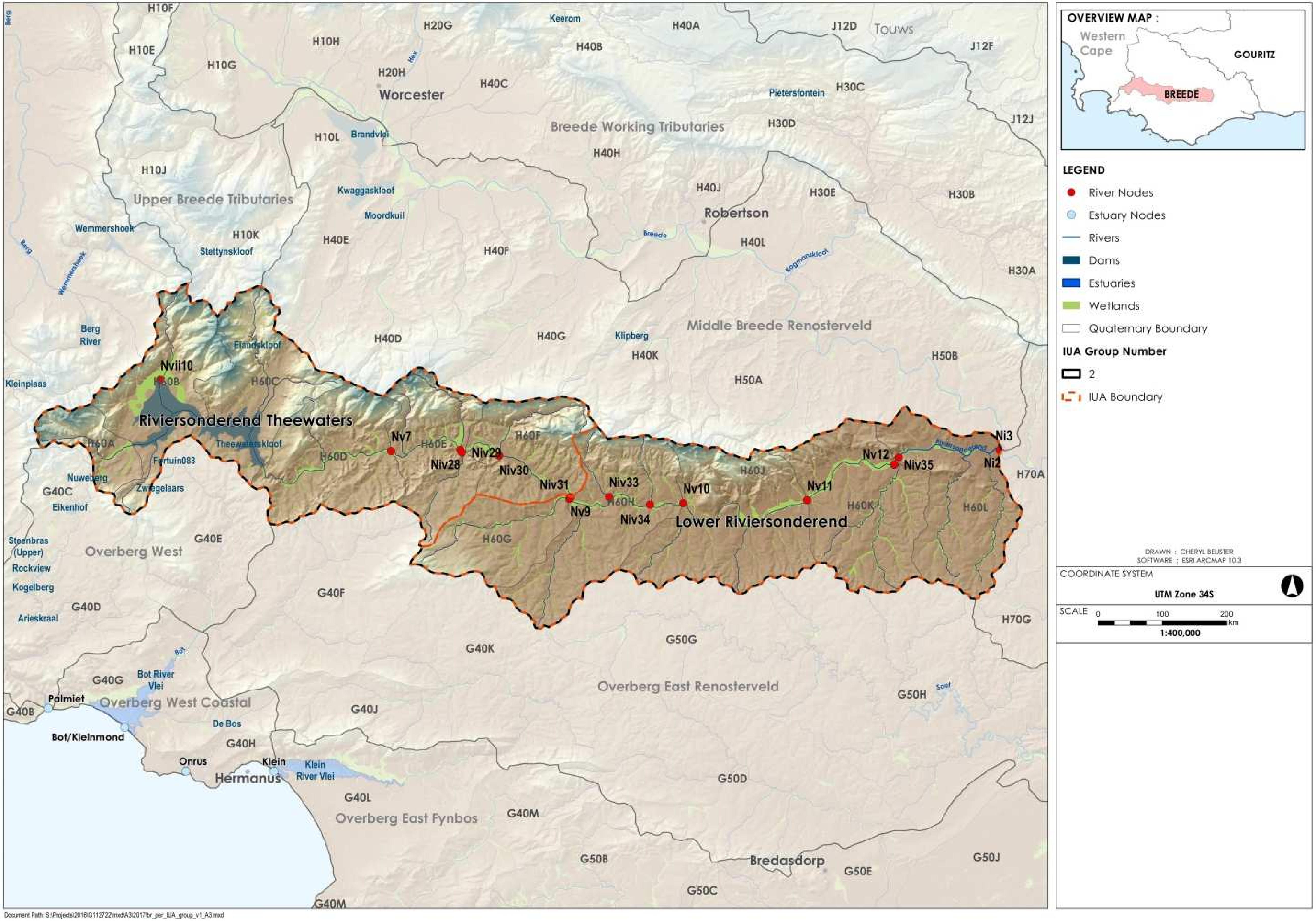

Figure 4.2 The nodes and significant water resources for the Riversonderend Theewaters, and Lower Riviersonderend IUAs

4.2.3 Lower Breede Renosterveld (F11)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.4 and Figure 4.3. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at six of the ten nodes, apart from at Niv24 the Leeu, Niv24a the Klip, Niv25 the Buffeljags and Niv26 the Slang Rivers, where increasing flow did not improve the ecological conditions up from an E; current day flows were kept at all these nodes,
- results in no deficits in flow volume at any of the nodes and at the last node in this tier of nodes, and creates a surplus at the estuary,
- the current day flows are higher than the Reserve flows required to sustain the D conditions of most of the tributaries and the Breede River.
- Reserve flows were selected at all nodes,
- The Tradouw River is in good condition and is therefore important from a conservation perspective, but in this example Reserve flows lower than that of the current day were routed down the river dropping its ecological condition to a D,

Table 4.4 Ecologically sustainable base configuration scenario for Lower Breede Renosterveld

River	NODE	QUAT	Results based on annual %				Annual flow (MCM)			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Leeu	Niv24	H70A	E	E	80.0	80.0	4.9	4.9	0.0	Kept current day
Klip	Niv24a	H70B	E	E	90.5	90.5	24.4	24.4	0.0	Kept current day
Breede	Nv2	H70B	C	C	51.9	50.2	1023.3	916.3	107.0	
Huis	Nvii14	H70C	C	D	71.5	33.9	2.4	1.1	1.2	
Tradouw	Nii3	H70D	B	D	71.9	29.1	14.6	6.0	8.6	
Buffeljags	Niv25	H70F	E	E	70.1	63.1	87.4	78.8	8.6	Kept current day
Breede	Niii4	H70G	C	C	53.4	51.0	1117.8	999.3	118.5	
Breede	Nviii3	H70H	B	B	53.6	50.9	1125.5	1002.2	123.2	
Slang	Niv26	H70J	E	E	84.5	84.5	8.9	8.9	0.0	Kept current day
Bree estuary	Nxi2	H70K	B	B	48.2	46.2	1137.2	1014.0	123.2	Kept current day

Figure 4.3 The nodes and significant water resources for the Lower Breede Renosterveld IUA

4.2.4 Overberg West (H16) and Overberg West Coastal (B5)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.5 and Figure 4.4. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at Niv43 the Swart and Nxi8 the Onrus estuary, where increasing flow did not improve the ecological conditions up from an E; Reserve flows were selected at all these nodes,
- results in no deficits in flow volume at any of the Palmiet River nodes and at the last node in this tier of nodes, and creates a surplus at the estuary.
- current day flows were selected for the Buffels estuary Bxi1, and at the Dwars/Louws and Krom/Ribbok Rivers in the Palmiet River basin,
- Reserve flows were selected at all other nodes,
- results in no deficits in flow volume at any of the Bot River nodes and creates surpluses at the Bot River estuary and the Onrus estuary,
- here, the current day flows are higher than the Reserve flows (where Reserve flows were selected) required to sustain the D conditions annually and seasonally, apart from the Witklippieskloof River Piv10 and a node on the Palmiet River Pvi1, both in the Palmiet River basin, and the Swart River Niv43, where Reserve flows are higher in the dry season than natural.

Table 4.5 Ecologically sustainable base configuration scenario for Overberg West and Overberg West Coastal

River	NODE	QUAT	Results based on annual %				Annual flow (MCM)			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Palmiet	Piii1	G40C	C	D	87.4	31.3	37.9	16.2	21.8	
Witklippieskloof	Piv10	G40C	D	D	40.3	49.7	8.9	8.7	0.2	
Palmiet	Piv9	G40C	D	D	33.2	33.1	33.8	32.8	1.0	
Palmiet	Pvi1	G40C	D	D	45.5	47.6	61.0	54.5	6.4	
Klipdrif	Piv8	G40C	D	D	93.2	58.3	12.7	9.4	3.3	
Klein-Palmiet	Piv4	G40D	D	D	72.2	53.8	11.1	8.1	3.0	
Krom/Ribbok	Piv7	G40D	D	D	22.2	22.2	9.6	9.6	0.0	Kept current day
Palmiet	Piii2	G40D	C	C	49.1	41.7	131.6	100.7	30.9	
Dwars/Louws	Piv12	G40D	C	C	98.8	98.8	24.9	24.9	0.0	Kept current day
Palmiet	Piii3	G40D	B	B/C	58.0	47.5	174.9	133.5	41.4	
Palmiet estuary	Pxi1	G40C	C	C	58.0	47.1	177.9	134.2	43.8	
Buffels (Oos) estuary	Bxi1	0	B	B	56.4	56.4	8.8	8.8	0.0	Kept current day
Swart	Niv43	G40F	E	E	78.5	58.8	37.4	24.7	12.7	
Bot	Niii5	G50E	C	C	77.8	60.0	62.4	43.5	18.8	
Bot estuary	Nxi6	G40G	C	C	75.1	57.4	77.7	53.6	24.1	
Onrus estuary	Nxi8	0	E	E	51.9	40.8	4.7	3.7	1.0	

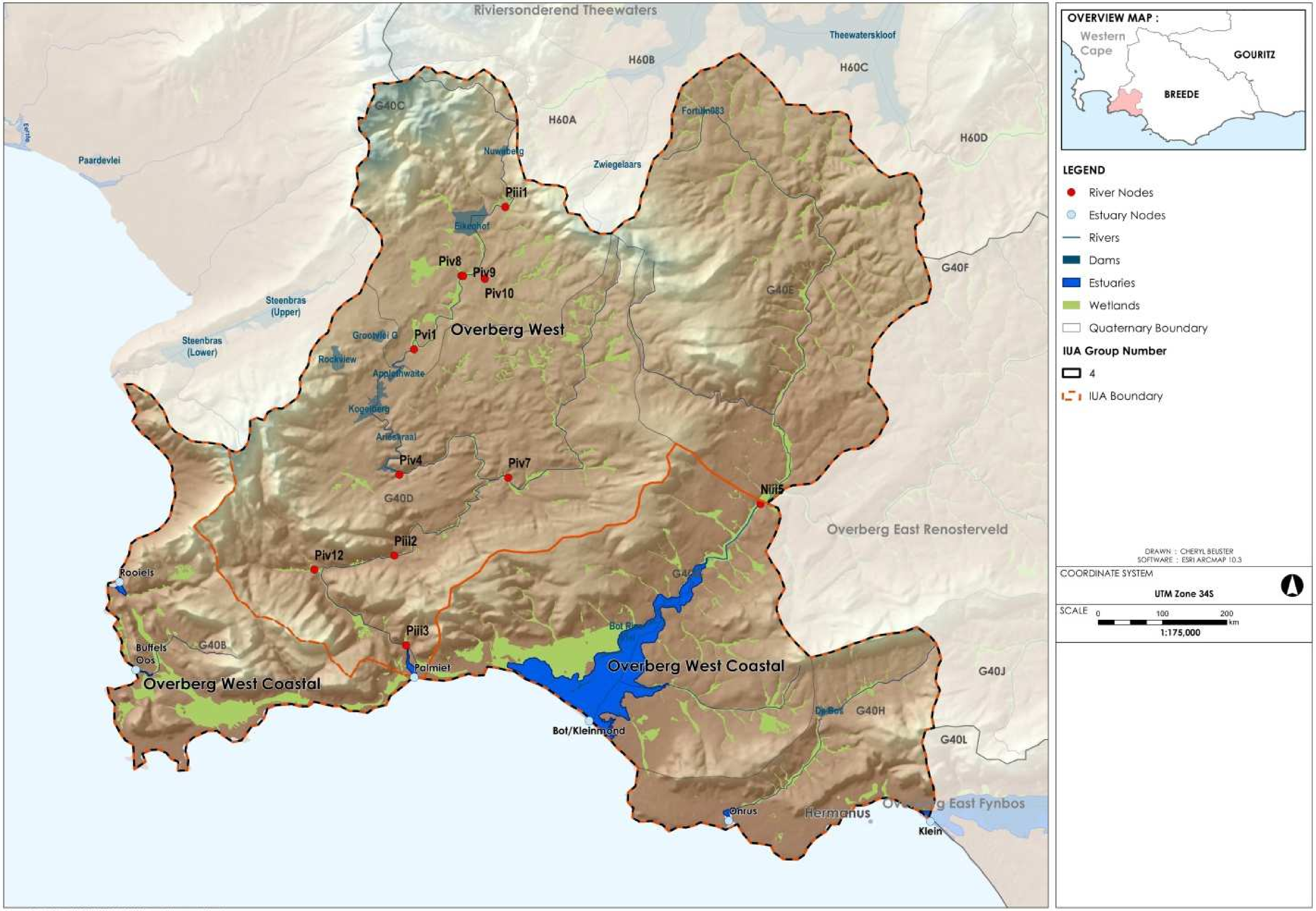

Figure 4.4 The nodes and significant water resources for the Overberg West Coastal and Overberg West IUAs

4.2.5 Overberg East Renosterveld (F10) and Overberg East Fynbos (H17)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.6 and Figure 4.5. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at Niv45 the Steenbok River, Nv24 and Nii5 the Kars River, where increasing flow did not improve the ecological conditions up from an E; Reserve flows were selected at all these nodes,
- results in no deficits in flow volume at any of the nodes and at the last node in the tiers of nodes, and creates surpluses at Nxi7 the Klein, Nxi5 the Uilkraal, Nxi3 the Ratel, Nxi1 the Heuningnes, and Nii7 De Hoopvlei,
- current day flows were selected for the Uiulkraal estuary Nxi5, and at Ni4 the Nuwejaar and Nvii15 and N iv44 the Heuningnes Rivers,
- Reserve flows were selected at all other nodes,
- here, the current day flows are higher than the Reserve flows (where Reserve flows were selected) required to sustain the D conditions annually and seasonally at all nodes apart from Nx8, the Uilkraal River, where Reserve flows are higher in the dry season than natural.

Table 4.6 Ecologically sustainable base configuration scenario for Overberg East Renosterveld and Overberg East Fynbos

River	NODE	QUAT	Results based on annual %				Annual flow (MCM)			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Hartbees	Nii4	G40J	D	D	79.1	58.8	16.0	10.8	5.2	
Steenbok	Niv45	G40K	E	E	91.3	58.8	10.1	6.3	3.7	
Klein	Nv23	G40K	C	C	84.7	58.5	38.4	25.3	13.1	
Klein estuary	Nxi7	G40L	C	C	73.4	55.3	51.2	36.8	14.4	
Uilkraal	Nx8	G40M	C	C	58.4	58.8	1.5	1.4	0.1	
Uilkraal estuary	Nxi5	G50A	D	D	36.2	36.2	6.8	6.7	0.1	Kept current day
Ratel estuary	Nxi3	G50A	C	C	90.1	59.5	3.4	2.3	1.2	
Nuwejaar	Ni4	G50B	C	C	45.5	45.5	6.2	6.2	0.0	Kept current day
Heuningnes	Nvii15	G50C	D	D	46.1	46.1	8.9	8.9	0.0	Kept current day
Heuningnes	Niv44	G50C	D	D	46.2	46.2	9.4	9.4	0.0	Kept current day
Kars	Nv24	G50E	E	E	89.2	58.8	13.9	9.1	4.8	
Kars	Nii5	G50C	E	E	84.7	58.8	18.5	12.7	5.8	
Heuningnes estuary	Nxi1	G50F	D	D	66.6	53.9	29.5	23.6	5.9	
Sout	Nii6	G50H	D	D	70.6	58.8	3.1	2.5	0.6	
DeHoopVlei	Nii7	G50H	B	C	89.0	39.1	24.9	10.5	14.3	

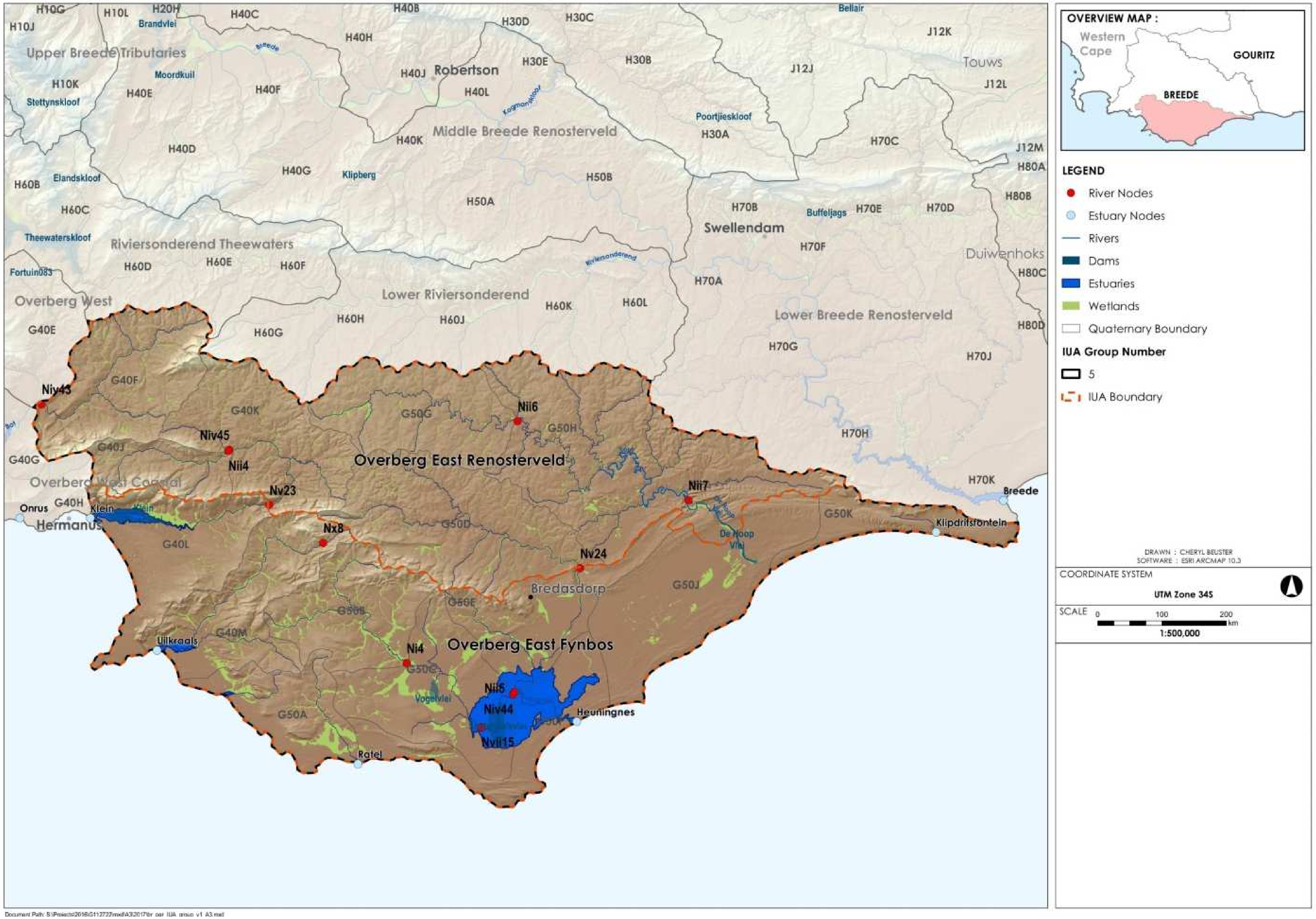

Figure 4.5 The nodes and significant water resources for the Overberg East Renosterveld and Overberg East Fynbos IUAs

4.3 Gouritz River basin and Outeniqua region

4.3.1 Duiwenhoks (F12) and Hessequa (I18)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.7 and Figure 4.6. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at giii5 the upper Duiwenhoks, where increasing flow did not improve the ecological conditions up from an E,
- results in no deficits in flow volume at any of the nodes and at the last nodes in these tiers of nodes, and creates a surplus leaving the lower most quaternaries at the estuaries gxi2 (Duiwenhoks estuary) and gxi3 (Goukou estuary), and
- current day flows were kept at two nodes because routing Reserve flows through these nodes reduced their ecological condition or that of nodes downstream, and
- the annual average current day flows are higher than the Reserve flows required to sustain the D conditions.

Table 4.7 Ecologically sustainable base configuration scenario for Duiwenhoks and Hessequa

River	NODE	QUAT	Results based on annual %				Flow MCM			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Duiwenhoks	giii5	H80B	E	E	93.3	51.7	58.7	34.2	24.5	
Duiwenhoks	gv11	H80D	D	D	93.2	51.0	70.7	40.7	30.0	
Duiwenhoks	giii8	H80D	D	D	93.5	50.7	78.5	44.8	33.7	
Duiwenhoks estuary	Gxi2	H80E	C	C/D	91.1	49.5	81.6	46.5	35.1	
Korinte	giii6	H90C	D	D	88.1	88.1	30.4	30.4	0.0	Kept current day
Goukou	giii7	H90C	C/D	C/D	87.0	87.0	44.6	44.6	0.0	Kept current day
Goukou	gv10	H90D	D	D	83.9	81.8	78.8	76.7	2.1	
Goukou	gv41	H90E	C	C	82.5	74.9	87.6	79.2	8.5	
Goukou estuary	Gxi3	0	C	C	80.6	72.9	89.9	81.0	9.0	

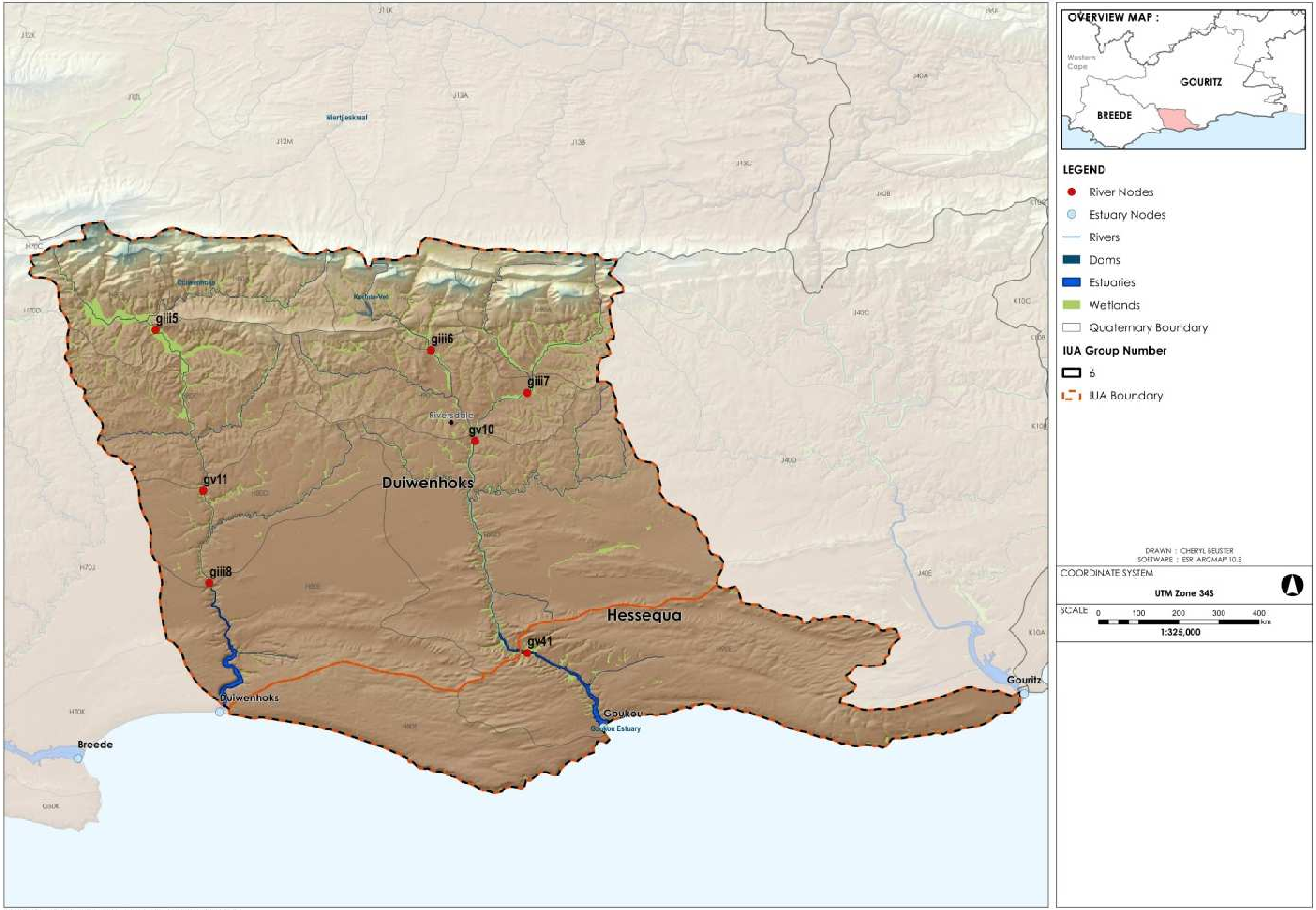

Figure 4.6 The nodes and significant water resources for the Duiwenhoks and Hessequa IUAs

4.3.2 Touws (E8)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.8 and Figure 4.7. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at gviii1 the Doring River and gv6/giv32 the Groot River, where their condition dropped into a D/E category as a result of cascading a mixture of Reserve and current day flows through the basin,
- results in no deficits in flow volume at any of the nodes and at the last node in this tier of nodes, and creates a surplus leaving the lower most quaternary at gii3,
- the Buffels catchment upstream of Floriskraal Dam should be considered for conservation priority and any scenario going forward should maintain current day flows rather than select the Reserve flows routed into the Dam as in this example,
- the annual average current day flows are higher than the Reserve flows required to sustain the D conditions of most of the tributaries and the Riviersonderend River.

Table 4.8 Ecologically sustainable base configuration scenario for Touws

River	NODE	QUAT	Results based on annual %				Flow MCM			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Ysterdams	giv30	J12C	D	D	40.8	40.8	1.4	1.4	0.0	Kept current day
Donkies	giv31	J12B	D	D	47.3	47.3	3.8	3.8	0.0	Kept current day
Touws	giv28	J12D	D	D	44.1	40.7	8.9	7.8	1.2	
Touws	giv27	J12H	B	C	44.9	35.8	13.2	10.9	2.4	
Brak	giv26	J12K	C	C	13.8	13.8	0.4	0.4	0.0	Kept current day
Doring	gviii1	J12L	C/D	D/E	43.8	24.2	1.2	0.7	0.5	
Touws	gv5	J12M	B/C	C	43.0	33.6	15.5	12.6	2.9	
Buffels	giv34	J11C	A	B	97.2	52.5	12.7	7.1	5.6	
Buffels	gv25	J11F	C	C	92.3	50.5	22.6	12.9	9.7	
Buffels	gv4	J11J	C	C/D	66.4	49.9	16.5	14.4	2.1	
Groot	gv6	J11K	D	D/E	44.5	31.8	12.7	10.5	2.1	Kept current day
Groot	giv32	J11K	D	D/E	38.9	28.6	11.8	9.6	2.1	Kept current day
Groot	gv7	J13B	C	C	39.8	30.2	29.8	24.8	5.1	Kept current day
Groot	gii3	J13C	B	C	42.0	31.2	33.4	27.0	6.4	

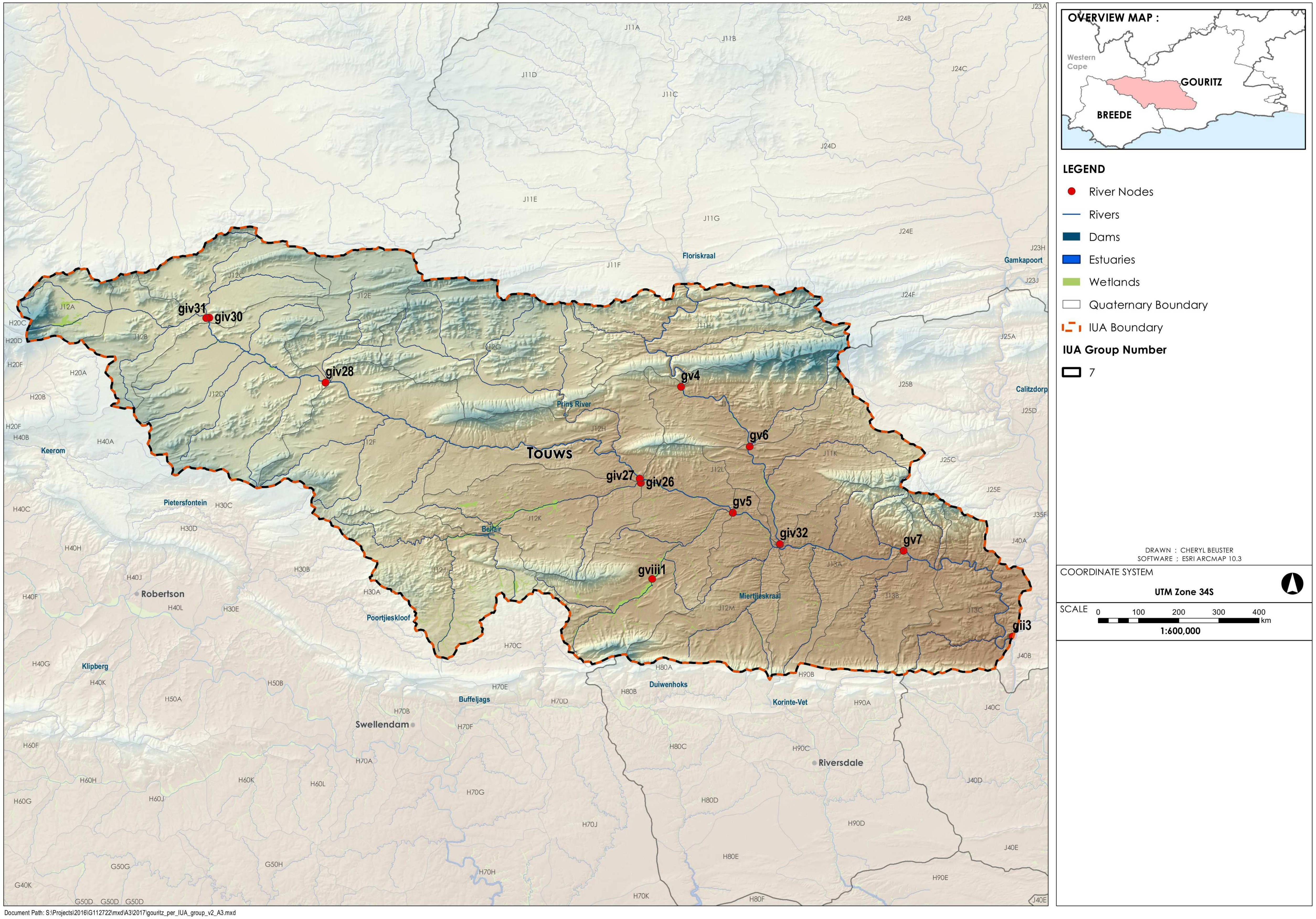

Figure 4.7 The nodes and significant water resources for the Touws IUA

4.3.3 Gamka-Buffels (C6)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.9 and Figure 4.8. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes,
- results in no deficits in flow volume at any of the nodes and at the last node in this tier of nodes, gv27,and creates a surplus leaving the lower most quaternary,
- Reserve flows were selected at all nodes,
- the Dwyka and Gamka Rivers and their tributaries could be considered for conservation potential being in good condition and flowing relatively naturally.

Table 4.9 Ecologically sustainable base configuration scenario for Gamka-Buffels

River	NODE	QUAT	Results based on annual %				Flow MCM		
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current
Gamka	gv18	J21B	B	C	78.3	38.7	20.7	11.5	9.2
Gamka	giv3	J21D	B	C	76.3	38.1	24.8	13.4	11.4
Koekemoers	giv1	J22F	C	D	85.9	30.9	6.5	2.6	3.9
Leeu	giv2	J22K	C	D	35.9	16.1	7.5	3.4	4.2
Gamka	gv17	J23F	B	C	66.2	30.9	40.1	19.8	20.3
Gamka	giv21	J23F	B	C/D	59.7	29.2	42.4	22.6	19.8
Gamka	gv27	J23J	C	D	59.5	29.0	43.0	23.0	20.0
Dwyka	gv14	J24E	A	C	84.4	33.6	3.4	1.6	1.8

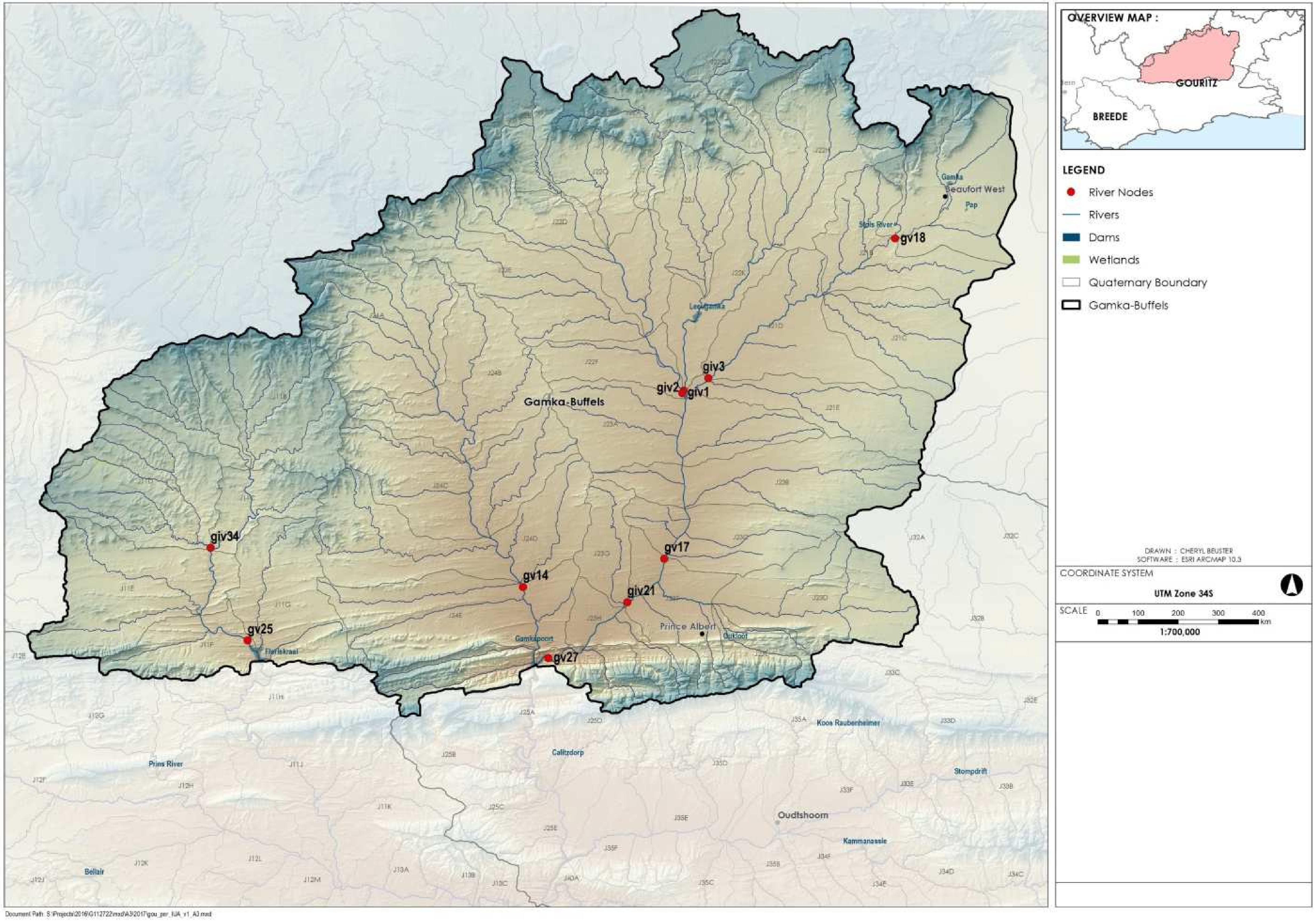

Figure 4.8 The nodes and significant water resources for the Gamka-Buffels IUA

4.3.4 Gouritz-Olifants (D7), Lower Gouritz (F13), Groot Brak (G14) and Coastal (G15)

The ESBC results and comparison with current day flows for these groupings of IUAs are shown in Table 4.10 and **Error! Reference source not found.**. These results of the analysis using the balancing tool show that the ESBC scenario:

- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at giv11 and gv19 the Olifants River and giv9 the Grobbelaars River, where increasing flow did not improve the ecological conditions up from an E,
- Reserve flows are predicted to improve the condition of giv10 to a D/E, up from an E condition,
- results in a deficit at giv11 on the Olifants River, that may be removed if current day flows are selected in this position instead, and at gv19 despite their being current day flows in place at this node and some upstream nodes,
- Reserve flows were selected at most of the nodes in the Gouritz-Olifants to demonstrate the creation of a surplus in the receiving lower most node on the Gouritz River at gi4,
- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at giv25 the Brandwag River, where routing Reserve flows drops the condition from a D to a D/E,
- results in no deficits in flow volume at any of the nodes and at the last node in this tier of nodes, and creates a surplus leaving the lower most quaternary at node gv9,
- the Groot Brak River could be considered for conservation interest, where Reserve flows were selected in this illustrative example to make water available and dropped the condition of the upper node gviii2 from a B/C to a C/D,
- meets and exceeds the annual flow requirements for a D at all the nodes, apart from at gviii6 the Gwaing River, gx6 the Piesang River, where increasing flow did not improve the ecological conditions up from an E so Reserve flows were routed down these rivers to improve the seasonal distribution,
- results in a slight deficit at gviii7 the Swart River but otherwise provides surpluses at the estuary outlets,
- current day flows were kept through the Malgate and Malgas Rivers as routing Reserve flows dropped their conditions down below that of a D category,
- the majority of the rivers in this region are of conservation interest and flow near natural,
- the current day flows are higher than the Reserve flows required to sustain the D conditions for all the rivers.

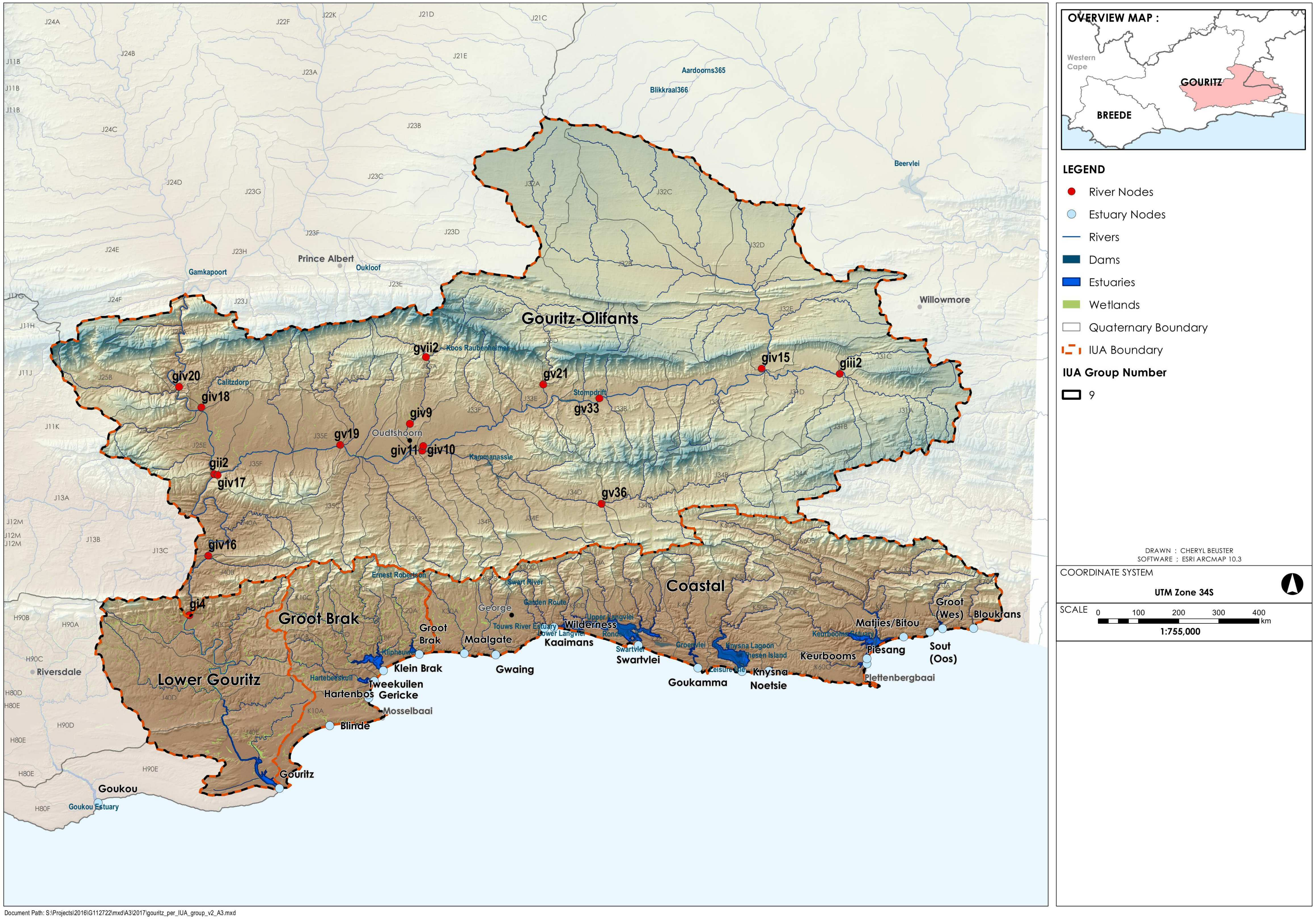

Figure 4.9 The nodes and significant water resources for the Gouritz-Olifants (D7), Lower Gouritz (F13), Groot Brak (G14) and Coastal (G15) IUAs

Table 4.10 Ecologically sustainable base configuration scenario for Gouritz-Olifants, Lower Gouritz, Groot Brak and Coastal

River	NODE	QUAT	Results based on annual %				Flow MCM			Note
			Current EC (PES 2014)	Scenario (ESBC) EC	Current Ave monthly as % nMAR	Scenario Ave monthly as % nMAR	Current cum flow	Scenario cum flow	Surplus/deficit relative to Current	
Gamka	giv20	J25A	C/D	D	51.5	30.0	44.5	27.6	16.9	
Nels	giv18	J25D	D	D	57.8	57.8	6.1	6.1	0.0	Kept current day
Gamka	gii2	J25E	C	C/D	49.3	32.9	54.6	41.1	13.4	
Olifants	giii2	J31C	C	C	84.1	53.1	10.1	6.8	3.3	
Traka	giv15	J32E	C	D	79.5	34.4	2.2	1.1	1.1	
Olifants	gv33	J33B	D	D	79.3	54.5	19.9	14.4	5.5	
Meirings	gv21	J33E	C	D	90.4	39.2	19.4	8.8	10.6	
Olifants	giv11	J33F	E	E	48.4	45.8	37.6	39.1	-1.6	
Kammanassie	gv36	J34D	C/D	D	71.9	42.5	31.2	16.6	14.6	
Kammanassie	giv10	J34F	E	D/E	38.6	41.8	24.4	24.1	0.4	
Grobbelaars	gvii2	J35A	C	C	83.2	83.2	13.9	13.9	0.0	Kept current day
Grobbelaars	giv9	J35A	E	E	66.8	66.8	20.1	20.1	0.0	Kept current day
Olifants	gv19	J35E	E	E	50.9	51.6	115.8	117.0	-1.2	Kept current day
Olifants	giv17	J35F	D	D	52.8	49.0	134.8	125.5	9.3	
Gouritz	giv16	J40A	C	C	56.2	43.6	218.4	174.1	44.3	
Gouritz	gi4	J40B	C	C	54.9	41.6	265.8	205.2	60.6	
Gouritz	gv28	J40D	D	D	56.7	40.4	292.7	213.0	79.7	
Gouritz	gv9	J40E	C	D	60.1	38.9	342.0	225.7	116.3	
Gouritz estuary	Gxi1	K10A	C/D	D	62.0	38.6	378.9	239.6	139.3	
Brandwag	giv25	K10D	D	D/E	94.9	47.9	17.1	8.8	8.3	
Moordkuil	gv39	K10F	D	D	55.0	40.2	8.4	6.3	2.2	
Klein-Brak estuary	Gxi4	0	C	C/D	89.8	43.8	35.5	17.3	18.2	
Groot-Brak	gviii2	K20A	B/C	C/D	93.6	37.0	14.4	6.1	8.3	
Varing	gviii12	K20A	C/D	D	97.1	53.9	5.8	3.3	2.5	
Varing	gviii3	K20A	D	D	74.6	53.1	4.9	3.6	1.3	
Groot-Brak	gvii7	K20A	B/C	B/C	43.1	41.0	12.4	11.7	0.7	
Groot-Brak estuary	Gxi5	0	D	D	57.8	40.1	18.0	12.6	5.4	
Maalgate	gviii4	K30A	D	D	95.1	95.1	14.5	14.5	0.0	Kept current day
Maalgate	gvii8	K30A	D	D	95.1	95.1	28.5	28.5	0.0	Kept current day
Maalgate	Gxi6	0	B	B/C	96.3	83.9	35.7	31.3	4.5	
Malgas	gvii9	K30B	C	C	95.3	95.3	16.5	16.5	0.0	Kept current day
Gwaing	gviii6	K30B	E	E	95.3	72.8	32.5	25.7	6.8	
Gwaing estuary	Gxi7	0	B	C	98.7	59.9	52.8	33.0	19.8	
Swart	gviii7	K30C	D	D	24.1	27.3	4.1	4.3	-0.3	
Kaaimans	gvii11	K30C	B	D	94.0	27.3	17.5	5.0	12.5	
Silver	gviii8	K30C	B	D	94.0	27.3	14.0	4.0	10.0	
Kaaimans estuary	Gxi8	0	B	D	72.1	27.8	35.3	13.4	21.9	
Touws	gvii12	K30D	B	C	93.6	35.4	15.6	6.1	9.5	
Klein estuary	gx8	K30D	D	D	93.6	54.5	2.3	1.4	0.9	
Wilderness estuary	Gxi9	0	C	D	88.5	33.3	29.0	11.2	17.8	
Diep	giii10	K40A	B	C/D	96.6	37.0	12.0	4.9	7.0	
Hoekraal	giii13	K40B	B	C	92.4	32.0	25.8	9.5	16.3	
Karatara	gvii13	K40C	B	D	94.2	28.0	10.5	3.3	7.2	
Karatara	giii11	K40C	B	D	94.2	25.1	31.9	9.1	22.8	
Swartvlei estuary	Gxi10	0	B	D	90.9	29.5	92.5	31.5	61.0	
Goukamma	gviii9	K40E	B/C	C/D	87.3	35.7	26.5	11.2	15.4	

Goukamma estuary	Gxi11	0	B	C	87.3	35.6	46.2	19.2	27.0	
Knysna	gvii14	K50A	B	D	95.5	28.4	25.4	7.5	17.8	
Gouna	gviii11	K50B	B	D	94.3	28.2	44.1	13.1	31.0	
Knysna	giii12	K50A	A/B	C/D	92.1	25.4	25.4	7.5	18.0	
Knysna estuary	Gxi12	0	B	D	95.0	25.1	86.0	23.2	62.8	
Noetzie	gviii10	K60G	B	C	91.7	44.5	4.4	2.1	2.3	
Noetsie estuary	Gxi13	0	B	C	91.7	43.3	5.1	2.3	2.8	
Piesang	gx3	K60G	E	E	91.7	61.6	3.7	2.6	1.1	
Piesang estuary	Gxi14	0	D	D	91.7	52.3	6.4	3.7	2.7	
Keurbooms	giv6	K60C	C	D	84.1	35.9	39.1	17.6	21.5	
Palmiet	giv5	K60D	A	C	79.5	31.1	33.7	13.6	20.1	
Keurbooms	gx9	K60E	B	C	81.5	33.7	75.0	32.3	42.7	
Bitou	giv4	K60F	C	D	96.9	32.0	23.0	8.0	15.0	
Keurbooms estuary	Gxi15	0	A/B	C	87.2	33.1	106.8	42.4	64.4	
Buffels	gx4	K70A	B	C	91.1	35.9	1.6	0.6	1.0	
Matjies/Bitou estuary	Gxi16	0	B	C	91.1	35.9	3.2	1.3	2.0	
Sout	gx5	K70A	B	D	91.1	30.0	3.5	1.1	2.3	
Sout(Oos) estuary	Gxi17	0	A	C	91.1	30.0	4.4	1.4	3.0	
Bloukrans	gvii15	K70B	B	D	77.5	30.0	24.2	9.4	14.8	
Bloukrans estuary	Gxi18	0	A	C	91.8	30.0	31.4	10.2	21.1	

5 Preparation of other data for the classification scenario analyses

5.1 Yield modelling and Water Supply Augmentation

5.1.1 Definition of surface water yield

In a water resources augmentation context, surface water yield is generally expressed as the maximum annual withdrawal at a specific annual assurance (as %) of supply (also expressed as recurrence interval in years of failure of supply). However, for this study, yield is defined as the average annual water supply, expressed as 12 monthly averages. This definition meets the requirements of the basin configuration tool methodologies used for the ecological condition determinations under the different scenarios formulated for this study, as well as for the concomitant economic analyses.

5.1.2 Quantifying surface water yield

No Water Resources Yield Model (WRYM) configurations were generally available for the Breede-Gouritz WMA (except a few local sub-system setups). Hence, the surface water modelling will be undertaken with the available WR2012 Pitman rainfall-runoff catchment model configurations for the WMA. For each agreed scenario, the WR2012 Pitman model configuration, as refined for this study, will be changed as required by that scenario and the resulting 90 years of monthly streamflows simulated at each node of interest in each IUA, followed by calculation of each node's 12 monthly average streamflows.

5.1.3 Scaling up or down to IUA level

The consequences of changes in surface water yields brought about each scenario are evaluated at the IUA scale. However, given that the simulated yield usually represents the integrated contributions of various components of the surface water system, while IUAs do not necessarily constitute logical surface water system units, the changes in yield will be either aggregated or disaggregated to the IUA scale, as the case may be. This process will also include spatial proportioning of domestic versus irrigation demands on surface resources.

5.1.4 Surface water options for meeting shortfalls or utilising surpluses

Simulation of specific scenarios can be expected to result in surface water supply shortfalls, after meeting the EWR, at most locations of interest, while less frequently, surpluses may be expected to be indicated.

For each simulated scenario with surface water shortfalls after meeting the relevant EWRs, several options will be assessed for meeting the shortfall, including increased groundwater use where possible (section 041). Furthermore, one or more of the following bulk surface water intervention options may be super-imposed on the configured WR2012 Pitman models, as appropriate, in search of reconciling projected future surface water requirements with availability:

- Water conservation and water demand management (WC/WDM). This intervention is usually a component of the low-growth water demand projection.
- Re-use of treated effluent.
- New or increased run-of-river diversions from rivers.
- Construction of new dams (instream or off-channel) or raising of existing dams.

- Increased demands placed on existing supply sources that are not yet fully utilised.
- Transfer schemes, transferring water either into or out of the WMA, or between sub-systems in the WMA.

For each simulated scenario with surface water surpluses after meeting the relevant EWRs, surpluses may be re-allocated to downstream shortfall locations in the same system.

A list of potential surface water supply intervention options and potential implementation dates has been compiled, following our scrutiny of the "*Situation Assessment Report"* produced as part of the Breede-Gouritz Catchment Management Strategy Study (Golder, 2016), as well as the outputs of more recent water resource planning studies by DWS, Department of Agriculture, Forestry and Fisheries (DAFF) and municipalities.

5.1.5 Inclusion of climate change

Potential changes to surface water availability due to climate change over the whole of South Africa were examined by Cullis *et al* (2015) by application of more than 300 climate change impact models for different carbon emission scenarios. For this Study, the quaternary catchment streamflow changes relative to current day for a relatively severe "dry" scenario - the 10th percentile case – will be selected from the "drying" side of the spectrum of outcomes for the Study area from Cullis *et al* (2015). For every node the proportional mean monthly streamflow changes ("deltas") under this scenario will be super-imposed on the current day mean monthly streamflow values at that node. These changed nodal mean monthly streamflow values will then be input to the basin configuration tool and used to determine the impact on ecological condition at the nodes.

5.2 Groundwater availability modelling

The scenarios to be assessed consider the impact of changing ecological status (and hence flow requirement), or changing water requirement (and hence ecological status). It is assumed in groundwater balance modelling, that if groundwater contribution to baseflow (GWBF) is maintained, there is no impact of increased groundwater use on GWBF, and hence groundwater's contribution to meeting EWR (refer to ERW report). Groundwater's role in scenario analysis is therefore to quantify the increased water demand that can be met by groundwater use. The increased demand may derive from demand driven scenarios, or from a surface water shortfall where surface water is required to meet a specific EWR in conservation driven scenarios.

To support scenario evaluation, a groundwater balance model has been established, and is described in the EWR report. The changing groundwater use, per scenario, also impacts the present status of groundwater (defined by use/recharge), and will be reported per scenario. The selected Water Resources Class will therefore be related to a particular groundwater demand and recommended category for groundwater.

5.3 Wetlands

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. The associated hydrogeomorphic (HGM) unit characteristics for each wetland resource unit were 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 hydroperiod. The NFEPA dataset classifies wetlands up to the HGM unit (Level 4) scale of classification, whilst the FSP dataset classifies wetlands up to the hydrological regime (Level 5), but does not extend over the entire study area.

The methodology proposed for assessment is therefore as follows:

- For all important wetland systems associated with river systems the associated EWR river node will have qualitative data relating to the wetland systems in the upper catchment. This will be considered a dual “wetland” and “river” node.
- For all important wetland systems not associated with river systems, i.e. groundwater driven systems, will also be considered a “wetland node” and have associated qualitative data relating to the wetland system.

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