Determination of Water Resource Classes and Associated Resource Quality Objectives for the Berg Catchment (WP10987)

August 2018

Resource Units Prioritisation Report

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Bold type indicates this report

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3	RDM/WMA9/00/CON/CLA/0316	Water Resources Information Gap Analysis and Models
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17	RDM/WMA9/00/CON/CLA/0718	Final Project Close Out Report.

List of Abbreviations

DRIFT	Downstream Response to Instream Flow Transformation
DWS	Department of Water and Sanitation
EC	Ecological Condition
EcoSpec	EcoSpecification
EGSAs	Ecosystems goods, services and attributes
EHI	Estuary Health Index
EIS	Ecological Importance and Sensitivity
EWRs	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Area
GDP	Gross Domestic Product
GRU	Groundwater Resource Unit
GWBF	Groundwater Contribution to Baseflow
HGM	Hydrogeomorphic Unit
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resources Management
MAR	Mean annual runoff
nMAR	Natural mean annual runoff
NWA	National Water Act
PES	Present Ecological Status
QUAT	Quaternary catchment
RC	Reference Condition
RDM	Resource Directed Measures
REC	Recommended ecological class
RQO	Resource Quality Objective
RU	Resource Unit
SWSA-gw	Strategic Water Source Areas for Groundwater
TMG	Table Mountain Group
WARMS	Water Allocation Registration Management System
WCWSS	Western Cape Water Supply System
WRC	Water Resource Class
WRCS	Water Resources Classification System
WWTW	Wastewater Treatment Works

Executive Summary

The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned a study to determine Water Resource Classes (WRCs) and associated Resource Quality Objectives (RQOs) for all significant water resources in the Berg Catchment.

The 7-step procedure established by the Department of Water Affairs in 2011 (DWA, 2011) is being applied to determine the Resource Quality Objectives (RQOs) for river, estuary, wetland, dam and groundwater resources in the Berg catchment. These procedural steps established for this case study to determine RQOs in the catchment include the following:

- Step 1. Delineate the Integrated Units of Analysis (IUAs) and define the Resource Units (RUs)
- Step 2. Establish a vision for the catchment and key elements for the IUAs
- Step 3. Prioritise and select preliminary Resource Units for RQO determination
- Step 4. Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change
- Step 5. Develop draft RQOs and Numerical Limits
- Step 6. Agree Resource Units, RQOs and Numerical Limits with stakeholders
- Step 7. Finalise and Gazette RQOs.

In terms of the RQO determination process, Step 1 (Delineation) and Step 2 (Visioning) have been completed as part of the Classification phase of this study. This report documents the approach adopted and the outcomes of the implementation of Step 3 of the RQO determination procedure.

The RUs were evaluated using the RU Prioritization tool developed by DWS (DWAF, 2011)).

A summary of the priority resource units (RUs) for rivers, estuaries, dams, wetlands and groundwater resource units are summarised on Table 0.1. These represent the RUs for which RQOs should be developed.

The prioritized RUs for determining RQOs have been identified using the following criteria:

- All river RUs in the Berg Catchment irrespective of their scores
- All estuaries in the Berg Catchment irrespective of their scores. However, none of the river outlets in the catchment were prioritised
- Dams determined from prioritisation process with a priority weighting of > 0.6
- Wetlands RUs as determined from the prioritisation process
- Groundwater RUs scoring >40 in the scoring system, and designated as a priority “3”.

Table 0.1 Summary of results of the prioritisation process for the Berg Catchment

IUA	Prioritised Resource Units (RUs)				
	River	**Estuary**	**Dam**	**Wetland**	**Groundwater**
D8 Upper Berg	Bviii1 Bvii13 Biii3		Berg River Dam Wemmershoek Dam	SWSA* SEEP	G10A G10B
D9 Middle Berg	Bvii5 Bviii11 Bvii3			West Coast Shale Renosterveld FLOODPLAIN (Berg)	
C5 Berg Tributaries	Biii4 Bi1			SWSA* SEEP	G10E
B4 Lower Berg	Bvii12 Bvii6		Voëlvlei Dam Misverstand Dam	West Coast Shale Renosterveld FLOODPLAIN (Berg) Northwest Sandstone Fynbos SEEP and FLOODPLAIN (Boesmans River) Kiekoesvlei DEPRESSION Koekiespan DEPRESSION	G10J
A1 Berg Estuary		Berg (Groot)		Southwestern Shale Fynbos UNCHANNELED VALLEY BOTTOM (Berg)	G10M
A2 Langebaan		Langebaan		Salt marsh SEEP (Geelbek)	G10M
A3 West Coast				Southwest Sand Fynbos DEPRESSION (Yzerfontein)	G21B
D10 Diep	Bv1 Biv6	Rietvlei/ Diep		Rietvlei Southwest Sand Fynbos FLOODPLAIN and Dune Strandveld FLOODPLAIN (seasonal) Riverlands DEPRESSION and SEEP	G21D
E11 Peninsula	Bviii6 Bvii20	Wildevöelvlei		Sand Fynbos DEPRESSION (Pick n Pay Reedbeds) Sand Fynbos DEPRESSION (Wildvoelvlei) Sand Fynbos DEPRESSION (seasonal) SWSA* UNCHANNELLED VALLEY-BOTTOM	
E12 Cape Flats	Bvii7	Zandvlei		Zeekoeivlei DEPRESSION (open water and seasonal) Rondevlei DEPRESSION (open water and seasonal) Nooiensfontein FLOODPLAIN Blouvlei DEPRESSION Princessvlei DEPRESSION SEEP (Philippi seasonal wetlands)	G22C G22D G22E
D6 Eerste	Biii6 Biv8	Eerste		SWSA* SEEP	
D7 Sir Lowry's	Bvii22 Bvii21 Bviii9	Lourens	Steenbras Reservoir Steenbras Upper Dam	SWSA* SEEP	
TOTAL	**20**	**7**	**6**	**24**	**11**

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1 Introduction

1.1 Background

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

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

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

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

The Chief Directorate: Water Ecosystem has therefore commissioned a study to determine Water Resource Classes (WRCs) and associated Resource Quality Objectives (RQOs) for all significant water resources in the Berg Catchment, i.e. the Berg / Olifants-Doring Water Management Area (WMA) that lie outside the Olifants-Doring section of the WMA. This includes the area of the former Berg WMA (i.e. former WMA 19). The Berg River is the largest catchment in the Study Area, which also includes a number of smaller catchments such as the Diep, Kuils, Eerste, Lourens, Sir Lowry’s, Steenbras, as well as various small catchments on the Cape Peninsula and along the West Coast.

The 7-step Water Resource Classification procedure described in the WRCS Overview Report (DWAF, 2007a) has been completed for the Berg catchment and has resulted in the delineation of 18 integrated units of analysis (IUAs), as well as a recommended Water Resource Class for each IUA or part thereof.

The three Water Resource Classes are defined as:

- *Class I: Minimally used*: The configuration of ecological categories of the 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 ecological categories of the 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 ecological categories of the water resources within a catchment results in an overall water resource condition that is significantly altered from its pre-development condition.

With the Classification phase of this study completed, the current next phase of the study comprises the 7-step procedure (DWA, 2011) towards determination of RQOs for all significant water resources in the Berg Catchment.

Previous RQO determination studies were reviewed to determine an appropriate approach for the current study. Reports of relevant previous studies that are referred to are the RQO determination reports for the Crocodile (West), Marico, Mokolo and Matlabas catchments (DWS, 2015), for the Olifants WMA (DWS, 2014) and the Upper Vaal WMA (DWS, 2014).

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 Berg Catchment.
- Determine RQOs using the DWS Procedures to Determine and Implement RQOs for all significant water resources in the Berg Catchment.

The outcome from the study will be a recommended water resource class for each integrated unit of analysis and associated Resource Quality Objectives for prioritised resource units.

1.3 Scope of this phase of the study

The main objective of this study is to determine Resource Quality Objectives (RQOs) for all significant water resources in the Berg Catchment that must give effect to the Water Resources Classes that have been determined in the previous phase of the study. To this end, the 7-step process for determining RQOs, described in DWA (2011) and depicted in Figure 1-1, is being implemented.

Once gazetting has been finalised, implementation, monitoring and review would then follow.

Step 1: Delineate the Integrated Units of Analysis (IUAs) and define the Resource Units (RUs)

Step 2: Establish a vision for the catchment and key elements for the IUAs

Step 3: Prioritise and select preliminary Resource Units for RQO determination

Step 4: Prioritise sub-components for RQO determination, select indicators for monitoring and

Step 5: Develop draft RQOs and Numerical Limits

Step 6: Agree Resource Units, RQOs and Numerical Limits with stakeholders

Step 7: Finalise and Gazette RQOs

Figure 1-1 The seven-step process for RQO determination (DWA, 2011)

In terms of the RQO process outlined in Figure 1-1, Step 1 (Delineation) and Step 2 (Visioning) have been completed as part of the Classification phase of this study. This report documents the approach adopted and the outcomes of the implementation of Step 3 of the above RQO determination procedure.

1.4 Study area, RUs and IUAs

The study area covers all significant water resources of the Berg Catchment. The Berg River is the largest catchment in the Study Area, which also includes a number of smaller catchments such as the Diep, Kuils, Eerste, Lourens, Sir Lowry's, Steenbras, as well as various small catchments on the Cape Peninsula and along the West Coast. The study area includes secondary catchments G1 and G2 and G40A.

During the Classification phase of the study, resource units for rivers, wetlands, dams, groundwater and estuaries as well as a total of 12 Integrated Units of Analysis (IUAs) were delineated in the Berg Catchment.

The IUAs approximate socio-economic boundaries, delineated to facilitate the integration of ecological and socio-economic aspects required for the evaluation of scenarios during the Classification phase of the study (DWS, 2017). The delineation of the Resource Units and the IUAs is described in the *Resource Unit and Integrated Units of Analysis Delineation Report* (DWS, 2016b).

The recommended water resource classes for each IUA are given in Table 1-1 and shown in Figure 1-2.

Table 1-1 Recommended water resource Classes for the Berg Catchment

IUA Name	IUA Code	Quaternary Catchments	Recommended Water Resource Class
Upper Berg	D8	G10C, G10B, G10A	II
Middle Berg	D9	G10D	III
Berg Tributaries	C5	G10G, G10E	II
Lower Berg	B4	G10K, G10L. G10J, G10H, G10F	III
Berg Estuary	A1	G10M	II
Langebaan	A2	G10M	II
West Coast	A3	G21A, G21B	III
Diep	D10	G21C, G21D, G21E, G21F	III
Peninsula	E11	G22B, G22A	II
Cape Flats	E12	G22C, G22D, G22E	III
Eerste	D6	G22G, G22H, G22F	III
Sir Lowry's	D7	G22J, G22K. G40A	II

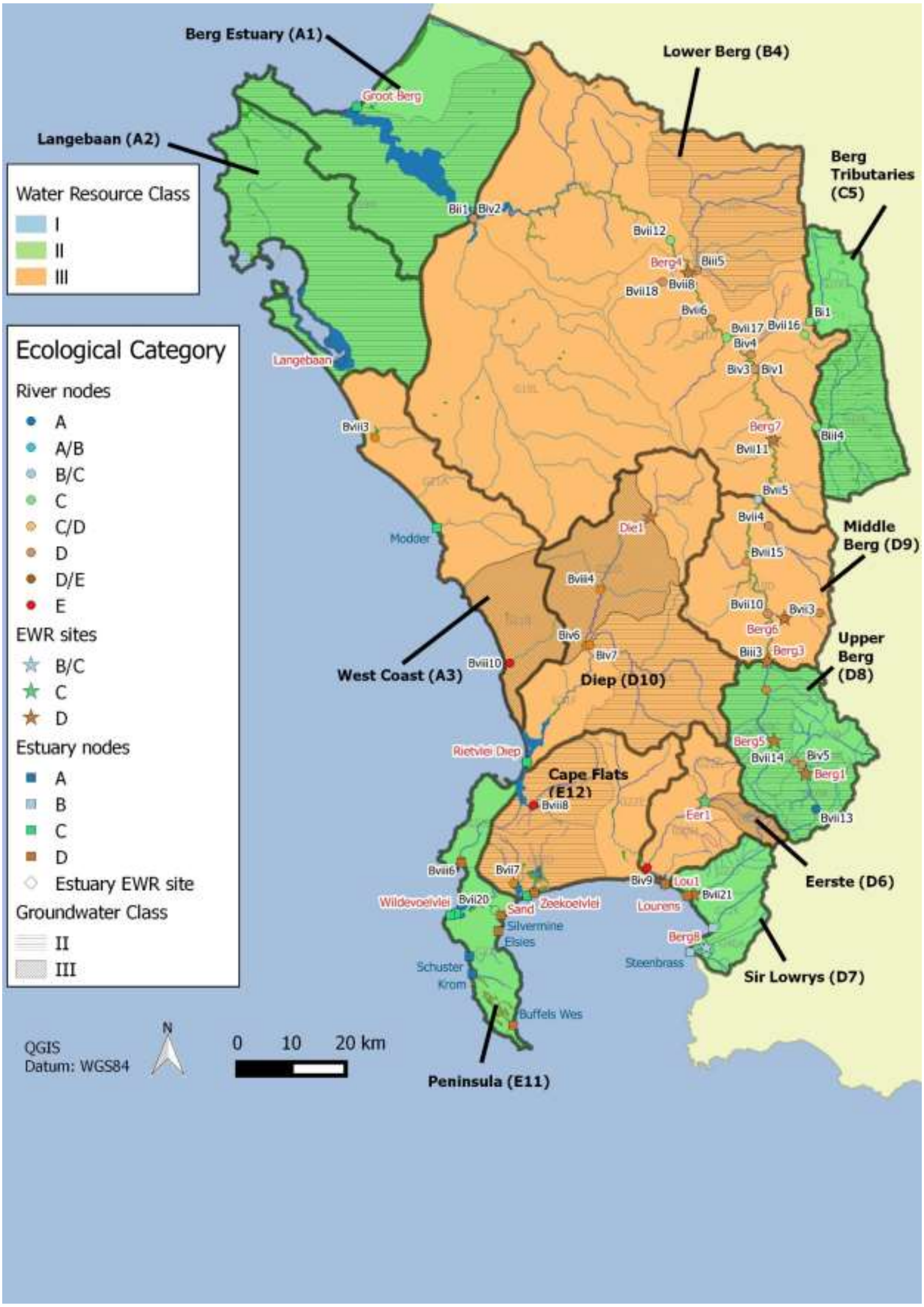

Figure 1-2 Recommended water resource Classes for the Berg Catchment

2 Approach

2.1 Resource Quality Objectives process overview

For the determination and implementation of RQOs, a seven-step procedure was established (DWA, 2011). This process is interlinked with the Water Resources Classification process and forms part of an Adaptive Management Cycle that is used as an improved water resources management practice. Overall the Adaptive Management Cycle process consists of delineating the resource units (RU), setting a vision for the catchment, prioritise, select and evaluate RUs for RQOs, drafting RQOs and numerical limits, and agreeing these with the stakeholders to finalise and Gazette the RQOs, and finally moving to implementing, monitoring and reviewing before restarting the process for corrections and improvements.

Ideally the RQOs should be set for each Resource Unit, as per the Water Resource Classification System recommendations. In reality however, due to the large number of Resource Units within the Berg catchment, it is necessary to prioritise and to select the most useful Resource Units for RQO determination. In terms of the seven-step RQO determination process, Step 1 (Delineation) and Step 2 (Visioning) have been explained and completed as part of the Classification phase of this study (Figure 2-1). The purpose of Step 3 of the Procedure to Determine and Implement Resource Quality Objectives (DWA, 2011) is to select and prioritise preliminary Resource Units using the RU prioritisation tool for RQO determination. The evaluation of the RU priority ratings for selection are then done (Step 4), and the RQOs and numerical limits are drafted (Step 5). These will then be discussed and agreed at the stakeholder engagement workshops (Step 6). This process will allow for the selection of at least one RU to represent each IUA that will then be monitored after the gazetting of the RQOs (Step 7).

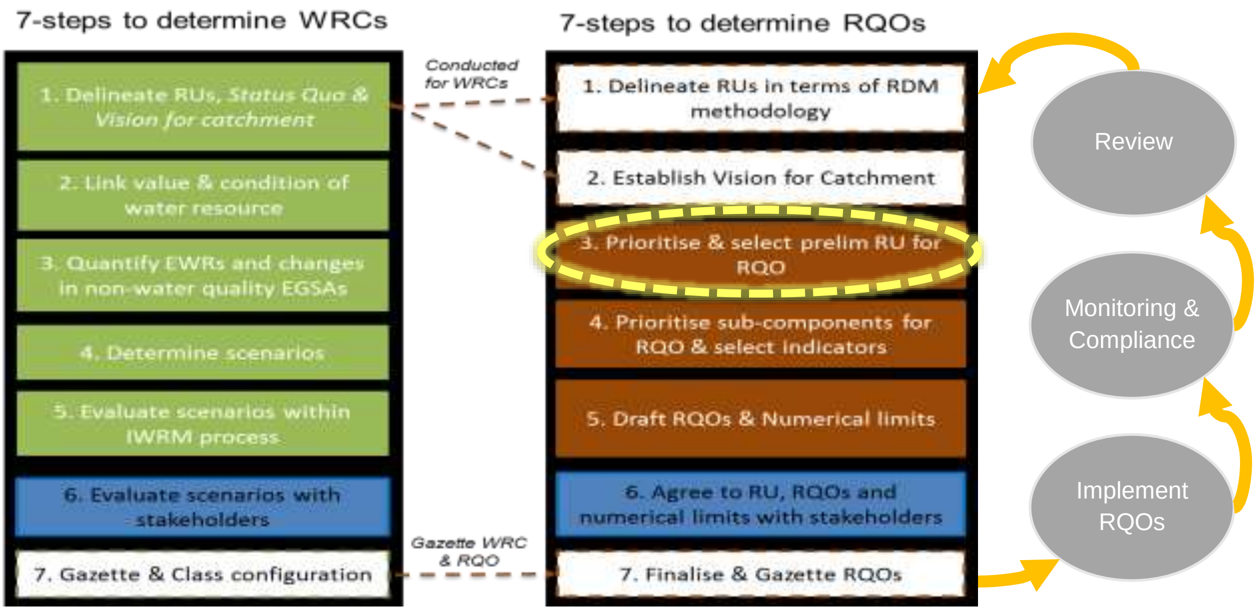

Figure 2-1 Integration of the seven-step processes for WRC determination and the RQO determination (DWA, 2011), incorporating the three additional steps to implement the Adaptive Management Cycle

Management, monitoring and compliance are the three additional steps of the Adaptive Management Cycle, to be implemented after the seven-step RQO process. This introduces a continual learning and improvement procedure to be in place, which allows for changes to be made to align the RQOs with the vision for the resource. The changes, if needed, will indicate that the measures that are in place to protect the water resource are not sufficient to comply with the RQOs set, or alternatively that the RQOs that have been set are not realistic, and the process will need to be revisited to correct these issues.

2.2 Resource Unit Prioritisation overview

The Resource Unit Prioritisation (Step 3) comprise an iterative process of prioritising the RUs within the study area, based on levels of threat in relation to conservation and socio-economic importance. To guide this selection process, and to facilitate the standard selection of prioritised resource units/sub-quaternaries, a decision support tool has been developed, using an MS Office Excel spreadsheet (DWA 2011). This tool, named the Resource Unit Prioritisation Tool (RUPT), incorporates a multi criteria decision analyses approach to assess the importance of monitoring each RU, as part of management operations, to identify important RUs and it is used for the Resource Unit Prioritisation step.

The Resource Unit Prioritisation step comprises the population of information in the RUPT for each RU. In this tool standardized rankings and weightings have been applied, and those criteria and sub-criteria with the highest ranking are regarded as the most important criteria for consideration in prioritising resource units, with the highest weightings contributing more towards the summary score for the criteria and sub-criteria being assessed. To promote consistency in the application of the tool, any changes to standard weightings should be documented and justified with an appropriate rationale.

A number of sub-steps are followed during Step 3. These are briefly enumerated below:

1. Extract and map catchment and Resource Unit level information
2. Determine the position of each Resource Unit within the IUA
3. Assess the importance of each Resource Unit to users
4. Determine the level of threat posed to water resource quality for users
5. Assess the importance of each Resource Unit to ecological components
6. Determine the level of threat posed to water resource quality for the environment
7. Identify Resource Units for which management action should be prioritised
8. Assess practical considerations associated with RQO determination for each Resource Unit
9. Evaluate the relative ranking and weighting of each criterion
10. Select Preliminary Resource Units for RQO determination using prioritisation scores
11. Complete the information sheet for the Resource Unit Prioritization Tool.

The Resource Unit Prioritisation Tool focusses on the prioritisation of RUs for rivers, wetlands and estuaries. However for the wetland prioritisation process, the application of a standardised prioritisation tool has been particularly difficult for wetlands, due to the cumbersome and time-consuming process involved in using the tool (INR, 2017). A different method was thus followed for this study, using a procedure for determining wetland RQOs that is under development as part of a concurrent study being undertaken through the Water Research Commission (INR, 2017) which intends to address the limitations of current wetland prioritisation methodologies.

For the dam and groundwater prioritisation processes there was a need to adopt a different set of criteria and sub-criteria appropriate to these resources, which intends to address the limitations of current methodologies. A Resource Unit Prioritisation Tool for the prioritisation of RUs for dams was developed, based upon relevant prioritisation criteria for the rivers prioritisation, and the addition of dam-specific criteria.

The specific approaches used to prioritise the river, dam, wetland, estuary and groundwater resources within the Berg Catchment are discussed below.

2.3 River Resource Unit prioritisation

2.3.1 Delineation of River Resource Units

The river resource units chosen were the biophysical and allocation nodes from the WRCS, since these were located using a variety of biophysical, water resource related, hydrological and ecological reasons (Table 2-1). This was necessary in order to align the outcomes of the process described below with that from the WRCS, described using nodes within IUAs and also since the nodes represent all the significant water resources in the study area. There are also nodes in all the quaternary catchments and this level of information is useful for water resource planning and groundwater based studies.

Table 2-1 The rules for establishing WRCS nodes

TIER	Data/GIS layers	Procedure for river node selection: Filtering process	Procedure for river node selection: Additional explanation	Minimum unit
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)	HydI Class 1: HydI = 1 to 4 (perennial).	Place node at each Quaternary intersection where there is a change in HydI Class.	
		HydI Class 2: HydI = 5 (seasonal).		
		HydI 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.	
		Group 2: Lower Foothills.		
		Group 3: Lowland Rivers.		
		Group 4: Rejuvenated Floodplains.	Place node at the head of the estuary.	
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 (Kleyn-hans, 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.		

[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	
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
			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 intersection where the area covered by farm dams in the up-stream quaternary is > 5 times that of the downstream quaternary.	Quaternary
			v. Place a node on a river imme-diately upstream of the confluence with an Inter Catchment 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 cumu-lative 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 procedures linked to the Classification 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

The second level of ranking was done using the river RU prioritisation tool, as described below for all quaternary catchments and nodes in the study area.

2.3.2 Prioritisation of river Resource Units

The river RU Tool was used to rank RUs relative to one another. The tools' standard scoring and ranking of scores were used throughout; no changes were made to the default settings. Some of the more important data used to answer the questions posed by the tool are provided in the results tables (Table 3-1, see Section 3.1).

The scores given to the RUs used, to rank them relative to one another, are provided in Appendix A.

The following criteria were assessed, using the tool:

- The position of the RU in the IUA, where:
  - RUs on a main stem river at the base of an IUA were given a score of 1;
  - and those not on a main stem river nor at the base of an IUA were given a 0;
- The importance of the RU to users, such as recreational use, tourism, scientific benefits, aesthetic, cultural or spiritual benefits, where:
  - RUs with no cultural services were given a 0;
  - RUs with some services were given a 0.5;
  - RUs providing very important cultural services were given a 1;
- RUs that support the livelihoods of significant vulnerable communities, such as water, food or grazing and raw materials, where:
  - RUs with limited support were given 0;
  - RUs with some support were given 0.5;
  - RUs with an important role were given 1;
- RUs with strategic or international obligations, for the generation of power, or for water-related agreements, such as the RAMSAR convention; where:
  - RUs not important were scored 0;
  - RUs with moderate importance were scored 0.5;
  - Important RUs were scored 1;
- RUs that provide supporting or regulating services, such as flood attenuation, water purification, flow regulation, erosion control, sediment retention and disease and pest control, where:
  - RUs with limited support were given 0;
  - RUs with some support were given 0.5;
  - RUs with an important role were given 1;
- RUs that contribute to the economy, where:
  - RUs that make no contribution were given 0;
  - RUs that make a moderate contribution were given a 0.5;
  - RUs that make a significant contribution were given a 1;
- The level of threat posed to the water quality for users, where:
  - RUs where the level of threat is low were scored 0;
  - RUs where the threat is moderate were scored 0.5;
  - RUs where the threat was high were scored 1;

- The ecological importance of the RUs, for example a high ecological importance and sensitivity (EIS), a good ecological condition, an NFEPA (National Freshwater Ecosystem Protection Area, Critical Biodiversity Area (CBA) or Ecological Support Area (ESA), where:
    - Low to moderate EIS was scored 0;
    - High EIS was scored 0.5;
    - Very high EIS was scored 1;
    - Ecological condition lower than a B were scored 0;
    - Ecological condition B was scored 0.5;
    - Ecological condition > B scored 1;
    - No NFEPA scored 0;
    - NFEPA support areas scored 0.5;
    - NFEPAs scored 1;
    - Low irreplaceability scored 0;
    - ESAs scored 0.5;
    - CBAs scored 1;
- The level of threat posed to the water quality for the environment, where:
    - RUs where the level of threat is low were scored 0;
    - RUs where the threat is moderate were scored 0.5;
    - RUs where the threat was high were scored 1;
- RUs where management action should be prioritised, where:
    - RUs in a D condition or greater where given a 0;
    - RUs in a D/E condition or lower where given a 1[2];
- Practical considerations, such as the existence of EWR sites and DWS gauging weirs, where:
    - RUs with no such information were given a 0;
    - RUs with a gauging weir where given a 0.5;
    - RUs with EWR sites and/or gauging weirs were given a 1;
    - RUs with poor accessibility or that are unsafe to monitor were given a 0;
    - RUs with moderate accessibility and safety were given a 0.5;
    - RUs with good accessibility safety were given a 1;

Where there was more than one sub-quaternary river ranked in each quaternary the overall ranks were averaged. Results were reported at the level of quaternary catchments to align with those of the estuary, wetlands and groundwater prioritisation results.

[2] It was assumed that the Rating Guideline for the Management Considerations criteria was intended to refer to “D Category” and not “C category”

2.4 Estuary Resource Unit prioritisation

The RUPT Tool, published by DWA (2011), was used to prioritise estuaries and river outlets. The RUPT uses a range of criteria that assesses the importance of monitoring each RU as part of management operations. This includes the position of Resource Units within an IUA, user and ecological considerations, practical constraints and management considerations. Key criteria considered in the evaluation process included the following:

- Provision of cultural services to society
- Provision of supporting livelihoods of significant vulnerable communities
- Importance in meeting strategic requirements and international obligations
- Provision of supporting and regulating services
- Contributing to the economy (GDP and job creation) in the catchment (e.g. commercial agriculture, industrial abstractions and bulk abstractions by water authorities)
- Level of threat posed to users
- EIS category
- Present ecological status
- Priority in provincial / fine scale aquatic biodiversity plans
- Level of threat posed to ecological components of the estuary
- Estuaries with PES lower than a D Category or lower than the accepted gazetted category
- Availability of EWR site data or other monitoring data (RHP, DWS gauging weirs etc.)
- Accessibility of resource unit for monitoring
- Safety risk associated with monitoring RUs.

2.5 Dam Resource Unit prioritisation

The preliminary screening list for prioritisation of the existing dams prepared for the *Resource Unit and Integrated Units of Analysis Delineation Report* (DWS, 2016b), followed a conservative approach where all the dams located within the study area were subjected to a first high-level screening, as follows:

- The National List of Registered Dams (DWS, 2016), kept by the Dam Safety Office of DWS, was filtered to view dams that are in the Berg catchment,
- High or significant hazard potential dams were selected,
- Category 2 or category 3 dams were selected, in terms of dam safety legislation, and
- Dams with a capacity of more than 3 million m^3 were selected.

A further screening process was then undertaken to identify the Dams RUs that should be prioritised. As a prioritisation tool has not yet been developed for the RU prioritisation of dams, the existing surface water prioritisation tool was adapted to prioritise dams. The adaptations to the tool (Excel spreadsheet) were done to make the prioritisation more relevant to dams whilst trying to limit significant changes to the criteria and the ranking system that was applied in the original RUPT tool. Some information has been captured in the tool as comments pertaining to relevant cells.

The following criteria were assessed, using the tool:

- The location of the RU, where:
  - RUs on a main/large stem river were given a score of 1
  - and those not on a main/large stem river were given a 0

- The importance of the RU to users, such as recreational use, tourism, scientific benefits, aesthetic, cultural or spiritual benefits, where:
    - RUs with no cultural services were given a 0
    - RUs with some services were given a 0.5
    - RUs providing very important cultural services were given a 1
- RUs that support the livelihoods of significant vulnerable communities, such as water, food or grazing and raw materials, where:
    - RUs with limited support were given 0
    - RUs with some support were given 0.5
    - RUs with an important role were given 1
- RUs with strategic or international obligations, for the generation of power, or for water-related agreements, such as the RAMSAR convention, where:
    - RUs not important were scored 0
    - RUs with moderate importance were scored 0.5
    - Important RUs were scored 1
- RUs that provide supporting or regulating services, such as water supply, flood attenuation, water quality control, stream flow regulation, and sediment retention, apart from the common function of water storage, where:
    - RUs with limited support were given 0
    - RUs with some support were given 0.5
    - RUs with an important role were given 1
- RUs that contribute to the economy, where:
    - RUs that make no contribution were given 0
    - RUs that make a moderate contribution were given a 0.5
    - RUs that make a significant contribution were given a 1
- The level of threat posed to the water quality for users, where:
    - RUs where the level of threat is low were scored 0;
    - RUs where the threat is moderate were scored 0.5;
    - RUs where the threat was high were scored 1;
- The ecological importance of the RUs, linked to the flow releases for ecological purposes, where:
    - RUs with a low ecological support function were scored 0
    - RUs with a moderate ecological support function were scored 0.5
    - RUs with a high ecological support function were scored 1
- The level of threat posed to the water quality for the environment, where:
    - RUs where the level of threat is low were scored 0
    - RUs where the threat is moderate were scored 0.5
    - RUs where the threat was high were scored 1
- Practical considerations, such as the existence of EWR sites and DWS gauging weirs, where:
    - RUs with no such information were given a 0
    - RUs with a gauging weir where given a 0.5

- RUs with EWR sites and/or gauging weirs were given a 1
- RUs with poor accessibility were given a 0
- RUs with moderate accessibility were given a 0.5
- RUs with good accessibility were given a 1
- RUs that are unsafe to monitor were given a 0
- RUs with moderate safety were given a 0.5
- RUs with good safety were given a 1

2.6 Wetland Resource Unit prioritisation

2.6.1 Review of the Wetland Resource Unit Prioritisation Tool (WRPT)

The procedure to develop and implement RQOs (DWA, 2011) was designed to be applied to rivers, wetlands and estuaries, and to have a similar approach for different water resources. The model comes with three variants, for the different water resources, which are essentially very similar.

The use of the standardised WRPT has proved particularly problematic for wetland resources, due to the unrealistic input data requirements and the cumbersome and time-consuming process involved in using the tool (INR, 2017). A key component of RQO methodology is the need to ensure sustainable use of large numbers of wetlands and, although various tools have been developed to facilitate management of wetlands, application at a landscape level has not been met. Thus, the approach to prioritising wetlands in this study follows the draft procedure developed as part of a WRC project, aimed at developing procedures for setting wetland RQO's (including wetland prioritisation), that is currently underway (INR 2017).

From an EWR perspective, important wetlands include those that have both ecological importance for the maintenance of biodiversity ecosystem integrity, as well as those that provide ecosystem services. In terms of ecosystem services, wetland prioritisation needs to consider both the ability of a wetland to provide services as well as the demand for such services within the catchment. These two aspects therefore define the importance of wetlands in terms of ecosystem services.

The prioritisation of Wetland RUs is done within each Wetland Region, and is based on those wetlands that have been defined as important in terms of ecological importance and for provision of ecosystem services (Figure 2-2).

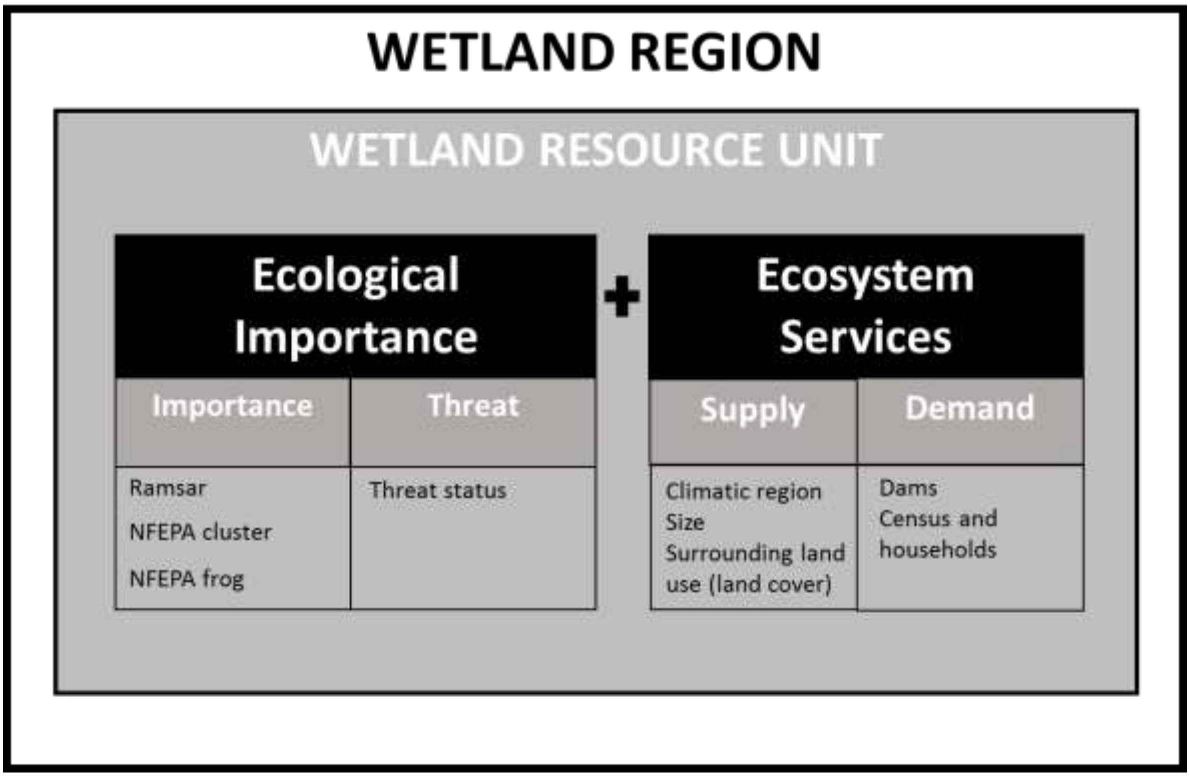

Figure 2-2 Conceptualisation of how Wetland Resource Units are nested within Wetland Regions

2.6.2 Development of a consolidated wetland map

The most up-to-date, consolidated wetland map in the Western Cape was used (Cape Nature Wetland Map, 2017). This wetland map consolidated an updated version of the NFEPA Wetlands map (NFEPA.elim.Z2) with additional land cover-derived delineations and flood modelling. These additions added an extra 85 000 ha of wetlands to the Western Cape NFEPA layer, which resulted in a wetland coverage of 300 000 ha in the Western Cape (Genevieve Pence, Cape Nature, per coms).

2.6.3 Recap of Wetland Regions

Wetland Regions in the study area were defined according to EcoRegion, which is influenced by geological and climatic controls. The hydrogeomorphic (HGM) unit, used for classification of wetland type, relates to location in the landscape; therefore it is important to consider the Wetland Regions, as these provide an overview of the underlying controls of wetland types. As different Wetland Regions have different characteristics it is also important to maintain a representation of these Regions in the prioritisation process.

2.6.4 Ecologically Important Wetlands

The Ecological Importance of wetlands was defined in each Wetland Region. This allowed for a regional representation of ecologically important wetlands in the study area.

Methodology to define Ecological Importance of wetlands

The ecological Importance of a wetland was defined according to the presence of important frogs as defined in NFEPA, whether the wetland was a NFEPA cluster and whether the wetland was a Ramsar wetland. It was also considered important to determine whether the wetland was under threat, as these wetlands would have a higher priority in terms of requiring conservation measures. The latest NBI vegetation layer was used for this, which indicated vegetation that was considered to be under different levels of threat. Threat status was used as a means to allow for the spatial scale of the study area to be effectively represented.

The Ecological Importance ranking was applied to each Wetland Region. The weighting of each of the spatial layers considered both ecological importance and threat status per Wetland Region (Table 2-2).

Table 2-2 Adjustment factor to account for the influence of ecological importance of the wetland

Ecological Importance	NFEPA cluster	NFEPA frogs	Ramsar	Critically endangered	Endangered	Threatened	Least Threatened
NFEPA cluster	0.25						
NFEPA frogs		0.25					
Ramsar			0.25				
Threat status				1	0.8	0.6	0

The ecological importance methodology was applied in GIS. A wetland layer was created in GIS by using the "union" tool for each layer. The ranking per wetland within each Wetland region was based on the cumulative value of each layer. This provided a wetland layer for ecological importance per Wetland Region.

2.6.5 Ecosystem services

Identifying supply and demand for ecosystem services broadly identifies "hotspots" for regulating and supporting services provided by wetlands across the study area. The WET-Ecoservices tool (Kotze et al. 2007) identifies eight important regulating and supporting services provided by wetlands including flood attenuation, streamflow regulation, carbon storage and numerous water quality enhancement benefits (Table 2-3). A supply map for each of these services and demand map for two of the services was generated using desktop information. The approach to identifying wetlands that supply specific ecological services and the areas of greatest demand for such services are described below.

Table 2-3 Regulating and supporting services provided by wetlands (extracted from Kotze et al. 2007)

<table>
<tr><td rowspan="8">Regulating and supporting benefits</td><td colspan="2">Flood attenuation</td><td>The spreading out and slowing down of floodwater in the wetland, thereby reducing the severity of floods downstream</td></tr>
<tr><td colspan="2">Streamflow regulation</td><td>Sustaining streamflow during low flow periods</td></tr>
<tr><td rowspan="5">Water quality enhancement benefits</td><td>Sediment trapping</td><td>The trapping and retention in the wetland of sediment carried by runoff waters</td></tr>
<tr><td>Phosphate assimilation</td><td>Removal by the wetland of phosphates carried by runoff water</td></tr>
<tr><td>Nitrate assimilation</td><td>Removal by the wetland of nitrates carried by runoff water</td></tr>
<tr><td>Toxicant assimilation</td><td>Removal by the wetland of toxicants (e.g. metals, biocides and salts) carried by runoff water</td></tr>
<tr><td>Erosion control</td><td>Controlling of erosion at the wetland site, principally through the protection provided by vegetation</td></tr>
<tr><td colspan="2">Carbon storage</td><td>The trapping of carbon by the wetland, principally as soil organic matter</td></tr>
</table>

Methodology to define wetlands that supply ecosystem services

Climate

The first step in determining the wetlands that provide important ecosystem services are to determine the climatic region of the study area. This involved using the mean annual precipitation and Potential Evapo-Transpiration to define three climatic regions (Arid, Semi-arid and Humid). These different regions have an impact on the capabilities of a wetland (under natural vegetation) to supply a range of ecosystem services.

Wetland size

The supply of ecosystem services is also dependent on wetland size and the different land uses across the catchment (represented through land cover types). In order to account for this each wetland was assigned a climatic adjustment factor. The potential supply of ecosystem services from wetlands in different climatic settings was also adjusted to its extent. A relative adjustment factor on a scale of 0 to 1 was applied with the largest wetland receiving a factor or 1 and all other wetlands receiving an adjustment factor relative to the largest wetland.

Surrounding land use

The location and extent of different land cover types may also affect the capability of a wetland to supply ecosystem services. Some land cover types, such as commercial annual crops, may occur within a wetland and considerably diminish the ecological condition of the wetland and its ability to supply certain ecosystem services (Kotze, 2016). Other land cover types may occur in the upslope catchment of a wetland with less direct impacts. The capability of a wetland to supply ecosystem services was adjusted based on the type and extent of the surrounding land covers. Generic adjustment factors which account for the influence of land cover types occurring within the wetland and in the wetland's upslope catchment were developed for seven land cover types. The adjustment factors were then multiplied by the proportional extent of identified land covers.

Strategic water source area

The Strategic Water Source Areas spatial layer was also used to determine areas in the study area which contribute to river and groundwater resources. Wetlands in Strategic Water Source Areas were given a score of "1" in the supply map.

Table 2-4 Adjustment factor to account for the influence of land-cover types occurring in the wetland on the capability of a wetland to supply the ecosystem services given in Table 2-3

	Ecosystem service	Land-cover type							SWSA
		Natural	Dams	Crops	Alien trees[1]	Mining	Eroded	Urban infrastructure	
1	Sediment trapping & Erosion control	1.0	0.8	0.3	0.8	0.4	0.2	0.7	
2	Phosphate, nitrate and toxicant assimilation	1.0	0.8	0.1	0.6	0.2	0.2	0.1	
3	Flood attenuation	1.0	0.8	0.4	1.1	0.3	0.4	0.0	
4	Streamflow regulation	1.0	0.6	0.5	0.5	0.2	0.5	0.0	
5	Carbon storage	1.0	0.6	0.2	0.6	0.0	0.2	0.2	
6	Provision of water	1.0	1.1	0.2	0.2	0.0	0.4	0.0	
7	Harvestable resources	1.0	0.5	0.2	0.3	0.0	0.3	0.0	
8	Cultivated foods	0.0	0.0	1.0	0.0	0.0	0.0	0.0	
9	Strategic Water Source Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

The supply methodology was applied in ArcGIS. For the land-use related services (1-8) for each service, in each wetland, the starting scores from Table 2-4 were multiplied by the relative adjustment factor for extent. The resulting scores for each service in each wetland were adjusted to account for land-cover impacts. This entails estimating the total extent of different land cover types. The proportional extent of each land cover was multiplied by the adjustment factor for each impact. The final supply score for each service was calculated by adjusting the climatic scores by both extent and land cover impacts. This was done by multiplying the climatic score adjusted by extent by the adjustment factors for land cover impacts.

Methodology for establishing areas of greatest demand for wetland ecosystem services

The two main ecosystem services focused on in terms of demand were the demand for sediment trapping and erosion control, and water quality amelioration as these were considered to be the most important services required in the study area. The study area has many dams, which are reaching their storage capacity due to the accumulation of sediment from upstream catchments. The trapping of sediments in these upstream catchments by wetlands is therefore critical for water security in the region. Water quality amelioration is also important in urban areas where surface water resources are under pollution pressure.

In order to determine the demand for sediment avoidance it is necessary to first determine the presence of water supply dams in the study area. Quaternary catchments which have water supply dams within them were identified by using the national dam layer from DWS. All quaternary catchments that contain a dam were scored a 2. All upstream quaternary catchments were given a score of 1. All other catchments were scored a 0.

2.7 Groundwater Resource Unit prioritisation

The framework for RU prioritisation focusses on the prioritisation of river RUs (DWA, 2011). It requires a set of criteria and sub-criteria to be rated to calculate a priority rating for resource units. Therefore, a set of criteria and sub-criteria appropriate to groundwater were selected for the groundwater prioritisation process, based on available datasets and following the examples set by recent studies (specifically studies in the Olifants-Doorn and Olifants). The selected criteria and the relative weights applied is shown in Table 2-5.

The criteria are summarised as:

- Importance for (human) users: groundwater plays an important role in supporting domestic supply to several towns in the catchment. This is evaluated through assessing the (current and planned future) supply source to each town, and scoring RUs according to the number of settlements supported. In addition to use for domestic supply, groundwater plays an important role in supporting activities contributing to the economy (GDP, job creation) in several areas of the catchment (e.g. commercial agriculture, industrial abstraction). These areas and ‘beneficiaries’ were assessed by Le Maitre *et al*, 2017, and are included as a sub-criteria. Lastly; strategic water source areas for groundwater have been defined, and take into account areas of high groundwater availability and high or strategic groundwater use (Le Maitre *et al*, 2017), and these areas are also included as a sub-criteria.
- Level of surface water – groundwater interaction: groundwater has a variable role in supporting the environment through discharge to surface water that maintains EWRs. Where groundwater has a significant potential role in meeting EWRs, these areas are prioritised in order to protect this contribution. In addition, the presence of priority wetlands that are likely to be groundwater-fed is also included as a sub-criteria.
- Threat posed to users: the various aquifers in the resource unit may be at risk of abstraction that is not maintainable, or of water quality impacts. The threat of water quality impact is taken into account in the prioritisation through the i) assessment of water quality data to identify medium to long-term declining trends (completed for the Status Quo phase of the project); ii) the assessment of the presence of poor water quality currently; and iii) the assessment of potential risks to water quality.
- The threat of over-abstraction is also taken into account through the assessment of: i) water level data to identify medium to long-term declining trends ii) the stress index (use/recharge) under present day; and iii) under likely future conditions is used as an indication of where over-abstraction may be a risk, although this is not a definitive indicator. The future stress index is based on the results of the ‘spatially targeted’ scenario.
- Practical considerations: in order to implement and enforce RQOs, they must be measureable. Resource units with a sufficient groundwater monitoring network are therefore prioritised.

A challenge applying the rating shown in the table is that some of the sub-criteria refer to data that is spatially discretised below the scale of the groundwater resource unit i.e. the sub-criteria can have a spatial variability across the resource unit. However, only one rating can be applied per resource unit. Generally speaking, the sub-criteria category which covers the largest part of the resource unit was assigned. Furthermore, a conservative or worst case was often applied, for example if declining water level trends were noted in one part of a resource unit, but not in another, the resource unit still scored a "1" for declining water level trends.

A final score is derived for each quaternary catchment. The final resource unit prioritisation rating score (0-100, low to high) has been divided into three categories from 1 (not priority), 2 (low priority), 3 (high priority). The categories were based on the distribution of the final scores, and a cut-off value of >40 (out of 100) was selected as representative of high priority 3.

In addition, a handful of quaternary catchments were amended manually based on the following reasoning:

- It would be favourable to have at least one quaternary catchment per GRU prioritised for development of RQOs. Therefore, in GRUs with no quaternary catchments scoring a "3", the quaternary catchment with the highest score in that GRU (although less than 40) was manually assigned a "3". These catchments are marked with in red "3" in Table 3-13. This was not applied where all scores in the GRU were low, i.e. there is no worth of defining RQOs.
- In cases where a quaternary catchment resulted with a score "3"; however no data exists on which to base RQOs (and yet the catchment scored highly on all other sub-criteria hence resulted in a 3). These catchments were manually downgraded to a purple "2" in Table 3-13.

Table 2-5 Criteria and sub-criteria used to prioritise groundwater resource units, showing the weighting and rating applied (following DWA, 2011)

Criterion	Points	Sub-criteria	Sub-crieria weight as a % of the criteria (and as Points)	Rating guideline (equivalent to a factor)
Importance for users	25	RUs in which groundwater is important in supporting domestic supply (current or future)	60 (15 points)	0 – RUs which do not support settlements 0.5 – RUs supporting some settlements (1-2) 1 – RUs supporting several sole-supply settlements (>2)
		RUs within strategic water source areas for groundwater (high groundwater availability & strategic use)	20 (5 points)	0 - RUs outside of SWSA-gw 1 – RUs within SWSA-gw
		RUs most important in supporting activities contributing to economy (GDP, job creation) (e.g. commercial agriculture, industrial abstraction, bulk abstraction by water authorities)	20 (5 points)	0 – RUs which do not directly support any activities which contribute to economy [as indicated by <0.1l/s/km2] 0.5 – RUs which moderately support activities which provide a contribution to economy [as indicated by 0.1-0.3l/s/km2] 1 – RUs which significantly support activities which contribute to the economy [as indicated by >0.3l/s/km2]
Level of surface water – groundwater interaction	30	Relevance of groundwater contribution to maintain required low flow conditions (EWR - MLF)	50 (15 points)	0 – Rus without relevant groundwater contribution (low GWBF/EWR) (GWBF/EWR < 11%) 0.5 – Rus where groundwater contribution supports low flow condition (GWBF/EWR moderate, 12-75%) 1 – Rus where groundwater contribution is crucial to maintain low flow condition (GWBF/EWR high >75%)
		Relevance of groundwater contribution to maintain priority groundwater-dependent ecology	50 (15 points)	0 – RUs without priority groundwater-dependent systems (estuaries / wetlands) 1 – RUs with priority groundwater-dependent systems (estuaries / wetlands)
Threat posed to users	30	Water quality (current impacts): Medium to Long-term declining trend in natural water quality	16 (5 points)	0 – RUs where no trend is visible 0.5 – RUs where short-term trend is potentially visible, or minor 1 – RUs where long-term trend is visible, or where no data is available to assess trend

Criterion	Points	Sub-criteria	Sub-crieria weight as a % of the criteria (and as Points)	Rating guideline (equivalent to a factor)
		Water quality (current impacts): Presence of poor quality category (currently)	17 (5 points)	0 – RUs with category I water quality 0.5 – RUs with category II water quality 1 – RUs with category III water quality
		Water quality (future impacts): Potential risk to groundwater quality	17 (5 points)	0 – RUs where risk is low (low hazards, low vulnerability) 0.5 – RUs where risk is moderate (moderate hazards, moderate vulnerability) 1 – RUs where risk is high (high hazards, high vulnerability)
		Water quantity (current impacts): Medium to Long-term declining trend in water or piezometric levels	16 (5 points)	0 – RUs where no trend is visible 0.5 – RUs where short-term trend is potentially visible, or minor 1 – RUs where long-term trend is visible, or where no data is available to assess trend
		Water quantity (current impacts): Presence of high stress category (currently)	17 (5 points)	0 – RUs where stress is low (category I) 0.5 – RUs where stress is moderate (category II) 1 – RUs where stress is high (category III)
		Water quantity (future impacts): Presence of high stress category (future)	17 (5 points)	0 – RUs where stress is low (category I) 0.5 – RUs where stress is moderate (category II) 1 – RUs where stress is high (category III)
Practical Considerations	15	Availability of water quality monitoring data (WMS monitoring boreholes) located within RU?	50 (7.5 points)	0 – Rus where no resource quality information exists 0.5 – Rus for which a moderate level of resource quality information exists (1-8 points) 1 – Rus for which there is a good availability of resource quality information (>8 points)
		Availability of water level monitoring data (DWA monitoring boreholes) located within RU?	50 (7.5 points)	0 – Rus where no water level information exists 0.5 – Rus for which a moderate level of water level information exists (1-8 points) 1 – Rus for which there is a good availability of water level information (>8 points)

3 Results

3.1 Priority River Resource Units

The results of the Resource Prioritisation Tool for River RUs are listed in Table 3-1. The RU priority scores are shown, where rank 1 has the highest priority and rank 5 have the lowest priority. Rank 1 Resource Units (in bold) are the top 10 of the total 49 that were ranked, rank 2 are the next 10 most important and so on.

Table 3-1 Priority Resource Units in the Berg catchment

IUA	#	Quat	Sq code	Node	Comment	River	Position	Users	Environ	Manage	Score	Rank
Upper Berg	**1**	**G10A**	**G10A-09199**	**Bvii13**	**Gauge**	**Berg**	**0.25**	**0.05**	**0.13**	**0.13**	**0.55**	**1**
Upper Berg	**2**	**G10A**	**G10A-09172**	**Bviii1**	**D/s of Berg River dam at EWR 1 - C**	**Berg**	**0.25**	**0.13**	**0.21**	**0.13**	**0.71**	**1**
Upper Berg	3	G10A	G10A-09153	Biv5	U/s of confluence with Berg	Franschoek	0.00	0.08	0.09	0.10	0.27	3
Upper Berg	4	G10B	G10B-09136	Biii2	U/s of confluence with Berg	Wemmershoek	0.00	0.00	0.17	0.10	0.27	3
Upper Berg	5	G10C	G10C-09145	Bvii14	Gauge	Dwars	0.00	0.01	0.11	0.10	0.22	4
Upper Berg	6	G10C	G10C-09028	Bvii2	Skuifraam pump station area	Berg	0.00	0.01	0.08	0.08	0.16	4
Upper Berg	7	G10C	G10D-08957	Biii3	At gauging weir G1H020	Berg	0.25	0.00	0.01	0.23	0.49	2
Middle Berg	**8**	**G10C**	**G10D-08928**	**Bviii11**	**At EWR 7 u/s of confluence with Kromme - C**	**Pombers**	**0.00**	**0.09**	**0.17**	**0.25**	**0.51**	**1**
Middle Berg	9	G10D	G10D-08928	Bvii3	North of Wellington, G1H037, d/s EWR 6 - D	Kromme	0.00	0.09	0.17	0.25	0.51	2
Middle Berg	10	G10D	G10D-08893	Bvii10	D/s of confluence Kromme, at gauging weir G1H015	Berg	0.00	0.01	0.01	0.10	0.12	5
Middle Berg	11	G10D	G10D-08819	Bvii15	Gauge	Doring	0.00	0.00	0.03	0.10	0.13	5
Middle Berg	12	G10D	G10D-08803	Bvii4	At gauging weir G1H041	Kompanjies	0.00	0.00	0.01	0.10	0.11	5
Middle Berg	**13**	**G10D**	**G10F-08726**	**Bvii5**	**At gauging weir G1H036 and u/s of EWR 3 - D**	**Berg**	**0.25**	**0.07**	**0.08**	**0.13**	**0.52**	**1**
Lower Berg	14	G10F	G10F-08669	Bvii11	U/s of Voelvlei canal	Berg	0.00	0.07	0.08	0.08	0.23	4
Berg Tributaries	15	G10E	G10F-08505	Biii4	At gauging weir G1H008	Klein Berg	0.25	,04	0.09	0.13	0.50	2
Lower Berg	16	G10J	G10F-08505	Biv3	U/s of confluence with Berg	Klein-Berg	0.00	0.00	0.09	0.08	0.17	4
Lower	17	G10J	G10J-	Biv1	U/s of confluence	Berg	0.00	0.07	0.08	0.08	0.23	4

IUA	#	Quat	Sq code	Node	Comment	River	Position	Users	Environ	Manage	Score	Rank
Berg			08520		Klein-Berg, d/s Voelvlei canal							
Lower Berg	18	G10J	G10J-08464	Bvii16	Gauge	Leeu	0.00	0.00	0.06	0.10	0.16	4
Berg Tributaries	19	G10G	G10G-08382	Bi1	At gauging weir G1H028, pristine wilderness 100%	Vier-en-Twintig	0.25	0.01	0.08	0.10	0.44	2
Lower Berg	20	G10H	G10H-08338	-		Krom	0.00	0.09	0.00	0.08	0.16	4
Lower Berg	21	G10J	G10J-08433	Biv4	U/s of confluence with Berg	Vier-en-twintig	0.00	0.00	0.01	0.08	0.09	5
Lower Berg	22	G10J	G10J-08487	Bvii17	Gauge	Sandspruit	0.00	0.00	0.00	0.10	0.10	5
Lower Berg	23	G10J	G10J-08414	Bvii6	D/s of EWR 4, above Misverstand Dam G1H013 - D	Berg	0.00	0.16	0.14	0.13	0.42	2
Lower Berg	24	G10J	G10J-08366	Biii5	At gauging weir G1H035	Matjies	0.00	0.00	0.01	0.10	0.11	5
Lower Berg	25	G10J	G10J-08319	Bvii8	U/s Misverstand reservoir, d/s confluence with Matjies	Berg	0.00	0.08	0.08	0.08	0.24	4
Lower Berg	26	G10J	G10J-08322	Bvii18	Gauge	Moreesburg Spruit	0.00	0.00	0.06	0.10	0.16	4
Lower Berg	27	G10K	G10K-08197	Bvii12	3.5 km d/s of Misverstand reservoir, at EWR 5 - D	Berg	0.25	0.07	0.08	0.13	0.52	1
Lower Berg	28	G10L	G10L-08287	Bii1	U/s of confluence with Berg	Sout	0.00	0.00	0.02	0.08	0.09	5
Lower Berg	29	G10L	G10K-08152	Biv2	U/s of confluence with Sout, head of estuary	Berg	0.00	0.07	0.08	0.08	0.23	4
Berg Estuary	30	G10 M	G10M-08178	Bvii19	Berg estuary at Gauge		0.00	0.00	0.00	0.00	0.00	5
West coast	31	G21A	G21A-08690	Bviii3	Inflow to Yzerfontein salt pan		0.00	0.00	0.12	0.23	0.35	3
Lower Berg	32	G21B	G21B-08896	Bviii10	Cumulative at outlet G22B	Sout	0.00	0.06	0.11	0.23	0.40	3
Diep	33	G21C	G21C-08703	-		Riebecks	0.00	0.00	0.12	0.23	0.35	3
Diep	34	G21D	G21D-08761	Bv1		Diep	0.00	0.09	0.11	0.25	0.45	2
Diep	35	G21D	G21D-08825	Bviii4	U/s of confluence with Diep	Swart	0.00	0.08	0.11	0.23	0.41	3
Diep	36	G21D	G21D-08906	Biv6	At EWR Die1	Diep	0.00	0.09	0.11	0.23	0.42	2
Diep	37	G21E	G21E-08962	Biv7		Mosselbank	0.00	0.09	0.11	0.23	0.42	3
Diep	38	G21F	G21F-09037	Bviii5	Cumulative at outflow G21F	Diep	0.00	0.00	0.00	0.00	0.00	5

IUA	#	Quat	Sq code	Node	Comment	River	Position	Users	Environ	Manage	Score	Rank
Cape Flats	39	G22C	G22C-09142	Bviii8	U/s of confluence Black	Elsieskraal	0.00	0.06	0.06	0.23	0.35	3
Cape Flats	40	G22D	G22D-09294	Bvii7	At EWR site	Keysers	0.00	0.11	0.12	0.23	0.46	2
Cape Flats	41	G22E	G22E-09207	-		Kuils River	0.00	0.09	0.01	0.20	0.30	3
Peninsula	**42**	**G22B**	**G22B-09261**	**Bviii6**	**At EWR site**	**Hout Bay**	**0.25**	**0.11**	**0.14**	**0.25**	**0.75**	**1**
Peninsula	43	G22A	G22A-09324	Bvii20	Town	Silvermine	0.25	0.05	0.09	0.10	0.49	2
Eerste	**44**	**G22F**	**G22F-09205**	**Biii6**	**At EWR Eer1**	**Jonkershoek**	**0.25**	**0.13**	**0.16**	**0.13**	**0.66**	**1**
Eerste	45	G22G	G22G-09120	Biv8		Klippies	0.00	0.14	0.09	0.23	0.46	2
Eerste	46	G22H	G22E-09207	Biv9	U/s confluence Eerste	Kuils	0.00	0.11	0.09	0.21	0.41	3
Sir Lowrys	**47**	**G22J**	**G22J-09266**	**Bvii21**	**At EWR Lou1**	**Lourens**	**0.25**	**0.11**	**0.14**	**0.13**	**0.62**	**1**
Sir Lowrys	**48**	**G22K**	**G22K-09315**	**Bviii9**	**Cumulative at outlet G22K**	**Sir Lowry's Pass**	**0.25**	**0.10**	**0.11**	**0.10**	**0.56**	**1**
Sir Lowrys	**49**	**G40A**	**G40A-09346**	**Bvii22**	**At EWR 8, u/s of estuary mouth - B/C**	**Steenbras**	**0.25**	**0.15**	**0.22**	**0.10**	**0.73**	**1**

While a Target Ecological Conditions (TEC) and an associated environmental water requirement (EWR) are given for each river node, it is recommended that detailed RQOs including hydrology, geomorphology, water quality, habitat conditions and ecology only be written for the top 20 prioritised RUs of all Resource Units assessed. The top 20 identified river RUs of all RUs assessed ~~in the Berg Catchment~~ are given inTable 3-2.

Table 3-2: Top twenty prioritised River RUs for which it is recommended RQOs be developed

IUA	Quat	Node	Description and Reason for Priority	River	Score
Peninsula	G22B	Bviii6	At EWR site. Existing EWR site just upstream of inflow into Hout Bay. One of two strongly flowing perennial rivers on the Peninsula that has three reservoirs important for water supply to the city of Cape Town. The upper reaches are conserved in the Oranjekloof Nature Reserve where Ghost Frogs breed.	Hout Bay	0.75
Steenbras	G40A	Bvii22	At EWR 8, u/s of estuary mouth - B/C. The Steenbras River is impounded by two reservoirs that supply water to the City of Cape Town, and receive Inter Basin Transfers from other reservoirs. This site is important to maintain baseflows downstream of the reservoirs for the river and as inflow into the estuary.	Steenbras	0.73
Upper Berg	G10A	Bviii1	D/s of Berg River dam at EWR 1 – C. This site is already monitored by the DWS REMP programme and also was part of the Berg River Monitoring Programme. The gauge records E-flows released from the Berg River Dam.	Berg	0.71
Eerste	G22F	Biii6	At EWR Eer1. Important for quality of river flows through Stellenbosch. Also, to sustain flows during the dry season currently abstracted by the Stellenbosch Municipality upstream in Jonkershoek Nature Reserve. This site represents one of the few urban rivers in good condition, an example that should be exemplified.	Jonkershoek	0.66
Lourens	G22J	Bvii21	At EWR Lou1. This river is one of the major rivers that drain through the Cape Flats, starting through expensive farmland, then again representing one of the few urban	Lourens	0.62

IUA	Quat	Node	Description and Reason for Priority	River	Score
			rivers in good condition, as it flows through Somerset West. This river is a Protected Natural Environment (PNE). The gauge at this site records flows important as outflow through the estuary into False Bay.		
Sir Lowrys	G22 K	Bviii9	Cumulative at outlet G22K. Flows through an expensive residential development and the historic town of Sir Lowry's Pass village, important economically and socially respectively. This river is one of the few rivers that still flows perennially through the Cape Flats that support important wetland habitat.	Sir Lowry's Pass	0.56
Upper Berg	G10 A	Bvii13	Gauge. Outlet of IUA. Upstream of Berg River dam, this gauge records important inflows into the dam that are used to adjust the EWR releases made downstream of the dam into the Berg River. This area is now an important conservation area and this river reach is one of the few upper foothill rivers left in the Western Cape that is unregulated and in good condition.	Berg	0.55
Middle Berg	G10 D	Bvii5	At gauging weir G1H036 and u/s of EWR 3 – D. Existing EWR site at Hermon. This site is important as it is located downstream of the towns of Paarl and Wellington and the gauge here records flows in the river prior to any releases being made from Voelvlei dam. It is also the conduit for releases made to sustain agriculture downstream. It is also a site already being monitored by the DWS REMP and the Berg River Monitoring Programme.	Berg	0.52
Lower Berg	G10 K	Bvii12	3.5 km d/s of Misverstand reservoir, at EWR 5 – D. Existing EWR site that is gauged to record flows downstream of Misverstand that are important to sustain the Berg River estuary. It is also a site already being monitored by the DWS REMP and the Berg River Monitoring Programme.	Berg	0.52
Middle Berg	G10 C	Bviii1 1	At EWR 7 u/s of confluence with Kromme – C. Existing EWR site that is important to record flows and conditions in the Pombers River that receives water via Gawie se water, a canal that delivers water abstracted from the Upper Witte River in the Breede River Basin.	Pombers	0.51
Middle Berg	G10 D	Bvii3	North of Wellington, G1H037, d/s EWR 6 – D. Existing EWR site that is important to record flows and conditions in the Kromme River that receives water via Gawie se water, a canal that delivers water abstracted from the Upper Witte River in the Breede River Basin.	Kromme	0.51
Berg Tribs	G10 E	Biii4	At gauging weir G1H008. Location for diversion of inflows into Voelvlei Dam. This site is also located near the IUA outlet as it gathers flows from all these important tributaries.	Klein Berg	0.5
Upper Berg	G10 C	Biii3	At gauging weir G1H020. This site is important as it records flows through the town of Paarl and downstream of water releases made from the Berg River Dam at the Skuifraam Supplement Scheme. It is also a site already being monitored by the DWS REMP and the Berg River Monitoring Programme.	Berg	0.49
Peninsula	G22 A	Bvii20	Outlet of IUA. This is one of two perennially flowing rivers on the Peninsula and the entire catchment is situated in the Silvermine Nature Reserve, part of the Table Mountain National Park.	Silvermine	0.49
Cape Flats	G22 D	Bvii7	At EWR site. This is an important tributary of the Diep River, the most important and largest river basin on the West Coast supporting a diverse range of agricultural practices.	Keysers	0.46
Eerste	G22 G	Biv8	The Klippies is an important tributary of the Eerste River that flows through the informal settlement of Kayamandi. It is an existing DWS monitoring site.	Klippies	0.46
Diep	G21 D	Bv1	Outlet of IUA and inflow to estuary. The Diep is the main river basin on the West Coast and the estuary supports major recreational and expensive residential property.	Diep	0.45

IUA	Quat	Node	Description and Reason for Priority	River	Score
Berg Tribs	G10G	Bi1	At gauging weir G1H028, pristine wilderness 100%. Location for diversion of inflows into Voelvlei Dam.	Vier-en-Twintig	0.44
Lower Berg	G10J	Bvii6	D/s of EWR 4, above Misverstand Dam G1H013 – D. It is also a site already being monitored by the DWS REMP and the Berg River Monitoring Programme.	Berg	0.42
Diep	G21D	Biv6	At EWR Die1. This gauge downstream of the town of Malmesbury records flows and conditions that support the agricultural activities downstream and also the effect that the town and supporting industry are having on the water quality of this river.	Diep	0.42

3.2 Priority Estuary Resource Units

Results of the RU prioritisation for all estuaries and river outlets are presented in Table 3-3.

Scores allocated for the position in the IUA are the same for all systems (=0.25) as they are all located at the terminal end of their respective catchments. Scores for "Concern for users", "Concern for environment" and "Management and practical considerations" vary in accordance with the individual characteristics of each estuary/outlet. "Total Prioritisation Score" is a weighted sum of each of the above subcomponent scores, and along with "Priority Rating" indicates overall importance of each estuary/outlet in the study area.

Estuaries scored between 0.3 and 1.0, while the river outlets all scored 0.3 due to the limited services they are able to provide. Estuaries with a "Priority Rating" between 0.8 and 1.0 are considered to be of greatest importance, while those with scores between 0.5 and 0.7 are average importance, and those with scores lower than 0.4 or less are considered of low importance.

Importance scores allocated to estuaries in terms of the RU Prioritisation Tool (RUPT) do not correspond well with the overall importance score and rank scores assigned to all estuaries in South Africa by Turpie *et al*. (2013, Table 3-4). Important systems such as the Berg, Diep and Langebaan Lagoon (the latter not rated by Turpie *et al.* 2013) do not score highly when assessed by the RU Prioritisation Tool, while systems that score poorly in terms of conservation importance (e.g. Schuster and Silvermine) scored highly with the RUPT). It is recommended that RQOs be developed for all estuaries in the Berg Catchment irrespective of their scores. However, RQOs for estuaries that score highly in terms of conservation importance need to be more detailed and stringent than for the low priority systems. It is not considered necessary to develop RQO for any of the river outlets in the catchment. Additional information for eight of the most significant estuaries in the study area were obtained during the EWRs phase of this study and provide useful information and background on which to base the recommended RQOs and monitoring for these estuaries.

Despite being identified as one of the priority estuaries in the study area, after consultation with Stakeholders it was recommended that the Zeekoievlei estuary not be included as a priority estuary as the estuary portion is very limited and that the focus should be on managing it as a wetland resource unit.

Table 3-3 Resource unit priority scores for estuaries (bold text) and river outlets

	Berg (Groot)	Paternosterbaai	**Lange baan**	Dwars (Noord)	Dwars (Suid)	**Modder**	Jacobsbaai	Loerbaai	Bok	Silwerstroom	Springfontein	Sout (Suid)	**Rietvlei/ Diep**	**Sout (Wes)**
Position in IUA	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Concern for users	0.25	0.00	0.25	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.13
Concern for environment	0.23	0.00	0.19	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.13
Management and practical considerations	0.25	0.06	0.13	0.06	0.06	0.20	0.06	0.00	0.00	0.06	0.00	0.06	0.25	0.18
Total Prioritization Score	0.98	0.31	0.81	0.31	0.31	0.70	0.31	0.25	0.25	0.31	0.25	0.31	0.98	0.68
Priority Rating	1.0	0.3	0.8	0.3	0.3	0.7	0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.7

	Hout baai	**Wildevöel vlei**	**Bokram spruit**	**Schuster**	**Krom**	**Buffels Wes**	**Elsies**	**Silver mine**	**Sand**	**Zeekoe**	**Eerste**	**Lourens**	**Sir Lowry's Pass**	**Steen bras**
Position in IUA	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Concern for users	0.10	0.13	0.10	0.04	0.02	0.02	0.10	0.10	0.23	0.10	0.21	0.10	0.09	0.09
Concern for environment	0.06	0.11	0.06	0.00	0.00	0.00	0.06	0.11	0.19	0.15	0.19	0.19	0.08	0.13
Management and practical considerations	0.23	0.23	0.23	0.07	0.05	0.17	0.23	0.23	0.25	0.22	0.21	0.25	0.08	0.07
Total Prioritization Score	0.64	0.71	0.64	0.36	0.32	0.44	0.64	0.69	0.91	0.72	0.86	0.79	0.50	0.54
Priority Rating	0.6	0.7	0.6	0.4	0.3	0.5	0.6	0.7	0.9	0.7	0.9	0.8	0.5	0.5

The intensity of the shading indicates relative priority.

Table 3-4 Overall importance score and rank of all estuaries (Turpie et al, 2013)

ESTUARY (West to East)	Plant	Invert	Fish	Bird	Bio-diversity	Size	Habitat	ZTR	Importance Score*	National Rank
Berg (Groot)	90	80	100	100	97.5	100	100	90	98.4	3
Rietvlei/Diep	100	80	80	100	96.0	100	10	60	72.5	55
Houtbaai	60	10	10	10	42.5	10	50	90	36.1	176
Wildevoëlvlei	100	30	30	100	86.0	80	90	60	82.0	29
Bokramspruit	10	10	10	40	29.5	10	10	60	19.9	233
Schuster	10	10	10	10	10.0	10	10	60	15.0	246
Krom	100	10	10	10	68.5	10	10	60	29.6	204
Silvermine	90	10	20	10	63.5	30	50	10	41.4	155
Sand	70	80	80	100	91.5	90	70	10	77.4	45
Eerste	50	10	30	80	64.5	40	40	10	43.1	149
Lourens	60	10	20	60	51.5	30	30	10	33.4	189
Sir Lowry's Pass	90	10	20	10	63.5	20	20	10	29.9	202
Steenbras	10	30	20	10	17.5	20	10	20	16.9	240

Note: Data presented includes four component scores of the importance score (biodiversity, size, habitat and zonal type rarity (ZTR), and the four component scores of the biodiversity score (plants, invertebrates, fish and birds). Source: Turpie et al. (2013).

3.3 Priority Dam Resource Units

The preliminary screening list for prioritisation of the existing dams prepared for the Resource Unit and Integrated Units of Analysis Delineation Report (DWS, 2016b) was revisited and refined. The specifics of these dams are shown in Table 3-5.

Table 3-5 Pre-screened Dams Resource Units

No of dam	Name of dam	Quaternary Drainage Area	Completion date	Completion date raising	River or Watercourse	Wall type	Capacity (1000 m^3)	Purpose / use	Owner
G100/03	Voëlvlei Dam	G10F	1971		Vogelvlei	Earthfill	168 000	Domestic and Industrial supply	Dept. of Water and Sanitation
G100/02	Berg River Dam	G10A	2008		Berg	Rockfill	130 000	Domestic supply and irrigation	Trans-Caledon Tunnel Authority (TCTA)
G100/13	Wemmershoek Dam	G10B	1957		Wemmershoek	Rockfill	58 644	Domestic and Industrial supply	Cape Town Metropolitan Municipality
G400/30	Steenbras Reservoir	G40A	1921	1954	Steenbras	Gravity	36 133	Domestic and Industrial supply	Cape Town Metropolitan Municipality
G400/51	Steenbras Upper Dam	G40A	1977		Steenbras River	Earthfill	31 767	Domestic and Industrial supply	Cape Town Metropolitan Municipality
G104/BS	Broodkraal Dam	G10K	1998		Berg River tributary	Earthfill	9 100	Irrigation	Broodkraal Landgoed (Pty) Ltd
G100/06	Misverstand Weir	G10K	1977		Berg River	Arch & gravity	7 737	Domestic and Industrial supply	Dept. of Water and Sanitation
G104/BT	Platkloof Dam	G10K	1998		Platkloof River	Earthfill	3 050	Irrigation	Tweede Stuiwe Plase (Edms) Bpk.

Results of the RU prioritisation for the pre-screened dams are presented in Table 3-6.

Scores allocated for the "Position in the IUA", "Concern for Users", "Concern for Environment" and "Management and Practical Considerations" vary in accordance with the individual characteristics of each dam. The "Total Prioritisation Score" is a weighted sum of each of the above sub-component scores, and along with "Priority Rating" indicates overall importance of each dam in the WMA. Dams with a "Priority Rating" of between 0.6 and 1.0 are considered to be of the greatest importance, while those with scores lower than 0.4 or less are considered of low importance.

Table 3-6 Resource unit priority scores for dams

Criteria	Voëlvlei Dam	Berg River Dam	Wemmershoek Dam	Steenbras Reservoir	Steenbras Upper Dam	Broodkraal Dam	Misverstand Weir	Platkloof Dam
Position in IUA	0.00	0.13	0.00	0.13	0.13	0.00	0.13	0.00
Concern for users	0.22	0.14	0.12	0.12	0.14	0.03	0.13	0.05
Concern for environment	0.06	0.25	0.00	0.06	0.06	0.00	0.06	0.00
Management and practical considerations	0.13	0.13	0.08	0.13	0.13	0.08	0.13	0.08
Total Prioritization Score	0.41	0.64	0.20	0.43	0.45	0.11	0.44	0.12
Relative Priority Rating	0.63	1.00	0.31	0.68	0.71	0.16	0.68	0.19

The intensity of the shading indicates relative priority.

It is recommended that RQOs be developed for the dams in the Berg catchment with a "Priority Rating" of higher than 0.6. After consultation with Stakeholders, it was however decided to also include Wemmershoek Dam in the list of prioritised dams for RQOs, even though it was not initially included in the list or priority RUs.

The priority Dam RUs are as follows:

Table 3-7 Prioritised Dam Resource Units

Dam	IUA	Reason for prioritisation
Berg River	Upper Berg	The dam is located on the main stem of the upper Berg River, with the unique capacity to make flood releases to the downstream EWR site in the Berg River. This is a large and important dam for water supply to the WCWSS and the regulation of supply, also for irrigation.
Wemmershoek	Upper Berg	While the dam's priority score is below the priority rating cut-off value, stakeholders at the Technical Task Group meeting 2 was of the opinion that the dam is so important from a user's perspective, that it should still be prioritised, which was agreed to.
Voëlvlei	Lower Berg	This is the 2nd largest dam in the Western Cape Province, and is especially important for urban supply to the WCWSS as well as for recreational activities. Even though it is an off-channel dam fed by river diversions, its significant contribution to economic activities, and the location of an EWR site just downstream of the dam's release point in the Berg River makes it a high priority. Should the Michell's Pass intervention be implemented, this dam would be significantly influenced.

<table>
<tr><th>Dam</th><th>IUA</th><th>Reason for prioritisation</th></tr>
<tr><td>Misverstand</td><td>Lower Berg</td><td>The weir is located on the main stem of the lower Berg River, and regulates abstraction to supply towns in the lower Berg River catchment and coastal areas. There are many recreational activities at the dam. An EWR site is located just downstream of the weir on the Berg River.</td></tr>
<tr><td>Steenbras Reservoir (lower dam)</td><td>Sir Lowry’s</td><td rowspan="2">The lower Steenbras Dam is located immediately downstream of the Upper Streenbras Dam, and the dams are managed together. There is upstream agriculture that can influence future water quality. An EWR site is located just downstream of the lower dam wall. The dams form an important component of urban and industrial supply to the WCWSS.</td></tr>
<tr><td>Steenbras Upper</td><td>Sir Lowry’s</td></tr>
<tr><td>Wemmershoek</td><td>Upper Berg</td><td>This dam is owned and management by the City of Cape Town and is a critical water supply option. Despite not being identified in the initial list of priority dams it was considered to be of significant importance.</td></tr>
</table>

The dams are illustrated in Figure 3-1 overleaf.

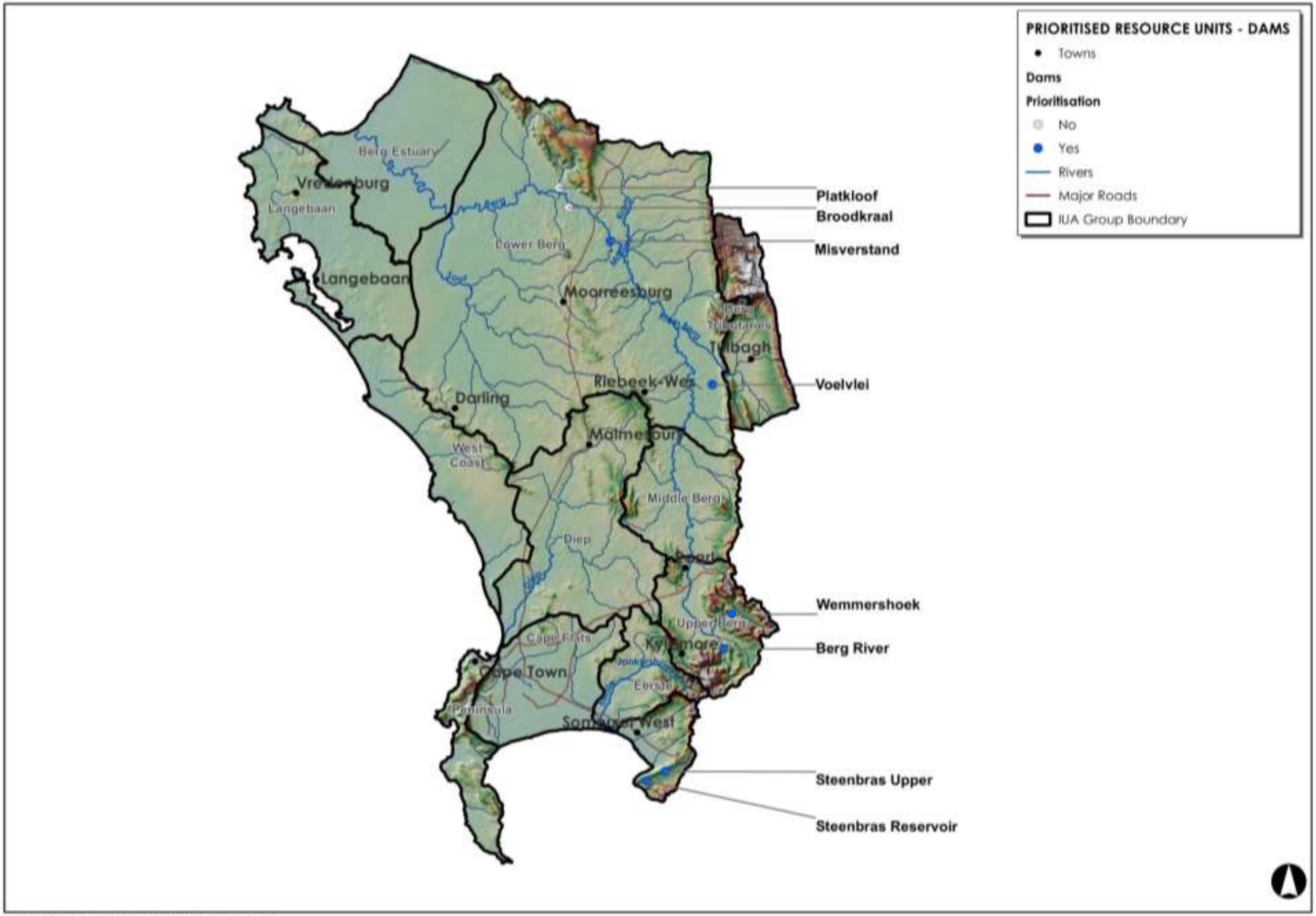

Figure 3-1 Preliminary Dams Resource Units delineated for the Berg Catchment

3.4 Priority Wetland Resource Units

3.4.1 Wetland Regions

As described in the Status Quo Report (DWS, 2016), the study area has 5 Wetland Regions. These are as follows:

- **G1 (Berg) Catchment:**
  - South Western Coastal Belt_Sand (WR1) Wetland Region
  - South Western Coastal Belt_Shale (WR2) Wetland Region
  - Western Folded Mountains (WR3) Wetland Region
- **G2 Catchment:**
  - South Western Coastal Belt_Sand (WR1) Wetland Region
  - South Western Coastal Belt_Shale (WR2) Wetland Region
  - Southern Folded Mountains (WR4) Wetland Region
  - Southern Folded Mountains_Peninsula (WR5) Wetland Region

3.4.2 Ecologically important wetlands

For each of these 5 Wetland Regions the upper twenty percent (20%) of ecologically important wetlands were determined. The Ecological Importance ranking was based on both ecological importance and threat status. In general, the highest priority wetlands were wetlands of high ecological importance and high threat status.

Table 3-8 Integration matrix to identify ecological importance

		Threat	
		High	**Low**
Ecological Importance	**High**	Implement restoration and rehabilitation to conserve ecologically important areas that are under threat.	Retain low current threat and possible future threat in ecological important areas.
	Low	Areas of least concern	Areas of least concern

The most ecologically important wetlands (highest 20%) in each Wetland Region were as follows:

Table 3-9 Ecologically important wetlands (highest 20%) per Wetland Region

Wetland Region	NFEPA cluster	NFEPA frogs	Ramsar	Critically endangered	Endangered	Vulnerable	Least Threatened	Score
South Western Coastal Belt_Sand (WR1)	x	/x		x				1.25
	x	x				x		1.10
	x	/x	/x		x			1.05
South Western Coastal Belt_Shale (WR2)		x		x				1.25
	x	x			x			1.10
Western Folded Mountains (WR3)				x				1.00
	x					x		0.85
Southern Folded Mountains (WR4)				x				1.00
Southern Folded Mountains_Peninsula (WR5)		x		x				1.25
	x	/x			x			1.05

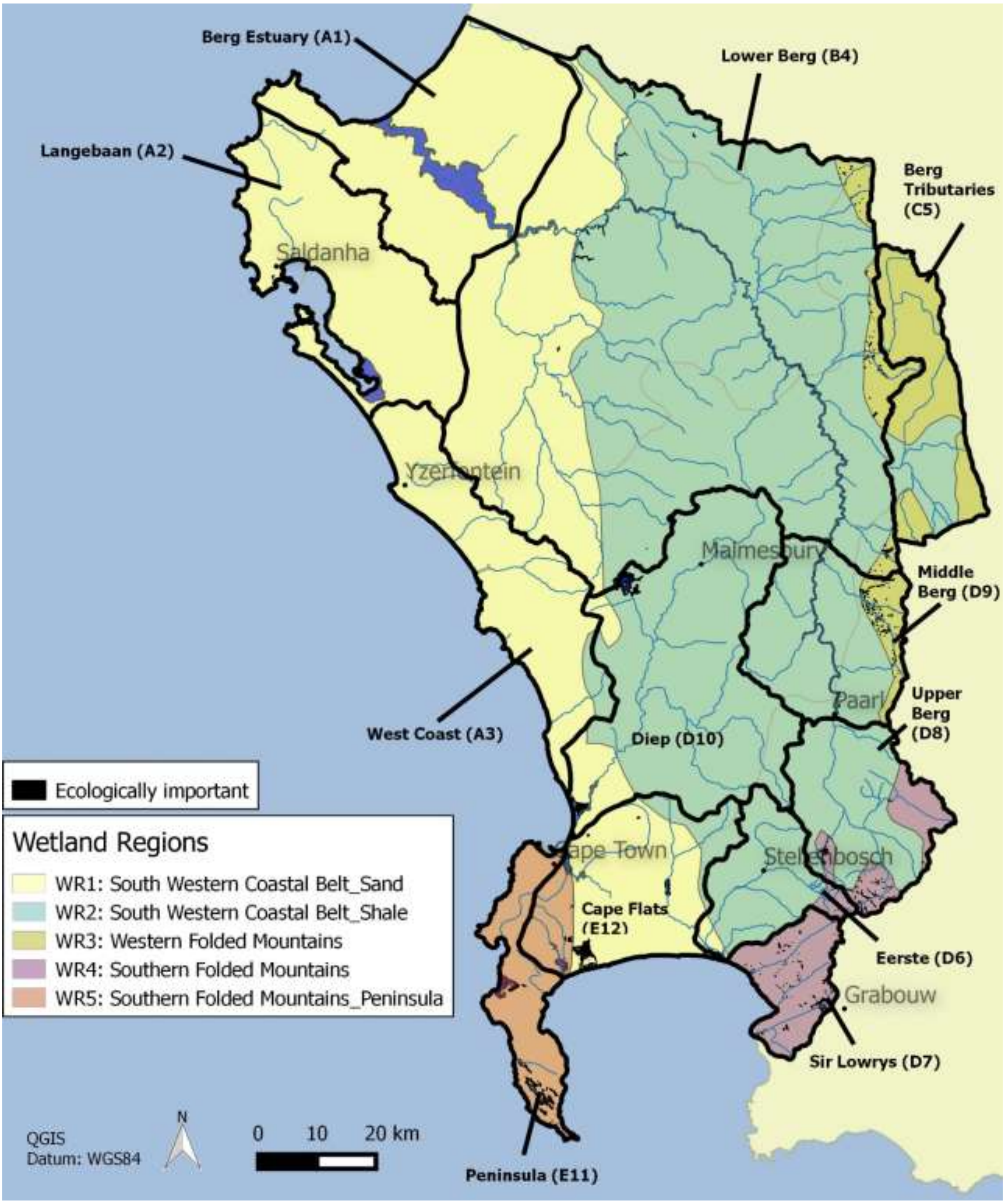

Figure 3-2 Ecologically important wetlands per Wetland Region in the study area

3.4.3 Ecosystem services

The ecosystem services supplied by all wetlands were calculated using the Land Use methodology. The top forty percent of wetlands were chosen as the wetlands supplying the highest level of ecosystem services. The final Ecosystem services supply layer is a cumulative layer of each service.

Supply of ecosystem services

Supply of flood attenuation

The wetland which supplies high levels of flood attenuation is the Berg River Floodplain. Most of the wetlands which supply high levels of flood attenuation are floodplain wetlands.

Supply of streamflow regulation

Similarly the Berg River Floodplain provides important streamflow regulation services, although most streamflow regulation occurs in the upper catchment.

Supply of sediment avoidance and erosion control

Sediment avoidance and erosion control are provided by wetlands in the study area, particularly due to the large number of wetlands.

Supply of phosphate, nitrate and toxicant assimilation; carbon storage, water provision and harvestable resources

Water quality amelioration is important in most of the catchment due to the urban and agricultural land uses.

Supply of cultivated foods

High levels of supply of cultivated goods occurs in many wetlands associated with agricultural areas.

Supply of water source areas

The Strategic Water Source Areas mainly occur in the high lying headwater regions, therefore not in the South Western Coastal Belt_Sand (WR1) Wetland Region. Wetlands within the Southern Folded Mountains_Peninsula (WR5), Southern Folded Mountains (WR4), Western Folded Mountains (WR3) and upper South Western Coastal Belt_Shale (WR2) Wetland Regions have wetlands which provide key strategic water sources. In particular hillslope seep wetlands.

Demand for ecosystem services

In terms of demand for ecosystem services, there is a demand for sediment avoidance in the Berg Catchment, due to the dams in the study area. There is also a high demand for water quality enhancement across most of the study area.

Demand and supply of ecosystem services

Areas where there is a high Demand and a high Supply of an ecosystem service by wetlands are considered important, but similarly areas where there is a high demand but a low Supply of an ecosystem service are also considered important. If there is a wetland within the area of high demand, even though the wetland is not providing a high supply of the ecosystem service the wetland must still be considered as important due to the high demand in that area.

Table 3-10 Integration matrix to identify ecosystem services hotspots

		Supply	
		High	Low
Demand	High	Retain to meet current demand. Implement management action to limit impact of heavy demand and ensure continued supply.	Implement restoration and rehabilitation to help meet current demand.
	Low	Retain to meet low current and possible future demand.	Areas of least concern

3.4.4 Integration of ecological importance and ecosystem services

These layers were integrated to provide a list of wetland resource units for prioritisation according to high ecological importance and high supply/demand of ecosystem services (Figure 3-3 and Table 2-5).

Table 3-11 Integration matrix to identify wetland resource unit

		Demand.Supply			
		High.High	High.Low	Low.High	Low.Low
Ecological Importance. Threat	High.High				
	High.Low				
	Low.High				
	Low.Low				

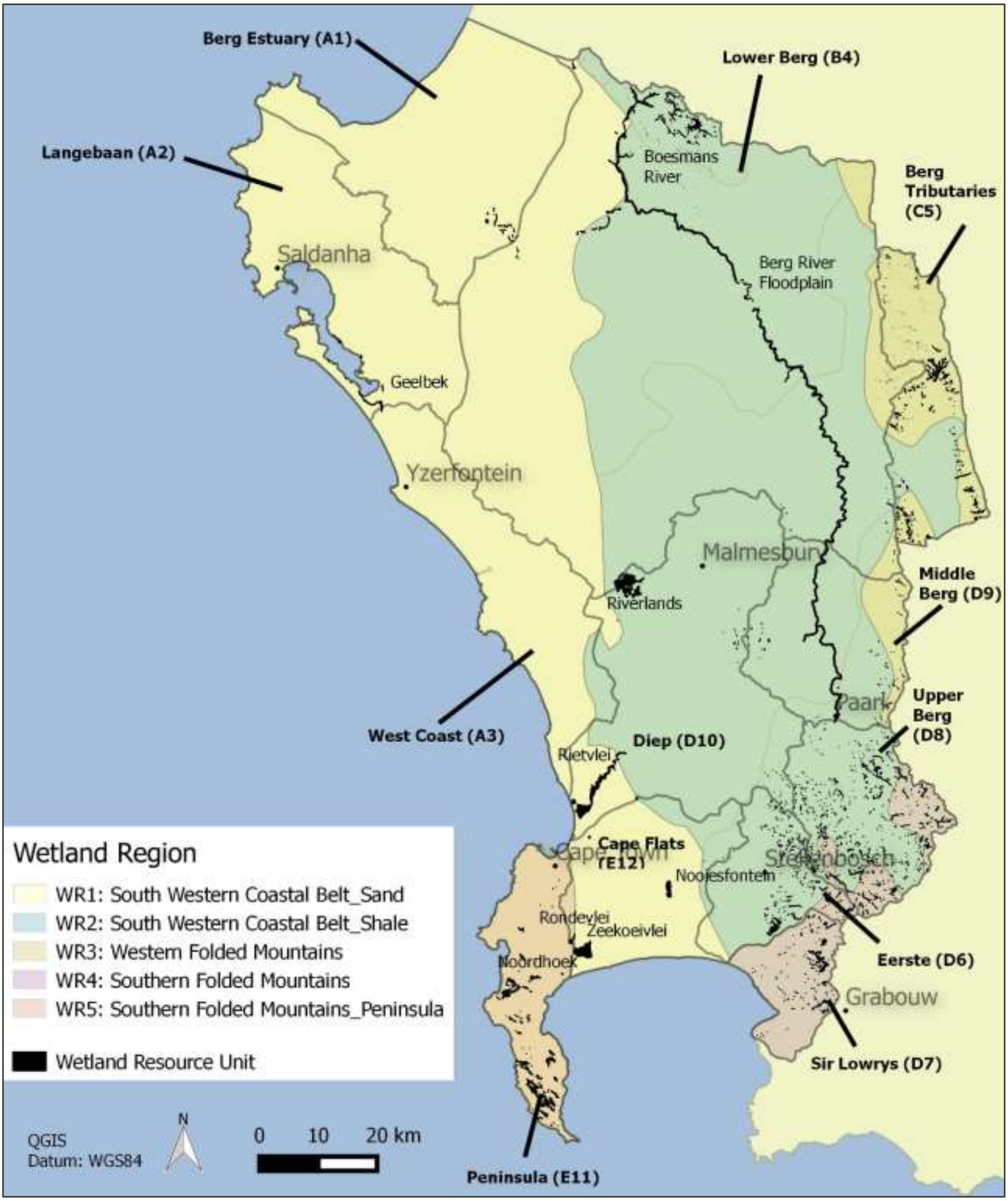

Figure 3-3 The integration of supply, demand and ecological importance for prioritisation of wetlands

Table 3-12 Wetland resource unit prioritisation

IUA	Wetland Region	Wetland Resource Unit	Name	Ecol NB	Supply	Demand
A1 Berg Estuary	South Western Coastal Belt_Sand (WR1)	Southwest Shale UNCHANNELLED VALLEY-BOTTOM WETLAND	Berg	x	x	
A2 Langebaan	South Western Coastal Belt_Sand (WR1)	Salt marsh SEEP	Geelbek	x	x	x
A3 West Coast	South Western Coastal Belt_Sand (WR1)	Southwest Sand Fynbos DEPRESSION	Yzerfontein		x	x
B4 Lower Berg	South Western Coastal Belt_Sand (WR1)	Southwest Sand Fynbos_Floodplain and UNCHANNELLED VALLEY-BOTTOM WETLAND	Sout	x		
	South Western Coastal Belt_Shale (WR2)	West Coast Shale Renosterveld_FLOODPLAIN	Berg	x		
		Northwest Sandstone Fynbos_SEEP	Boesmans River	x	x	x
		West Coast Shale Renosterveld DEPRESSION	Kiekoesvlei		x	x
		West Coast Shale Renosterveld DEPRESSION	Koekiespan		x	x
C5 Berg Tributaries	Western Folded Mountains (WR3)	Southwest Alluvium Fynbos_SEEP	SWSA	x	x	x
		Northwest Sandstone Fynbos_SEEP	SWSA	x	x	x
D6 Eerste	South Western Coastal Belt_Shale (WR2)	Southwest Granite Fynbos_ SEEP	SWSA	x	x	x
		Southwest Shale Fynbos_ SEEP	SWSA	x	x	x
D7 Sir Lowry's	Southern Folded Mountains (WR4)	Southwest Sandstone Fynbos_SEEP	SWSA	x	x	x
		Southwest Granite Fynbos_ SEEP	SWSA	x	x	x
D8 Upper Berg	Southern Folded Mountains (WR4)	Southwest Sandstone Fynbos_SEEP	SWSA	x	x	x
		Southwest Alluvium Fynbos_FLAT	SWSA	x	x	x
		Southwest Granite Fynbos_ SEEP	SWSA	x	x	x
D9 Middle Berg	South Western Coastal Belt_Shale (WR2)	West Coast Shale Renosterveld_FLOODPLAIN	Berg	x	x	
D10 Diep	South Western Coastal Belt_Shale (WR2)	DEPRESSION and SEEP	Riverlands	x		
	South Western Coastal Belt_Sand (WR1)	Southwest Sand Fynbos_FLOODPLAIN	Rietvlei	x	x	x
	South Western Coastal Belt_Sand (WR1)	Dune Strandveld_FLOODPLAIN	Rietvlei	x	x	x
E11 Peninsula	Southern Folded Mountains_Peninsula (WR5)	Southwest Sandstone Fynbos_UNCHANNELLED VALLEY-BOTTOM, FLAT	SWSA	x	x	x
		Sand Fynbos DEPRESSION	Pick and Pay Reedbeds	x	x	x
		Southwest Sandstone Fynbos DEPRESSION	Wildvoelvlei		x	x

IUA	Wetland Region	Wetland Resource Unit	Name	Ecol NB	Supply	Demand
		Southwest Sandstone Fynbos DEPRESSION	Seasonal	x	x	x
E12 Cape Flats	South Western Coastal Belt_Sand (WR1)	DEPRESSION	Rondevlei	x	x	x
		DEPRESSION seasonal	Rondevlei	x		
		DEPRESSION	Zeekoeivlei	x	x	x
		DEPRESSION seasonal	Zeekoeivlei	x		
		West Coast Granite Renosterveld_FLOODPLAIN	Nooiensfontein	x	x	x
		Southwest Sand Fynbos_FLOODPLAIN	Blouvlei	x	x	x
		SEEP seasonal	Philippi wetlands	x	x	x
	Southern Folded Mountains_Peninsula (WR5)	DEPRESSION	Princess Vlei	x	x	x

3.5 Priority Groundwater Resource Units

Priority Groundwater RUs in the region are listed in Table 3-13.

The individual rating (factor) applied for each sub-criteria is provided in Table 3-13, showing how each GRU scored per sub-criteria, thus demonstrating why that GRU is considered important.

The automatic scoring system has resulted in a sensible selection of resource units; high priorities corresponds with those areas known to be important to users, important for SW-GW interaction, and areas known to be under threat. Given the weights applied, the prioritisation process has highlighted those areas where there is high current or future use (G21A, and Cape Flats), and areas where there is a high SW-GW interaction (G10J, G10L, G10M). These high priority areas appear distributed across the catchment.

The scoring system naturally selected at least one quaternary catchment per GRU, except in the case of the GRU for 10-Malmesbury where the quaternary catchment with the highest score within the GRU was allocated as a high priority. In addition, no quaternary catchments are prioritised in the 7-Piketberg GRU, because G30A received a low score, and RQOs were developed for G30D in the Olifants-Doorn study (DWA, 2014).

No priority GRUs are selected in the 1-Peninsula and 3-Helderberg GRUs, because the scores for each quaternary catchment were lower, and it was deemed acceptable by stakeholders that no groudnwater RQOs need to be developed in these areas as they are not considered priorities.

Table 3-13 Prioritised Groundwater resource units (i.e. those scoring >40 in the scoring system, and designated as a priority "3")

			GRU	4-Paarl-Upper Berg	4-Paarl-Upper Berg	5-Tulbagh Valley	6-24 Rivers	8-West Coast	8-West Coast	9-Atlantis	10-Malmesbury	1-Peninsula	2-Cape Flats	2-Cape Flats	2-Cape Flats
			Quat	G10A	G10B	G10E	G10J	G10L	G10M	G21B	G21D	G22B	G22C	G22D	G22E
			Resulting score:	47.7	46.3	42.7	47.4	65.9	80.0	62.9	39.0	37.2	42.8	60.3	42.7
Criteria:	Criteria weight:	Sub-criteria:	Sub-criteria weight:	Rating per sub-criteria per resource unit											
Importance for users	25	Supporting domestic use	60	0.5	0	0.5	0	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5
		Presence of SWSA-gw	20	1	1	1	0	1	1	1	0	1	1	1	1
		Supporting economic activities	20	1	1	1	0.5	0	0	0.5	0.5	0.5	0.5	0.5	1
Level of SW-GW interaction	30	GW maintain low flow	50	0.5	1	0	1	1	1	0.5	0	0.5	0.5	0.5	1
		GW maintain priority ecology	50	0	1	1	1	1	1	1	0.5	0	0	1	0
Threat posed to users	30	Water Quality: Declining trend	16	0	0	0	0	1	0	0	0	1	0	0	0
		Water Quality: Poor quality category	17	0	0	0.5	0.5	0.5	0.5	0.5	0	0.5	0	0.5	0
		Water Quality: Risk	17	0.5	0	0	0	0	1	1	0.5	0.5	1	1	1
		Water quantity: Declining trend	16	0	0	0	1	1	1	0	1	1	0	0	0
		Water quantity: High stress (current)	17	0	0	0.5	0	0	0	1	0	0	0.5	0.5	0
		Water quantity: High stress (future)	17	1	0.5	1	0	0	0.5	1	0.5	0	1	1	1
Practical considerations	15	Quality monitoring data	50	1	0	0	0	0.5	1	0	1	0	0	0	0
		Level monitoring data	50	1	0.5	0	1	1	1	1	0	0	1	1	0

4 Conclusion

4.1 Summary of prioritised RUs

A summary of the priority RUs for rivers, estuaries, dams, wetlands and groundwater resource units are presented below. These represent the list of proposed RUs for which RQOs should be developed.

The prioritized RUs for determining RQOs have been identified using the following criteria:

- All river RUs in the Berg Catchment irrespective of their scores
- All estuaries in the Berg Catchment irrespective of their scores. However, none of the river outlets in the catchment were prioritised
- Dams determined from prioritisation process with a priority weighting of > 0.6
- Wetlands RUs as determined from the prioritisation process
- Groundwater RUs scoring >40 in the scoring system, and designated as a priority "3".

The prioritisation approach is resource-specific, for example enabling different areas to be prioritised for surface water and groundwater respectively. This is necessary, given that the criteria for each differ. However, in certain circumstances, the RQO for one resource may require the RQO of another resource to be developed to support it. These likely interactions have also been considered in terms of determining the final list of prioritised RUs and will also be reflected in the proposed RQOs for different RUs.

The resource units listed in Table 4-1 are mapped in Figure 4-1.

Table 4-1 Summary of results of the prioritisation process for Berg Catchment

IUA	Prioritised Resource Units (RUs)				
	River	Estuary	Dam	Wetland	Groundwater
D8 Upper Berg	Bviii1 Bvii13 Biii3		Berg River Dam Wemmershoek Dam	SWSA* SEEP	G10A G10B
D9 Middle Berg	Bvii5 Bviii11 Bvii3			West Coast Shale Renosterveld FLOODPLAIN (Berg)	
C5 Berg Tributaries	Biii4 Bi1			SWSA* SEEP	G10E
B4 Lower Berg	Bvii12 Bvii6		Voëlvlei Dam Misverstand Dam	West Coast Shale Renosterveld FLOODPLAIN (Berg) Northwest Sandstone Fynbos SEEP and FLOODPLAIN (Boesmans River) Kiekoesvlei DEPRESSION Koekiespan DEPRESSION	G10J
A1 Berg Estuary		Berg (Groot)		Southwestern Shale Fynbos UNCHANNELED VALLEY BOTTOM (Berg)	G10M
A2 Langebaan		Langebaan		Salt marsh SEEP (Geelbek)	G10M
A3 West Coast				Southwest Sand Fynbos DEPRESSION (Yzerfontein)	G21B
D10 Diep	Bv1 Biv6	Rietvlei/ Diep		Rietvlei Southwest Sand Fynbos FLOODPLAIN and Dune Strandveld FLOODPLAIN (seasonal) Riverlands DEPRESSION and SEEP	G21D

IUA	Prioritised Resource Units (RUs)				
	River	Estuary	Dam	Wetland	Groundwater
E11 Peninsula	Bviii6 Bvii20	Wildevöelvlei		Sand Fynbos DEPRESSION (Pick n Pay Reedbeds) Sand Fynbos DEPRESSION (Wildvoelvlei) Sand Fynbos DEPRESSION (seasonal) SWSA* UNCHANNELLED VALLEY-BOTTOM	
E12 Cape Flats	Bvii7	Zandvlei		Zeekoeivlei DEPRESSION (open water and seasonal) Rondevlei DEPRESSION (open water and seasonal) Nooiensfontein FLOODPLAIN Blouvlei DEPRESSION Princessvlei DEPRESSION SEEP (Philippi seasonal wetlands)	G22C G22D G22E
D6 Eerste	Biii6 Biv8	Eerste		SWSA* SEEP	
D7 Sir Lowry's	Bvii22 Bvii21 Bviii9	Lourens	Steenbras Reservoir Steenbras Upper Dam	SWSA* SEEP	
TOTAL	**20**	**7**	**6**	**24**	**11**

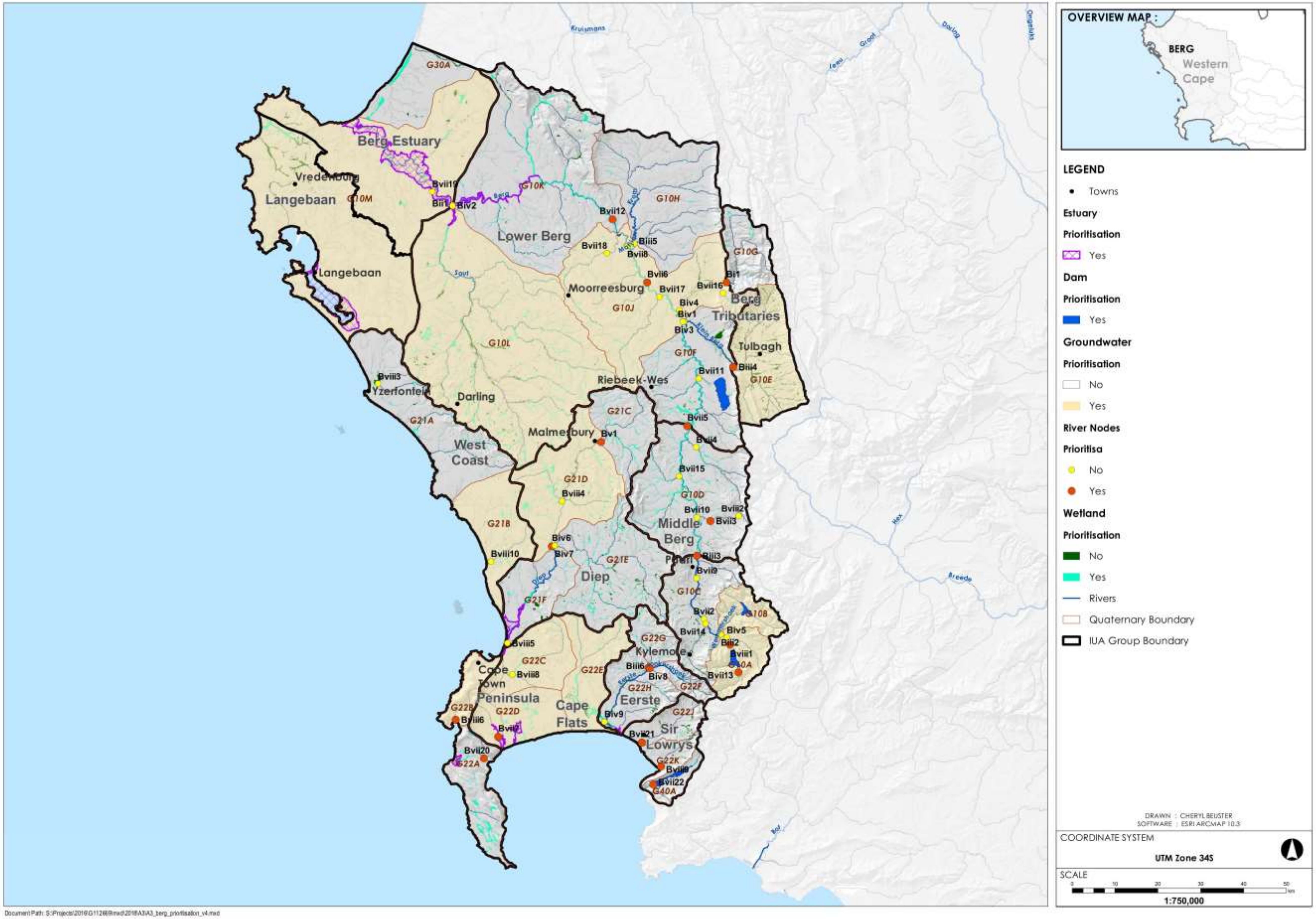

Figure 4-1 Summary of results of the prioritisation process for the Berg Catchment

4.2 Addressing uncertainties

Some of the key limitations and uncertainties which may influence the confidence of the outcomes of the RU prioritisation process, which should be considered when implementing the RQOs, are described below.

4.2.1 Rivers

The river prioritisation tool provides a good overview of important considerations but gives unnecessary priority to IUA outlets, which skewed the results away from the EWR sites in some areas. No adjustments were made to the default settings in the tool to adjust when calculating the results or to adjust for this, however consideration was given to other factors such as existing EWR sites or specific river resource units identified by stakeholders, to ensure that these resource units were also included in the recommended list for determining RQOs.

4.2.2 Estuaries

Some large discrepancies were evident between importance scores allocated using the RUPT Tool and the conservation importance ranking that has been established for estuaries in South Africa (Turpie *et al*. 2013). Both ranking systems thus need to be taken into account when prioritising estuaries for the development of RQOs. It is recommended that RQOs be develop for all estuaries in the Berg Catchment.

4.2.3 Dams

While there had been previous attempts to include the dam RU prioritisation methodology in the RQO process, there is no agreed/standardised tool to prioritise dams. The prioritisation approach followed in this report was a two-tier screening. The first level of screening was documented in the Resource Unit and Integrated Units of Analysis Delineation Report (DWS, 2016b) of this study, and was refined in this report, and was largely based on the size and importance of dams for water supply. The existing surface water prioritisation tool was then adapted, in this assessment, to prioritise the pre-screened dams.

The adaptation to the tool was done to make the prioritisation more relevant to dams whilst trying to limit significant changes to the criteria and the ranking system that was applied in the original RUPT tool. It is recommended that these prioritisation criteria be critically evaluated and further refined.

4.2.4 Wetlands

The methodology for prioritising wetlands, and used in this study is currently under development. An important factor in this is included user value as well as ecological importance to the prioritisation of wetlands. This prioritisation approach is largely based on the consideration of spatial overlays of data in a GIS system and is therefore relatively mechanical in its approach. There are however limitations in the quality of the spatial data available, and in particular the scale at which wetlands are delineated. Where available other systems for prioritisation wetlands have been considered, such as the NFEPA wetlands to ensure alignment, where possible with the prioritised RUs for RQOs and other priority wetlands.

4.2.5 Groundwater

The groundwater prioritisation follows examples of other previous studies, however, the resulting score is sensitive to the weights applied, which are largely subjective. Those weights selected have attempted to strike a balance in the final prioritisation, prioritising both resource units important for human use (settlements using groundwater for domestic supply, and areas where groundwater use supports economic activities), and resource units important for supporting ecological functioning. Practical considerations have received a lower score, based on the assumption that lack of current monitoring should not prohibit implementation of RQOS, and that necessary monitoring must be established to protect resources. Whilst the resulting prioritisation makes sense in terms of the important areas of the Berg, input from DWS is sought on final prioritisation, and the impact of different weights on the final results.

4.3 Way forward

The next step of the RQO determination process, Step 4, consists of prioritising sub-components for RQO determination and the selection of indicators for monitoring. Each of the prioritised RUs identified during Step 3, and indicated in this report, will be analysed in more detail, to identify which sub-components present in these RUs should be protected, in order to support water resource dependent activities and/or to maintain the integrity and ecological functioning of the water resource. This analysis will be done using the RU Evaluation Tool.

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