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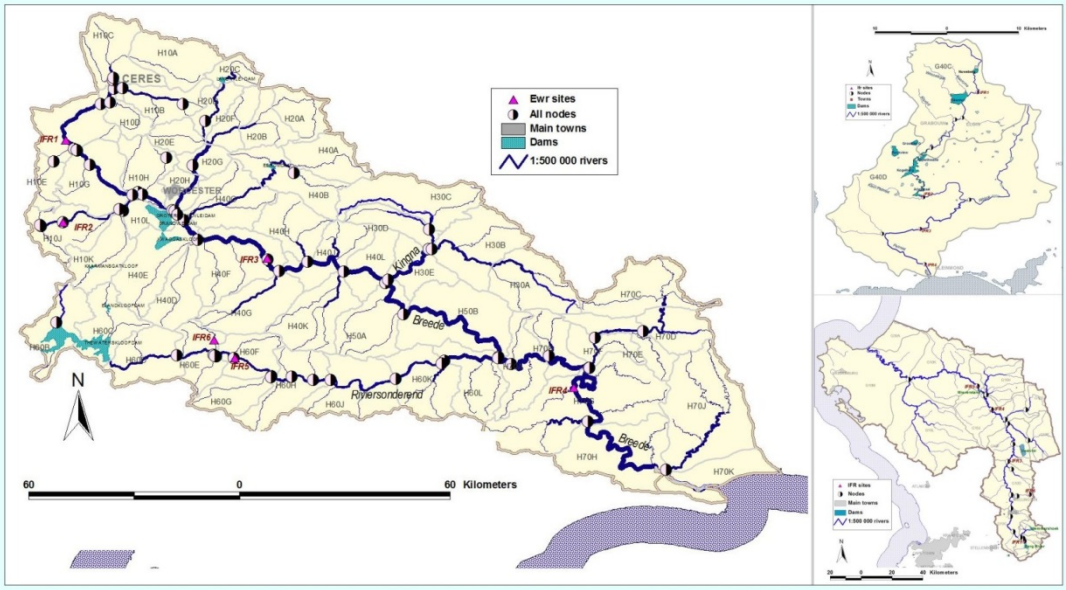
DEPARTMENT OF WATER AFFAIRS
DIRECTORATE : OPTIONS ANALYSIS

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

Report No 1 : Ecological Water Requirement Assessments

Volume 1 : Riverine Environmental Water Requirements



Final

June 2012

Department of Water Affairs
Directorate: Options Analysis

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

APPROVAL

Title	:	Ecological Water Requirement Assessments Riverine Environmental Water Requirements
Consultants	:	Western Cape Water Consultants Joint Venture
Report status	:	Final
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STUDY TEAM: Approved for the Joint Venture:

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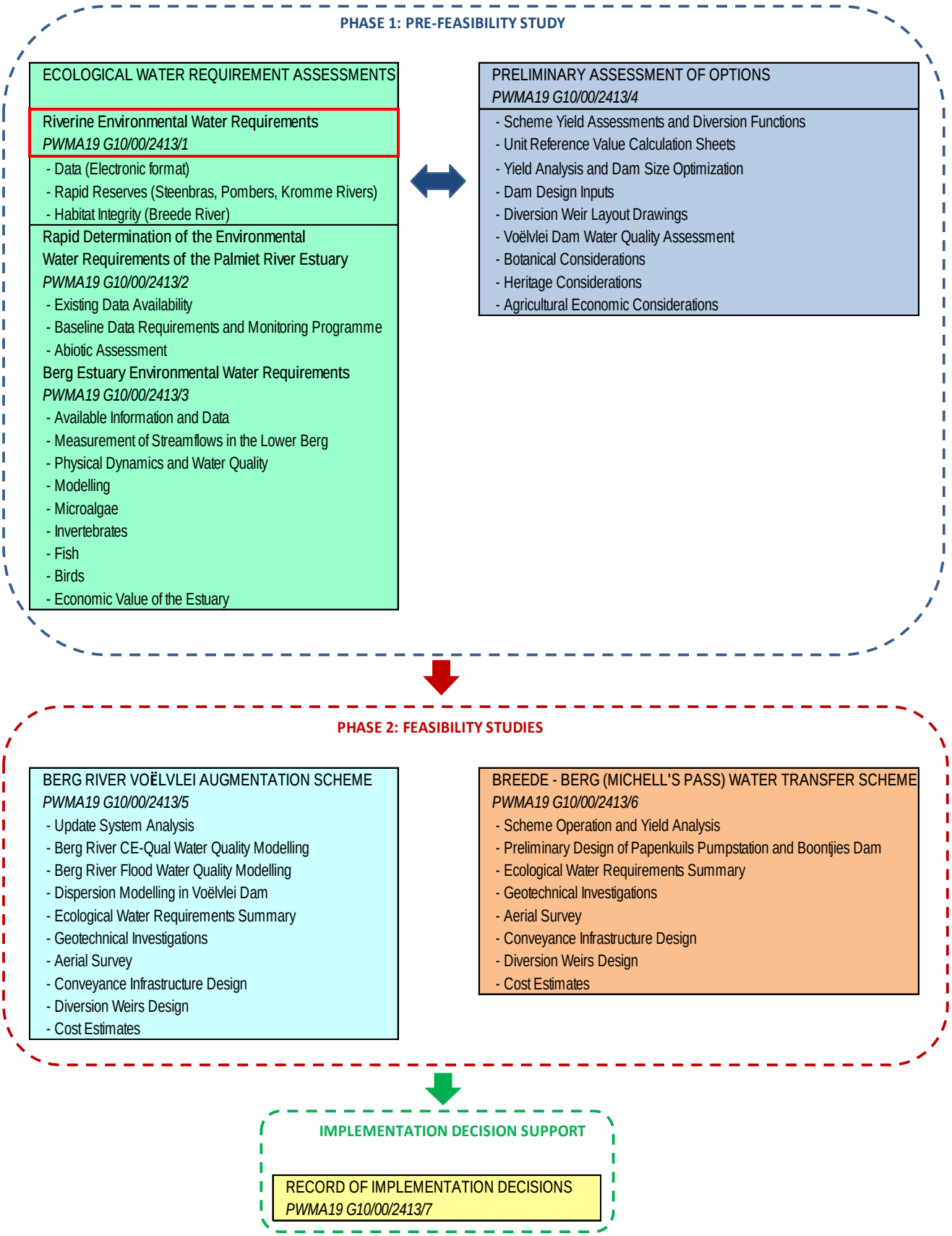
STUDY REPORT MATRIX DIAGRAM



EXECUTIVE SUMMARY

INTRODUCTION

This report (Report 1, Volume 1) addresses the generation of Ecological Water Requirement (EWR) data for the rivers in the study catchments.

It adopts the procedures outlined for undertaking the ecological aspects of the steps in the Water Resources Classification System (WRCS) *(*Dollar *et al.* 2006*)* for the Breede, Palmiet and Berg Catchments. These are specifically the identification of nodes for which Ecological Water Requirements data are generated and the extrapolation of information from representative sites to other nodes.

EWR DATA GENERATED

EWR data were generated for:

- Sixty-three river nodes in the Breede River catchment (Figure 1.1)
- Ten river nodes in the Palmiet River catchment (Figure 1.2), and;
- Twenty-three river nodes in the Berg River catchment (Figure 1.3).

The EWR data are available in electronic format only.

EWR data for the Palmiet and Berg estuaries are available in other project reports, *viz*.:

- Report 1, Vol 2: Palmiet Estuary EWR Report
- Report 1, Vol 3: Berg Estuary EWR Report 1

EWR data for the Breede Estuary is available in DWAF (2003).

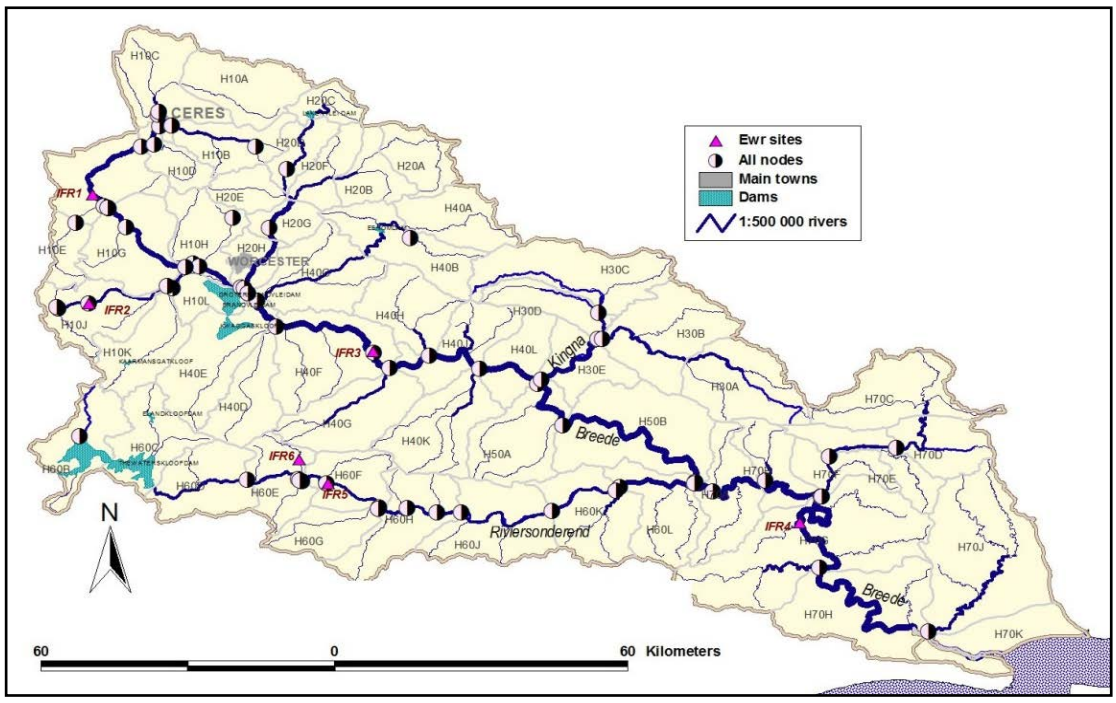


Figure 1.1 The Breede River catchment, showing the sixty-three nodes established.

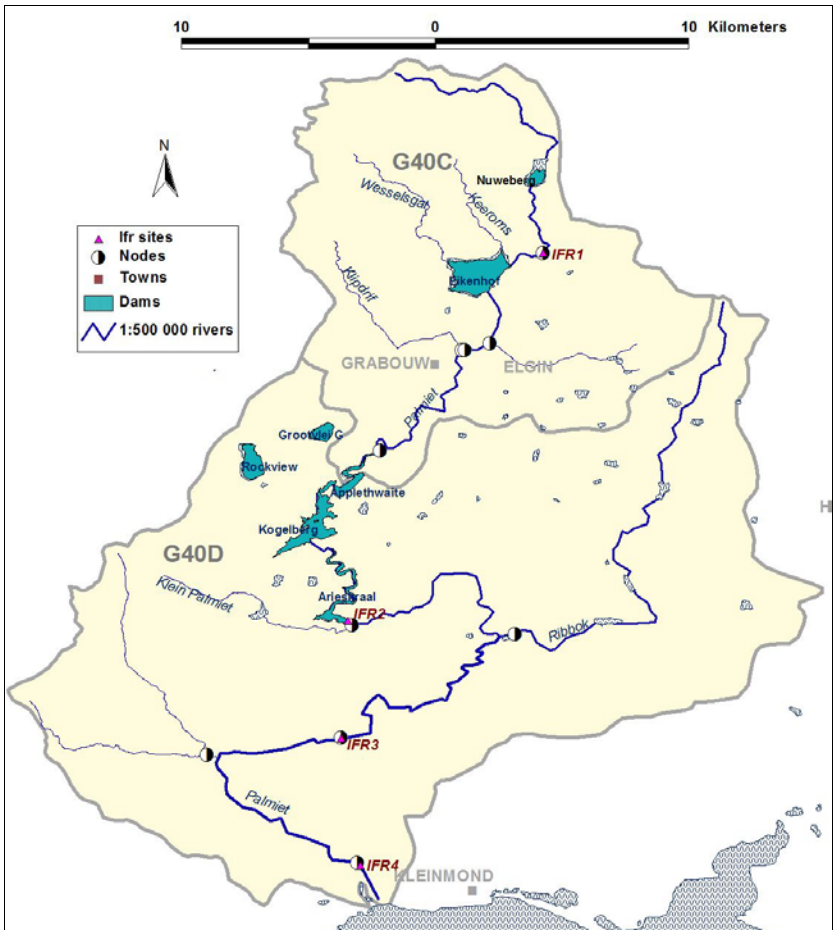


Figure 1.2 The Palmiet River catchment, showing the 10 nodes established**.**

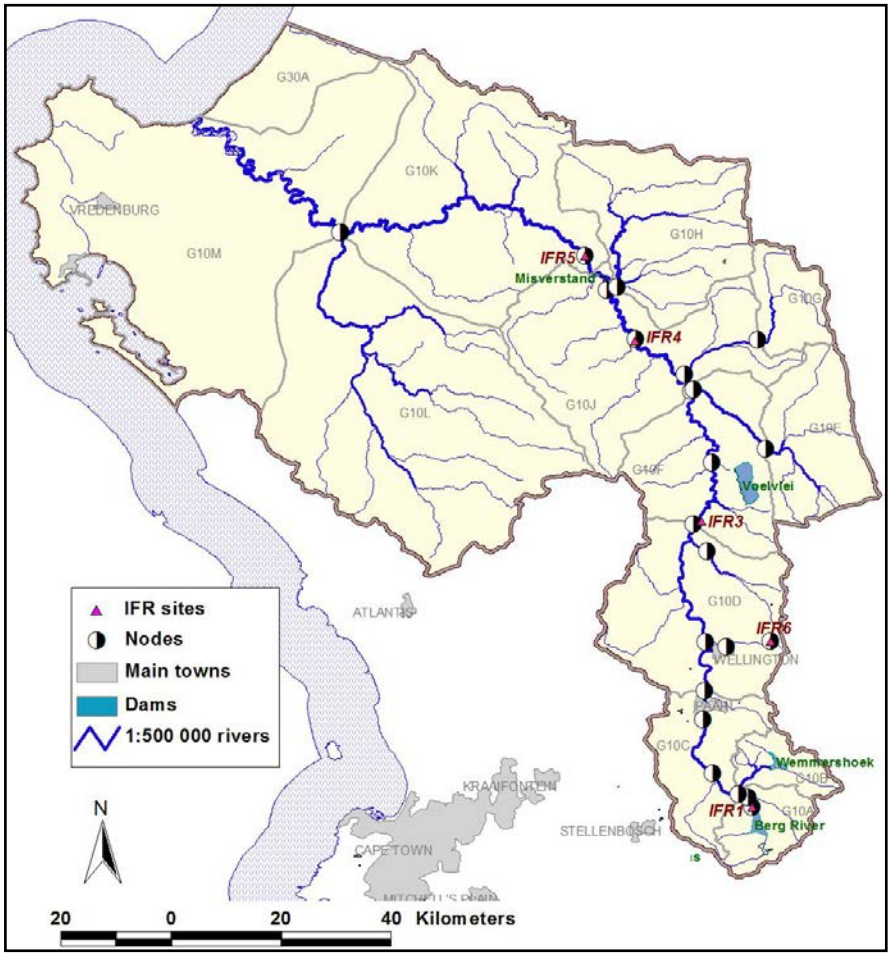


Figure 1.3 The Berg River catchment, showing the 23 nodes established**.**

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LIST OF ACRONYMS

a^{-1}	Per annum
AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
D/s	Downstream
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry (pre-2009)
EC	Ecological Category
ECOREGION:	A recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterise that region
EIS	Ecological Importance and Sensitivity: ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience)
EPHEMERAL:	Characterised as episodic, and lasting only a short time
ECOLOGICAL RESERVE:	The requirement for water that is allocated to sustain ecosystem functions and is directly aligned with options for human use arising from rivers to deliver a suite of ecosystem goods and services to society.
EWR	Environmental Water Requirement: prescribes water regimes needed to sustain the ecological values of water dependent ecosystems at a low level of risk
GAI	Geomorphology Driver Assessment Index
GEOMORPHIC ZONE:	A section of river distinguished by its position in the longitudinal profile and which is dominated by macro-reaches having characteristic valley form and valley-floor shape
GIS	Geographical Information System
HI	Habitat Integrity: A measure of the ability of an ecosystem to support and maintain a balanced, integrated, adaptive community of organisms that has a species composition, diversity and functional organisation comparable to that of natural habitat of the region
HI	Hydrological Index
IBT	Inter Basin Transfer
IWA	International Water Agreement
m^3s^{-1}	Cubic meters per second
MAR	Mean Annual Run-off
masl	meters above sea level
MCM	Million cubic meters
MIRAI	Macroinvertebrate Response Assessment Index
nMAR	Natural Mean Annual Run-off
nMean Q	Natural mean discharge
NODE:	A modelling point which "represent(s) the downstream end of a reach or area for which a suite of relationships apply
NWA	National Water Act
PERENNIAL:	Characterised as throughout the year, constantly
PES	Present Ecological Status:
QUATERNARY:	Refers to drainage regions of the fourth order
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
RQS	Resource Quality Services: Chief Directorate of DWA)
SASS5	South African Scoring System version 5

U/s	Upstream
VEGRAI	Riparian Vegetation Response Assessment Index
WCWSS	Western Cape Water Supply System
WRCS	Water Resources Classification System
WMA	Water Management Area

1 INTRODUCTION

1.1 GENERAL BACKGROUND

The Western Cape Water Supply System (WCWSS) serves the City of Cape Town (CCT), other urban users and irrigators. It comprises infrastructure owned and operated by both the CCT and the Department of Water Affairs (DWA).

The Western Cape Reconciliation Strategy Study (DWAF 2007) reviewed the future water requirement scenarios of greater Cape Town and the reconciliation options for meeting these water requirements within a planning horizon to 2030. It identified potential suites of options for meeting future water demand from the WCWSS. It also identified various alternative implementation options, which offered flexibility in planning, such that possible changes in the projected water requirements could be accommodated. One set of implementation options is to further develop the surface water resources of the Berg and Breede Water Management Areas (WMAs).

In July 2008, the then Department of Water Affairs and Forestry (DWAF) (now Department of Water Affairs; DWA) appointed the Western Cape Water Consultants Joint Venture to undertake Pre-feasibility and Feasibility level investigations of the potential development of six surface water options, namely:

- the Michell's Pass Diversion Scheme;
- the First Phase Augmentation of Voëlvlei Dam;
- Further Phases of Voëlvlei Dam Augmentation;
- the Molenaars River Diversion;
- the Upper Wit River River Diversion;
- Further Phases of the Palmiet Transfer Scheme.

This entailed investigations in three major catchments, *viz*. Breede, Palmiet and Berg Catchments.

1.1.1 Environmental Water Requirements and the Ecological Reserve

The South African National Water Act (NWA; RSA 1998) provides for the protection of water resources through the apportioning of an agreed amount of the water available in a system to facilitate maintenance of the natural environment in some pre-agreed condition. This water needs to be of an appropriate volume and quality, and be available at the appropriate time of the year, to fulfil its purpose, and is known as the Ecological Reserve.

To arrive at the Ecological Reserve, the Environmental Water Requirements (EWRs) for the maintenance of affected rivers, estuaries, wetlands and groundwater are first determined for a range of future conditions. These are then assessed against other requirements in the basin, such as provision of water for off-stream use, as part of a consultative process to decide on acceptable future conditions for the various ecosystems (DWAF, 2009; Dollar *et al*., 2006). The agreed future condition and the EWRs for maintaining such become the Ecological Reserve.

1.1.2 Environmental Water Requirement data generated for use in the Pre-Feasibility and Feasibility Studies Western Cape Water Supply System

The original proposal for this study envisaged that the EWR data required to assess the various water-resource development options would be based, for the most part, on existing information and would be limited to the river reaches immediately downstream of the proposed water-resource developments. However, the present level of water use and water-resource

development in the study catchments necessitated a basin-level assessment, so that the cumulative effects of the existing and proposed new water-resource developments could be evaluated. This was particularly important because some of the existing water-resource developments in these catchments do not make any Reserve releases, e.g., Theewaterskloof Dam (Breede River Catchment), Steenbras Dam (Steenbras River Catchment) and Wemmershoek Dam (Berg River Catchment). Furthermore, Reserve-related data were not available for some key parts of the catchment, specifically the Palmiet and the Berg estuaries. The EWRs of both of these estuaries had been assessed in the past (Taljaard 2000; Granger 1994, respectively) but the available data were neither at the resolution required for this study, nor had they been generated at a sufficient level of confidence to warrant their use in the study.

DWA also realized that the sorts of data that would be needed in this study would also be needed in other initiatives aimed at assessing the potential for additional water use in the catchments, such as the All Towns Reconciliation Study, *ad hoc* license applications and the Classification Processes required in terms of Act 36 of the NWA (RSA 1998). The classification of water resources is intended to provide the framework within which various RDM and other activities take place as envisaged within the NWA (Parts 1 to 3 of Chapter 3). It was therefore decided to analyse, generate and arrange the data for this study in line with that required for the Water Resources Classification System (WRCS; Dollar *et al.* 2006: Section 2) as this provided the most useful and robust guidance for the generation and arrangement of basin-level EWR data.

Accordingly, the 'Reserve' tasks as originally envisaged in the proposal were expanded to include undertaking the ecological aspects of the steps in the WRCS *(*Dollar *et al.* 2006*)* for the Breede, Palmiet and Berg Catchments, Reserve determinations for the Palmiet and Berg Estuaries, Rapid Reserve determinations for the Steenbras, Pombers and Kromme (Volume 1, Appendix 4), and a resource economics assessment of the implications of flow change in the Berg River Estuary (Volume 3) which forms part of a Comprehensive Reserve determination for the Berg River Estuary (Table 1.1).

Table 1.1 Reserve-related tasks in the WCWSS

Task No.	Description
1	Generation of catchment-wide Reserve estimates for the Breede and Palmiet Catchments as per the technical requirements of the WRCS.
2	Generation of catchment-wide Reserve estimates for the Berg River Catchments as per the technical requirements of the WRCS.
3	Rapid II Reserve assessments (quantity) for the Steenbras, Pombers and Kromme Rivers.
4	Comprehensive Reserve determination for the Berg River Estuary.
5	Resource Economics Assessment of the implications of flow change in the Berg River Estuary.
6	Rapid Reserve determination for the Palmiet River Estuary.

1.2 PURPOSE OF THIS REPORT

This report (Volume 1) addresses the generation of EWR data for the rivers in the study catchments:

Main Report: This report, which covers Tasks 1 and 2 (Table 1.1), and as such is a synthesis of existing EWR data, and the additional data generated in Tasks 3, 4 and 6.

Appendix 1: EWR data for the Breede River (only available electronically).
Appendix 2: EWR data for the Palmiet River (only available electronically).
Appendix 3: EWR data for the Berg River (only available electronically).

Appendix 4: Task 3.1: Rapid II Reserve assessments (quantity) for the Steenbras, Pombers and Kromme Rivers.

Appendix 5: Habitat Integrity report, Breede River.

Tasks 4, 5 and 6 are addressed in separate reports.

1.3 LAYOUT OF THIS REPORT

Section 1: This section is a brief introduction to the study in general and the EWR aspects thereof in particular.

Section 2: A brief description of the WRCS.

Section 3: Description of the WRCS node selection procedure.

Section 4: Node selection for the Breede Catchment

Section 4: Node selection for the Palmiet Catchment

Section 5: Node selection for the Berg Catchment

Section 6: Describes the generation of EWR data for the study catchments.

2 THE WATER RESOURCES CLASSIFICATION SYSTEM

The WRCS, which is a requirement of the NWA (RSA 1998), provides for a structured process to identify the agreed trade-off point between resource protection and development of river basins, through an assessment of the economic, social and ecological implications any future condition for a given water resource (Dollar *et al*. 2006). It is designed for use in Classification Processes for every WMA in the country, the outcome of which will be the setting of the Management Class, Reserve and Resource Quality Objectives (RQOs) by the Minister of Water Affairs or delegated authority for significant water resources (river, estuary, wetland and aquifer) in each WMA.

A Management Class, which describes the desired condition of the resource, and concomitantly, the degree to which it can be utilized, will be chosen for an entire catchment or sub-catchment (Dollar *et al.* 2006). The Management Class can range from Minimally to Heavily used (Table 2.1), and sets the boundaries for the volume, distribution and quality of the Ecological Reserve and RQOs, and thus the potential allocatable portion of a water resource for off-stream use. This has considerable economic, social and ecological implications.

Table 2.1 Proposed Management Classes (Dollar *et al.* 2006)

Class I: Minimally used
The configuration of water resources within a catchment results in an overall water resource condition that is minimally altered from its pre-development condition.
Class II: Moderately used
The configuration of water resources within a catchment results in an overall water resource condition that is moderately altered from its pre-development condition.
Class III: Heavily used
The configuration of water resources within a catchment results in an overall water resource condition that is significantly altered from its pre-development condition.

Many of the steps or procedures of the WRCS are similar to those undertaken as part of the "Resource Directed Measures" (RDM) process during which, among other things, EWRs are specified. Once gazetted, the WRCS will be used in place of the Preliminary Reserve studies that have been undertaken to date. For those catchments where Intermediate or Comprehensive Reserve studies have already been completed, the WRCS extends the data generated by those studies for use in the Classification Process. The WRCS is currently undergoing the process of gazetting.

2.1 STEPS IN THE WRCS UNDERTAKEN FOR WCWSS

The WRCS comprises seven broad steps:

1. Delineate the units of analysis and describe the status quo of the water resources;
2. Link the value and condition of the water resource;
3. Quantify the ecological water requirements and changes in non-water quality ecosystem goods, services and attributes;
4. Determine an Ecologically Sustainable Base Configuration scenario and establish the starter configuration scenarios;
5. Evaluate the scenarios within the Integrated Water Resource Management process; and
6. Gazette the Management Class and its configuration.

Step 1(d) of the WRCS is to "Define a network of significant resources and establish biophysical and allocation nodes" (Figure 2.1), which are used as the basis of the Classification Process.

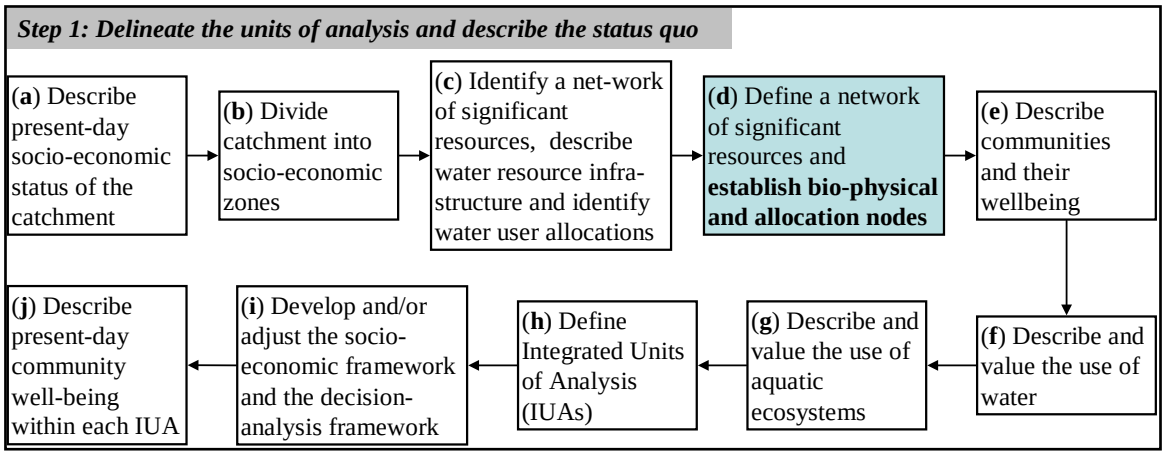

Figure 2.1 The procedures undertaken as part of Step 1 of the WRCS.

The first sub-steps of Step 1(d) are to identify significant resources, describe water resource infrastructure and identify water user allocations (Brown *et al*. 2006). Then further sub-steps are undertaken, namely:

- The establishment of ecosystem-specific units.
- The identification of areas of interaction between ecosystems.
- The identification of nodes that will account for the interactions between ecosystems.
- The establishment of allocation nodes.

2.1.1 WRCS nodes

For the purposes of WRCS, a node is a modelling point which "represent(s) the downstream end of a reach or area for which a suite of relationships apply" (Brown *et al.*, 2006, pg. 90).

2.2 INFORMATION AND GIS LAYERS REQUIRED

The following information and GIS layers are required to complete the procedure of selecting nodes:

- Quaternary, secondary and primary catchment boundaries (from http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.htm)
- Rivers on a 1:500 000 scale (from http://www.dwaf.gov.za/iwqs/gis_data/RHP data.htm)
- Level I Ecoregions (from http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.htm)
- Gauging weirs – from Department of Water Affairs and Forestry (DWAF)
- Geomorphic zones by Rowntree and Wadeson (1999) (from Chief Directorate Resource Quality Services, Department of Water Affairs (DWA)
- Environmental Water Requirements (EWR) sites (from relevant Reserve studies).
- Hydrological Index Classes based on the hydrological index of Hughes and Hannart (2003) as modified by Dollar *et al*. (2006) and Brown *et al*. (2006).
- Ecological Importance and Sensitivity categories and Present Ecological Status (or habitat integrity) (from various reports, DWA database, updated and augmented with fieldwork in WCWSS).

3 NODE SELECTION PROCEDURE

This Section describes establishing the biophysical and allocation nodes for (Figure 3.1):

- the Breede River catchment, which is part of the Breede WMA;
- the Palmiet River catchment, which is also part of the Breede WMA; and
- the Berg River catchment, which is part of the Berg WMA.

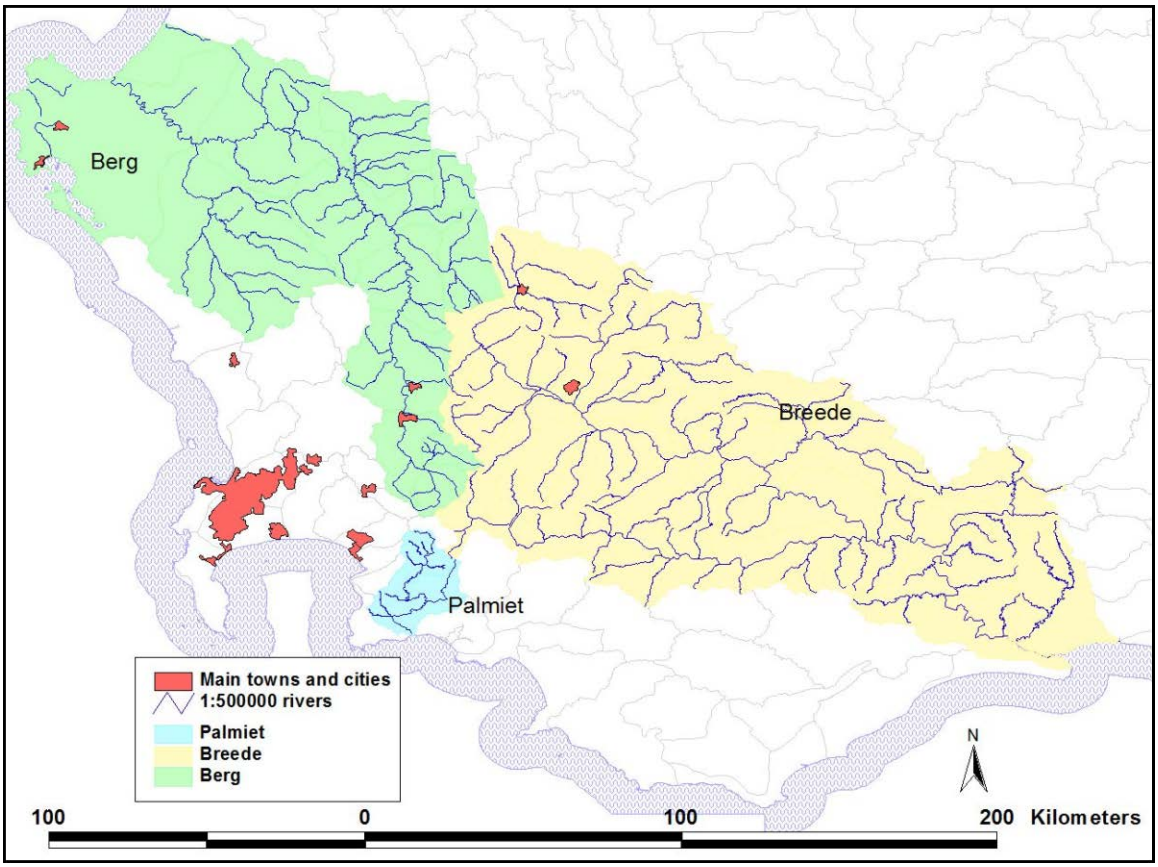

Figure 3.1 The Breede, Palmiet and Berg River catchments

The node selection procedure developed for the WRCS is outlined in Table 3.1. Eleven "tiers" of information are sequentially assessed, and rules applied, in order to establish nodes for each tier. Nodes are added sequentially for Tiers I to Tier VIII, where after rationalisation rules are applied to eliminate nodes for which EWRs are not required, e.g., impoundments (Tier VII). Then additional nodes are added as required for Tiers V-IIX, and rationalisation rules are applied again to eliminate nodes for which hydrological information is unlikely to be available and/or nodes that are too close to each other (Tier IX). Thereafter, nodes are again added where additional information is needed at a particular quaternary catchment or at a sub-quaternary level for planning or allocation purposes where information is required for an international water agreement.

3.1 TIER I – ECOREGION LEVEL 1

The data used for the Level I Ecoregions were obtained from www.dwaf.gov.za (Kleynhans *et al*., 2005).

In Tier I, ecoregions that make up less than 5% of the total area of the primary catchment and where more than 75% is represented elsewhere are excluded. Thereafter, a Tier I node is placed at each quaternary boundary where more than 75% of the upstream quaternary is comprised of a different Ecoregion from the downstream quaternary.

3.2 TIER II – HYDROLOGICAL INDEX

Tier nodes are based on an assessment of perenniality, using a summary of the hydrological indices (HI) developed for South African Rivers by Hughes and Hannart (2003). Dollar *et al*. (2006) subsequently divided these into nine HI Classes (HIC), which Brown *et al*. (2006) grouped into three HI groups, *viz*., Perennial (HIC 1 to 4), Seasonal (HIC 5) and Ephemeral (HIC 6 to 9).

In Tier II a node is placed at each quaternary boundary downstream of a change in HI group. Where a Tier I node is already established, no additional node is created.

3.3 TIER III – GEOMORPHIC ZONES

Tier III node allocation is based on the geomorphic zones of Rowntree and Wadeson (1999). Four geomorphic zones are recognised, *viz*.:

- Group 1: Mountain Headwater, Mountain Stream, Transitional and Upper Foothills.
- Group 2: Lower Foothills.
- Group 3: Lowland Rivers.
- Group 4: Rejuvenated Floodplains.

In Tier III a node is placed at each quaternary intersection where more than 75% of the river in the upstream quaternary is comprised of a different geomorphic zone (group) from the downstream reach. Nodes are also to be placed at the head of estuaries. Where a Tier I or II node has already been established no new node is created.

3.4 TIER IV – TRIBUTARIES

In Tier IV nodes are placed on the main river and on any significant tributary immediately upstream of their confluence. Where a node is already established, no additional node is created.

3.5 TIER V – ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY

In Tier V a node is placed at each quaternary boundary downstream of a quaternary of high or very high Ecological Importance and Sensitivity (EIS). Where a node is already established, no additional node is created.

3.6 TIER VI – PRESENT ECOLOGICAL STATUS / HABITAT INTEGRITY

In Tier VI a node is placed at each quaternary boundary where more than 75% of the upstream catchments are of a different Present Ecological Status or Habitat Integrity (PES/HI) from the downstream quaternary. Where a node is already established, no additional node is created.

3.7 TIER VII – INFRASTRUCTURE

Tier VII may involve both addition and deletion of nodes. Unless a node has already been established in previous tiers, Tier VII nodes are added at gauging weirs, upstream of dams, upstream of mines or towns, below changes in density of farm dams and at Inter Basin Transfers (IBTs). Where a node is already established, no additional node is created.

Nodes are deleted if they are inundated by impoundments or if they describe upstream sections for which no description is required, e.g. impoundments.

3.8 TIER VIII – RDM DATA

In Tier VIII a node is placed at the quaternary boundary immediately downstream of an EWR site. Where a node is already established, no additional node is created.

3.9 TIER IX – FIRST LEVEL RATIONALISATION

In Tier IX one of a pair of nodes that are less than 10 km apart is removed. Nodes that describe a section of river that contributes less than 1% of nMAR of the basin are also removed. However, Tier I nodes and nodes specifically required for scenario analysis should not be deleted.

3.10 TIER X – WATER RESOURCES MANAGEMENT, PLANNING OR ALLOCATION REQUIREMENTS

In Tier X nodes are to be added where information is required for planning or allocation purposes or other procedures. Where a node is already established, no additional node is created.

3.11 TIER XI – INTERNATIONAL WATER AGREEMENTS

In Tier XI a node is placed at where information is required for an IWA.

Table 3.1 The rules for establishing WRCS nodes.

TIER	Data/GIS layers	Procedure for river node selection		Minimum unit
		Filtering process	Additional explanation	
I	Ecoregions Level I (Kleynhans *et al*., 2005)	Exclude Ecoregions that comprise < 5% of the total area of the primary catchment AND where >75% is represented elsewhere.	Place node at each Ecoregion/ quaternary catchment intersection where >75% of the upstream quaternary is comprised of a different Ecoregion from the downstream quaternary.	Quaternary
II	Hydrological index Classes (HydI) (Dollar *et al*., 2006) derived from the hydrological index (Hughes and Hannart, 2003)	Hydl Class 1: HydI = 1 to 4 (perennial).	Place node at each Quaternary intersection where there is a change in HydI Class.	
		Hydl Class 2: HydI = 5 (seasonal).		
		Hydl Class 3: HydI = 6 to 9 (ephemeral).		
III	Geomorphic zones (Rowntree and Wadeson, 1999[1]).	Group 1: Mountain Headwater, Mountain Stream, Transitional and Upper Foothills.	Place node at each quaternary intersection, where >75% of the upstream quaternary is comprised of a different geomorphic zone from the downstream quaternary. Place node at the head of the estuary.	
		Group 2: Lower Foothills.		
		Group 3: Lowland Rivers.		
		Group 4: Rejuvenated Floodplains.		
IV	Tributaries	Two nodes: one for each river upstream of the confluence.	Place node at the nearest quaternary intersection on each river.	
V	Ecological Importance and Sensitivity Category (EISC)	Use EISC information (Kleynhans, 2000) and augment with local data where applicable.	Place node at each quaternary intersection downstream of high or very high EISC.	
VI	Present Ecological Status (PES)/Habitat Integrity (HI)	Use PES information (Kleynhans, 2000) and augment with local data where applicable.	Place node at each quaternary intersection, where > 75% of the upstream quaternary is comprised of a different PES/HI from the downstream quaternary. If sub-quaternary data are available, then adjust the information accordingly.	
		Group 1: A and B.		
		Group 2: C.		
		Group 3: D.		
		Group 4: E and F.		
VII	Infrastructure	This Tier comprises both establishment of river nodes and some rationalisation of previously established nodes.		
		(a) Insertions.	i. Place a node at each DWAF gauging weir for which there is a hydrological record.	Sub-quaternary

[1] These zones have been determined by DWAF's Chief Directorate: Resource Quality Services (CD: RQS) for the 1:500 000 rivers coverage for the whole of South Africa, and are available on request from the CD: RQS.

TIER	Data/GIS layers	Procedure for river node selection		Minimum unit
		Filtering process	**Additional explanation**	
			ii. Place a node at the upstream limit of the inundation of any major dam.	
			iii. Place a node upstream of mines, towns or other localities likely to influence water quality.	
			iv. Place a node at each quaternary inter-section where the area covered by farm dams in the upstream quaternary is > 5 times that of the downstream quaternary.	Quaternary
			v. Place a node on a river immediately upstream of the confluence with an Inter Basin Transfer (IBT).	Sub-quaternary
		(b) Deletions.	vi. Remove any nodes that are inundated by impoundments.	
			vii. Remove any nodes that describe upstream sections for which no description is required, e.g. impoundments.	
VIII	RDM data	Comprehensive or Inter-mediate Reserve determinations.	Place a node at the nearest quaternary boundary downstream of each Ecological Water Requirement (EWR) site.	
IX	First level rationalisation	Minimum distance between nodes = 10 km.	i. Delete nodes that are less than 10 km (river length) apart. Retain the node that is closest to a quaternary intersection.	n/a
		Minimum contribution to natural Mean Annual Runoff (nMAR) = 1%.	ii. Delete nodes where the cumulative contribution to nMAR <1%.	
X	Water resource management /planning/ allocation	Where applicable for hydrology/ water resource management/ planning/ allocation.	It is essential that ecological information can be provided at a scale (and locations) relevant to other proecedures linked to the Classicfi-cation Process. If these are not already captured in the node delineation process described above, insert nodes at relevant positions as dictated to by other procedures linked to the Classification Process.	Sub-quaternary
XI	International Water Agreements (IWA)	Based on IWAs signed between South Africa and neighbouring countries.	Place node at each quaternary intersection where required for an IWA.	Sub-quaternary

Node selection for the Breede River catchment

Sixty-three WRCS nodes were selected in the Breede River catchment. This Section summarises the decisions at each tier and the details of the nodes selected.

3.12 TIER I – ECOREGION LEVEL 1

There are four Level I Ecoregions within the Breede River catchment area, *viz*., Southern Coastal Belt (38%), Southern Folded Mountains (33%), Western Folded Mountains (26%) and very small portions of South Western Coastal Belt (3%).

Three Tier I nodes were added (Table 3.2; Figure 3.2).

Table 3.2 Three Tier I nodes (based on Level 1 Ecoregions) in the Breede system.

Node	Comment	River	LON (E)	LAT (S)	Quaternary
Ni1	U/s of confluence with Poesjenels	Breede	19.72813	-33.84932	H40F
Ni2	U/s of confluence with Riviersonderend	Breede	20.28653	-34.06804	H50B
Ni3	U/s of confluence with Breede	Riviersonderend	20.28513	-34.07071	H60L

Western Folded Mountains	WFM
Southern Folded Mountains	SFM
Southern Coastal Belt	SCB

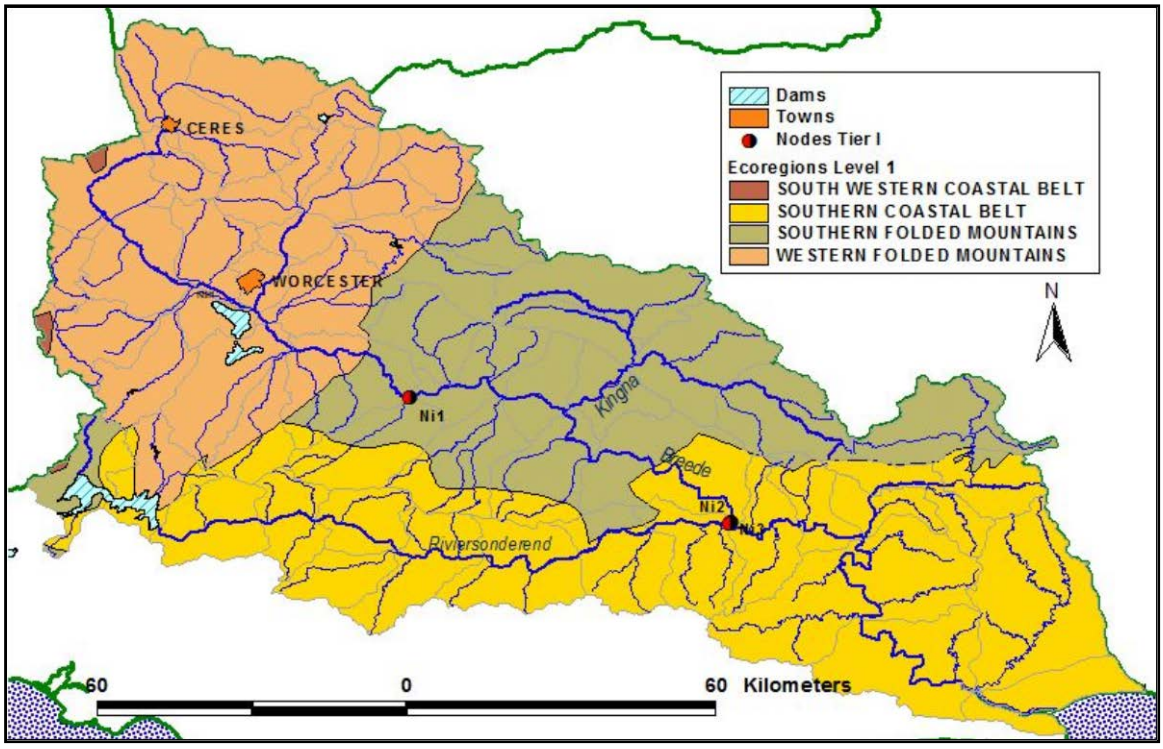

Figure 3.2 The Breede River catchment, showing the ecoregions and three Tier I nodes.

3.13 TIER II – HYDROLOGICAL INDEX

Two Tier II nodes were created (Table 3.3; Figure 3.3).

Table 3.3 Two Tier II nodes (based on Hydrological Index (HI) Types) in the Breede River catchment.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI
Nii1	D/s of Hex/ Breede confluence	Breede	19.46299	-33.70234	H10L/H10H	WFM	2
Nii2	At gauging weir H3H011, u/s of confluence with Breede	Kogmanskloof /Kingna	20.00324	-33.87040	H30E	SFM	1

Western Folded Mountains	WFM
Southern Folded Mountains	SFM
Southern Coastal Belt	SCB

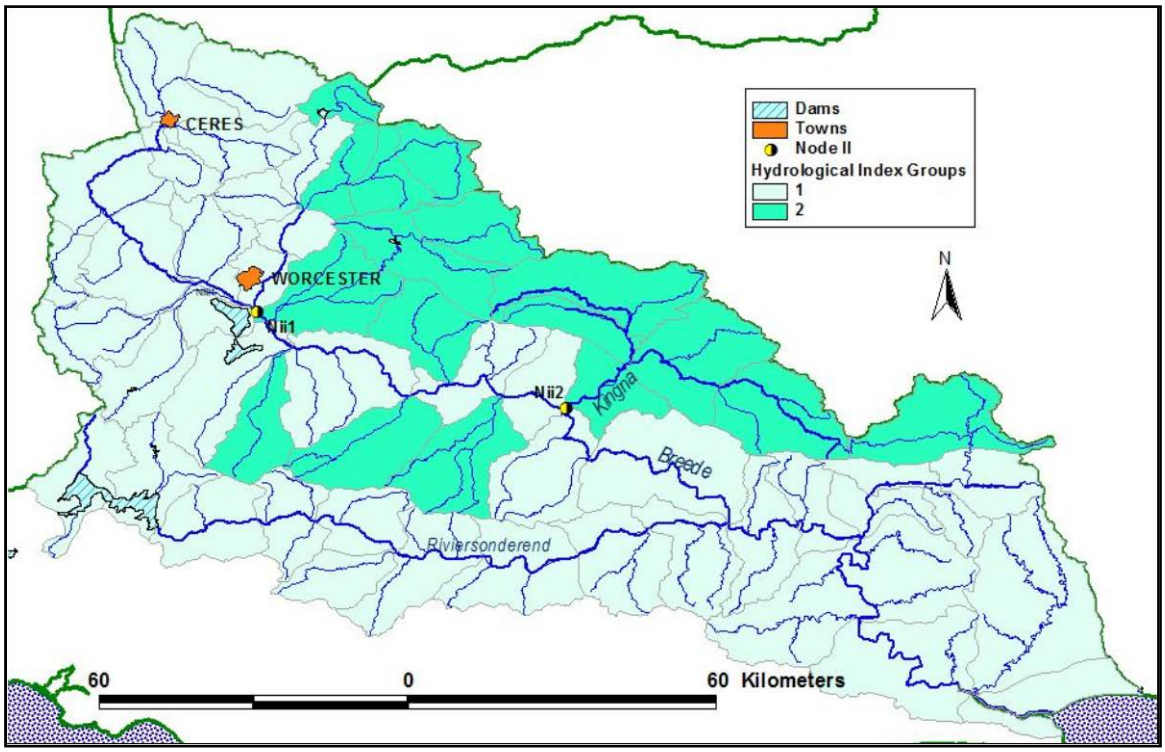

Figure 3.3 The Breede River catchment, showing the Hydrological Index groups and two Tier II nodes.

3.14 TIER III – GEOMORPHIC ZONES

Four Tier III nodes were established (Table 3.4; Figure 3.4) including one immediately upstream of the estuary at the H70G quaternary boundary. The top of the estuary was given as 34.25 S and 20.5111 E (Bohlweki SSI Environmental 2008).

Table 3.4 Four Tier III nodes (based on geomorphic zones (GZ)) in the Breede system.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Niii1	U/s of confluence with Molenaars (Smalblaar)	Breede	19.34871	-33.65347	H10G	WFM	1	LR
Niii2	U/s of confluence with Breede	Breede	19.89084	-33.84818	H40J	SFM	1	LF
Niii3	U/s of confluence with Boesmans	Breede	20.04238	-33.95968	H50A	SFM	1	LF
Niii4	D/s of EWR 4, at Napkei confluence	Breede	20.51240	-34.23484	H70G	SCB	1	E

Lower Foothills	LF
Lowland River	LR
Estuary	E

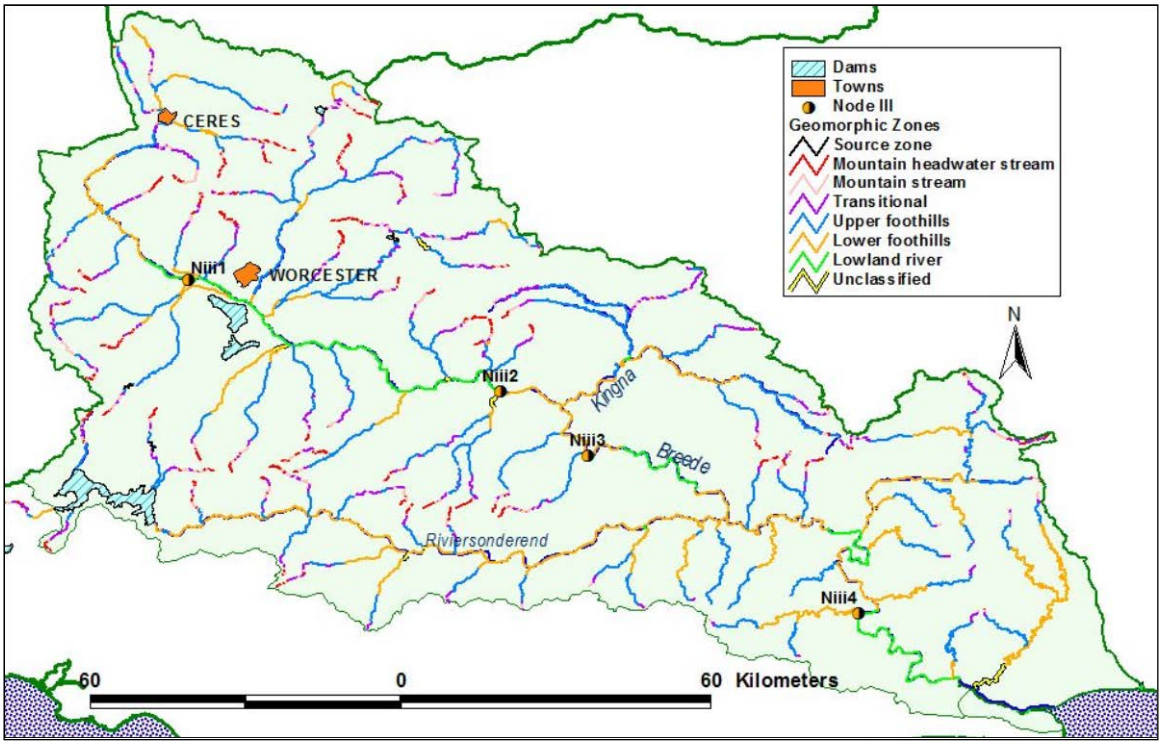

Figure 3.4 Breede River catchment, showing the geomorphic zones and four Tier III nodes.

3.15 TIER IV – TRIBUTARIES

Thirty-one Tier IV nodes were created (Table 3.5; Figure 3.5).

Table 3.5 Thirty-one Tier IV nodes (for tributaries) in the Breede system.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Niv1	U/s of confluence with Dwars	Koekedou	19.29834	-33.35961	H10C	WFM	1	UF
Niv2	U/s of confluence with Koekedou	Dwars	19.30059	-33.35445	H10C	WFM	1	LF
Niv3	U/s of confluence with Breede	Titus	19.32356	-33.37987	H10B	WFM	1	LF
Niv4	U/s of confluence with Breede	Witels	19.29239	-33.41749	H10D	WFM	1	T
Niv5	U/s of confluence with Breede	Wit	19.19943	-33.53577	H10F	WFM	1	LF
Niv6	U/s of confluence with Breede	Wabooms	19.20618	-33.53827	H10F	WFM	1	UF
Niv7	U/s of confluence with Slanghoek	Slanghoek	19.24024	-33.57666	H10G	WFM	1	UF
Niv8	U/s of confluence with Breede	Bothaspruit/ Witrivier	19.36343	-33.64720	H10H	WFM	1	LF
Niv9	U/s of confluence with Breede	Hartbees/ de Wetskloof	19.37469	-33.65185	H10H	WFM	1	T
Niv10	U/s of confluence with Breede	Hex	19.45648	-33.69419	H20H	WFM	1	LF
Niv11	U/s of confluence with Breede	Nuy	19.48130	-33.71801	H40C	WFM	2	LF
Niv12	Just South of Rawsonville	Holsloot	19.32507	-33.69400	H10K	WFM	1	LF
Niv13	U/s of confluence with Breede, d/s of Hoeks/Doring (Bobbejaans/Kiese)	Doring	19.52113	-33.76716	H40D	WFM	1	U
Niv14	U/s of confluence with Breede	Keisers	19.88989	-33.85032	H40K	SFM	2	U
Niv15	U/s of confluence with Breede	Vink	19.79753	-33.82419	H40H	SFM	2	U
Niv18	U/s of confluence with Kogmanskloof	Kingna	20.11600	-33.79284	H30B	SFM	2	LF
Niv20	U/s of confluence with Keisie	Pietersfontein	20.10834	-33.73904	H30C	SFM	2	UF
Niv24	U/s of confluence with Riviersonderend	Leeu	20.31862	-34.08595	H70A	SCB	1	UF
Niv24a	U/s of confluence with Riviersonderend	Klip	20.41509	-34.06616	H70B	SCB	1	UF
Niv25	U/s of confluence with Riviersonderend	Buffeljags	20.52031	-34.09445	H70F	SCB	1	LF
Niv26	U/s of confluence with Breede	Slang	20.71492	-34.35731	H70J	SCB	1	U
Niv28	U/s of confluence with Riviersonderend,	Baviaans	19.55670	-34.06331	H60E	SCB	1	UF

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
	d/s of EWR 6 on Baviaans							
Niv29	U/s of confluence with Riviersonderend	Sersants	19.55914	-34.06608	H60E	SCB	1	UF
Niv30	U/s of confluence with Riviersonderend	Gobos	19.60911	-34.07054	H60F	SCB	1	UF
Niv31	U/s of confluence with Riviersonderend	Kwartel	19.70304	-34.12027	H60G	SCB	1	LF
Niv33	U/s of confluence with Riviersonderend	Soetmelksvlei	19.75634	-34.11850	H60H	SCB	1	UF
Niv34	U/s of confluence with Riviersonderend	Slang	19.81128	-34.12776	H60H	SCB	1	UF
Niv35	U/s of confluence with Riviersonderend	Kwassadie	20.14142	-34.08539	H60K	SCB	1	LR
Niv40	U/s of confluence with Molenaars	Elands	19.11566	-33.73389	H10J	WFM	1	T
Niv41	U/s of confluence with Molenaars	Krom	19.11231	-33.73017	H10J	WFM	1	T
Niv42	Just South of Rawsonville	Molenaars (Smalblaar)	19.31593	-33.68995	H10J	WFM	1	UF

*** bad quaternary catchment boundary

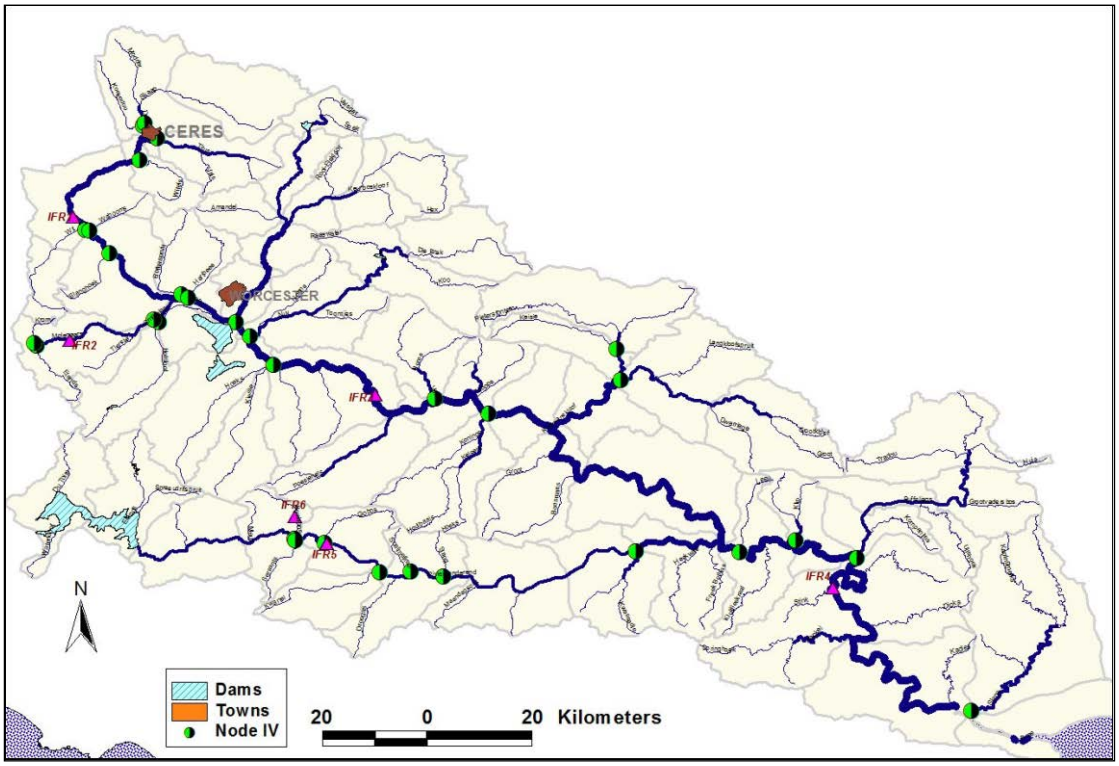

Figure 3.5 The Breede River catchment, showing the thirty-one Tier IV nodes.

3.16 TIER V – ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY

Fourteen[2] Tier V nodes were added (Table 3.6; Figure 3.6).

Table 3.6 Fourteen Tier V nodes (EISC) in the Breede system.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Nv1	5.5 km d/s of Niv11 and R43 road crossing	Breede	19.52242	-33.76610	H40E	WFM	1	LR
Nv2	U/s of confluence with Buffeljags	Breede	20.51719	-34.09571	H70B	SCB	1	LR
Nv3	U/s of confluence with Hex (at Brandvlei reservoir)	Breede	19.45102	-33.69282	H10H	WFM	1	LR
Nv4	At confluence with Nuy	Breede	19.47851	-33.71831	H40C	WFM	2	LR
Nv5	Under Theewaterskloof reservoir	Riviersonderend	19.20831	-34.02612	H60B	SCB	1	LF
Nv6	At Theewaterskloof dam wall	Riviersonderend	19.28997	-34.07729	H60C	SCB	1	LF
Nv7	2.5 km u/s of confluence with Meul	Riviersonderend	19.46327	-34.06361	H60D	SCB	1	LF

[2] Note that four of these were later removed in the Tier VII rationalisation stage (Section 3.18).

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Nv8	South of Genadendal, d/s of R404 bridge	Riviersonderend	19.56392	-34.06627	H60E	SCB	1	LF
Nv9	At confluence with Kwartel, EWR 5	Riviersonderend	19.70425	-34.11639	H60F	SCB	1	LF
Nv10	D/s of confluence with Slang and Lindeshof town	Riviersonderend	19.85624	-34.12656	H60H	SCB	1	LF
Nv11	9 km u/s of Stormsvlei, alongside N2	Riviersonderend	20.02322	-34.12470	H60J	SCB	1	LF
Nv12	D/s of confluence with Kwassadie	Riviersonderend	20.14743	-34.07773	H60K	SCB	1	LF
Nv13	At Suurbrak	Buffeljags	20.65671	-34.00276	H70D	SCB	1	LF
Nv14	U/s of Buffeljags Dam	Buffeljags	20.53304	-34.01939	H70E	SCB	1	LF

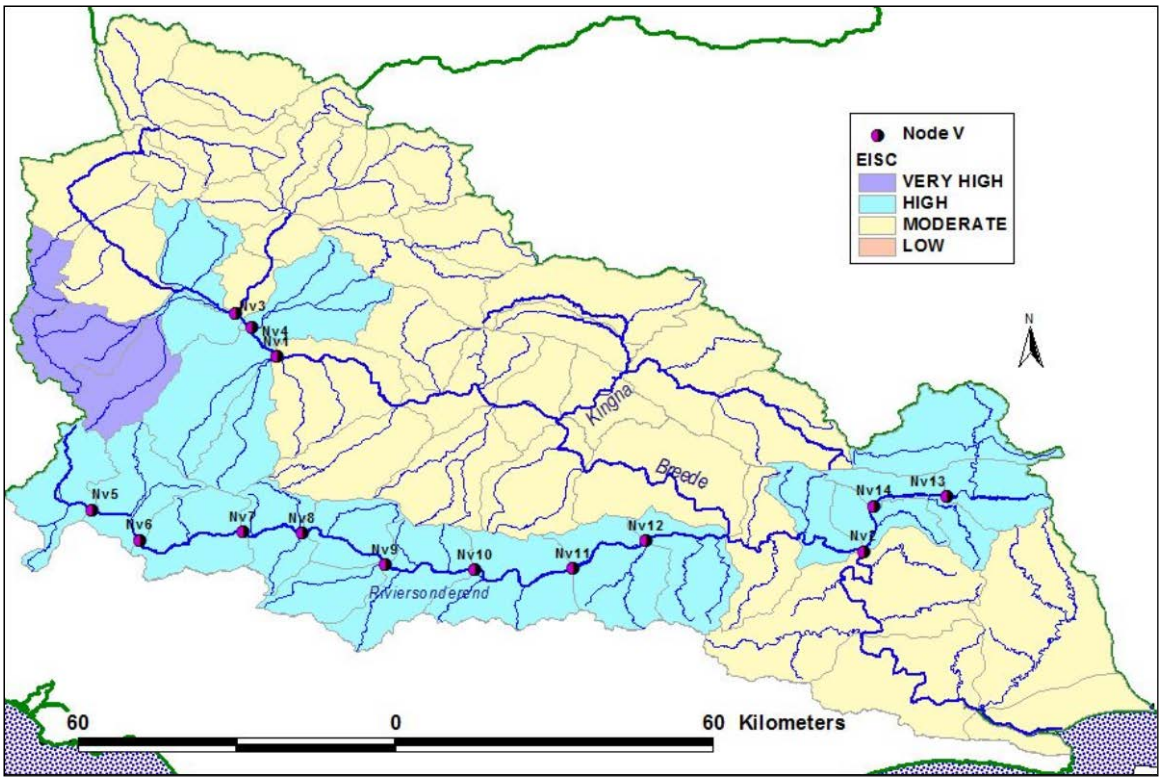

Figure 3.6 The Breede River catchment, showing the fourteen Tier V nodes.

3.17 TIER VI – PRESENT ECOLOGICAL STATUS / HABITAT INTEGRITY

Four Tier VI nodes were added (Table 3.7; Figure 3.7).

Table 3.7 Four Tier VI nodes (PES) in the Breede system.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Nvi1	U/s of confluence with Kogmanskloof	Breede	19.99688	-33.87915	H40L	SFM	1	LF
Nvi2	At Tweede Tol on Bainskloof Pass (R303)	Wit	19.14786	-33.56785	H10E	WFM	1	UF
Nvi3	U/s of junction of roads R46/ R43	Breede	19.26843	-33.42148	H10D	WFM	1	UF
Nvi4	2 km d/s of confluence with Dwars/ Titus	Breede	19.30243	-33.38080	H10C	WFM	1	UF

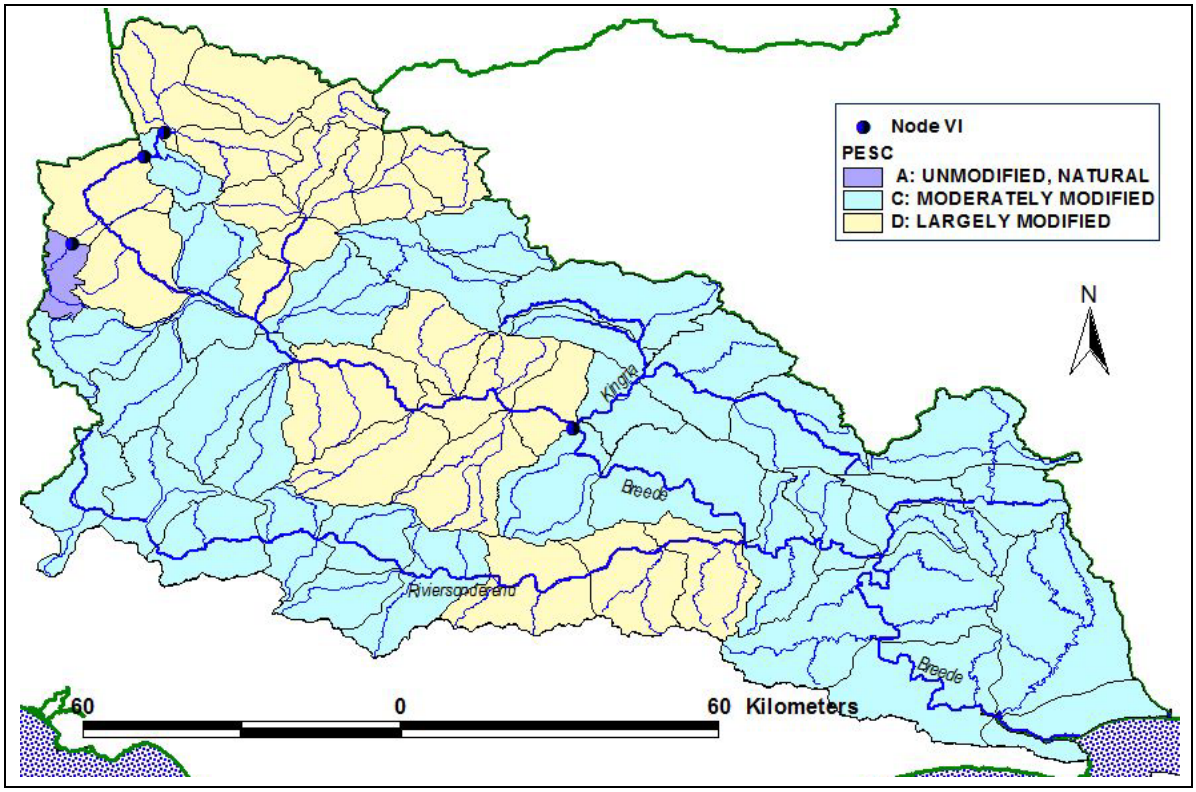

Figure 3.7 The Breede River catchment, showing the four Tier VI nodes.

3.18 TIER VII – INFRASTRUCTURE

3.18.1 Nodes added

Nine Tier VII nodes were added (Table 3.9; Figure 3.8).

Table 3.8. Nodes added for each of the Tier VII criteria

Reason	Nodes added
Gauging weirs	7 nodes (H1H016, H1H018, H1H020, H2H005, H2H006, H4H008, H4H017)
At the u/s limit of the inundation of any major dam	1 node (Nvii10), above Theewaterskloof Dam
U/s of mines, towns or other localities likely to influence water quality	1 (u/s of Ashton)
Where the area covered by farm dams in the u/s quaternary is more than five times that of the d/s quaternary	0
On a river immediately u/s of the confluence with an Inter Basin Transfer (IBT)	0

Table 3.9 Nine Tier VII nodes (infrastructure) in the Breede system.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Nvii2	At gauging weir H1H018, EWR 2	Molenaars	19.17085	-33.72392	H10J	WFM	1	UF
Nvii3	At gauging weir H1H016, u/s of confluence with Titus	Rooikloof	19.47768	-33.42146	H10B	WFM	1	T
Nvii4	At gauging weir H2H005, 7 km West of Hex River Valley	Sanddrif	19.53609	-33.46457	H20D	WFM	1	UF
Nvii5	At gauging weir H4H008, 2.3 km North of Worcester	Koo	19.76294	-33.59730	H40B	SFM	2	U

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Nvii6	At gauging weir H1H020, 7.5 km North of Worcester	Hartbees	19.43593	-33.55895	H10H	WFM	1	MH
Nvii7	At gauging weir H2H006, North of Worcester on N1	Hex	19.50331	-33.57849	H20G	WFM	1	UF
Nvii8	At gauging weir H4H017, EWR 3	Breede	19.69470	-33.81871	H40F	SFM	1	LR
Nvii9	U/s of of confluence with Kogmanskloof	Keisie	20.10679	-33.79276	H30D	SFM	2	LR
Nvii10	U/s of Theewaterskloof Dam	Du Toits	19.15394	-33.97951	H60B	SFM	1	UF

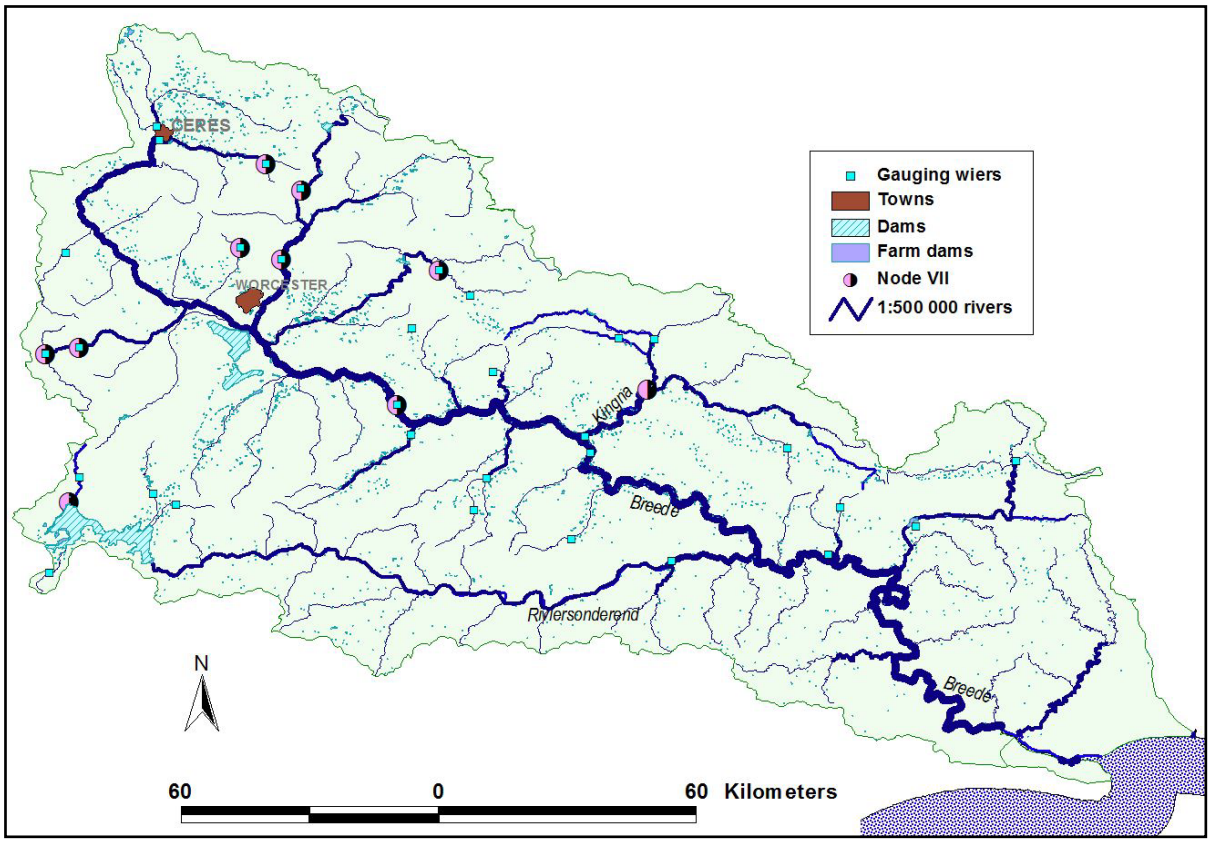

Figure 3.8 The Breede River catchment, showing the nine Tier VII nodes.

3.18.2 Nodes removed

Two Tier V nodes (Nv5 and Nv6) were removed, one inundated by, and one immediately downstream of Theewaterskloof Dam. Node Nv14, originally placed just downstream of Buffeljags dam, was not removed, but moved just upstream of the dam.

3.19 TIER VIII – RDM DATA

There are six EWR sites[3] in the Breede River catchment. However, only one additional Tier VII node was created, at EWR Site 1, as nodes had already been placed at the other EWR sites in previous Tiers (Table 3.10).

[3] Called IFR (Instream Flow Requirement) sites in some of the older literature.

Table 3.10 EWR sites in the Breede system; Tier VIII node created downstream of EWR Site 1.

SITE	NAME	LON (E)	LAT (S)	Node	Comment	Lon (E)	Lat (S)
EWR 1	D/s of confluence with Wabooms, nearest quaternary boundary to EWR1	19.207	-33.540	Nviii1	H10F boundary	19.2073	-33.5399
EWR 2	Molenaars d/s of gauging weir H1H018	19.170	-33.720	x	Nvii2 already in place		
EWR 3	Breede u/s of la Chasseur	19.690	-33.820	x	Nvii8 already in place		
EWR 6	Baviaans u/s of gauge above Genadendal	19.560	-34.020	x	Niv28 already in place		
EWR 5	Riviersonderend near Greyton (campsite)	19.610	-34.070	x	Nv9 already in place		
EWR 4	Lower Breede u/s of Stink, d/s Felix Unite camp	20.480	-34.150	x	Niii4 already in place		

3.20 TIER IX – FIRST LEVEL RATIONALISATION

Sixty percent of the quaternary catchments contributed less than 1% of nMAR (non-cumulative) and about 68% of the quaternaries are less than 250 km^2, so the %nMAR rule was not applied as it would have resulted in the elimination of the majority of nodes. The following nodes were removed because of the small distance to another node:

- Niii2 deleted – less than a kilometre upstream of Niv14
- Nv1 deleted – about nine km downstream of Nii2
- Nv4 deleted – about two km downstream of Nii2.

3.21 TIER X – WATER RESOURCES MANAGEMENT, PLANNING OR ALLOCATION REQUIREMENTS

No additional nodes were added in this Tier.

3.22 TIER XI – INTERNATIONAL WATER AGREEMENTS

No additional nodes were added in this Tier.

3.23 SUMMARY OF NODE INFORMATION FOR THE BREEDE

Sixty-three nodes were established following the rules summarised in Table 3.1 (Figure 3.9). The nodes are listed in Table 3.11 (the "node table"), which is arranged by quaternary catchment, river system and latitude. The "NodeCode" gives the Tier number e.g. Niii5, identifies a Tier III node. The second number is simply an identifier for the Arcview cover. Altitude, required for the Extrapolation Decision Support System, is given to the nearest 20m. EISC and PES indicated are the desktop estimates of Kleynhans (2000). These data have been updated as part of the tasks completed for this report. These updated data are presented in Report 1, Volume1, Appendix 5.

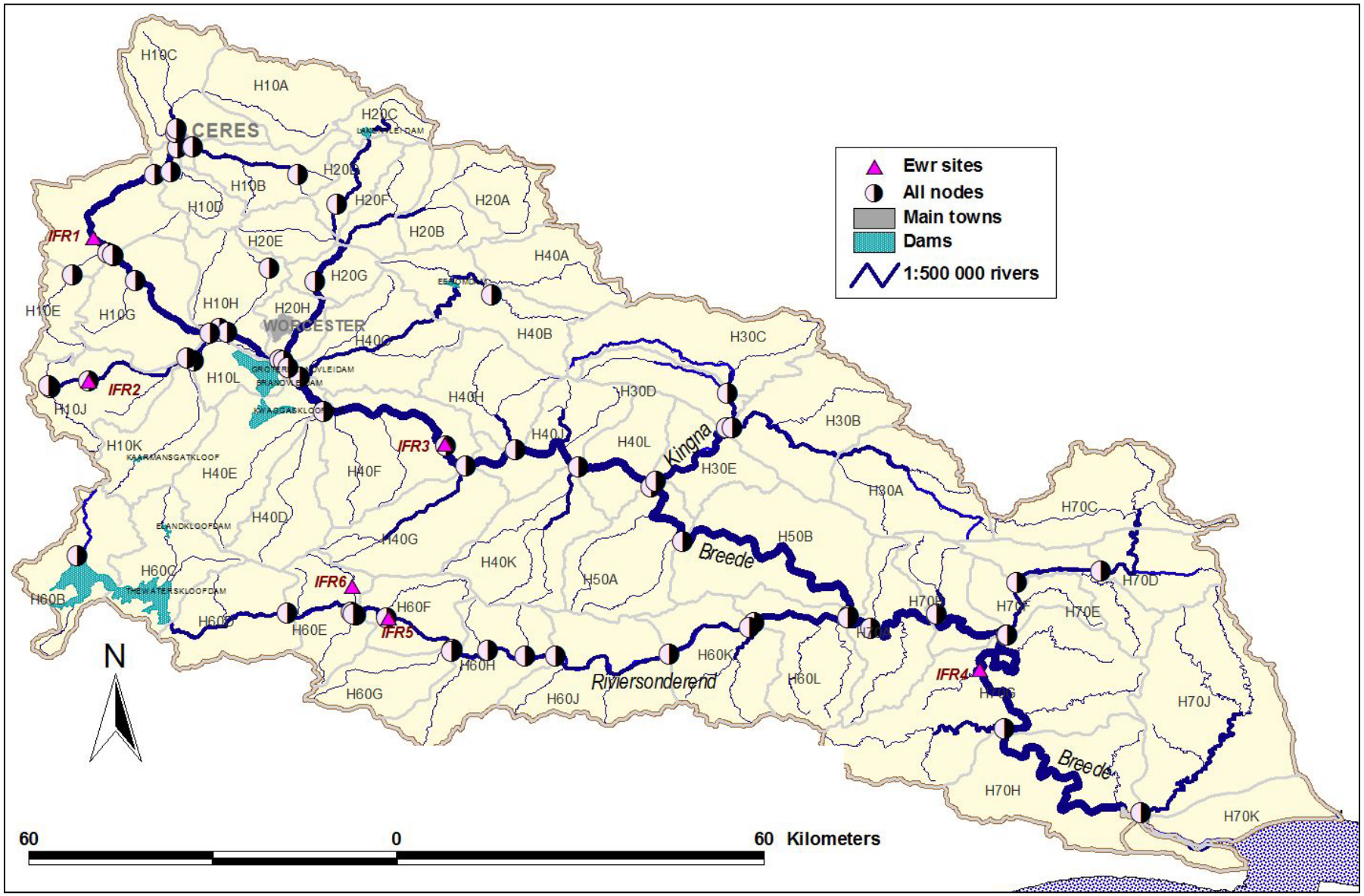

Figure 3.9 The Breede River catchment, showing the sixty-three nodes established.

Table 3.11 Node table for the Breede River catchment (quat=quaternary, ER=Ecoregion, HI=Hydrological Index, GZ=geomorphological zone, Alt=altitude, EISC=ecological importance and sensitivity, PES=present ecological status)

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ	EISC	Alt	PES
Niv1	U/s of confluence with Dwars	Koekedou	19.29834	33.35961	H10C	WFM	1	UF	M	460	C
Niv2	U/s of confluence with Koekedou	Dwars	19.30059	33.35445	H10C	WFM	1	LF	M	460	D
Niv3	U/s of confluence with Breede	Titus	19.32356	33.37987	H10B	WFM	1	LF	M	460	D
Nvii3	U/s of confluence with Titus, at gauge H1H016	Rooikloof	19.47768	33.42146	H10B	WFM	1	T	M	960	D
Nvi4	2 km d/s of confluence with Dwars/ Titus	Breede	19.30243	33.38080	H10C	WFM	1	UF	M	440	C
Niv4	U/s of confluence with Breede	Witels	19.29239	33.41749	H10D	WFM	1	T	M	320	B
Nvi3	U/s of junction of roads R46/ R43	Breede	19.26843	33.42148	H10D	WFM	1	UF	M	300	C
Nvi2	At Tweede Tol on Bainskloof Pass (R303)	Wit	19.14786	33.56785	H10E	WFM	1	UF	VH	280	B
Nviii1	D/s confluence with Wabooms, nearest quaternary boundary to EWR 1	Breede	19.20737	33.53969	H10F	WFM	1	LF	M	240	D/E
Niv6	U/s of confluence with Breede	Wabooms	19.20618	33.53827	H10F	WFM	1	UF	M	240	D
Niv5	U/s of confluence with Breede	Wit	19.19943	33.53577	H10F	WFM	1	LF	M	240	D
Niv7	U/s of confluence with Slanghoek	Slanghoek	19.24024	33.57666	H10G	WFM	1	UF	M	220	D
Niv40	U/s of confluence with Molenaars	Elands	19.11566	33.73389	H10J	WFM	1	T	VH	520	B
Niv41	U/s of confluence with Molenaars	Krom	19.11231	33.73017	H10J	WFM	1	T	VH	520	B
Nvii2	At gauging weir H1H018, EWR 2	Molenaars	19.17085	33.72392	H10J	WFM	1	UF	VH	380	B
Niv42	Just South of Rawsonville	Molenaars (Smalblaar)	19.31593	33.68995	H10J	WFM	1	UF	VH	220	D
Niv12	Just South of Rawsonville	Holsloot	19.32507	33.69400	H10K	WFM	1	LF	VH	220	D
Nvii4	At gauging weir H2H005, 7 km West of Hex River Valley	Sanddrif (Spek)	19.53609	33.46457	H20D	WFM	1	UF	M	460	D
Nvii7	At gauging weir H2H006, North of Worcester on N1	Hex	19.50331	33.57849	H20G	WFM	1	UF	M	320	D
Niv10	U/s of confluence with Breede	Hex	19.45648	33.69419	H20H	WFM	1	LF	M	200	D
Niii1	U/s of confluence with Molenaars (Smalblaar)	Breede	19.34871	33.65347	H10G	WFM	1	LR	H	200	C
Niv8	U/s of confluence with Breede	Bothaspruit/ Witrivier	19.36343	33.64720	H10H	WFM	1	LF	H	200	D
Nvii6	At gauging weir H1H020, 7.5 km North of Worcester	Hartbees	19.43593	33.55895	H10H	WFM	1	MH	H	560	C
Niv9	U/s of confluence with Breede	Hartbees/ de Wetskloof	19.37469	33.65185	H10H	WFM	1	T	H	200	E
Nvii5	At gauging weir H4H008, 2.3 km North of Worcester	Koo	19.76294	33.59730	H40B	SFM	2	U	M	720	C
Nv3	U/s of confluence with Hex (at Brandvlei reservoir)	Breede	19.45005	33.69210	H10H	WFM	1	LR	H	200	C
Nii1	D/s of Hex/Breede confluence	Breede	19.46299	33.70234	H10L/H10H	WFM	2	LR	H	200	C
Niv11	U/s of confluence with Breede	Nuy	19.48130	33.71801	H40C	WFM	2	LF	H	200	C
Niv13	U/s of confluence with Breede, d/s of Hoeks/Doring (Bobbejaans/Kiesie)	Doring	19.52113	33.76716	H40D	WFM	1	U	H	200	E
Nvii8	At gauging weir H4H017, EWR 3	Breede	19.69470	33.81871	H40F	SFM	1	LR	M	180	C/D
Ni1	U/s of confluence with Poesjenels	Breede	19.72813	33.84932	H40F	SFM	2	LR	M	180	D
Niv14	U/s of confluence with Breede	Keisers	19.88989	33.85032	H40K	SFM	2	U	M	160	E
Niv15	U/s of confluence with Breede	Vink	19.79753	33.82419	H40H	SFM	2	U	M	180	E

Niv20	U/s of confluence with Keisie	Pietersfontein	20.10834	33.73904	H30C	SFM	2	UF	M	280	E
Niv18	U/s of confluence with Kogmanskloof	Kingna	20.11600	33.79284	H30B	SFM	2	LF	M	220	E
Nvii9	U/s of confluence with Kogmanskloof	Keisie	20.10709	33.79276	H30D	SFM	2	LR	M	220	E
Nii2	At gauging weir H3H011, u/s of confluence with Breede	Kogmanskloof	20.00323	33.87040	H30E	SFM	1	LF	M	140	D
Nvi1	U/s of confluence with Kogmanskloof	Breede	19.99688	33.87915	H40L	SFM	1	LF	M	140	D
Niii3	U/s of confluence with Boesmans	Breede	20.04238	33.95968	H50A	SFM	1	LF	M	120	C
Ni2	U/s of confluence with Riviersonderend	Breede	20.28653	34.06804	H50B	SCB	1	LF	M	80	C
Niv24	U/s of confluence with Riviersonderend	Leeu	20.31862	34.08595	H70A	SCB	1	UF	M	80	E
Niv24a	U/s of confluence with Riviersonderend	Klip	20.41509	34.06616	H70B	SCB	1	UF	H	80	E
Nv13	At Suurbraak	Buffeljags	20.65671	34.00276	H70D	SCB	1	LF	H	120	C
Nv14	U/s of Buffeljags Dam	Buffeljags	20.53304	34.01939	H70E	SCB	1	LF	H	80	E
Niv25	U/s of confluence with Riviersonderend	Buffeljags	20.52031	34.09445	H70F	SCB	1	LF	M	60	D
Nv2	U/s of confluence with Buffelsjag	Breede	20.51719	34.09571	H70B	SCB	1	LR	M	60	C
Niii4	D/s of EWR 4, at Napkei confluence	Breede	20.51240	34.23484	H70G	SCB	1	E/LF	H	20	C
Niv26	U/s of confluence with Breede	Slang	20.71492	34.35731	H70J	SCB	1	U	M	20	C
Nvii10	U/s of Theewaterskloof Dam	Du Toits	19.15394	33.97951	H60B	SFM	1	UF	H	320	B
Nv7	2.5 km u/s of confluence with Meul	Riviersonderend	19.46327	34.06361	H60D	SCB	1	LF	H	240	C
Niv28	U/s of confluence with Riviersonderend, d/s of EWR 6 on Baviaans	Baviaans	19.55670	34.06331	H60E	SCB	1	UF	VH	220	B
Niv29	U/s of confluence with Riviersonderend	Sersants	19.55914	34.06608	H60E	SCB	1	UF	H	220	D
Niv30	U/s of confluence with Riviersonderend	Gobos	19.60911	34.07054	H60F	SCB	1	UF	H	200	E
Nv8	South of Genadendal, d/s of R404 bridge	Riviersonderend	19.56392	34.06627	H60E	SCB	1	LF	H	220	D
Niv31	U/s of confluence with Riviersonderend	Kwartel	19.70304	34.12027	H60G	SCB	1	LF	H	180	D
Nv9	At confluence with Kwartel, EWR 5	Riviersonderend	19.70425	34.11639	H60F	SCB	1	LF	H	180	E
Niv33	U/s of confluence with Riviersonderend	Soetmelksvlei	19.75634	34.11850	H60H	SCB	1	UF	H	180	D
Niv34	U/s of confluence with Riviersonderend	Slang	19.81128	34.12776	H60H	SCB	1	UF	H	160	C
Nv10	D/s of confluence with Slang and Lindeshof town	Riviersonderend	19.85624	34.12656	H60H	SCB	1	LF	H	160	D
Nv11	9 km u/s of Stormsvlei, alongside N2	Riviersonderend	20.02322	34.12470	H60J	SCB	1	LF	H	120	D
Niv35	U/s of confluence with Riviersonderend	Kwassadie	20.14142	34.08539	H60K	SCB	1	LR	H	100	E
Nv12	D/s of confluence with Kwassadie	Riviersonderend	20.14743	34.07773	H60K	SCB	1	LF	H	100	D
Ni3	U/s of confluence with Breede	Riviersonderend	20.28513	34.07071	H60L	SCB	1	LF	H	80	D

Western Folded Mountains	WFM
Southern Folded Mountains	SFM
Southern Coastal Belt	SCB
South Western Coastal Belt	SWCB
***** bad quaternary boundary**	

Lowland River	LR	Transitional	T
Lower Foothills	LF	Unclassified	Uc
Upper foothills	UF	Mountain headwater	MH
		Estuary	E

A/B: Natural/Largely Natural
B: Largely natural
C: Moderately modified

VH=Very High
H=High
M=Moderate

4 NODE SELECTION FOR THE PALMIET RIVER CATCHMENT

Ten WRCS nodes were selected in the Palmiet River catchment. This Section summarises the decisions at each tier and provides the details of the nodes selected.

4.1 TIER I – ECOREGION LEVEL 1

There is only one Level I Ecoregion in the Palmiet River catchment, *viz*., the Southern Folded Mountains, so no Tier I nodes were added.

4.2 TIER II – HYDROLOGICAL INDEX

The Palmiet River is perennial, so no Tier II nodes were added.

4.3 TIER III – GEOMORPHIC ZONES

Three Tier III nodes were added (Table 4.1; Figure 4.1) including one upstream of the estuary.

Table 4.1 Three Tier III nodes (based on geomorphic zones (GZ)) in the Palmiet system.

Node	Comment	River	LAT (S)	LON (E)	Quat	ER	HI	GZ
Piii1	U/s Eikenhof Dam, at EWR 1	Palmiet	-34.11531	19.05344	G40C	SFM	1	MS/UF
Piii2	At EWR 3	Palmiet	-34.28588	18.98388	G40D	SFM	1	UF/LF
Piii3	Top of estuary, at EWR 4	Palmiet	-34.33070	18.99098	G40D	SFM	1	UF/LF

Mountain Stream	MS	Lower Foothill	LF
Upper Foothill	UF	Estuary	E

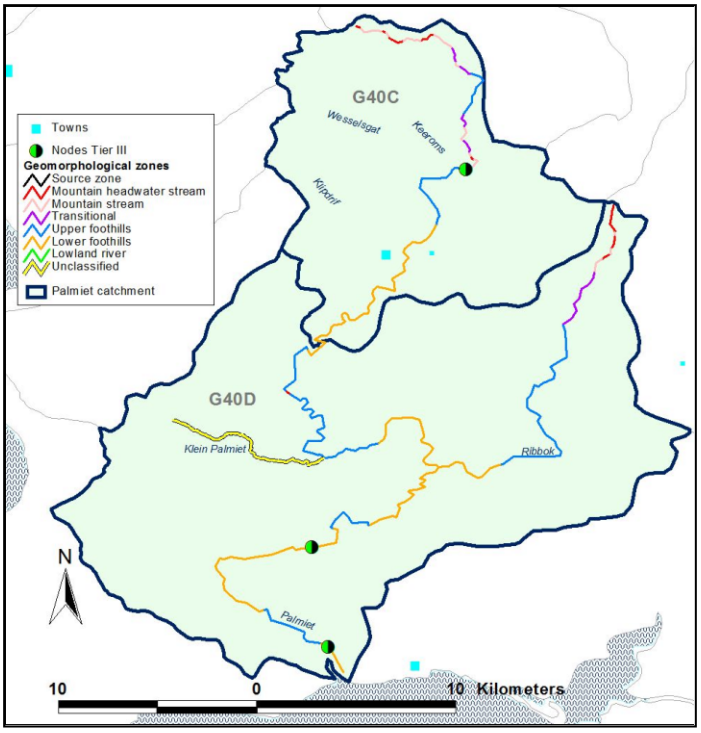

Figure 4.1 Palmiet River catchment, showing geomorphic zones and three Tier III nodes.

4.4 TIER IV – TRIBUTARIES

Ten Tier IV nodes were created (Table 4.2; Figure 4.2). Four of these were later removed during rationalisation.

Table 4.2 Ten Tier IV nodes (for tributaries) in the Palmiet system.

Node	Comment	River	LAT (S)	LON (E)	Quat	ER	HI	GZ
Piv3	D/s of Dwars, Louws, Palmiet confluence	Palmiet	-34.29217	18.94051	G40D	SFM	1	LF
Piv4	U/s of confluence with Palmiet	Klein-Palmiet	-34.24584	18.98786	G40D	SFM	1	Uncl
Piv5	U/s of confluence with Klein-Palmiet	Palmiet	-34.24430	18.98779	G40D	SFM	1	UF
Piv6	U/s of confluence with Krom	Palmiet	-34.24868	19.03918	G40D	SFM	1	LF
Piv7	U/s of confluence with Palmiet	Krom	-34.24897	19.04561	G40D	SFM	1	LF
Piv8	U/s of confluence with Palmiet, 0.5 km u/s of R231	Klipdrif	-34.14871	19.02679	G40C	SFM	1	Uncl
Piv9	U/s of confluence with Klipdrif, 0.5 km u/s of R231	Palmiet	-34.14880	19.02777	G40C	SFM	1	LF
Piv10	U/s of confluence with Palmiet	Witklippieskloof	-34.14637	19.03684	G40C	SFM	1	Uncl
Piv11	U/s of confluence with Witklippieskloof	Palmiet	-34.14515	19.03655	G40C	SFM	1	
Piv12	D/s of Dwars/ Louws confluence [1]	Dwars/ Louws	-34.29163	18.93654	G40D	SFM	1	LF

[1] This section of river below the confluence of the Dwars and the Louws, just before entering the Palmiet, is unnamed on the 1:50 000 maps.

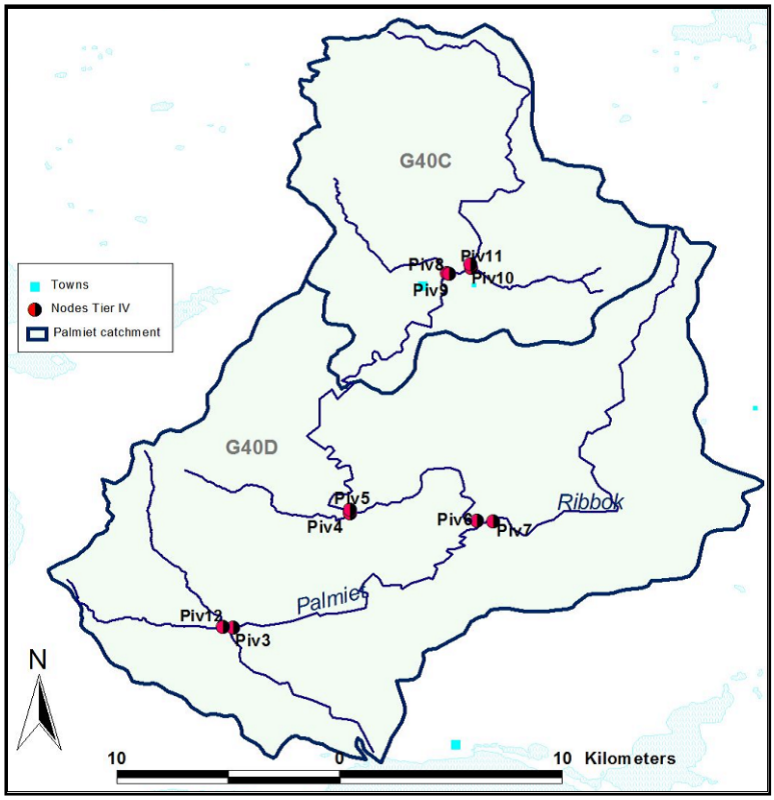

Figure 4.2 The Palmiet River catchment, showing the ten Tier IV nodes.

4.5 TIER V – ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY

No Tier V nodes were added.

4.6 TIER VI – PRESENT ECOLOGICAL STATUS / HABITAT INTEGRITY

One Tier VI node was added (Table 4.3, Figure 4.3) where a PES of largely modified in G40C changed to moderately modified in the downstream quaternary G40D. The position of the node was shifted so that it was upstream of Applethwaite Dam.

Table 4.3 One Tier VI node (PES) in the Palmiet River catchment.

Node	Comment	River	LAT (S)	LON (E)	Quat	ER	HI	GZ
Pvi1	U/s of Applethwaite reservoir	Palmiet	-34.18428	18.99791	G40C	SFM	1	LF

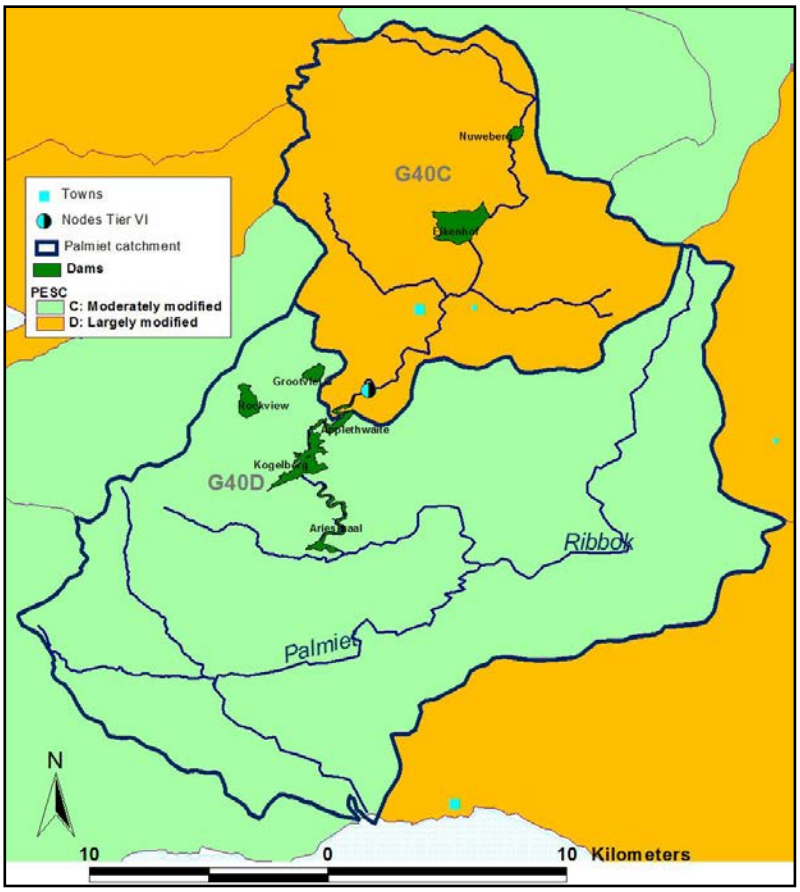

Figure 4.3 The Palmiet River catchment, showing the one Tier VI node.

4.7 TIER VII – INFRASTRUCTURE

4.7.1 Nodes added

Three Tier VII nodes were added (Table 4.4, Table 4.5 and Figure 4.4) (these were removed in the Tier VIII rationalisation).

Table 4.4. Nodes added for each of the Tier VII criteria

Reason	Nodes added
Gauging weirs	0
At the u/s limit of the inundation of any major dam	3
U/s of mines, towns or other localities likely to influence water quality	0
Where the area covered by farm dams in the u/s quaternary is more than five times that of the d/s quaternary	0
On a river immediately u/s of the confluence with an Inter Basin Transfer (IBT)	0

Table 4.5 Three Tier VII nodes (infrastructure) in the Palmiet system.

Node	Comment	River	LAT (S)	LON (E)	Quat	ER	HI	GZ
Pvii1	U/s of Eikenhof Dam	Wesselsgat	-34.11715	19.02121	G40C	SFM	1	Unkn
Pvii2	U/s of Eikenhof Dam	Keeroms	-34.11249	19.04078	G40C	SFM	1	Unkn
Pvii3	U/s of Nuweberg Dam	Palmiet	-34.08424	19.05523	G40C	SFM	1	UF

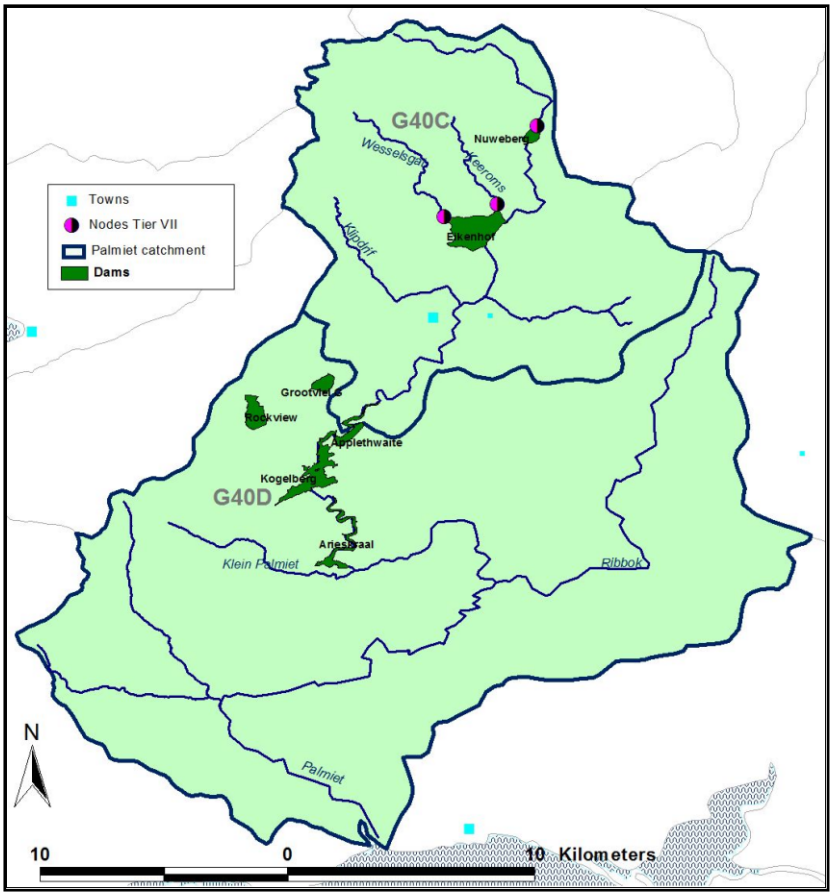

Figure 4.4 The Palmiet River catchment, showing the three Tier VII nodes that were added and then eliminated.

4.7.2 Nodes removed

Nodes that are inundated by an impoundment and are located such that they would describe an upstream section of river for which no description is required, e.g. a dam, were removed. Two nodes were removed:

- Piv5 (downstream of Arieskraal Dam)
- Piv11 (downstream of Eikenhof Dam)

4.8 TIER VIII – RDM DATA

There are four EWR sites in the Palmiet River catchment (Table 4.6). However, no additional Tier VIII nodes were created as nodes near or at EWR sites had already been created in previous Tiers.

Table 4.6 EWR sites in the Palmiet system.

Site	Name	LAT (S)	LON (E)	Node at previous Tier
1	EWR Site 1	-34.11436	19.05545	Piii1
2	EWR Site 2	-34.24398	18.98642	Piv5
3	EWR Site 3	-34.28571	18.98457	Piii2
4	EWR Site 4	-34.33053	18.99073	Piii3

4.9 TIER IX – FIRST LEVEL RATIONALISATION

There are only two quaternaries in the Palmiet River catchment, so the relative contribution to MAR of the quaternaries was not a consideration. The following nodes were removed:

- Pvii1, Pvii2 and Pvii3 were removed as they described very short lengths of river above impoundments.
- Piv3 on the mainstem was removed as it was 4 km below Piii2
- Piv6 on the mainstem was removed as it was 8 km below Piv4.

4.10 TIER X – WATER RESOURCES MANAGEMENT, PLANNING OR ALLOCATION REQUIREMENTS

No nodes were added in this Tier.

4.11 TIER XI – INTERNATIONAL WATER AGREEMENTS

No nodes were added in this Tier.

4.12 SUMMARY OF NODE INFORMATION FOR THE PALMIET

Ten nodes were established for the Palmiet River catchment, using the rules summarised in Table 3.1. The nodes are listed Table 4.7 (the “node table”), which is arranged by quaternary catchment and latitude. The “NodeCode” gives the Tier number e.g. Niii5, identifies a Tier III node. The second number is simply an identifier for the Arcview cover. Altitude, required for the Extrapolation Decision Support System, is given to the nearest 20m.

Table 4.7 Node table for the Palmiet catchment (quat=quaternary, ER=Ecoregion, HI=Hydrological Index, GZ=geomorphological zone, Alt=altitude, EISC=ecological importance and sensitivity, PES=present ecological status).

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ	EISC	PES	Alt
Pvi1	U/s of Applethwaite reservoir	Palmiet	18.99791	-34.18428	G40C	SFM	1	LF	M	D	260
Piv9	U/s of confluence with Klipdrif, 0.5 km u/s of R321	Palmiet	19.02777	-34.14880	G40C	SFM	1	LF	M	D	280
Piv8	U/s of confluence with Palmiet, 0.5 km u/s of R321	Klipdrif	19.02679	-34.14871	G40C	SFM	1	Uncl	M	D	280
Piv10	U/s of confluence with Palmiet, 0.5 km West of R321	Witklippieskloof	19.03684	-34.14637	G40C	SFM	1	Uncl	M	D	280
Piii1	U/s Eikenhof Dam at EWR 1	Palmiet	19.05545	-34.11436	G40C	SFM	1	MS→UF	M	C	340
Piii3	Top of estuary, at EWR 4	Palmiet	18.99073	-34.33053	G40D	SFM	1	UF→LF	VH	B	5
Piv12	D/s of confluence of Dwars and Louws[1]	Dwars/ Louws	18.93654	-34.29163	G40D	SFM	1	LF	VH	C	60
Piii2	At EWR 3	Palmiet	18.98457	-34.28571	G40D	SFM	1	UF→LF	VH	C	60
Piv7	U/s of confluence with Palmiet	Krom/ Ribbok	19.04561	-34.24897	G40D	SFM	1	LF	VH	C	120
Piv4	U/s of confluence with Palmiet	Klein-Palmiet	18.98786	-34.24584	G40D	SFM	1	Uncl	VH	C	160

Western Folded Mountains	WFM
Southern Folded Mountains	SFM
Southern Coastal Belt	SCB
South Western Coastal Belt	SWCB

Mountain Stream	MS
Upper Foothill	UF
Lower Foothill	LF
Lowland River	LR
Transitional	T
Estuary	E
Unclassified	Uncl

A/B: Natural/Largely Natural
B: Largely natural
C: Moderately modified

VH=Very High
H=High
M=Moderate

1 This section of river d/s of the confluence of the Dwars and the Louws,u/s of the Palmiet River, is unnamed on the 1:50 000 maps.

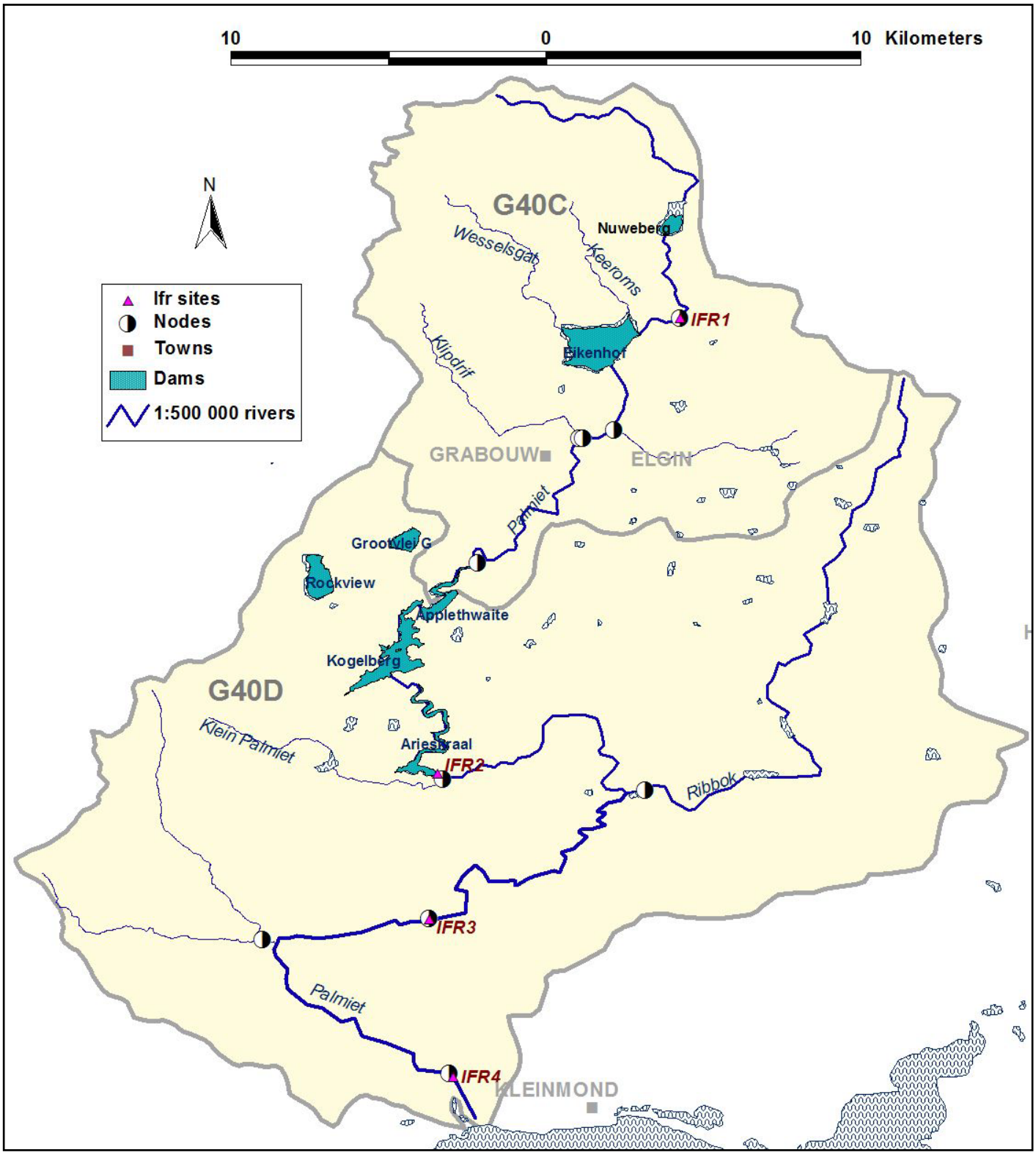

Figure 4.5 The Palmiet River catchment, showing the final set of 10 nodes.

5 NODE SELECTION FOR THE BERG RIVER CATCHMENT

Twenty-three nodes were established for the Berg River catchment. This section summarises the decisions at each tier and provides the details of the nodes selected.

5.1 TIER I – ECOREGION LEVEL 1

There are two Level I Ecoregions within the Breede River catchment area, *viz*., South-western Coastal Belt and Western Folded Mountains. One Tier I node was created (Table 5.1; Figure 5.1).

Table 5.1 One Tier I node (based on Level 1 Ecoregions) in the Berg River catchment.

Node	Comment	River	LON (E)	LAT (S)	Quat	Ecoregion
Bi1	At gauging weir G1H028	Vier-en-Twintig	19.06080	-33.13390	G10G	WFM

Western Folded Mountains WFM
South Western Coastal Belt SWCB

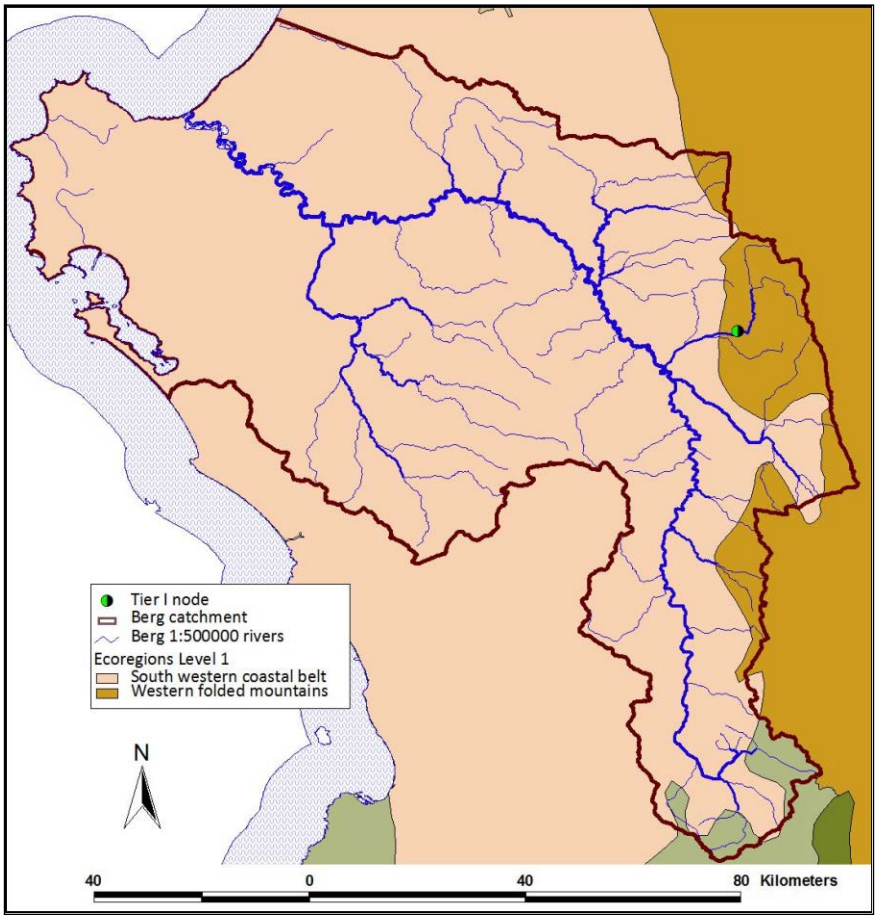

Figure 5.1 The Berg River catchment, showing the ecoregions and one Tier I node.

5.2 TIER II – HYDROLOGICAL INDEX

One Tier II node was created (Table 5.2, Figure 5.2).

Table 5.2 One Tier II node (based on HI groups) in the Berg Rive catchment.

Node	Comment	River	LON (E)	LAT (S)	Quat	Ecoregion	HI
Bii1	U/s of confluence with Berg	Sout	18.38059	-32.95847	G10L	SWCB	2

Western Folded Mountains	WFM
South Western Coastal Belt	SWCB

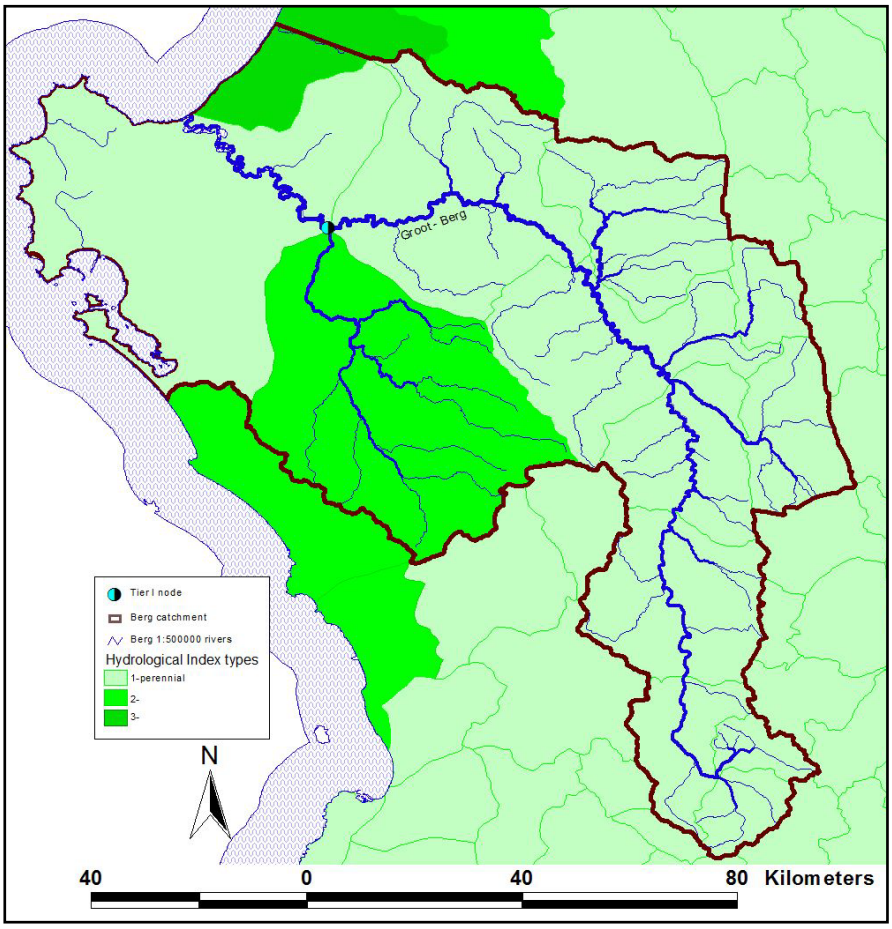

Figure 5.2 The Berg River catchment, showing the Hydrological Index groups and one Tier II node.

5.3 TIER III – GEOMORPHIC ZONES

Four Tier III nodes were added (Table 5.3; Figure 5.3), including one just upstream of the estuary.

Table 5.3 Four Tier III nodes (based on geomorphic zones) in the Berg River catchment.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Biii2	U/s of confluence with Berg	Wemmershoek	19.03034	-33.87662	G10B	SWCB	1	LR→LF
Biii3	1.5 km d/s of Paarl and confluence with Hugos, at gauging weir G1H020	Berg	18.97438	-33.70766	G10C	SWCB	1	UF→LF
Biii4	At gauging weir G1H008	Klein Berg	19.07438	-33.31159	G10E	SWCB	1	LF
Biii5	D/s of confluence of Krom and Assegaaibosspruit, at gauging weir G1H013	Matjies	18.83264	-33.04735	G10H	SWCB	1	LF

Lower Foothills	LF
Lowland River	LR
Estuary	E

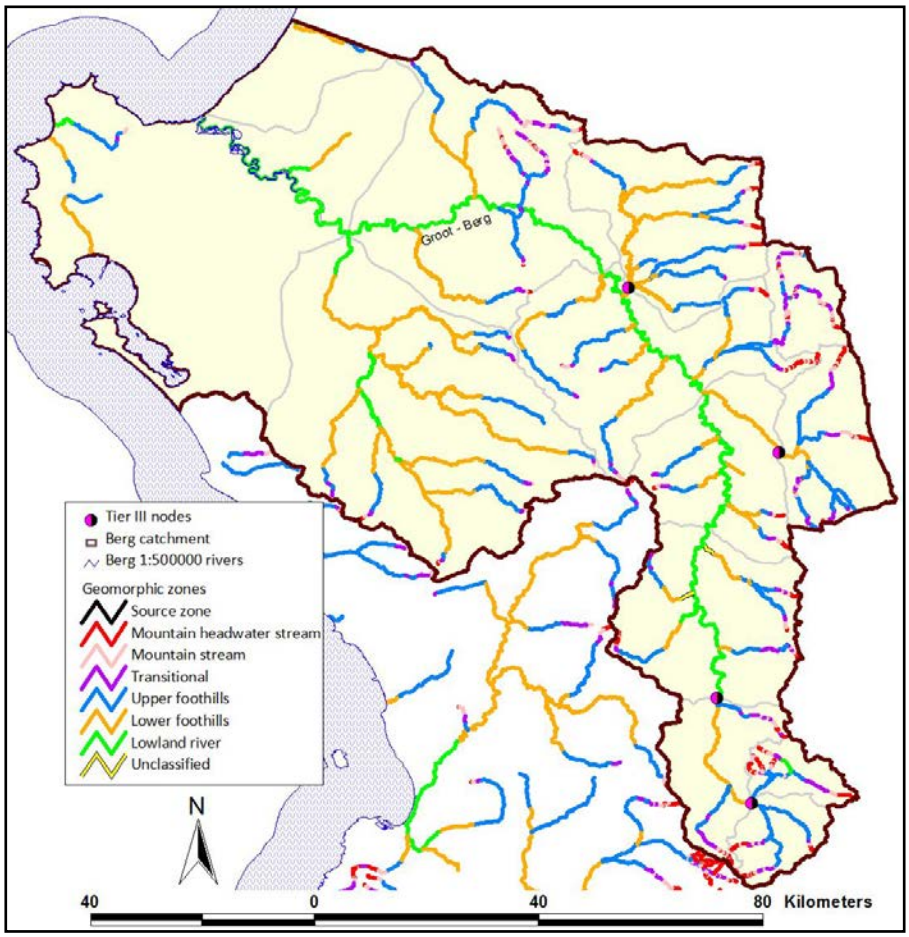

Figure 5.3 The Berg River catchment, showing the geomorphic zones and four Tier III nodes.

5.4 TIER IV – TRIBUTARIES

Five Tier IV nodes were created (Table 5.4, Figure 5.4).

Table 5.4 Five Tier IV nodes (for tributaries) in the Berg River catchment.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Biv1	U/s of confluence with Klein-Berg	Berg	18.95037	-33.21477	G10F	SWCB	1	LR
Biv2	U/s of confluence with Sout, head of estuary	Berg	18.38080	-32.95804	G10K	SWCB	1	LF
Biv3	U/s of confluence with Berg	Klein-Berg	18.95629	-33.21508	G10F	SWCB	1	LF→LR
Biv4	U/s of confluence with Berg	Vier en twintig	18.94183	-33.19003	G10J	SWCB	1	LF→LR
Biv5	U/s of confluence with Berg	Franschoek	19.04550	-33.88126	G10A	SWCB	1	UF→LF

Figure 5.4 The Berg River catchment, showing the five Tier IV nodes.

5.5 TIER V – ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY

No Tier V nodes were added.

5.6 TIER VI – PRESENT ECOLOGICAL STATUS / HABITAT INTEGRITY

No Tier V nodes were added.

5.7 TIER VII – INFRASTRUCTURE

5.7.1 Nodes added

Eleven Tier VII nodes were added (Table 5.5; Table 5.6 and Figure 5.5).

Table 5.5. Nodes added for each of the Tier VII criteria

Reason	Nodes added
Gauging weirs (As part of the WCWSS, calibration gauges were established - preference was given to these when adding nodes)	7: Bvii3 (G1H037), Bvii4 (G1h041), Bvii5 (G1H036), Bvii6 (G1H013), Bvii7 (G1H043), Bvii10 (G1H015), Bvii12 (G1H031)
At the u/s limit of the inundation of any major dam	1: Bvii8 (Misverstand)
U/s of mines, towns or other localities likely to influence water quality	3: Bvii2 (Skuifraam pump station), Bvii2 (Paarl), Bvii11 (Voelvlei canal)
Where the area covered by farm dams in the u/s quaternary is more than five times that of the d/s quaternary	0
On a river immediately u/s of the confluence with an IBT	0

Table 5.6 Eleven Tier VII nodes (infrastructure) in the Berg River catchment.

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ
Bvii2	Skruifraam pump station area, 1.0 km d/s of confluence with Dwars	Berg	18.98828	-33.84149	G10C	SWCB	1	LF
Bvii3	North of Wellington, at gauging weir G1H037	Krom/Kromme	19.00971	-33.63549	G10D	SWCB	1	UF
Bvii4	At gauging weir G1h041	Kompanjies	18.97811	-33.47920	G10D	SWCB	1	LF
Bvii5	At gauging weir G1H036 and u/s of EWR 3	Berg	18.95691	-33.43499	G10D	SWCB	1	LR
Bvii6	D/s of EWR 4, at gauging weir G1H013	Berg	18.86193	-33.13282	G10J	SWCB	1	LR
Bvii7	At gauging weir G1H043 (removed later)	Sandspruit	18.89299	-33.16077	G10J	SWCB	1	LF
Bvii8	U/S Misverstand reservoir, d/s of confluence Matjies	Berg	18.81488	-33.05225	G10J	SWCB	1	LR
Bvii9	U/s of Paarl	Berg	18.97234	-33.75494	G10C	SWCB	1	LF
Bvii10	D/s of confluence with Krom/ Kromme, at gauging weir G1H015	Berg	18.97668	-33.62711	G10D	SWCB	1	LF
Bvii11	U/s of Voelvlei canal.	Berg	18.98714	-33.33408	G10F	SWCB	1	LR
Bvii12	3.5 km d/s of Misverstand Dam, at EWR 5	Berg	18.77929	-32.99602	G10K	SWCB	1	LR

*Note: there are three rivers with the name 'Krom River' in the Berg River catchment.

5.7.2 Nodes removed

No nodes were removed at this stage.

Figure 5.5 The Berg River catchment, showing eleven Tier VII nodes.

5.8 TIER VIII – RDM DATA

There were five EWR sites in the Berg River catchment prior to this study and a Rapid II Reserve assessment was completed for the Kromme, Pombers and Steenbras Rivers (Volume 1: Appendix 4) as part of this study, creating a sixth EWR site. Nodes had already been created at four EWR sites at previous tiers, and so two new nodes were created, at EWR Site 1 and EWR Site 6 (Table 5.7; Figure 5.6).

Table 5.7 EWR sites in the Berg River catchment; two nodes were created.

SITE	River, and description of location	LON (E)	LAT (S)	Node	LON (E)	LAT (S)
EWR Site 1	Upper Berg	19.05225	-33.89653	Bviii1	19.05225	-33.89657
EWR Site 3	Berg, Hermon	18.97000	-33.43000	Bvii5		
EWR Site 4	Berg, Heuningberg, u/s of Drie Heuwels gauge	18.86113	-33.13531	Bvii6		
EWR Site 5	Berg, Nuwedrif, de Brug gauging weir	18.77930	-32.99604	Bvii12		
EWR Site 6	Krom/ Kromme	19.05225	-33.89653	Bviii2	19.08166	-33.62577

Figure 5.6 The Berg River catchment, showing the two Tier VIII nodes and the EWR sites.

5.9 TIER IX – FIRST LEVEL RATIONALISATION

Node Bvii7 was removed, as the Sandspruit contributes minimally to the MAR of quaternary catchment G10J, the whole quaternary contributing only 1.2% of the Berg catchment's MAR.

5.10 TIER X – WATER RESOURCES MANAGEMENT, PLANNING OR ALLOCATION REQUIREMENTS

No nodes were added in Tier X.

5.11 TIER XI – INTERNATIONAL WATER AGREEMENTS

No nodes were added in Tier XI.

5.12 SUMMARY OF NODE INFORMATION FOR THE BERG RIVER CATCHMENT

Twenty-three nodes were established in the Berg River catchment, using the rules summarised in Table 3.1. The details of all nodes are listed in the node table (Table 5.8) arranged by quaternary and latitude. The "NodeCode" gives the Tier number e.g. Biii5, identifies a Tier III node. The second number is simply an identifier for the Arcview cover. Altitude, required for the Extrapolation Decision Support System, is given to the nearest 20m.

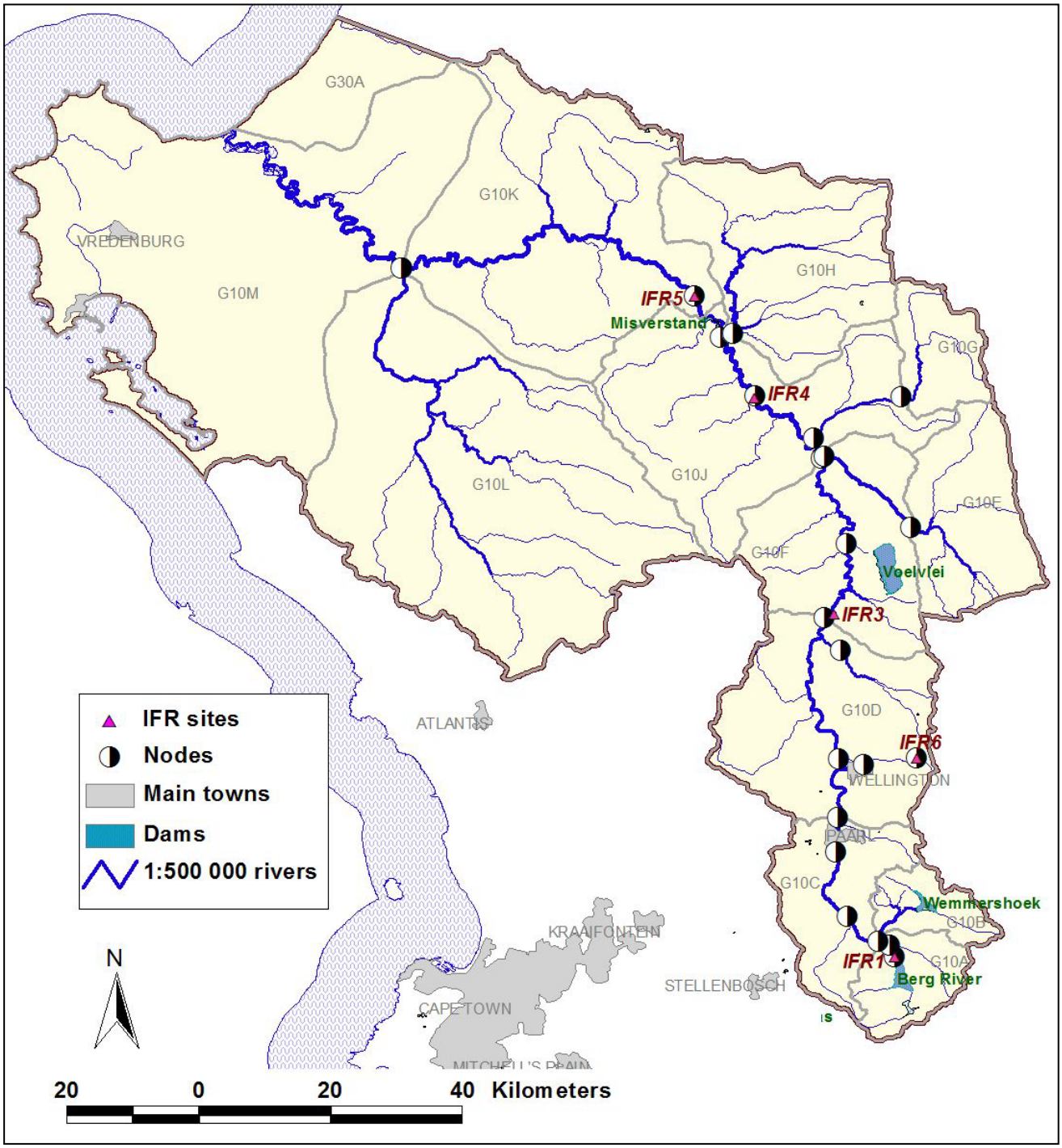

Figure 5.7 The Berg River catchment, showing the final set of 23 nodes.

Table 5.8 Node table for the Berg River catchment (quat=quaternary, ER=Ecoregion, HI=Hydrological Index, GZ=geomorphological zone, Alt=altitude, EISC=ecological importance and sensitivity, PES=present ecological status).

Node	Comment	River	LON (E)	LAT (S)	Quat	ER	HI	GZ	Alt (m)	EISC	PES
Bviii1	D/s of Berg River dam at EWR 1	Berg	19.05265	-33.89657	G10A	SWCB	1	UF	180	H	C
Biv5	U/s of confluence with Berg	Franschoek	19.0455	-33.88126	G10A	SWCB	1	UF→LF	180	H	D
Biii2	U/s of confluence with Berg	Wemmershoek	19.03034	-33.87662	G10B	SWCB	1	LR→LF	160	H	D
Bvii2	Skuifraam pump station area, 1.0 km d/s of confluence with Dwars	Berg	18.98828	-33.84149	G10C	SWCB	1	LF	140	L	D
Bvii9	U/s of Paarl	Berg	18.97234	-33.75494	G10C	SWCB	1	LF	120	L	D
Biii3	At gauging weir G1H020	Berg	18.97438	-33.70766	G10C	SWCB	1	UF→LF	100	L	D
Bvii3	North of Wellington, at gauging weir G1H037	Krom/ Kromme	19.00971	-33.63549	G10D	SWCB	1	UF	120	M	D
Bvii10	D/s of confluence with Krom/ Kromme, at gauging weir G1H015	Berg	18.97668	-33.62711	G10D	SWCB	1	LF	100	M	D
Bviii2	At EWR 6, Rapid II Reserve, d/s of confluence with Pombers	Krom/ Kromme	19.08166	-33.62577	G10D	SWCB	1	UF	260	M	D
Bvii4	At gauging weir G1H041	Kompanjies	18.97811	-33.4792	G10D	SWCB	1	LF	80	M	D
Bvii5	At gauging weir G1H036 and u/s of EWR 3	Berg	18.95691	-33.43499	G10D	SWCB	1	LR	60	M	D
Biii4	At gauging weir G1H008	Klein Berg	19.07438	-33.31159	G10E	SWCB	1	LF	120	M	D
Bvii11	U/s of Voelvlei canal	Berg	18.98714	-33.33408	G10F	SWCB	1	LR	60	M	D
Biv3	U/s of confluence with Berg	Klein-Berg	18.95629	-33.21508	G10F	SWCB	1	LF→LR	60	M	D
Biv1	U/s of confluence Klein-Berg	Berg	18.95037	-33.21477	G10F	SWCB	1	LR	60	M	D
Bi1	At gauging weir G1H028	Vier-en-Twintig	19.0608	-33.1339	G10G	WFM	1	T→UF	140	H	B
Biii5	At gauging weir G1H035	Matjies	18.83264	-33.04735	G10H	SWCB	1	LF	40	M	D
Biv4	U/s of confluence with Berg	Vier-en-twintig	18.94183	-33.19003	G10J	SWCB	1	LF→LR	60	M	D
Bvii6	D/s of EWR 4, at gauging weir G1H013	Berg	18.86193	-33.13282	G10J	SWCB	1	LR	40	M	D
Bvii8	U/s Misverstand reservoir, d/s confluence with Matjies	Berg	18.81488	-33.05225	G10J	SWCB	1	LR	40	M	D
Bvii12	3.5 km d/s of Misverstand reservoir, at EWR 5	Berg	18.77929	-32.99602	G10K	SWCB	1	LR	20	H	D
Biv2	U/s of confluence with Sout, head of estuary	Berg	18.3808	-32.95804	G10K	SWCB	1	LF	5	L	D
Bii1	U/s of confluence with Berg	Sout	18.38059	-32.95847	G10L	SWCB	2	LR	5	L	D

Western Folded Mountains	WFM
Southern Folded Mountains	SFM
Southern Coastal Belt	SCB
South Western Coastal Belt	SWCB

***** bad quaternary boundary**

Lowland River	LR
Lower Foothills	LF
Upper foothills	UF
Transitional	T
Unclassified	Uc
Mountain headwater	MH
Estuary	E

A/B: Natural/Largely Natural
B: Largely natural
C: Moderately modified

VH=Very High
H=High
M=Moderate

6 GENERATION OF RIVER EWR DATA FOR THE STUDY CATCHMENTS

The desktop reserve model of Hughes and Münster (2000) was used to generate EWR estimates for all nodes in the three river systems. The results were calibrated using the results from past EWR assessments (Breede Catchment: Ewart-Smith and Brown 2002; Louw and Brown 2001; Palmiet Catchment: Brown *et al.* 2000; Berg Catchment: Brown 1996; Harding and Brown 2002) and some data generated in this study (Appendices 3 and 4). The assurance rules together with the time series of natural flows per node were used to construct representative time series' of EWR requirements (Appendices 1, 2 and 3). A short summary of the model follows (unless otherwise indicated, taken directly 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 of these magnitude data 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 flow rates ($m.s^{-1}$).

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 were there was no existing EWR data in close enough proximity to justify extrapolation of EWR data a straight desktop run, either Western Cape wet/dry was used. 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. In such cases the Reserve estimations for lower ecological categories had flows higher than the class above i.e. monthly flows in the time series of a D class were higher for the corresponding month in a C class. In order to resolve this issue the assurance rules for the ecological category B were used to generate all Reserve estimates for all ecological categories. These results were then calibrated using the results of EWR assessments for each different ecological category in the standard manner.

The EWR data is presented in Appendices 1, 2 and 3 for each of the three river systems separately. For each node the following data is presented in turn. A summary of the desktop estimate (*.tab) is followed by 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. In all cases and for each node a time series of monthly flow data for LOW FLOWS only was also generated and is summarised below the FULL FLOW data summaries.

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