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LETABA CATCHMENT RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT WATER QUALITY REPORT FINAL FEBRUARY 2006

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EXECUTIVE SUMMARY

BACKGROUND

The National Water Act (NWA, Act No. 36 of 1998, Section 3) requires that the Reserve be determined for rivers, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. The Resource Directed Measures Directorate (D: RDM) of DWAF, which oversees Reserve studies, identified that the Letaba River catchment requires the completion of a Comprehensive Ecological Reserve assessment before licensing and effective water resource planning can take place for the catchment. The result of the study below is for the water quality component of the Ecological Reserve study, which was conducted at a comprehensive level.

OVERVIEW OF THE CATCHMENT WITH REFERENCE TO WATER QUALITY ISSUES

Land use in the Letaba catchment consists largely of nature conservation in the form of national, provincial and private nature reserves and forest reserves. The primary land use along the rivers is citrus and sub-tropical fruit production, with grazing in the less fertile sandy loam soils. Removal of the vegetative cover by overgrazing has led to erosion in some places, resulting in an increased sediment load in the rivers. The main industrial development points are at Tzaneen, Nkowakowa and Giyani, with a number of sewage works spread throughout the catchment. Several old gold mines exist, which lie close to the Klein Letaba River towards the northern part of the study area. An overview of the catchment therefore indicates that water quality issues are mainly related to nutrient enrichment, and fluctuating instream temperature and oxygen levels due to extensive flow regulation in the catchment. In addition to being highly regulated, conditions in the Groot Letaba River (particularly downstream from Die Eiland) are impacted by citrus plantations in the area, resulting in elevated nutrient levels and instream toxicity.

METHODS AND INFORMATION USED

The water quality assessment was therefore conducted using best available methods, as outlined in Palmer et al. (2004). These are the updated methods of September 2003 (based on the DWAF methods manual of 2002) for the water quality Reserve and available on the web site, http://projects.shands.co.za/Hydro/hydro/WQReserve/main.htm.

The following information was used to conduct the present state. The confidence in the classifications were verified using the power statistic, G-Power.

- Literature regarding water quality conditions in the catchment, and a field survey undertaken in December 2003 to verify the delineation of Water Quality Sub-Units (WQSUs).
- Water quality data from selected DWAF monitoring points in the catchment, as well as spot samples taken during the December field survey. Samples were analysed at Resource Quality Services (RQS), DWAF.
- Biotic integrity data (macroinvertebrates) were sourced from the relevant specialist of the Letaba Reserve study for the EWR sites (intensive invertebrate monitoring conducted); other data was accessed from SASS (i.e. rapid monitoring using the South

African Scoring System version 5.0) surveys conducted of the Letaba catchment for the River Health Programme.

- Fish categories were included for the EWR sites from the relevant specialists of the Letaba Reserve study as an indicator of biotic response.
- Chlorophyll-a analyses were undertaken at selected points in the catchment as an indicator of algal abundance, during the field survey of December 2003 (therefore n=1). Samples were analysed for periphyton at the Coastal Research Group, Rhodes University. Phytoplankton data were not available.
- Spot samples were taken for in-stream toxicity testing from two points in the catchment in March 2004, as a preliminary indication of toxicity related to pesticide / herbicide use on citrus plantations (therefore n=1). The following acute screening toxicity tests were conducted at Rand Water: *Daphnia pulex*, the guppy *Poecilia reticulata* and an algal inhibition test.
- The following version of the salt model of Jooste (RQS, DWAF) was used to generate PES categories for inorganic salts: SALTBA21. Note that the model provides categories, but not values.
- Available data were screened for toxics, e.g. metals. Toxics are listed and assessed where data were available.
- As a method does not exist for assessing the present state of turbidity, results were compared to the domestic use Target Water Quality Range (TWQR), as aquatic ecosystem guidelines do not exist.
- As a document outlining dam operations was not available, information was obtained from the DWAF Polokwane office.

WATER QUALITY PES

The water quality variables used for the present state assessment are shown in Table 1, together with an indication of data confidence and availability per variable for the present state, availability of Reference Condition (RC) data, and overall confidence in the assessment. The confidences for nutrients and pH are based on G-Power estimates.

Table 2 shows the results of the PES assessment. Note that the methods manual (methods outlined in Palmer et al., 2004) was used for the assessment (column 1 of Table 2). The physico-chemical approach for assessing water quality state, as outlined in the Ecoclassification manual of Kleynhans et al. (2005), was used when evaluating the water quality consequences of different flow scenarios – the results of this assessment is shown in column 2 of Table 2. The recommended water quality category per EWR site is shown in column 3 of Table 2, and uses best judgement to combine the output of columns 1 and 2.

Table 1 Confidence in the water quality PES assessment shown per Water Quality Sub-Unit

Variable / Indicator	**Water Quality Sub-Unit**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8 + 9**	**10 + 11**	**12 + 13**	**14**	**15**
Inorganic salts (full suite of data used)	H	H	H	H	H	H	H	H	M	H	L	L
Nutrients	L	L	L	L	L	L	L	M	L	L	L	L
pH	H	H	H	H	H	H	H	L	H	H	L	L
Dissolved oxygen + temperature	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity	X	v	v	v	v	v	v	v	v	v	v	v
Chl-a (periphyton)	X	v	v	v	v	X	v	v	X	X	v	X
Macroinvertebrates	v	v	v	v	v	v	v	v	X	v	v	v
Fish	X	v	X	v	X	v	v	v	X	v	X	X
In-stream toxicity	X	X	X	v	X	X	X	X	X	X	X	X
Toxics	Only fluoride information available, so low confidence.											
RC data	X	v	v	v	X	v	v	v	X	X	X	X
PES data	M	M-H	L	H	H	M	H	H	M	M	L	L
Overall confidence in the assessment	M	H	L	H	M	M	H	M-H	L	L	VL	VL

H: high confidence M: medium confidence L: low confidence
VL: very low confidence v: data available X: no data available

Confidence in the present state assessments are generally medium to high, except for the Klein Letaba and Molototsi rivers, where minimal data were available.

The water quality present state assessment showed that the Letaba River system is generally in a fair to good water quality condition (categories B-C), with a hot spot occurring at EWR 2, i.e. Letsitele Tank. Current status is shown in the table below, as well as the water quality category used to design quality ecospecs (third column of Table 2).

Table 2 Results of the water quality present state assessment shown per WQSU and EWR site

Water Quality Sub-Unit and EWR site	PES: water quality - using methods manual	PES: water quality - using the Ecoclassification approach	Recommended water quality category of the overall REC (quality ecospecs)
Groot Letaba River			
WQSU 1	A/B		
WQSU 2: EWR 1	B	B	B
WQSU 3	B/C		
WQSU 4: EWR 3	C	C	C
WQSU 5	B		
WQSU 6: EWR 4	B/C	C	C
Letaba River			
WQSU 7: EWR 6 + 7 *	B	C	EWR 6: B/C EWR 7: B
Letsitele River			
WQSU 8 + 9: EWR 2	C/D	C	C
Middel Letaba River			
WQSU 10 + 11	B – B/C		
Klein Letaba River			
WQSU 13: EWR 5	B/C – C	B – B/C	B/C **
WQSU 14	B		
Molototsi River			
WQSU 15	B/C		

*: Note that as EWR 6 and 7 are located in the same WQSU, a single water quality PES assessment was provided. However, a recommended water quality category had to provided per EWR site, as shown in the third column.
**: The REC of B/C for EWR 5 therefore combines the results of the two assessment methods.

WATER QUALITY CONSEQUENCES OF DIFFERENT FLOW SCENARIOS

Water quality consequences of operational flow scenarios were assessed using flow-concentration modeling as a tool for assessing impacts, as well as the physico-chemical approach for assessing water quality state as outlined in the Ecoclassification manual of Kleynhans et al. (2005). The integration between quality and quantity that occurs at this stage therefore provides the decision-maker with information on in-stream water quality conditions under a variety of operational flow scenarios.

However, flow-concentration modeling was of limited usefulness in the Letaba study as time-series modeling could only be conducted for EWR sites 2 and 6, and only for Electrical Conductivity (EC) and Soluble Reactive Phosphorous (SRP).

Although flow scenarios do impact on water quality, impacts are generally not significant enough to change water quality status to another category. The only EWR site where flow scenarios would impact, and in fact improve water quality status, is EWR 7, where water quality status would improve from a current C to a B category under all flow scenarios.

RECOMMENDATIONS

The assessment of water quality was conducted carrying out methods updated from the DWAF methods manual of 2002, as well as the Ecoclassification approach as outlined in Kleynhans et al. (2005). Although the methods should be used together, i.e. the PES assessment using DWAF methods is used to populate the ratings tables in the Ecoclassification manual, there are no instructions in either manual as to how this procedure should take place. The Ecoclassification approach will also be using a model developed by Jooste of RQS, DWAF. A water quality manual should therefore be developed which includes instructions on how all these tools must be used to conduct a water quality assessment in an EWR study.

Further development is also required around the integration of water quality and quantity. Although flow-concentration modelling was used for this study, it was of little value as few constituents could be modelled.

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TERMINOLOGY AND ACRONYMS

D: RDM	Directorate: Resource Directed Measures
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category / Electrical Conductivity (i.e. context-dependent)
EWR	Ecological Water Requirements
ISP	Internal Strategic Perspective
KNP	Kruger National Park
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MSL	Mean Sea Level
MV	Marginal vegetation
NMMM	Nelson Mandela Metropolitan Municipality
NWA	National Water Act
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
RU	Resource Unit
SPATSIM	Spatial and Time Series Information Modelling (software)
SRP	Soluble Reactive Phosphorous
TIN	Total Inorganic Nitrogen
TP	Total Phosphorous
TSOFT	Time Series Display and Analysis Software
WMA	Water Management Area
WMS	Water Management System
WQSU	Water Quality Sub-Unit
WR90	Surface Water Resources of South Africa, 1990
WTW	Water Treatment Works
WQ	Water Quality

1. INTRODUCTION

1.1 BACKGROUND

The National Water Act (NWA, Act No. 36 of 1998, Section 3) requires that the Reserve be determined for rivers, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. It is therefore imperative that the Reserve is determined and its requirements are met before the needs of other economic activities can be satisfied. As the Department of Water Affairs and Forestry (DWAF) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources. The Directorate: Resources Directed Measures (D: RDM) is the directorate within DWAF responsible for ensuring that Reserve determinations take place before licensing can proceed.

The D: RDM identified that the Letaba River catchment requires the completion of a Comprehensive Reserve assessment before licensing can take place due to the stressed nature of this catchment. The available water resources cannot meet all the water requirements of the users in these catchments, without trade-off among water user sectors. The Reserve Determination process for the Letaba area was therefore initiated in 2004 and is made up of a number of studies. This report describes the process and results of the assessment conducted for the water quality component of the Ecological Reserve. The tasks addressed during this report are therefore only those related directly to water quality. The objective of this Ecological Reserve assessment is therefore to provide quantified and descriptive information regarding flows and associated concentrations of water quality constituents, which describe both the present state of the system and conditions for the selected Ecological Categories (EC).

1.2 WATER QUALITY IN THE ECOLOGICAL RESERVE

One of the underlying principles of the National Water Act and the DWAF's water resource strategy is that of water resource protection to ensure long-term sustainable use for people. Water resource protection and long-term use is therefore linked to the goods and services provided by the river. The Ecological Reserve determination for water quality encompasses a description of the current water quality status and therefore the river's capacity to provide services such as waste assimilation, how much it has changed from its reference state, and what water quality status is needed to sustain a particular level of ecosystem health or Ecological Category (EC).

Although the Ecological Reserve approach assesses frequency, magnitude and duration for flow, the same is not true for water quality. Water quality assessments still focus on magnitude (primarily the concentration of chemical constituents), with water quality modelling incorporating some degree of duration, where applicable. The water quality approach is therefore still primarily a hazard, and not risk-based, approach (DWAF, 2002). Hazard can be described as a state that may result in an undesired event, whereas risk includes the *probability* of that event. Risk therefore results from the existence of a hazard and uncertainty about its expression or effect.

The terms of reference for the water quality component of the Ecological Reserve for the Letaba catchment study area prescribed that water quality be assessed at a Comprehensive level using best available methods. Comprehensive methods are the updated methods of September 2003 for the water quality Reserve found on the Ninham Shand web-site *http://projects.shands.co.za/Hydro/hydro/WQReserve/main.htm* and outlined in Palmer et al. (2004). These methods are based on a methods manual produced for DWAF in 2002, entitled *Assessing water quality in ecological reserve determinations for rivers: Version 2, Draft 15.0, March 2002*, and discussions held at a workshop in Grahamstown in July 2003 regarding the water quality Reserve.

One of the objectives of current research around EWR assessments is to incorporate all the methods necessary to undertake an EWR assessment in SPATSIM (Spatial and Time Series Information Modelling software), an integrated information storage and modelling system developed by Prof Denis Hughes of the Institute for Water Research, Rhodes University. Water quantity methods have already been incorporated and used via this storage system, and water quality methods are currently being incorporated as part of a Water Research Commission-funded DSS project. Although the text of the methods has been included in SPATSIM, methods cannot yet be used through this storage system as calculations cannot yet be undertaken (Hughes, IWR, pers. comm.). Some of the methods have not been included, e.g. Jooste's inorganic salt assessment method, as the latest version of this method is not yet available from Dr Jooste. Although methods are currently being finalized in SPATSIM, this operating system was not available for use by the Letaba water quality team.

The generic 8-step Ecological Reserve procedure (as taken from IWR Source-to-Sea (2003)) is shown below as Figure 1.1. The detailed steps of the water quality Reserve are shown in Figure 1.2 (which also shows the links between water quality and quantity), and Table 1.1. The information was taken from the water quality manual on the Ninham Shand web-site, and modified at a March 2005 water quality ecoclassification workshop.

1.2.1 Ecoclassification

The ecoclassification (or ecological classification) process refers to the determination and categorisation of the Present Ecological State (PES) of various biophysical attributes of rivers compared to the natural/close to natural, reference condition (Kleynhans et al., 2005). This method has been developed to determine a river's ecostatus using a systematic and quantitative approach. The state of the river is therefore expressed in terms of its following biophysical components.

- Drivers (physico-chemical (as describes the chemical component of water quality only), geomorphology, hydrology) which provide a particular habitat template, and
- biological responses (fish, riparian vegetation and aquatic invertebrates).

Although the updated water quality manual (methods outlined in Palmer et al., 2004) was used to determine present state, the driver tables in the physico-chemical chapter of the Ecoclassification training manual were used to evaluate the water quality consequences of flow scenarios.

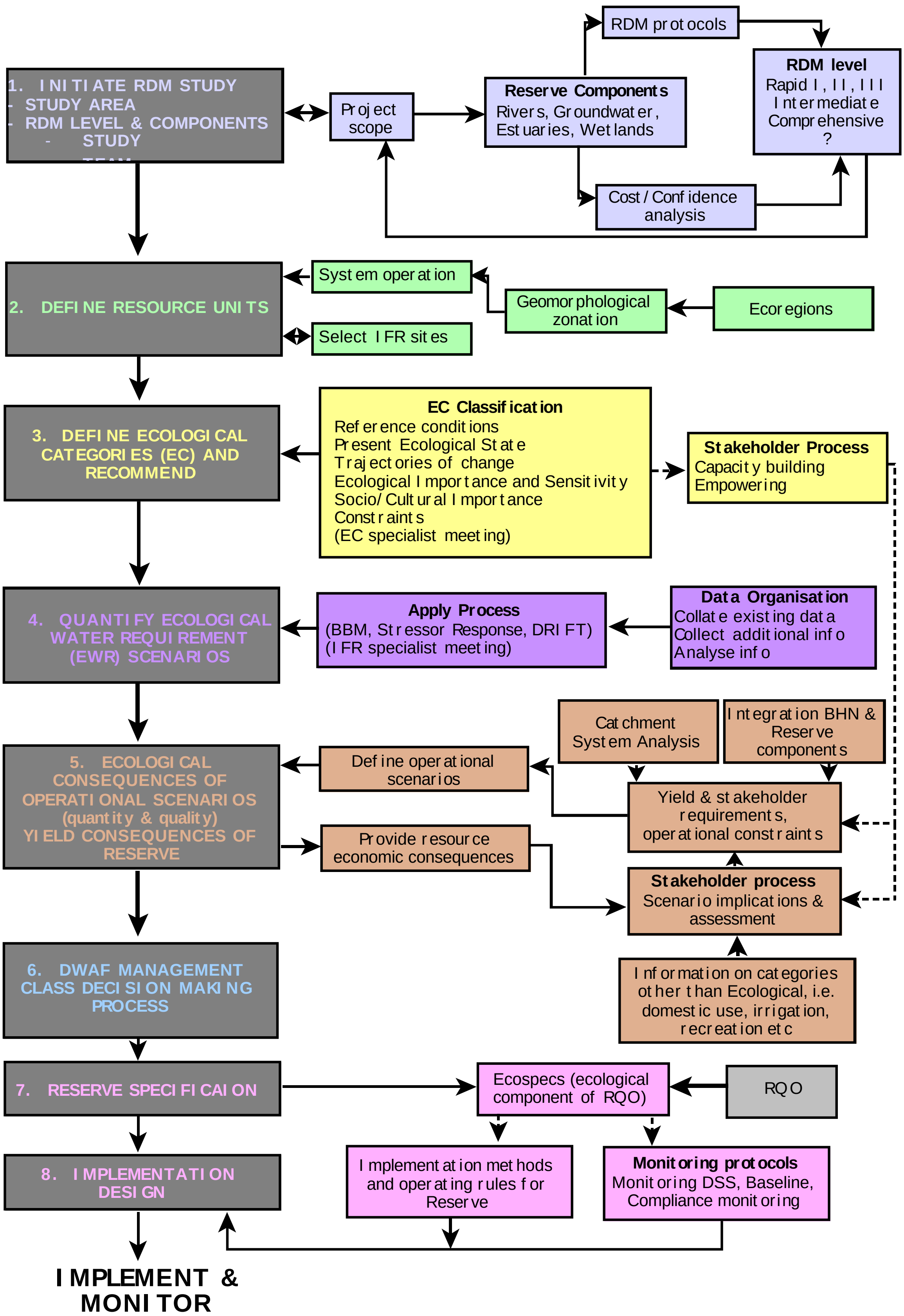


Figure 1.1: The 8-step Ecological Reserve procedure (IWR Source-to-Sea (2003))

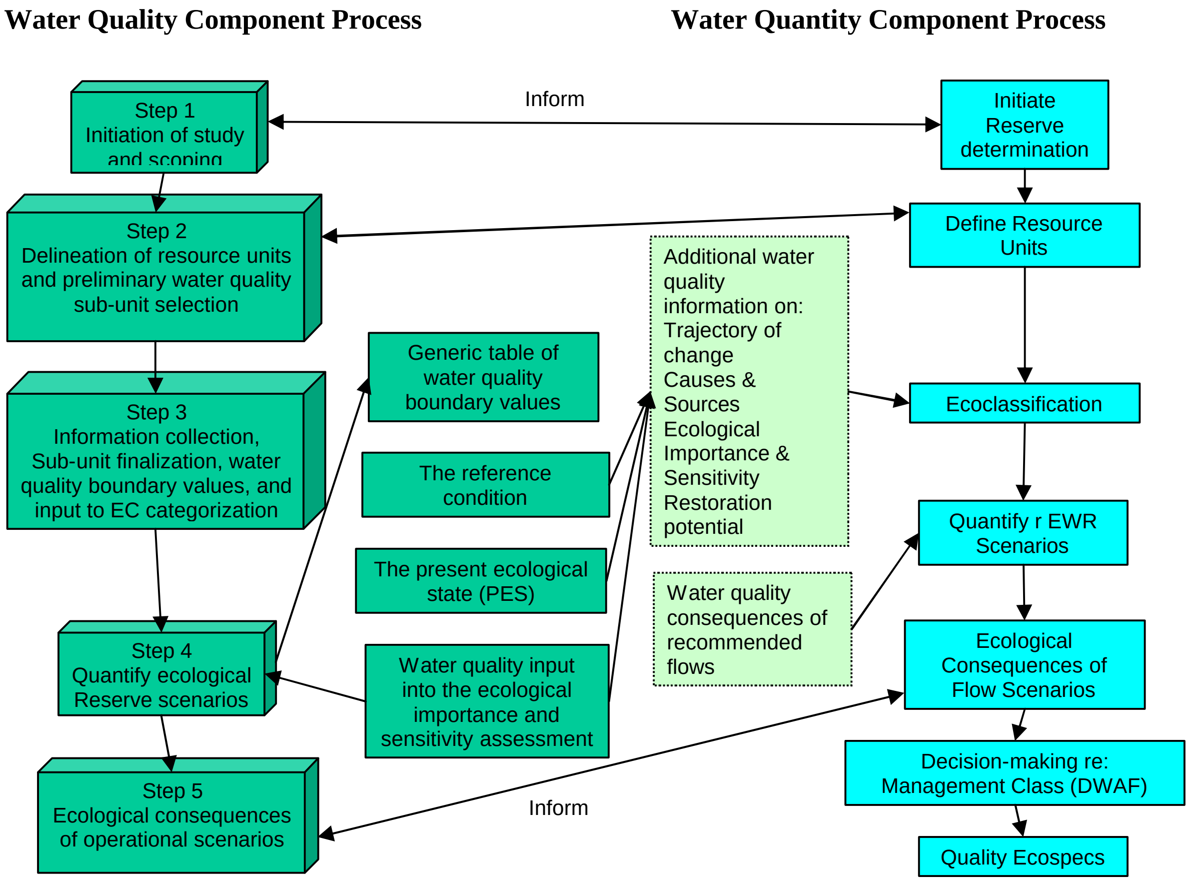


Figure 1.2: Flow diagram indicating the general approach for the water quality component of the Ecological Reserve determination study, as well as links between water quality and quantity.

Table 1.1: Summary of the 5 steps taken for the water quality component of the Ecological Reserve determination study.

Steps in the Reserve process	Quality component of the Ecological Reserve determination
1. Initiate Reserve determination • **Study area** • **Level, method and components** • **Study team**	Step 1: Initiate study and scoping 1) Study domain: Geographic scope • Length of river, tributaries, note point sources and refugia, level of confidence 2) Finalisation of water quality variables • 1. obligatory, 2. standard list, 3. optional additions which may need method development. For 3 take account of local geology, discharges and impacts, add variables on a site-specific basis
2. Define Resource Units	Step 2: Delineation of Resource Units (RU) and preliminary water quality sub-units (WQSU) selection 1) Delineation of resource units • Ecoregions, dams, tributaries = resource unit • Towns and pollution point-sources may define additional water quality sub-units 2) Preliminary site selection • Map physico-chemical and bio-monitoring sites, screen data availability e.g. length of data-set
3. Define Ecological Categories and recommend	Step 3: Information collection, site finalisation, water quality boundary values and input to EC categorization or Ecoclassification 1) Data preparation • Take account of inadequate data, and potential for modelling/extrapolation 2) Site finalisation • RU may need to be spilt into WQSU. If there are data gaps data can be extrapolated within RU (note changes in confidence), but not between RU. Data gaps signal need for data collection. 3) Water quality boundary values • Generic boundary-value tables • Reference condition • Present ecological state (PES) 4) Input to EC categorization or Ecoclassification • Water quality variable categories to be represented by an overall water quality category • Trends of change • Input into ecological importance and sensitivity
4. Quantify ecological scenarios	Step 4: Quantify ecological reserve scenarios 1) Take water quality boundary values + insights from EC workshop 2) Ecospecs • Per WQSU, boundary values for each variable, level of confidence • Clarifying comments, narrative descriptions linking values to site-specific information, including refugia and impact sources 3) Flow-concentration modelling • Apply flow-related information to ecological flow recommendations • Note where flow recommendation would mean WQ boundary conditions violated
5. Ecological consequences of operational scenarios (quantity and quality). Yield consequences of EWRs	Step 5: Ecological consequences of operational scenarios 1) Input into yield scenarios (use flow concentration modeling) 2) Input in water quality operational scenarios (to be developed)

1.3 PURPOSE OF THIS REPORT

The purpose of this report is:

- To describe the delineation of Resource Units (RUs) into Water Quality Sub-Units (WQSUs).
- To provide a present state assessment for water quality per WQSU.
- To provide a description of how flow-concentration modelling can be used to integrate water quality and water quantity during the EWR process.
- To provide the water quality consequences of a range of predicted flow scenarios.
- To provide ecological specifications for water quality for each selected EWR site.

1.4 REPORT STRUCTURE

The report has been produced according to the following structure:

Part 1 – Background to Ecological Water Requirements (EWR) and water quality in the Ecological Reserve
Part 2 – Study area
Part 3 – Delineation of Water Quality Sub-Units (WQSU)
Part 4 – Water Quality present state assessment
Part 5 – Flow-concentration modelling
Part 6 - Water quality consequences of selected flow scenarios
Part 7 – Ecological specifications for water quality per EWR site
Part 8 – Conclusions and recommendations
Part 9 - References

2. THE STUDY AREA

2.1 INTRODUCTION

The Letaba River catchment (Figure 2.1) is located in the Northern Limpopo Province of South Africa. The Letaba catchment (13 670 km^2) is drained by three main branches, i.e. the Groot, Middel and Klein Letaba. The Groot Letaba used to be perennial but has become only seasonal (SRK, 1989). Flow in the Klein and Middel Letaba Rivers is intermittent.

The mean annual precipitation (MAP) is 612mm, whilst the mean annual evaporation is 1 669mm. The mean annual runoff (MAR) is 574 million m^3 (ranging from 100 to 2 700 million m^3). The MAR in the Letaba catchment varies from more than 10% of the mean annual precipitation (MAP) in the wet mountainous zone, to less than 2% in the drier parts of the catchment. More than 60% of the MAR in this catchment derives from only 6% of the area (SRK, 1989).

More than 20 major dams have been constructed in the Groot Letaba River catchment. The Tzaneen Dam on the Groot Letaba River and the Middel Letaba Dam are the two largest dams in the Northern Province. Other large dams in the catchment include the Ebenezer, Magoebaskloof, Nsami and Modjadji dams. Forty-three structures have been built on the rivers and their tributaries, and 7 gauging and/or diversion weirs. The major problem in the Letaba River is one of quantity of water. If a reasonable flow regime can be maintained, then it is unlikely that water problems will occur in the future (Consultburo, 1998).

As mountain and foothill streams, the Groot Letaba, Letsitele, Thabina, Debengeni and Magoebaskloof rivers have very diverse in-stream habitats. The river channels contain steep bedrock and fixed boulder rapids with cascades and occasional waterfalls. Cobble riffles occur in lower gradient sections. Deep pools are present in all river sections (SRK, 1989).

2.2 LAND USE WITHIN THE CATCHMENT

Land use is dominated by nature conservation in the form of national, provincial and private nature reserves and forest reserves covering 60% of the catchment. A number of endangered species inhabit these reserves. Over 20% of the catchment is not used for any defined land use (SRK, 1989). The primary land use is citrus and sub-tropical fruit production. Apart from the alluvial soils along the rivers, the remainder of the catchment is characterized by sandy loam soils which are shallow and infertile and used for grazing, Removal of the vegetative cover by overgrazing has led to erosion in some places, resulting in an increased sediment load in the rivers.

The regional service centre, Tzaneen, is located along the Groot Letaba downstream of Tzaneen Dam, with little industrial development in the catchment. Northern Canners at Politisi and the industrial complex at Nkowakowa near Tzaneen provide the major industries. Industrial development points exist at Tzaneen, Nkowakowa and Giyani. Several old gold mines exist, which lie close to the Klein Letaba River towards the northern part of the study area. A number of sewage works are spread throughout the catchment (SRK, 1989).

An overview is presented below per river section.

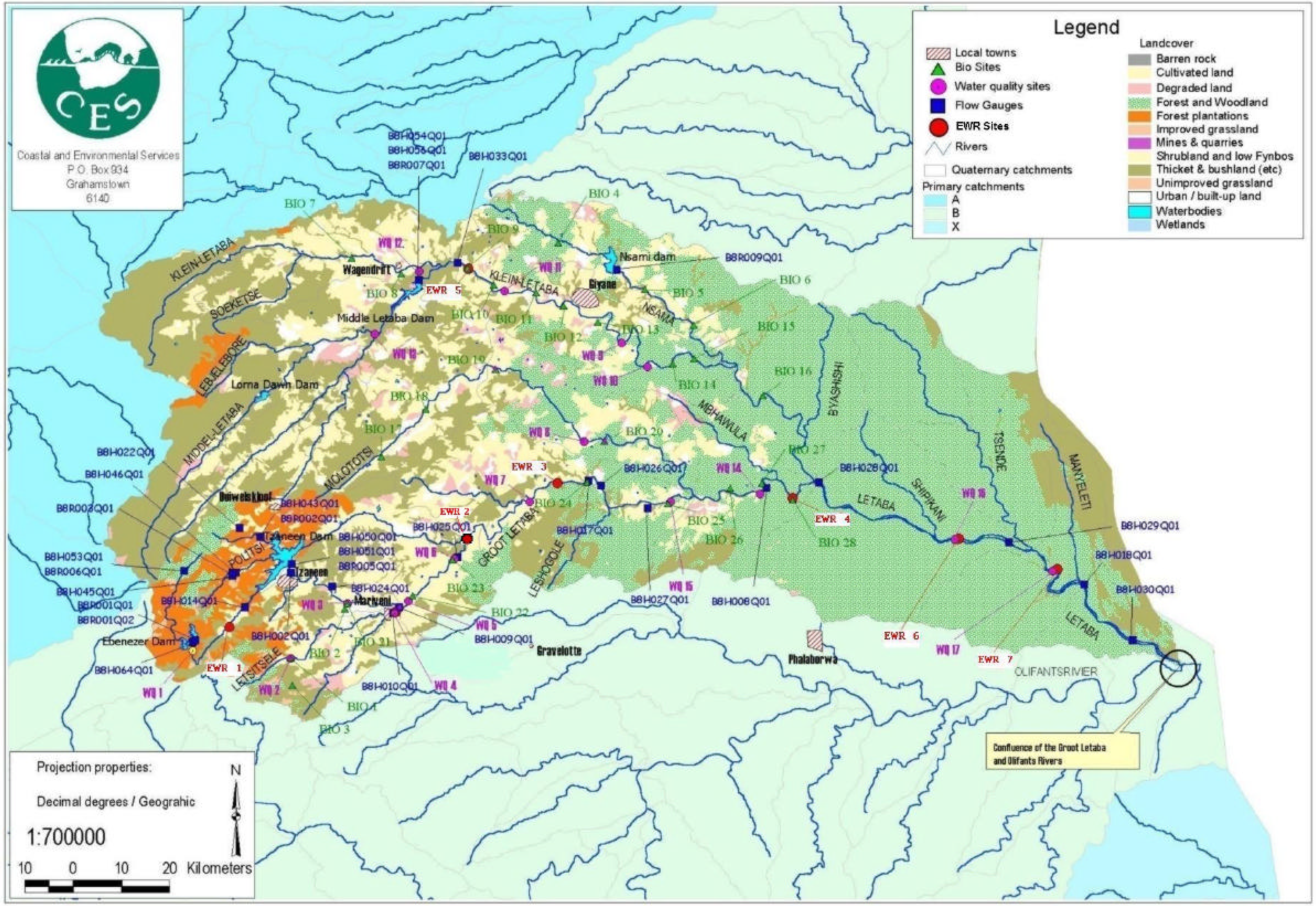


Figure 2.1: Land-use map of the Letaba catchment area showing water quality sub-units, EWR sites, DWAF monitoring points and biomonitoring sites.

2.3 THE GROOT LETABA HEADWATERS

The Groot Letaba headwater streams originate in the Drakensberg Escarpment, descending in long runs with an occasional riffle or pool. Bank sides are of gentle slope. Riparian vegetation is sparse. The natural grasslands have been replaced by commercial forestry. About 45% (more than 20 000 ha) of the total area of ecoregion 2.15 in the Letaba Catchment comprises plantations. Less than 5% is undeveloped grassland. Settlements are generally concentrated in the foothills area below the escarpment, concentrating along the main river valleys and lines of communication. More recently settlement has spread into the plains area.

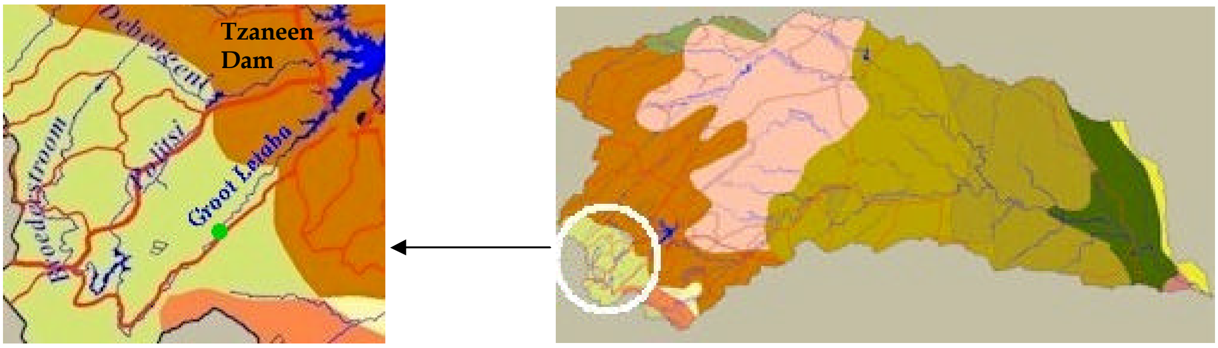


Figure 2.2: The Groot Letaba headwaters of the Letaba River catchment locating the Broederstroom, Politsi and Debengeni rivers (not assessed or sampled) upstream of Tzaneen Dam.

Bridge construction has disturbed bank vegetation, causing erosion. Bramble, lantana, bugweed, pines and other alien plants abound in this region (WRC, 2001).

2.4 POLITSI RIVER BELOW MAGOEBASKLOOF DAM, LETSITELE AND THABINA RIVERS

Downstream of Magoebaskloof Dam the Politsi River enters the Lowveld. A waterfall in the Letsitele River marks the transition from ecoregion 4.03 to ecoregion 4.04. Forestry plantations take up 30% of the total land cover of ecoregion 5.05 in this area and 64% of the area upstream of Tzaneen Dam. Subsistence farming covers 35% and commercial farming 7% of ecoregion 4.04. Ecoregion 5.05 in the Thabina and Letsitele catchments comprises 36% subsistence farming and 22% commercial farming.

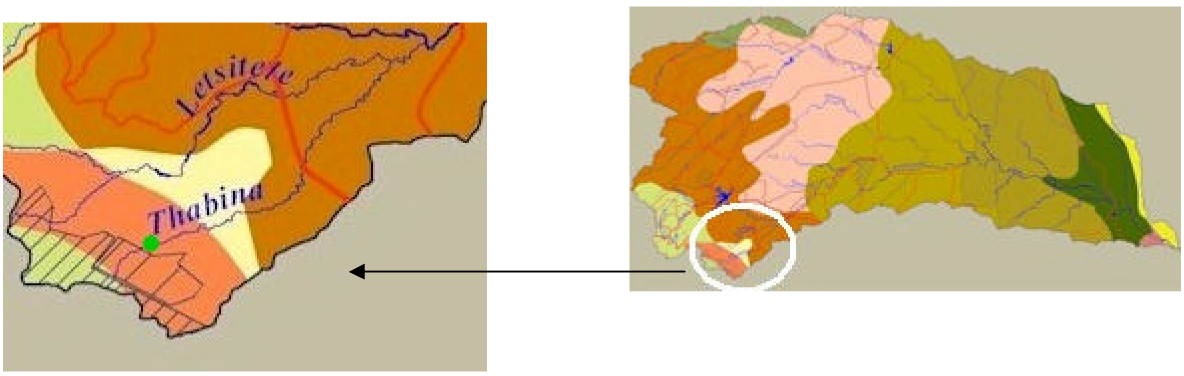


Figure 2.3: A map depicting the position of the Politsi River (RHS) below Magoebaskloof Dam and the Letsitele and Thabina rivers (LHS).

The riparian vegetation is in good condition along the Letsitele River, but invaded with numerous alien plants such as the castor-oil plant, sesbania, wild tobacco, large cocklebur and sugar cane. Small weirs allow abstraction for agricultural purposes and solid waste pollution occurs. The Letsitele River is used for irrigation and washing of clothes. Despite these impacts, the water quality and in-stream habitat is good. Both the Politsi and Thabina rivers were not sampled or assessed, however their value as input into the Letsitele system is noted. Magoebaskloof Dam, despite its small size, interrupts the natural flow pattern of the river. It is an irrigation dam with little capability for water releases, so that the resulting downstream flow pattern modifies river habitats along the Politsi River. The riparian vegetation is in good condition, but invaded with numerous alien plants such as the castor-oil plant, sesbania, wild tobacco, large cocklebur and sugar cane.

The Thabina River's riparian vegetation is under threat from excessive use by local communities and invasion by a host of alien plants, such as triffid weed (paraffin bush). No water is released from the Thabina Dam for ecological purposes. The seepage from the dam, the tributaries and the runoff that feeds the Thabina River downstream of the dam appears to be sufficient to maintain the in-stream habitat in good health (WRC, 2001).

2.5 GROOT LETABA RIVER BETWEEN TZANEEN DAM AND KNP

The Groot Letaba River has a rocky bed with many small channels and islands. The sharp descent from the Central Highlands to the Lowveld makes this an area of incised streams and numerous waterfalls. Commercial agriculture, of which more than 42% is under irrigation, covers 55% of the Groot Letaba catchment within ecoregion 5.05. Farming activities comprise nearly 25% of ecoregion 5.02 in this catchment outside of the KNP. This is made up of about 55% subsistence farming (20 800 ha) and nearly 40% commercial irrigated farmlands (14 300 ha). Hippos and crocodiles have successfully adapted to life in agricultural dams.

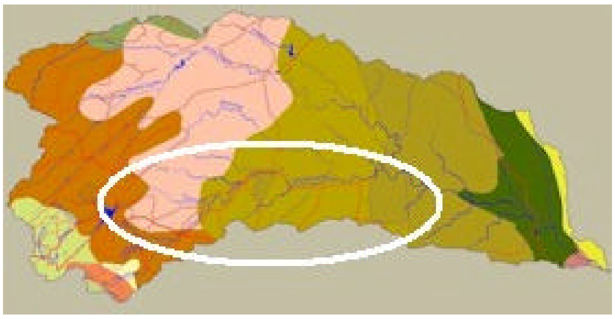


Figure 2.4: A map showing the Groot Letaba River between the Tzaneen Dam and the Kruger National Park.

Bridge construction has disturbed bank vegetation, causing erosion. Bramble, lantana, bugweed, pines and other alien plants abound in this region. Bananas compete with invasive alien plants like lantana, castor-oil plant, bugweed, large cocklebur and peanut butter cassia occur amongst the natural riparian vegetation.

Towards the eastern part of the Letaba River, local communities over-utilise the vegetation in the riparian zone through cutting and grazing. Alien plants have invaded the remaining riparian vegetation. The condition of the northern bank is worse than that of the southern bank. Agricultural pesticides and fertilisers affect water quality and are the biggest threat to the western section of the Groot Letaba River. Large weirs disrupt flows in river systems: apart from impeding fish migration, they cause bank scouring, sedimentation and loss of riparian vegetation (WRC, 2001).

2.6 KLEIN LETABA, MOLOTOTSI AND NSAMA RIVERS

The Klein Letaba, Nsama (not sampled or assessed) and Molototsi rivers are typical sandy lowveld rivers, with deeply incised river channels. Wide sandy runs are interspersed with occasional gravel riffles. Bedrock dykes cross these rivers at infrequent intervals, occasionally causing deep pools on their upstream sides. River flows vary considerably during a single annual cycle.

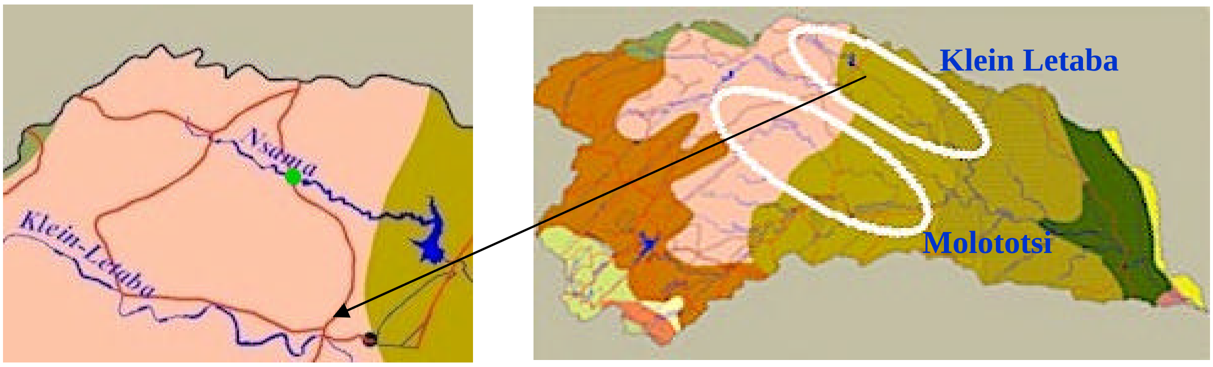


Figure 2.5: A map showing the position of the Klein Letaba, Molototsi and Nsama rivers.

The Molototsi River is a seasonal stream. The river is mostly a small trickle that disappears into the sand before it reaches the main river, but experiences occasional heavy flooding during the summer months. The Modjadji Dam, which stores water for domestic use along the Molototsi River, restricts flow downstream. This loss of flow is detrimental to the next 20-30km of river. Overgrazing, vegetation cutting and other poor agricultural practices occur in the catchment. Subsistence farming is the main land-use in the Molototsi (36%) and Nsama River catchments (32%). Urban developments comprise 6.5% and 5% of the total catchment areas respectively.

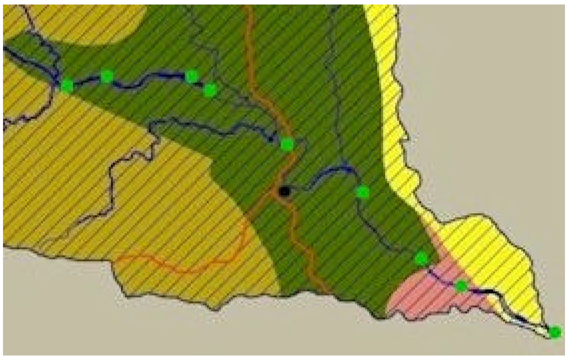
Subsistence farming takes up 35% of the total land use in ecoregion 5.03 in the Klein Letaba catchment and 20% in ecoregion 5.02 upstream of the confluence with the Nsama River. There is no commercial farming and less than 8% subsistence farming downstream of the confluence with the Nsama River. Agriculture consists of small-scale farming by rural communities and large commercial banana, papino, paw-paw and mango plantations upstream from Giyani. The commercial fruit farms are fed by the Middel Letaba Canal Irrigation Scheme. Apart from alien invasive plants such as large cocklebur, castor-oil plant and thistle in ecoregion 5.02, the riparian vegetation is in very good health along the Klein Letaba River.

Rural communities and cattle grazing impact on water quality along the Nsama River (not sampled or assessed), especially during the dry season. Washing, agriculture, cutting of trees and overgrazing within the riparian zone and other poor land use practices all contribute to this problem. Vegetation cutting by local communities and occurrence of alien invasive vegetation has negative impacts on the riparian habitats (WRC, 2001).

2.7 THE LETABA RIVER WITHIN THE KRUGER NATIONAL PARK

Below the confluence of the Groot and Klein Letaba rivers, (at the Kruger National Park border) the Letaba River channel takes on the characteristics of the Klein Letaba River. The Letaba River passes through a steep confined gorge just before joining the Olifants River near the Mozambique border.

The very sandy reaches of the Letaba River support only a narrow riparian vegetation band. The riverbed in ecoregion 5.01 is sandy with increasing occurrences of bedrock downstream. The Letaba River in the KNP forms multiple channels of up to 300 m wide. In ecoregion 5.07 and 6.01 the Letaba River flows through a series of gorges and ravines. These could form significant fish barriers if water flows were to drop below a certain level.



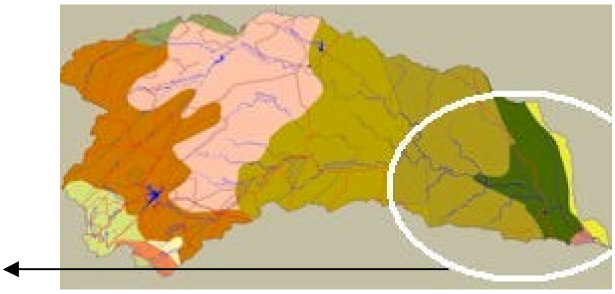


Figure 2.6: The Letaba River, which traverses the Kruger National Park to the south-east of the study area (RHS).

The Klein Letaba River carries high sediment loads because of erodible soils and poor land management in the catchment. At the confluence of the Groot and Klein Letaba rivers the gradient decreases and lower flow rates allow sediment to settle, aggravating the natural sand deposition. Impoundment and abstraction, mainly for agriculture, reduce the flow of the Groot Letaba River, causing further settling of sediment (WRC, 2001).

2.8 GENERAL WATER QUALITY CONDITIONS AND SUITABILITY FOR USE

The SRK report of 1989 states that most of the samples fall below the lowest reported criteria and that the water is chemically suitable for domestic use. Samples taken in the study area for the SRK study indicated that water quality was suitable for irrigation, livestock watering and industrial use.

Possible sources of pollution may be divided into two categories:

Diffuse source

- Agricultural fertilizers
- Agricultural insecticides, rodenticides and fungicides (i.e. biocides)
- Atmospheric deposition
- Rural domestic and sewage effluent runoff

Point sources

- Industrial effluent, and micro organic pollutants

- Domestic and treated sewage effluent
- Mining effluent

The Consultburo report of 1998 anticipated a deterioration in water quality in future as there was already a slight increasing trend in concentrations of a number of chemical constituents.

3. DETERMINATION OF WATER QUALITY SUB-UNITS

3.1 APPROACH

The geographic scope of the study was confirmed as part of the initiation of the study, and the following information accessed to assist in delineating WQSUs:

- A map of the catchment showing the location and names of DWAF monitoring stations, towns, dams and quaternary catchment boundaries (Figure 2.1)
- Locality of EWR sites (Table 3.1)
- A list of the DWAF monitoring stations in the study area (Table 3.2)
- Background information on water quality conditions in the study area
- Biological monitoring data produced during the River Health Programme, e.g. Angliss (2004)
- Level 1 ecoregion boundaries (http://www-dwaf.gov.za/IWQS/gis_data/ecoregions/get-ecoregions.htm)
- Possible point sources of pollution
- Major tributaries

Table 3.1: EWR site locations.

EWR number	Site name	River name	GPS coordinates Latitude, longitude, WGS84	
1	Appel	Groot Letaba	S23 55 03.7	E30 03 03.0
2	Letsitele Tank	Letsiteli	S23 53 17.0	E30 21 40.5
3	Die Eiland	Groot Letaba	S23 38 57.8	E30 39 38.3
4	Letaba Ranch	Groot Letaba	S23 40 39.1	E31 05 55.1
5	Klein Letaba	Klein Letaba	S23 15 02.9	E30 29 44.6
6	Lonely Bull	Letaba	S23 45 09.5	E31 24 26.3
7	Below Letaba bridge	Letaba	S23 48 35.4	E31 35 26.9

A preliminary selection of WQSUs was undertaken on the basis of the above information. These preliminary WQSUs were ground-truthed during a field survey of December 2003, and the final WQSUs selected. The results are shown in Table 3.3.

The code *WQ* on Table 3.3 refers to points where water samples were taken during the December survey for analysis by Resource Quality Services (RQS), DWAF. These points were registered on DWAF's Water Management System (WMS), the repository for national water quality data.

Table 3.2: DWAF water quality monitoring points available in the study area.

Feature ID	Feature Name	Latitude	Longitude
90523	B8H002Q01 AT MANORVLEI ON GROOT LETABA	-23.816667	30.165
90524	B8H008Q01 AT LETABA RANCH ON GROOT LETABA	-23.658056	31.05
90525	B8H009Q01 AT THE JUNCTION ON GROOT LETABA	-23.880278	30.366944
90526	B8H010Q01 LETSITELE RIVER AT MOHLABA'S RESERVE 567	-23.892222	30.355833
90527	B8H014Q01 AT GRYSAPPEL ON GROOT LETABA	-23.880556	30.079722
90528	B8H017Q01 AT PRIESKA ON GROOT LETABA	-23.645556	30.718611
90529	B8H018Q01 GREAT LETABA RIVER AT ENGELHARDT DAM/KRUGER NAT P	-23.838611	31.640833
90530	B8H022Q01 LITTLE LETABA TRIBUTARY 3 AT FREDERICKSDAL/WESTFA	-23.733333	30.069722
90532	B8H024Q01 GREAT LETABA IRRIG. NORTH CANAL INLET AT FLEURBAA	-23.841667	30.241667
90533	B8H025Q01 GREAT LETABA IRRIGATION N & N CANAL OUTLET AT LAB	-23.7875	30.475
90534	B8H026Q01 GREAT LETABA IRRIG. MASALAAL CANAL INLET AT PRIES	-23.654167	30.741667
90535	B8H027Q01 GREAT LETABA IRRI. MASALAAL CANAL OUTLET AT WATER	-23.695833	30.829167
90536	B8H028Q01 GREAT LETABA RIVER AT MAHLANGENE/KRUGER NAT PARK	-23.648611	31.147222
90537	B8H029Q01 GREAT LETABA RIVER AT MINGERHOUT DAM/KRUGER NAT P	-23.759167	31.500833
90538	B8H030Q01 GREAT LETABA RIVER AT KLIPKOPPIESDRIF/KRUGER NAT	-23.941667	31.730556
85569	B8H031 VERGELEGEN DAM	-23.775	30.1
103038	B8H031R01 DUIWELSKLOOF TREATM WORKS - VERGELEGEN DAM RAW WA	-23.775	30.1
103039	B8H031S01 DUIWELSKLOOF TREATMENT WORKS - TREATED WATER	-23.775	30.1
103040	B8H032R01 PIETERSBURG TREATMENT WORKS - EBENEZER DAM RAW WA	-23.941667	29.991667
103041	B8H032S01 PIETERSBURG TREATMENT WORKS - TREATED WATER	-23.941667	29.991667
90539	B8H033Q01 LITTLE LETABA RIVER AT TABAAN STATE LAND (LOCATIE	-23.24	30.475833
90540	B8H043Q01 HANS MERENSKY DAM ON RAMADIEPA RIV: DOWN STREAM W	-23.75	30.108333
90541	B8H045Q01 LEFT CANAL FROM MAGOEBASKLOOF DAM AT TURKSVYGBULT	-23.822222	30.056944
90542	B8H046Q01 MAGOEBASKLOOF DAM ON POLITSI RIVER: DOWN STREAM W	-23.816667	30.0625
90543	B8H050Q01 TZANEEN DAM ON GREAT LETABA RIVER: DOWN STREAM WE	-23.8	30.166667
90544	B8H051Q01 TZANEEN DAM ON GREAT LETABA RIVER: LEFT CANAL	-23.8	30.166667
B8H052Q01	PIETERSBURG PIPELINE	295800	234845
90546	B8H053Q01 DAP NAUDE DAM ON BROEDERSTROOM RIV: DOWN STREAM W	-23.8125	29.966667
90547	B8H054Q01 MIDDLE LETABA DAM ON MID. LETABA RIVER: RIGHT CAN	-23.271667	30.403056
90548	B8H056Q01 MIDDLE LETABA DAM ON MID LETABA RIV: DOWN STREAM	-23.271667	30.403056
90549	B8H064Q01 AT ONVERWACHT EBENEZER DAM ON GROOT LETABA	-23.945833	29.983889
90550	B8R001Q01 EBENEZER DAM ON GREAT LETABA RIVER: NEAR DAM WALL	-23.941667	29.9875
90551	B8R001Q02 EBENEZER DAM ON GREAT LETABA RIVER: POINT IN DAM	-23.941667	29.9875
90576	B8R002Q01 HANS MERENSKY DAM ON RAMADIEPA RIVER: NEAR DAM WA	-23.75	30.108333
90577	B8R003Q01 MAGOEBASKLOOF DAM ON POLITSI RIVER: NEAR DAM WALL	-23.816389	30.056111
90578	B8R005Q01 TZANEEN DAM ON GREAT LETABA RIVER: NEAR DAM WALL	-23.8	30.166667
90579	B8R006Q01 DAP NAUDE DAM ON BROEDERSTROOM RIVER: NEAR DAM WA	-23.8125	29.966667
90580	B8R007Q01 MIDDLE LETABA DAM ON MIDDLE LETABA RIV: NEAR DAM	-23.271667	30.403056
90581	B8R009Q01 NSAMI DAM ON NSAMI RIVER: NEAR DAM WALL	-23.253611	30.770556

Table 3.3: Water Quality Sub-Units (WQSU) and descriptive information for the Letaba Reserve study area. An indication is given as to whether DWAF is appropriate for defining either Reference Condition (RC) or Present Ecological State (PES).

WQSU	Description	Monitoring point data available and potential for assessing RC + PES	Land use activities and implications for water quality
1	Headwaters of Groot Letaba upstream of input to the Ebenezer Dam (on the R528 upstream of the bridge crossing)	Preferred DWAF mon. points: B8H064Q01 (Onverwacht Ebenezer Dam) **(PES)** OR B8R001Q01 (Ebenezer Dam Wall) **(RC and PES)** OR Alternatively B8H032S01 (Pietersburg Treatment Works-Ebenezer Dam-Treated), B8H053Q01 (Dap Naude Dam on Broederstroom River); B8R001Q02 (Point in Ebenezer Dam) WQ = No sample taken EWR = No site Biomonitoring site: Exists (Walmsley pers. comm.), but cannot be located (site may be in WQSU 2).	Main land use is afforestation (*Eucalyptus* and *Pinus* species). Some cultivated lands (bananas and citrus). Water quality problems relating to electrical conductivity. Water quality impacts relating to increased turbidity due to sedimentation (SRK, 1989; Consultburo, 1998).
2	Groot Letaba downstream of Ebenezer Dam (output) to upstream of Tzaneen Dam (input)	Preferred DWAF mon. points: B8H050Q01 Groot Letaba at Tzaneen Dam wall **(RC and PES)** or B8R005Q01 Groot Letaba at Tzaneen Dam wall **(RC and PES)** OR Alternatively: B8H014Q01(Grysappel) WQ = Site 1 (situated on the R528 bridge crossing the Groot Letaba) EWR = Site 1 (Appel: Tzaneen – close to DWAF site) Biomonitoring site: Exists (Walmsley pers. comm.), but cannot be located (site may be in WQSU 1).	Predominantly forested (*Eucalyptus* and *Pinus* species). Water is abstracted for irrigation (cultivated lands – bananas, mangos and tea plantations), few rural / urban settlements. Water quality problems relating to electrical conductivity. Increased turbidity due to sedimentation (SRK, 1989; Consultburo, 1998).
3	Groot Letaba downstream of Tzaneen Dam (output) to upstream of the confluence with the Letsitele River tributary	Preferred DWAF mon. points: B8H050Q01 downstream of Tzaneen Dam wall **(RC, PES)** WQ = Site 3 (situated below the Letaba Estate off the R529 from Tzaneen at a bridge crossing) EWR = No site Biomonitoring site = Nkowankowa Bridge (BIO 21)	Irrigation agriculture (cultivated lands – banana and citrus), industrial and urban / domestic water use (Tzaneen). Industrial activity noted **-** creosote plant and oxidation ponds (in Tzaneen), timber processing (before Letsitele tank on the R71). Water quality impact is minimal as most of the effluent is recycled or used for irrigation. Water quality problems relating to dissolved oxygen (SRK, 1989; Consultburo, 1998).
4	Groot Letaba downstream of confluence with Letsitele to upstream of Prieska Weir (after Hans Merensky Nature	Preferred DWAF mon. points: B8H009Q01 (Groot Letaba at ‘The Junction’) **(RC and PEC)** or B8H017Q01 Groot Letaba at Prieska **(RC)** OR	Main land use irrigation agriculture, namely citrus plantations (Noted: Strong biocide odour in the air). Water quality impacts relating to salinisation and release of

WQSU	Description	Monitoring point data available and potential for assessing RC + PES	Land use activities and implications for water quality
	Reserve)	Alternatively: B8H043Q01 Hans Merensky Dam on Ramadepa River - downstream) or B8R002Q01 (Hans Merensky Dam on Ramadepa River – near dam wall) WQ = Site 5 ('The Junction); Site 6 (Nagude Farm Estate); Site 7 (Bridge crossing at Sukkel Sukkel to Giyani) EWR = Site 3 Prieska Biomonitoring site = 'The Junction' (BIO 22) and Nagude (BIO 23)	biocides into the environment. Water quality problems relating to, for example chlorophyll-a, pesticides, herbicides, nitrogen and phosphate, Magnesium, Sodium etc (SRK, 1989; Consultburo, 1998)
5	Groot Letaba downstream of Prieska Weir (after Hans Merensky Nature Reserve) to upstream of the confluence with the Molototsi River tributary	Preferred DWAF mon. points: B8H017Q01 Groot Letaba at Prieska **(RC)** Alternatively: B8H026Q01 Groot Letaba irrig. Masalaal canal inlet at Prieska WQ = Site 15 Nondweni (downstream of Nondweni biomonitoring site and a weir and upstream of bridge crossing) EWR = No site Biomonitoring site = Nondweni (BIO 25)	Main land use is dense rural settlements (limited subsistence agriculture, with livestock). Very few citrus plantations or irrigation agriculture (one adjacent to the WQ sampling site). Very dry landscape. Where plantations exist and land use is irrigation agriculture: Water quality impacts relating to salinisation and release of biocides into the environment. WQ problems relating to, for example chlorophyll-a, pesticides, herbicides, nitrogen and phosphate, Magnesium, Sodium etc (SRK, 1989; Consultburo, 1998). Where rural settlements exist: Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).
6	Groot Letaba downstream of confluence with the Molototsi River tributary to upstream of the confluence with the Klein Letaba (northern boundary of the Groot Letaba Nature Reserve)	Preferred DWAF mon. point: B8H008Q01 Groot Letaba at Letaba Ranch (Groot Letaba Nature Reserve) **(RC and PES)** WQ = Site 14 (Rondaliekamp, Groot Letaba Nature Reserve) EWR = Site 4 Letaba Ranch Biomonitoring site = Letaba Ranch camp 3 (BIO 27), Slab weir and road bridge (BIO 26), and Letaba Ranch EWR site (BIO 28).	Rural / domestic water use and limited cultivated lands before the Nature Reserve. The water quality sampling point was taken in the Nature Reserve but downstream of dense rural settlements and informal settlements (limited subsistence agriculture and livestock).
7	Letaba River downstream of the Klein Letaba confluence with the Groot Letaba into the Kruger National Park (eastern boundary) to the Mozambique border.	Preferred DWAF mon. points: B8H028Q01 Letaba River at Mhlangeni Dam (KNP) **(RC and PES);** B8H029Q01 Letaba River Mingerhout Dam (KNP) **(RC)** or B8H018Q01 Letaba River at Engelhardt Dam **(RC)** Or Alternatively: B8H034 Letaba (Black Heron KNP) WQ = Site 16 (Upstream of Lonely Bull EWR site and	Kruger National Park – Protected land or conservation area.

WQSU	Description	Monitoring point data available and potential for assessing RC + PES	Land use activities and implications for water quality
		Mingerhout Dam) Site 17 (Upstream from Letaba Rest Camp at bridge crossing and upstream of Engelhardt Dam) EWR = Site 6, Lonely Bull and Site 7, Letaba Rest Camp Biomonitoring site: Sites within the Kruger National Camp .	
8	Upper Letsitele (Craighead Estate) to upstream of the R529 bridge crossing from Tzaneen to Lydenberg (just after Nkowankowa turn off)	Preferred DWAF mon. points: Possibly use point for WQSU 9. WQ = Site 2 (Craig Head Estate in Letsitele Valley upstream of bridge crossing) EWR = No site Biomonitoring site = Craighead Estate (BIO 1)	Main land use irrigation agriculture, namely citrus plantations (mangos and bananas). Also afforestation. Water quality impacts relating to salinisation and release of biocides into the environment. WQ problems relating to, for example chlorophyll-a, pesticides, herbicides, nitrogen and phosphate, Magnesium, Sodium etc (SRK, 1989; Consultburo, 1998).
9	Lower Letsitele downstream of the R529 bridge crossing to upstream of the confluence with the Groot Letaba	Preferred DWAF mon. points: B8H010Q01 Letsitele River at Mohlabas Reserve **(RC and PES)** WQ = Site 2 (upstream of Letsitele tank and downstream of bridge crossing) EWR = Site 4 Letaba Ranch Biomonitoring site: Letsitele tank (BIO 2)	Predominantly urban/domestic water use with little cultivated lands. Noted is the Nkowankowa Sewage works. Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).
10	Headwaters of the Middle Letaba to upstream (input) of the Middle Letaba Dam (north of Rotterdam settlement)	Preferred DWAF mon. points: B8H054Q01 Middle Letaba River at Middle Letaba Dam Wall **(PES)** OR Alternatively: B8R007Q01 (Middle Letaba Dam – near dam) WQ = Site 13 no sample taken as river dry (at a bridge crossing) EWR = No site Biomonitoring site: No site	Main land use is dense rural/urban settlements (limited subsistence agriculture, with livestock). Very dry landscape. Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).
11	Downstream of Middle Letaba Dam (output) to upstream of confluence with Klein Letaba	Preferred DWAF mon. points: B8H056Q01 (Middle Letaba Dam on Middle Letaba River – Downstream) WQ = Site 12 no sample taken (after dam wall) EWR = No site Biomonitoring site: No site	Main land use is dense rural/urban settlements (limited subsistence agriculture, with livestock). Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).

WQSU	Description	Monitoring point data available and potential for assessing RC + PES	Land use activities and implications for water quality
12	Upper/headwaters of the Klein Letaba upstream of the confluence with the Middle Letaba River	Preferred DWAF mon. points: No current monitoring point (Brandt, pers. comm.). B8H015 Little Letaba @ Rossbach (it was closed in 1978 due to a poor notch layout, but should still give an indication of what the flows where like during that period) WQ = No sample taken EWR = No site Biomonitoring site: Majosi sewage outflow (BIO 7)	Main land use is dense rural/urban informal settlements (limited subsistence agriculture, with livestock). Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).
13	Klein Letaba downstream of the confluence with the Middle Letaba to upstream of Giyani (upstream of weir before Elim road bridge crossing)	Preferred DWAF mon. points: B8H033Q01 Klein Letaba at Tabaan **(PES)** WQ = Site 11 (old mine d/s of EWR 5) EWR = Site 5 (Klein Letaba Malanga) Biomonitoring site: Below Middle Letaba Confluence (BIO 9); Hlaneki Weir (BIO 10)	Main land use is dense urban settlements and informal settlements, Giyani etc (limited subsistence and cultivated agriculture, with livestock). Noted: number of sewage works and waste disposal sites. Also area for malaria control (high risk area). Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).
14	Klein Letaba downstream of Giyani weir at Elim road to upstream of confluence with Groot Letaba	Preferred DWAF mon. points: No monitoring point found (confirmed with DWAF (Brandt, pers. comm.). WQ = Site 9 (just north of Ka-Ngove) and Site 10 (upstream of Mutsondi and Nsama tributary's - no sample taken as dry) EWR = No site Biomonitoring site: Below Giyani Sewage Works (BIO 13); Giyani Elim road bridge (BIO 8); Kremetart Big Tree (BIO 12)	Main land use is dense urban settlements and informal settlements, Giyani etc, with domestic effluent (limited subsistence and cultivated agriculture, with livestock). Noted: number of sewage works and waste disposal sites. Also area for malaria control (high risk area). Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998).
15	Headwaters of Molototsi River to upstream of the confluence with the Groot Letaba	Preferred DWAF mon. points: No point exists. WQ = Site 8 (no sample taken – at R529 bridge crossing to Giyani - river dry) EWR = No site Biomonitoring site: Below Modjadji Dam (BIO 17); Modjadji bridge (BIO 18), Sekhiming bridge (BIO 19); Dzumeri Weir (BIO 20)	Main land use is rural informal settlements, Ka-Dzumeri (limited subsistence and cultivated agriculture, with livestock). Very dry landscape. Headwater region of Molototsi has cultivated lands with formal settlements. Water quality impacts relating to sewage effluent leading to eutrophication. Water quality problems relating to, for example Total inorganic nitrogen, dissolved oxygen etc (SRK, 1989; Consultburo, 1998)

4. WATER QUALITY PRESENT STATE ASSESSMENT

4.1 INTRODUCTION

Although an EWR or Ecological Reserve study can aim to be conducted at a Comprehensive level, the results of the assessment can have differing levels of confidence, depending on the quality and extent of the available data (better data provide higher confidence results), the ability to collect additional data and/or to undertake field or laboratory studies, and/or the availability of appropriate modelling tools. Some of the factors that affect data quality have time and budget implications. Depending on the constraints of the budget, available time and the quality of existing data, ecological Reserve assessments can be undertaken so as to produce high, medium or low confidence results. The objective is therefore to provide the highest level of confidence within the resources available.

This section lists the results of the water quality assessment conducted for the Letaba Reserve Determination Study, and details the Present Ecological State (PES) assessment for each WQSU evaluated during the study. The confidence in the present state classification was verified using the power statistic, G-Power.

4.2 APPROACH

4.2.1 Recalibration of benchmarks

Each WQSU was assigned a Reference Condition (RC) and a Present Ecological State (PES), where possible, using available methods. The RC reflects the unimpacted state, whilst the PES reflects the current state in terms of water quality. This allows the specialist to recalibrate benchmarks for the various variables in relation to the RC, if the variables assessed do not correspond to the benchmark table categories provided in the methods manual.

Note that categories are described as Natural to Poor in the methods manual, but as the EWR process requires categories A – F, all benchmark tables were recalibrated accordingly (Table 4.1). The methods manual also does not differentiate categories such as Upper and Lower Good (i.e. A/B and B/C). The recalibration process also identified these categories.

Table 4.1: Recalibrated benchmarks for Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphorous (SRP), periphyton, pH, and biological indicators (i.e. macroinvertebrates and ASPT) using the A-F classification system

Descriptive classification + allocated range from methods manual	Numerical classification	Value per category
TIN		
Natural: = 0.25 mg/L	A	= 0.25 mg/L
Upper Good	A/B	0.5 mg/L
Good: 0.251 - 1.0 mg/L	B	0.75 mg/L
Lower Good	B/C	1.0 mg/L
Upper Fair	C	2.0 mg/L
Fair: 1.01 – 4.0 mg/L	C/D	3.0 mg/L
Lower Fair	D	4.0 mg/L
Poor: > 4.0 mg/L	E/F	> 4.0 mg/L
SRP or PO_4		
Natural: = 0.005 mg/L	A	= 0.005 mg/L

Descriptive classification + allocated range from methods manual	Numerical classification	Value per category
Upper Good	A/B	0.012 mg/L
Good: 0.0051 – 0.025 mg/L	B	0.02 mg/L
Lower Good	B/C	0.025 mg/L
Upper Fair	C	0.058 mg/L
Fair: 0.0251 – 0.125 mg/L	C/D	0.091 mg/L
Lower Fair	D	0.125 mg/L
Poor: > 0.125 mg/L	E/F	> 0.125 mg/L
pH		
Natural: 6.5 – 8.00	A	6.5 – 8.00
Upper Good	A/B	5th Percentile: 5.75 – 6.00 95th Percentile:8.05 – 8.37
Good: 5.75 – 8.05 and 6.46 – 9.00	B	5th Percentile: 6.00 – 6.24 95th Percentile:8.37 – 8.69
Lower Good	B/C	5th Percentile: 6.24 – 6.46 95th Percentile:8.69 – 9.00
Upper Fair	C	5th Percentile: 5.00 – 5.23 95th Percentile:9.05 – 9.36
Fair: 5.00 -5.7 and 9.05 – 10.00	C/D	5th Percentile: 5.23 – 5.46 95th Percentile: 9.36 – 9.67
Lower Fair	D	5th Percentile: 5.46 – 5.7 95th Percentile: 8.56 – 10.00
Poor: < 5.00 or > 10.0	E/F	< 5.00
PERIPHYTON		
Natural: < 1.7 mg/m^2	A	< 1.7 mg/m^2
Upper Good	A/B	1.7 – 8.13 mg/m^2
Good: 1.7 – 21 mg/m^2	B	8.13 – 14.56 mg/m^2
Lower Good	B/C	14.56 – 21 mg/m^2
Upper Fair	C	21 – 42 mg/m^2
Fair: 21 – 84 mg/m^2	C/D	42 – 63 mg/m^2
Lower Fair	D	63 – 84 mg/m^2
Poor: > 84 mg/m^2	E/F	> 84 mg/m^2
BIOLOGICAL INDICATOR (ASPT)		
Natural: 7	A	7
Upper Good	A/B	6.67
Good: 6	B	6.34
Lower Good	B/C	6
Upper Fair	C	5.67
Fair: 5	C/D	5.34
Lower Fair	D	5
Poor: < 5	E/F	< 5

4.2.2 Data collation

The following information was used to conduct the present state assessments listed in this document.

- Literature (SRK, 1989; Consultburo, 1998) regarding water quality conditions in the catchment, and a field survey undertaken in December 2003 to verify the delineation of WQSUs.
- Water quality data from selected DWAF monitoring points in the catchment (Table 4.2), as well as spot samples taken during the December field survey (Table 4.3). Samples were analysed at Resource Quality Services (RQS), DWAF.
- Biotic integrity data (macroinvertebrates) were sourced from the relevant specialist of the Letaba Reserve study for the EWR sites (intensive invertebrate monitoring conducted); other data was accessed from SASS (i.e. rapid monitoring using the South

African Scoring System version 5.0) surveys conducted of the Letaba catchment for the River Health Programme. RHP results are recorded in Angliss (2004).

- Fish categories are included for the EWR sites from the relevant specialists of the Letaba Reserve study.
- Chlorophyll-a analyses were undertaken at selected points in the catchment as an indicator of algal abundance, during the field survey of December 2003 (therefore n=1). Samples were analysed for periphyton at the Coastal Research Group, Rhodes University (Appendix A). Phytoplankton results are not available as samples were not properly analysed at RQS.
- Spot samples were taken for in-stream toxicity testing from two points in the catchment in March 2004, as a preliminary indication of toxicity related to pesticide / herbicide use on citrus plantations (therefore n=1). The following acute screening toxicity tests were conducted at Rand Water (Appendix B): *Daphnia pulex*, the guppy *Poecilia reticulata* and an algal inhibition test.
- The following version of the salt model of Jooste (RQS, DWAF) was used to generate PES categories for inorganic salts: SALTBA21. Note that the model provides categories, but not values.
- Available data were screened for toxics, e.g. metals. Toxics are listed and assessed where data were available.
- As a method does not exist for assessing the present state of turbidity, results were compared to the domestic use Target Water Quality Range (TWQR), as aquatic ecosystem guidelines do not exist.

TWQR for domestic use – turbidity: 0 – 1 NTU (DWAF, 1996).

- As a document is not yet available regarding dam operations, verbal information was 0obtained from the DWAF Polokwane office (Tunha, DWAF, pers. comm.).

Table 4.2: DWAF monitoring points that were utilized for the PES assessment.

WQSU	EWR site	DWAF monitoring point	Description of location
1	-	B8H053Q01	Dap Naude Dam on Broederstroom River: Downstream weir
2	1	B8H014Q01	At Grysappel on Groot Letaba River
3	-	B8H050Q01	Tzaneen Dam on Great Letaba River: Downstream weir
3	-	B8R005Q01	Tzaneen Dam on Great Letaba River: Near Dam Wall
4	3	B8H009Q01	At The Junction on Groot Letaba River
4	3	B8H017Q01	At Prieska on Groot Letaba River
5	-	B8H026Q01	Groot Letaba irrigation scheme. Masalaal Canal Inlet at Prieska
6	4	B8H008Q01	At Letaba Ranch on Groot Letaba River
7	6/7	B8H028Q01	Groot Letaba River at Mahlangene/Kruger National Park
7	6/7	B8H029Q01	Groot Letaba River at Mingerhout Dam/Kruger National Park
8/9	2	B8H010Q01	Letsitele River at Mohlaba's Reserve 567
10/11	-	B8H054Q01	Middle Letaba Dam on Middel Letaba River: Right canal
12	5	Not available	No water quality data is available for this area. Historical flow data only are available from B8H015, i.e. Klein Letaba at Rossbach (1970 – 1972). Due to similarities in land-use, this WQSU will be combined with WQSU 13.
13	5	B8H033Q0s	Klein Letaba River at Tabaan
14	-	Not available	Field survey data, WQ Site 9
15	-	Not available	Field survey data. WQ Site 8

Table 4.3: Sites sampled for water quality (macro-elements and nutrients, bacteriology, metals, turbidity) during field surveys of December 2003 or March 2004 (n=1)

Water quality site	WMS code	Feature name
1	187683	Driekuil @ R528 road bridge on tributary of Mphogodiba
2	187684	At Craighead on Letsitele River
3	187689	At bridge crossing just south of Letaba Estate on Groot Letaba
4	187685	At Letsitele Tank just downstream of R36 on Letsitele
5	187692	At the junction south of the R21 on Groot Letaba
6	187686	Nagude Estate on Groot Letaba
7	187687	At Letaba Drift at bridge on R529 to Giyani on Groot Letaba
8	187730	East of Ka-Dzumeri on Molototsi River
9	187688	Downstream of Giyani on the Klein Letaba River
10	Not sampled	
11	187690	At old mine on Klein Letaba River
12	187967	Location of de Knopneuzen on Klein Letaba River
13	187968	Sterkwater on Middel Letaba River
14	187691	Letaba Ranch at Rondaliakamp on Groot Letaba
15	187693	Downstream of Nondweni on Groot Letaba
16	187694	At Lonely Bull in the KNP
17	187695	Upstream of Letaba rest camp in the KNP
19	187969	At Diggers Rest on Groot Letaba

4.3 DATA MANIPULATION

Once the WQSUs had been delineated, data suitable for determining both the RC and PES were selected based on data frequency, the position of the DWAF monitoring point within the WQSU, and the length of the data record. DWAF water quality data were manipulated according to the following procedure:

- Generate files per DWAF monitoring point, and per RC or PES.
- In Excel, replace all "<" signs with half the value, e.g. replace <0.04 with 0.02, as a statistically approved method of manipulating water quality data below quantification levels.
- As Total Inorganic Nitrogen is required by the water quality method, produce TIN by adding (NO_2+NO_3) and NH_4.
- Generate scatter plots, box-and-whisker plots and summary statistics (e.g. means, 95th percentiles, 50th percentiles) per water quality variable.
- Table 4.4 briefly shows the calculations needed for both RC and PES assessments (for Comprehensive Reserve studies).

Table 4.4: Calculations required for the PES assessment for water quality (Comprehensive Reserve).

Variable	Methodology
Inorganic salts	Individual salts put into computer salt model. RC – unimpacted site 60 samples over 3 year period. 95th percentile (at this percentile 95% of the variable are situated below this point). PES 95th percentile with formulae
Nutrients (PO_4 and TIN)	RC – unimpacted site 60 samples over 3 year period. Median concentrations PES Assemble TIN & SRP from most recent 5 years. Calculate 50th percentile or median
Dissolved oxygen	RC – unimpacted site 5th percentile Check what values calculated and if benchmark values need to be changed PES 5th percentile
pH	RC – unimpacted site 5th and 95th percentiles Default benchmark boundary values if no data PES Comparing 5th & 95th percentile to table or calibrated table. NOTE: changes in DWAF pH determination method.
Turbidity	Optional variable. Should be incorporated if the land use practices indicate overgrazing, contour ploughing, removal of riparian vegetation and forestry. No assessment methodology available
Temperature	RC – unimpacted site 10th and 90th percentiles for each month No data – locally calibrated empirical relationship between air temp and water temp OR modeling – done by month and then calibrate 10th and 90th percentiles for each month PES As above or if no data then monitor for at least one seasonal cycle
Toxic substances e.g. metals, pesticides	RC – unimpacted site Toxic substances do not usually occur naturally, therefore value detected = RC PES 95th percentiles Additional information for Ammonia
Biological indicator of water quality	RC – unimpacted site RC for Level 2 Ecoregion used. If no data – then need SASS Values compared against the ASPT Scores in benchmark table. PES 3 or more sites per resource unit, and calculate median value
Chlorophyll-a	RC – unimpacted site 60 samples over 1-3 year period. Median concentrations PES If available – assemble data from last 5 years, calculate average of phytoplankton or median of periphyton If no data – expert judgment used (visual)
Toxicity	Not yet fully understood However, for the Letaba study water samples were gathered from identified sites where biocide use was evident. Biocide use and information was established by the circulation of questionnaires (Appendix G) to identified users in the study area.

- To assess the status of the inorganic salts, salt ions need to be aggregated and assessed against the benchmark tables in the methods manual. The SaltBA21 model of Jooste (RQS, DWAF) was used to generate this data. The model can be found at http://www.dwaf.gov.za/iwqs/gis_data/SaltBA21.exe
- Once the RC and PES values have been calculated and categories A – F assigned for each of the variables assessed, an integrated water quality category is produced per WQSU for present state.
- **Assessing data confidence:** In a water quality Reserve determination, the water quality specialist has to assess confidence in the data set used to assess the present ecological state. This assessment is conducted using a package called **G*Power**. G*Power (Version 2.0) is a freeware software package that can be used to provide an objective measure of the confidence in the data set used, and is available from http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/.

4.4 PRESENT ECOLOGICAL STATE (PES) RESULTS

PES assessments for water quality are shown per WQSU. WQSUs are presented per Resource Unit.

- **RESOURCE UNIT A - GROOT LETABA RIVER: HEADWATERS I.E. BROEDERSTROOM, TO TZANEEN DAM**

Water Quality Sub-Unit 1: Groot Letaba River – Headwaters to Ebenezer Dam

The main land-use is afforestation (*Eucalyptus* and *Pinus* species); some cultivated lands (bananas and citrus) exist. The monitoring point is at the upper end of the sub-unit and within the forested and cultivated area, and is at the weir downstream of the Dap Naude dam on the Broederstroom River.

No sampling was conducted during the field trip of December 2003.

Trend of change
It is expected that water quality will remain relatively stable over the short-term (5 years) and long-term (20 years).

Data confidence
The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Low
F	Low

River	Broederstroom (Groot Letaba River)	DWAF Water Quality Monitoring points		
WQSU	1	RC	No reference condition data	
EWR Site	-	PES	B8H053Q01 (2000 - 2003), n = 39	
Water Quality Constituents		Value	Category / Comment	
Inorganic salts (mg/L)	$MgSO_4$		A	
	Na_2SO_4		A	
	$MgCl_2$		A	
	$CaCl_2$		A	
	NaCl		A	
	$CaSO_4$		A	
Nutrients (mg/L)	SRP	0.012	A/B	
	TIN	0.338	A/B	
Physical variables	pH (pH units)	6.9 + 8.4	B	
	Temperature (° C)	No data	No impacts anticipated.	
	Dissolved oxygen (mg/L)	No data		
	Turbidity (NTU)	No data	Water quality impacts relating to increased turbidity due to sedimentation expected (SRK, 1989; Consultburo, 1998).	
Response variable	Chl-a: periphyton (mg/m^2)	Not sampled	-	
	Biotic community composition - macroinvertebrate (ASPT) score	Broederstroom, ASPT: 6.3, 1999 survey (Angliss, 2004)	B/C	
	In-stream toxicity	Not sampled	-	
Toxics	Fluoride (µg/L)	960	A	
Overall site classification		A/B		

Water Quality Sub-Unit 2: Groot Letaba River - Downstream Ebenezer Dam to Tzaneen Dam

The area is predominantly forested (*Eucalyptus* and *Pinus* species), with water abstracted for irrigation (cultivated lands – bananas, mangos and tea plantations) and rural / urban settlements. Although the Ebenezer Dam was built in 1959, i.e. before data was collected to describe the reference condition, it was not necessary to re-benchmark the A category, so RC data considered suitable.

The monitoring point is on the Groot Letaba River near EWR 1. A water quality sample was taken during the field survey of December 2003 (WQ Site 1).

Trend of change
It is expected that water quality will remain relatively stable over the short-term (5 years) and the long-term (20 years).

Data confidence

The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Low
F	Low

River	Groot Letaba River	**DWAF Water Quality Monitoring points**	
WQSU	2	**RC**	B8H014Q01 (1977 – 1979), n= 75
EWR Site	1	**PES**	B8H014Q01 (1999-2003), n = 69
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		A
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		A
	$CaSO_4$		A
Nutrients (mg/L)	SRP	0.017	B
	TIN	0.129	A
Physical variables	pH (pH units)	7.29 + 7.909	A
	Temperature (° C)	No data	Impacts expected as Ebenezer Dam releases to river are bottom releases (although dam wall not very high) (Tunha, DWAF, pers. comm.).
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	Median: 1.00 95th percentile: 4.00 (n=18) 10.2 (n=1, March 2004)	Increased turbidity expected due to sedimentation (SRK, 1989; Consultburo, 1998).
Response variable	Chl-a: periphyton (mg/m^2)	60.54	C/D
	Biotic community composition - macroinvertebrate (ASPT) score	Angliss, pers. comm. – A (SASS condition class)	C (EWR 1: flow-related)
	Fish score	Angliss+ Fouche, Letaba Reserve study	C
	In-stream toxicity	Not sampled	-
Toxics	Fluoride (μg/L)	149	A
Overall site classification			**B**

- **RESOURCE UNIT B**

Water Quality Sub-Unit 3: Groot Letaba River - Downstream Tzaneen Dam to upstream of the confluence with the Letsitele River

The primary land-use is irrigation agriculture (cultivated lands – banana and citrus), and industrial and urban / domestic water use (e.g. Tzaneen). Industrial activities exist e.g. a creosote plant and oxidation ponds (in Tzaneen), and timber processing (before Letsitele Tank on the R71). Water quality impacts are however expected to be minimal as most of the effluent is recycled or used for irrigation. Water quality problems relate to dissolved oxygen (SRK, 1989; Consultburo, 1998).

The monitoring point is on the Groot Letaba River downstream of Tzaneen Dam. However, the assessment is low confidence due to the small data record available for determining present state (n=19).

A water quality sample was taken during the field survey of December 2003 (WQ Site 3 situated below Letaba Estates).

Trend of change

It is expected that water quality will remain relatively stable over the short-term (5 years) and the long-term (20 years). This assessment was based on available data. TIN data showed a large amount of scatter.

Data confidence

The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	High
F	Low

River	Groot Letaba River	**DWAF Water Quality Monitoring points**	
WQSU	3	**RC**	B8H050Q01 1980 – 1984 n = 36
EWR Site	-	**PES**	B8H050Q01 (2000 – 2002), n = 19
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		B
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		A
	$CaSO_4$		A
Nutrients (mg/L)	SRP	0.18	A
	TIN	0.018	B
Physical variables	PH (pH units)	7.35 + 8.505	B
	Temperature (° C)	No data	Bottom releases from Tzaneen Dam into the river, so impacts extensive.
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	1.89 (n=1, Dec. 2003)	
Response variable	Chl-a: periphyton (mg/m^2)	59.63	C/D
	Biotic community composition - macroinvertebrate (ASPT) score	Nkowakowa, ASPT: 6.3, 1999 survey Nkowakowa, ASPT: 6.14, 2003 survey (Angliss, 2004)	B/C
	In-stream toxicity	Not sampled	-
Toxics	Fluoride (µg/L)	5	A
Overall site classification			**B/C**

- **RESOURCE UNIT C - GROOT LETABA RIVER: DOWNSTREAM OF CONFLUENCE WITH THE LETSITELE RIVER TO UPSTREAM OF CONFLUENCE WITH THE KLEIN LETABA (NORTHERN BOUNDARY OF THE GROOT LETABA NATURE RESERVE), INCLUDING THE CONFLUENCE WITH THE MOLOTOTSI RIVER**

Water Quality Sub-Unit 4: Groot Letaba River - Downstream of confluence with Letsitele River to Prieska Weir (after Hans Merensky Nature Reserve)

The primary land-use in the area is irrigation agriculture, particularly for citrus plantations (e.g. Nagude Farm Estate). Water quality issues therefore relate to the use of pesticides and herbicides, and expected elevated levels of chlorophyll-a, nitrogen and phosphates (SRK, 1989; Consultburo, 1998).

Water quality samples were taken during the field survey of December 2003, i.e. WQ Site 5 - 'The Junction; WQ Site 6 - Nagude Farm Estate; and WQ Site 7 - Bridge crossing at Sukkel-Sukkel to Giyani.

Monitoring data is presented for two points in the WQSU. Although there is higher confidence in the present state assessment using data from B8H009Q01 (n=81, PES Table A) at 'The Junction' than B8H017Q01 (n=15, PES Table B) at Prieska Weir, the former point is at the upper end of the WQSU. The data for the lower monitoring point is therefore presented for comparative purposes as the PES for a WQSU should more correctly be assessed using data from the downstream end of the unit. Based on data available from both monitoring stations, water quality conditions remain relatively stable across the WQSU.

Trend of change
An assessment of data from B8H009Q01 predicted stable water quality conditions in the short-term (5 years) and long-term (20 years).

Data confidence
The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Low
F	Low

PES Table A: B8H009Q01

<table>
<tr><td>River</td><td colspan="2">Groot Letaba River</td><td colspan="2">DWAF Water Quality Monitoring points</td></tr>
<tr><td>WQSU</td><td colspan="2">4</td><td>RC</td><td>B8H009Q01 (1976 – 1977), n = 93</td></tr>
<tr><td>EWR Site</td><td colspan="2">3</td><td>PES</td><td>B8H009Q01 (2000 - 2004), n = 81</td></tr>
<tr><td colspan="2">Water Quality Constituents</td><td>Value</td><td colspan="2">Category / Comment</td></tr>
<tr><td rowspan="6">Inorganic salts (mg/L)</td><td>$MgSO_4$</td><td></td><td colspan="2">B</td></tr>
<tr><td>Na_2SO_4</td><td></td><td colspan="2">A</td></tr>
<tr><td>$MgCl_2$</td><td></td><td colspan="2">A</td></tr>
<tr><td>$CaCl_2$</td><td></td><td colspan="2">A</td></tr>
<tr><td>NaCl</td><td></td><td colspan="2">B</td></tr>
<tr><td>$CaSO_4$</td><td></td><td colspan="2">A</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td>0.019</td><td colspan="2">B</td></tr>
<tr><td>TIN</td><td>0.416</td><td colspan="2">A/B</td></tr>
<tr><td rowspan="4">Physical variables</td><td>pH (pH units)</td><td>7.354 + 7.976</td><td colspan="2">A</td></tr>
<tr><td>Temperature (º C)</td><td>No data</td><td colspan="2" rowspan="2">No impacts expected.</td></tr>
<tr><td>Dissolved oxygen (mg/L)</td><td>No data</td></tr>
<tr><td>Turbidity (NTU)</td><td>WQ Site 5: 2.91
WQ Site 6: 2.20
WQ Site 7: 1.62
(n=1, Dec 2003)</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Response variable</td><td>Chl-a: periphyton (mg/m^2)</td><td>WQ Site 6: 45.77
WQ Site 7: 31.71</td><td colspan="2">C – C/D</td></tr>
<tr><td>Biotic community composition - macroinvertebrate (ASPT) score</td><td>The Junction, ASPT: 6.4
Nagude, ASPT: 6.56
Prieska, ASPT: 6.46,
1999 survey
Nagude, ASPT: 5.86
Prieska, ASPT: 5.58,
2003 survey
(Angliss, 2004)</td><td colspan="2">B

C - C/D

D (EWR 3: habitat + flow related)</td></tr>
<tr><td>Fish score</td><td>Angliss + Fouche,
Letaba Reserve study</td><td colspan="2">C</td></tr>
<tr><td>In-stream toxicity</td><td>The Junction
Daphnia pulex: 35% survival.

Poecilia reticulata: 80% survival.

Algal growth inhibition test: 68% inhibition.
(n=1, March 2004)

Prieska weir
Daphnia pulex: 100% survival.

Poecilia reticulata: 100% survival.

Algal growth inhibition test: 69% inhibition.
(n=1, March 2004)</td><td colspan="2">Sampled at The Junction i.e. downstream of confluence with Letsitele River and citrus plantations at Craighead Estates, as well as downstream of Letaba Estates on the Groot Letaba.

Evidence of acute and sub-lethal toxicity.

Sampled at Prieska Weir, i.e. downstream of extensive citrus plantations e.g. Nagude Farm Estates.

Some evidence of sub-lethal toxicity.</td></tr>
<tr><td>Toxics</td><td>Fluoride (µg/L)</td><td>116</td><td colspan="2">A</td></tr>
<tr><td colspan="2">Overall site classification</td><td colspan="3">C</td></tr>
</table>

PES Table B: B8H017Q01

River	**Groot Letaba River**	**DWAF Water Quality Monitoring points**	
WQSU	4	**RC**	B8H017Q01 (1980 - 1983), n = 72
EWR Site	3	**PES**	B8H017Q01 (1996 - 1998), n = 15
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		A
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		A
	$CaSO_4$		A
	Overall Category		A
Nutrients (mg/L)	SRP	0.015	B
	TIN	0.25	A
Physical variables	pH (pH units)	7.14 + 8.36	A/B
	Temperature (º C)	No data	No impacts expected.
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	WQ Site 5: 2.91 WQ Site 6: 2.20 WQ Site 7: 1.62 (n=1, Dec 2003)	
Response variable	Chl-a: periphyton (mg/m^2)	WQ Site 6: 45.77 WQ Site 7: 31.71	C – C/D
	Biotic community composition - macroinvertebrate (ASPT) score	The Junction, ASPT: 6.4 Nagude, ASPT: 6.56 Prieska, ASPT: 6.46, 1999 survey Nagude, ASPT: 5.86 Prieska, ASPT: 5.58, 2003 survey (Angliss, 2004)	B C - C/D D (EWR 3: habitat + flow related)
	Fish score	Angliss and Fouche, Letaba Reserve study	C
	In-stream toxicity	**The Junction** *Daphnia pulex*: 35% survival. *Poecilia reticulata*: 80% survival. Algal growth inhibition test: 68% inhibition. (n=1, March 2004) **Prieska weir** *Daphnia pulex*: 100% survival. *Poecilia reticulata*: 100% survival. Algal growth inhibition test: 69% inhibition. (n=1, March 2004)	Sampled at The Junction i.e. downstream of confluence with Letsitele River and citrus plantations at Craighead Estates, as well as downstream of Letaba Estates on the Groot Letaba. Evidence of acute and sub-lethal toxicity. Sampled at Prieska Weir, i.e. downstream of extensive citrus plantations e.g. Nagude Farm Estates. Some evidence of sub-lethal toxicity.
Toxics	Fluoride (µg/L)	18	A
Overall site classification			**C**

Water Quality Sub-Unit 5: Groot Letaba River - Downstream of Prieska Weir (after Hans Merensky Nature Reserve) to upstream of confluence with the Molototsi River

The main land-use in the area is dense rural settlements (limited subsistence agriculture, with livestock). Very few citrus plantations or irrigation agriculture exist, with the area being very dry. Where rural settlements exist, expected water quality impacts relate to sewage effluent leading to eutrophication.

A water quality sample was taken during the field survey of December 2003 (WQ Site 15 at Nondweni).

Suitable data is not available for the determination of PES, as data from B8H026Q01 is only available from 1980 – 1983. This data was used for a low confidence present state assessment (although more suitable for determining Reference Condition), and it is recommended that monitoring be re-instituted in the area.

Trend of change
It is expected that water quality will remain relatively stable over the short-term (5 years), but may decline over the long-term (20 years) due to increasing nutrient levels.

Data confidence
The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Low
F	Low

River	Groot Letaba River	**DWAF Water Quality Monitoring points**	
WQSU	5	**RC**	No reference condition data
EWR Site	-	**PES**	B8H026Q01 (1980 - 1983), n = 91
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		A
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		B
	$CaSO_4$		A
Nutrients (mg/L)	SRP	0.0025	A
	TIN	0.18	A
Physical variables	pH (pH units)	5.61 + 7.31	A
	Temperature (º C)	No data	No impact expected.
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	6.8 (n=1, Dec. 2003)	Turbidity levels elevated.
Response variable	Chl-a: periphyton (mg/m^2)	40.68	C
	Biotic community composition - macroinvertebrate (ASPT) score	Nondweni, ASPT: 5.72, 1999 survey (Angliss, 2004)	C
	In-stream toxicity	Not sampled	-

Toxics	Fluoride (μg/L)	5	A
Overall site classification			**B**

Water Quality Sub-Unit 6: Groot Letaba River - Downstream of confluence with Molototsi River to upstream of confluence with the Klein Letaba (northern boundary of the Letaba Ranch Nature Reserve)

Land-use is primarily rural and domestic water use, i.e. limited cultivated lands and subsistence agriculture and livestock, before entering Letaba Ranch Nature Reserve. The water quality monitoring point is situated near the lower end of the WQSU. A water quality sample was taken during the field survey of December 2003 (WQ Site 14 - Rondaliekamp, Letaba Ranch Nature Reserve).

Trend of change

It is expected that water quality will remain relatively stable over the short-term (5 years) and the long-term (20 years).

Data confidence

The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	High
F	Low

River	Groot Letaba River	**DWAF Water Quality Monitoring points**	
WQSU	6	**RC**	B8H008Q01 (1977 – 1978), n = 45
EWR Site	4	**PES**	B8H008Q01 (2000 – 2004), n = 59
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		A
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		B
	$CaSO_4$		A
Nutrients (mg/L)	SRP	0.03	C
	TIN	0.107	A
Physical variables	pH (pH units)	7.75 + 8.54	B
	Temperature (º C)	No data	Low flows result in increased temperatures (Angliss, pers. comm.).
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	Median: 2.91 95th percentile: 70.2 (n=40) Dec 2003: 9.29	Intermittent high levels recorded, so median more suitable for assessing general state.
Response variable	Chl-a: periphyton mg/m^2)	Not sampled	
	Biotic community composition - macroinvertebrate (ASPT) score	Letaba Ranch 3, ASPT: 6.5 Slab weir, ASPT: 7.4, 1999 survey Slab weir, ASPT: 5.0, 2003 survey (Angliss, 2004)	A – B D D (EWR 4: flow-related)

River	Groot Letaba River		**DWAF Water Quality Monitoring points**		
WQSU	6		**RC**	B8H008Q01 (1977 – 1978), n = 45	
EWR Site	4		**PES**	B8H008Q01 (2000 – 2004), n = 59	
Water Quality Constituents			**Value**		**Category / Comment**
	Fish score		Angliss + Fouche, Letaba Reserve study		C
	In-stream toxicity		Not sampled		
Toxics	Fluoride (µg/L)		246		A
Overall site classification					**B/C**

- **RESOURCE UNIT D**

Water Quality Sub-Unit 7: Letaba River - Downstream of Klein Letaba confluence with the Groot Letaba and into the Kruger National Park (eastern boundary) to the Mozambique border

Land-use in this RU and WQSU is protected land or conservation area, i.e. the Kruger National Park.

A water quality sample was taken during the field survey of December 2003 (WQ Site 16 - Upstream of Lonely Bull EWR site and Mingerhout Dam, and WQ Site 17 - Upstream from Letaba Rest Camp and upstream of Engelhardt Dam).

Monitoring data is presented for two points in the WQSU. Although there is higher confidence in the present state assessment using data from B8H028Q01 (n=100, PES Table A) than B8H029Q01 (n=21, PES Table B), the former point is at the upper end of the WQSU. The data for the lower monitoring point is therefore presented for comparative purposes as the PES for a WQSU should more correctly be assessed using data from the downstream end of the unit.

Based on data available from monitoring stations, water quality conditions remain relatively stable across the WQSU.

Trend of change

Data from monitoring station B8H028Q01 suggested a possible improvement in water quality over the short-term (5 years) and long-term (20 years). This trend was also shown by the data of B8H029Q01.

Data confidence

The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Low
F	Low

PES Table A

River	Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	7	**RC**	B8H028Q01 (1983 - 1987); n = 52	
EWR Site	6 & 7	**PES**	B8H028Q01 (2000 - 2004); n =100	
Water Quality Constituents		**Value**	**Category / Comment**	
Inorganic salts (mg/L)	$MgSO_4$		B	
	Na_2SO_4		A	
	$MgCl_2$		B	
	$CaCl_2$		B	
	NaCl		B	
	$CaSO_4$		A	
Nutrients (mg/L)	SRP	0.021	B/C	
	TIN	0.0625	A	
Physical variables	pH (pH units)	7.90 + 8.60	A/B	
	Temperature (º C)	No data	No impacts expected.	
	Dissolved oxygen (mg/L)	No data		
	Turbidity (NTU)	Site 16: 22.2 Site 17: data not available (n=1, Dec 2003)	High turbidity levels measured due to confluence with Klein Letaba.	
Response variable	Chl-a: periphyton (mg/m^2)	Site 16: 85.38 Site 17: 31.23	E/F (Site 16) – C (Site 17), therefore an improvement within the KNP.	
	Biotic community composition - macroinvertebrate (ASPT) score		D - EWR 6: flow-related D – EWR 7: flow-related	
	Fish score	Deacon, KNP data	C – EWR 6 C – EWR 7	
	In-stream toxicity	Not sampled	-	
Toxics	Fluoride (µg/L)	250	A	
Overall site classification		**B** (based on existing information)		

PES Table B

River	Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	7	**RC**	B8H028Q01 (1983 - 1987); n = 52	
EWR Site	6 & 7	**PES**	B8H029Q01 (1987 - 1991), n = 21	
Water Quality Constituents		**Value**	**Category / Comment**	
Inorganic salts (mg/L)	$MgSO_4$		A	
	Na_2SO_4		A	
	$MgCl_2$		A	
	$CaCl_2$		A	
	NaCl		A	
	$CaSO_4$		A	
Nutrients (mg/L)	SRP	0.018	B	
	TIN	0.228	A	
Physical variables	pH (pH units)	7.11 + 8.32	A/B	
	Temperature (º C)	No data	No impacts expected.	
	Dissolved oxygen (mg/L)	No data		
	Turbidity (NTU)	Site 16: 22.2 Site 17: 3.1 (n=1, Dec 2003)	High turbidity levels measured at Site 16.	
	Chl-a: periphyton (mg/m^2)	Site 16: 85.38 Site 17: 31.23	E/F (Site 16) – C (Site 17), therefore an improvement within the KNP.	

River	Letaba River	DWAF Water Quality Monitoring points	
WQSU	7	RC	B8H028Q01 (1983 - 1987); n = 52
EWR Site	6 & 7	PES	B8H029Q01 (1987 - 1991), n = 21

Water Quality Constituents		Value	Category / Comment
Response variable	Biotic community composition - macroinvertebrate (ASPT) score		D - EWR 6: flow-related D – EWR 7: flow-related
	Fish score	Deacon, KNP data	C – EWR 6 C – EWR 7
	In-stream toxicity	Not sampled	-
Toxics	Fluoride (µg/L)	230	A
Overall site classification		**B** (based on existing information)	

- **RESOURCE UNIT E – LETSITELE RIVER**

As land-use and impacts change along the RU, it was divided into two WQSUs. However, only one suitable DWAF water quality monitoring point exists, i.e. B8H010Q01near Letsitele Tank at EWR 2. As spot samples taken in December 2003 were considered inadequate to represent PES, WQSUs 8 and 9 were combined for the PES evaluation.

Water Quality Sub-Unit 8: Upper Letsitele River (Craighead Estate) to upstream of the R529 bridge crossing from Tzaneen to Lydenberg

The main land-use is irrigation agriculture, namely citrus plantations (mangos and bananas) and afforestation. Water quality impacts are expected to relate to salinisation, the release of pesticides / herbicides into the environment and elevated nutrient levels (SRK, 1989; Consultburo, 1998). A water quality sample was taken during the field survey of December 2003 (WQ Site 2 - Craig Head Estate in Letsitele Valley).

Water Quality Sub-Unit 9: Lower Letsitele River downstream of the R529 bridge crossing to upstream of the confluence with the Groot Letaba River

Land-use is predominantly urban / domestic water use with little cultivated lands. Water quality impacts are related to the presence of sewage effluent in the river (e.g. Nkowankowa Sewage Works) leading to potential eutrophication (SRK, 1989; Consultburo, 1998). A water quality sample was taken during the field survey of December 2003 (WQ Site 4 - upstream of Letsitele Tank).

Trend of change

It is expected that water quality will remain relatively stable over the short-term (5 years) and decline over the long-term (20 years).

Data confidence

The following confidences were generated using G-Power.

pH	Low
TIN	Low
SRP	High
EC	Low
F	Low

River	Letsitele River	DWAF Water Quality Monitoring points		
WQSU	8 & 9	**RC**	B8H010Q01 (1975 – 1977), n = 96 (TIN: n = 85)	
EWR Site	2	**PES**	B8H010Q01 (2000 - 2004), n = 83 (F: n = 62)	
Water Quality Constituents		**Value**	**Category / Comment**	
Inorganic salts (mg/L)	$MgSO_4$		A	
	Na_2SO_4		A	
	$MgCl_2$		A	
	$CaCl_2$		A	
	NaCl		A	
	$CaSO_4$		A	
Nutrients (mg/L)	SRP	0.126	E/F	
	TIN	0.624	B	
Physical variables	pH (pH units)	7.62 + 8.33	A/B	
	Temperature (º C)	No data	No impacts expected	
	Dissolved oxygen (mg/L)	No data		
	Turbidity (NTU)	Site 2: 0.05 Site 4: 2.53 (n=1, Dec 2003)		
Response variable	Chl-a: periphyton (mg/m^2)	Site 2: 38.83 Site 4: 106.52	C upstream to E/F at Letsitele Tank	
	Biotic community composition - macroinvertebrate (ASPT) score	Craighead, ASPT: 6.65 Letsitele Tank, ASPT: 7, 1999 survey Craighead, ASPT: 6.61 Letsitele Tank, ASPT: 5.30, 2003 survey (Angliss, 2004)	A/B (Craighead) – A (Letsitele Tank) B (Craighead) - D (Letsitele Tank) D (EWR 2: water quality-related)	
	Fish score	Angliss + Fouche, Letaba Reserve study	C	
	In-stream toxicity	Not sampled		
Toxics	Fluoride (μg/L)	148	A	
Overall site classification			**C/D - D**	

- **RESOURCE UNIT F: MIDDEL LETABA**

Although the Middel Letaba Dam divides this RU into two WQSUs, i.e. WQSU 10 and 11, little data was available for WQSU 11. The sub-units were therefore combined, particularly as land-use is similar across the RU.

Water Quality Sub-Unit 10: Headwaters of the Middel Letaba to upstream of the Middel Letaba Dam (north of Rotterdam settlement)

and

Water Quality Sub-Unit 11: Downstream Middel Letaba Dam to upstream of the confluence with the Klein Letaba River

The primary land-use is dense rural / urban settlements (there is limited subsistence agriculture, with livestock). Water quality impacts may relate to sewage effluent in the river leading to eutrophication (SRK, 1989; Consultburo, 1998). The Middel Letaba Dam was built in 1984. As no water is released into the river at this point, an assessment of present state for WQSU 11 is superfluous.

The water quality monitoring point, B8H054Q01, is at Middel Letaba Dam. A water quality sample was taken in WQSU 10 during a field survey of March 2004 (WQ Site 13 - Sterkwater on Middel Letaba upstream of the Middel Letaba Dam).

Trend of change
It is expected that water quality will remain relatively stable over the short-term (5 years) and decline marginally over the long-term (20 years).

Data confidence
The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Medium
F	High

River	Middel Letaba River	**DWAF Water Quality Monitoring points**	
WQSU	10 & 11	**RC**	No reference condition data
EWR Site	-	**PES**	B8H054Q01 (2000 – 2003), n = 75 (Fluoride: n = 63)
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		B
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		B
	$CaSO_4$		A
Nutrients (mg/L)	SRP	0.021	B/C
	TIN	0.154	A
Physical variables	pH (pH units)	7.72 + 8.51	B
	Temperature (º C)	No data	Middel Letaba Dam – releases only into irrigation canal (farmers + to Nsame Dam), therefore no releases to river.
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	Site 13: 3.18 (n=1, March 2004)	-
Response variable	Chl-a: periphyton (mg/m^2)	Not sampled	High levels of algae were noted below the dam. Flow minimal.
	Biotic community composition - macroinvertebrate (ASPT) score	Not sampled	-
	In-stream toxicity		
Toxics	Fluoride (µg/L)	221	A
Overall site classification		**B – B/C**	

- **KLEIN LETABA RIVER** (not defined as a RU of this study)

Water Quality Sub-Unit 12: Upper section of the Klein Letaba River upstream of the confluence with the Middel Letaba River

The main land-use in this area is rural / urban informal settlements (with limited subsistence agriculture and livestock). Water quality impacts may therefore be related to sewage effluent outputs leading to eutrophication (SRK, 1989; Consultburo, 1998).

No water quality data was available for this area. Historical flow data (1970 – 1972) only was available from B8H015, i.e. Little Letaba at Rossbach.

Due to similarities in land-use, this WQSU was combined with WQSU 13, but it is recommended that water quality monitoring be initiated in this area.

Water Quality Sub-Unit 13: Klein Letaba River downstream of the confluence with the Middel Letaba River to upstream of Giyani (upstream of weir before Elim road bridge crossing)

The main land-use is dense urban settlements (e.g. Giyani) and informal settlements (limited subsistence and cultivated agriculture, with livestock, occurs). A number of sewage works and waste disposal sites were noted in the area – expected water quality impacts are therefore related to sewage effluents in the river leading to eutrophication (SRK, 1989; Consultburo, 1998).
The water quality monitoring point used for determining the PES, B8H033Q01, was found in the upper section of the WQSU. A water quality sample was taken during the field trip of December 2003 (WQ Site 11 – Klein Letaba Old Mill Site). This is the site of an old abandoned gold mine in the area. An additional sample was taken in March 2004 (WQ Site 12 - Van De Knopneuzen on the Klein Letaba).

Trend of change
It is expected that water quality will remain relatively stable over the short-term (5 years) and long-term (20 years).

Data confidence
The following confidences were generated using G-Power.

pH	High
TIN	Low
SRP	Low
EC	Medium
F	Medium

<table>
<tr><td>River</td><td colspan="2">Klein Letaba River</td><td colspan="2">DWAF Water Quality Monitoring points</td></tr>
<tr><td>WQSU</td><td colspan="2">13</td><td>RC</td><td>No reference condition data</td></tr>
<tr><td>EWR Site</td><td colspan="2">5</td><td>PES</td><td>B8H033Q01 (1999 – 2003), n = 60
(Fluoride: n = 59)</td></tr>
<tr><td colspan="2">Water Quality Constituents</td><td colspan="2">Value</td><td>Category / Comment</td></tr>
<tr><td rowspan="6">Inorganic salts (mg/L)</td><td>$MgSO_4$</td><td colspan="2"></td><td>B</td></tr>
<tr><td>Na_2SO_4</td><td colspan="2"></td><td>A</td></tr>
<tr><td>$MgCl_2$</td><td colspan="2"></td><td>A</td></tr>
<tr><td>$CaCl_2$</td><td colspan="2"></td><td>A</td></tr>
<tr><td>NaCl</td><td colspan="2"></td><td>B</td></tr>
<tr><td>$CaSO_4$</td><td colspan="2"></td><td>A</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td colspan="2">0.025</td><td>B/C</td></tr>
<tr><td>TIN</td><td colspan="2">0.0645</td><td>A</td></tr>
<tr><td rowspan="4">Physical variables</td><td>pH (pH units)</td><td colspan="2">7.80 + 8.86</td><td>B/C</td></tr>
<tr><td>Temperature (° C)</td><td colspan="2">No data</td><td rowspan="2">No impacts expected.</td></tr>
<tr><td>Dissolved oxygen (mg/L)</td><td colspan="2">No data</td></tr>
<tr><td>Turbidity (NTU)</td><td colspan="2">Site 12: 409
(n=1, March 2004, at EWR 5)
Site 11: 0.05
(n = 1, Dec 2003, downstream of Site 12)</td><td>Very high value recorded at Site 12 with high flows (42 cumecs) – low confidence</td></tr>
<tr><td rowspan="4">Response variable</td><td>Chl-a: periphyton (mg/m^2)</td><td colspan="2">Not sampled.</td><td>High benthic algae at times of low flow (Angliss, pers. comm.)</td></tr>
<tr><td>Biotic community composition - macroinvertebrate (ASPT) score</td><td colspan="2">Hlaneki weir, ASPT: 5.5
Bends Scheme, ASPT: 6.5, 1999 survey

Bends Scheme, ASPT: 5.5, 2003 survey
(Angliss, 2004)</td><td>C/D (Hlaneki weir) – B (Bends Scheme)

C/D

D (EWR 5: flow-related)</td></tr>
<tr><td>Fish score</td><td colspan="2">Angliss + Fouche, Letaba Reserve study</td><td>C</td></tr>
<tr><td>In-stream toxicity</td><td colspan="2">Not sampled.</td><td>-</td></tr>
<tr><td>Toxics</td><td>Fluoride (µg/L)</td><td colspan="2">259</td><td>A</td></tr>
<tr><td colspan="2">Overall site classification</td><td colspan="3">B/C – C (flow dependent)</td></tr>
</table>

Water Quality Sub-Unit 14: Klein Letaba River downstream of Giyani weir at Elim road to upstream of confluence with the Groot Letaba River

The land-use is similar to that of WQSU 13. Expected water quality impacts relate to sewage effluent leading to eutrophication (SRK, 1989; Consultburo, 1998).

A water quality sample was taken during the field survey of December 2003 (WQ Site 9 - just north of Ka-Ngove). As this was the only data available for this section of the river, confidence in the assessment is very low and it is recommended that water quality monitoring be initiated.

Trend of change
A trend of change could not be calculated due to the limited data set (n=1).

Data confidence
Confidences could not be generated using G-Power as there was only 1 data set, therefore confidence is **low** for all variables.

<table>
<tr><td>River</td><td>Klein Letaba River</td><td colspan="3">DWAF Water Quality Monitoring points</td></tr>
<tr><td>WQSU</td><td>14</td><td>RC</td><td colspan="2">No reference condition data</td></tr>
<tr><td>EWR Site</td><td>-</td><td>PES</td><td colspan="2">Field survey data, WQ Site 9: n=1</td></tr>
<tr><td colspan="2">Water Quality Constituents</td><td colspan="2">Value</td><td>Category / Comment</td></tr>
<tr><td rowspan="6">Inorganic salts (mg/L)</td><td>$MgSO_4$</td><td colspan="2"></td><td>A</td></tr>
<tr><td>Na_2SO_4</td><td colspan="2"></td><td>A</td></tr>
<tr><td>$MgCl_2$</td><td colspan="2"></td><td>A</td></tr>
<tr><td>$CaCl_2$</td><td colspan="2"></td><td>A</td></tr>
<tr><td>NaCl</td><td colspan="2"></td><td>A</td></tr>
<tr><td>$CaSO_4$</td><td colspan="2"></td><td>A</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td colspan="2">0.182</td><td>B</td></tr>
<tr><td>TIN</td><td colspan="2">0.7</td><td>B</td></tr>
<tr><td rowspan="4">Physical variables</td><td>pH (pH units)</td><td colspan="2">8.875</td><td>B/C</td></tr>
<tr><td>Temperature (º C)</td><td colspan="2">No data</td><td rowspan="2">No impacts expected.</td></tr>
<tr><td>Dissolved oxygen (mg/L)</td><td colspan="2">No data</td></tr>
<tr><td>Turbidity (NTU)</td><td colspan="2">5.92
(n=1, Dec 2003)</td><td></td></tr>
<tr><td rowspan="3">Response variable</td><td>Chl-a: periphyton (mg/m^2)</td><td colspan="2">51.92</td><td>C/D
(only isolated pools available for sampling)</td></tr>
<tr><td>Biotic community composition - macroinvertebrate (ASPT) score</td><td colspan="2">Giyani-Elim road bridge, ASPT: 5.8
Kremetart Big Tree, ASPT: 5.94
Below Giyani STW, ASPT: 6.57,
1999 survey
(Angliss, 2004)</td><td>C – B (below STW)</td></tr>
<tr><td>In-stream toxicity</td><td colspan="2">Not sampled.</td><td>-</td></tr>
<tr><td>Toxics</td><td>Fluoride (µg/L)</td><td colspan="2">296</td><td>A</td></tr>
<tr><td colspan="2">Overall site classification</td><td colspan="3">B</td></tr>
</table>

- **MOLOTOTSI RIVER** (not defined as a RU of this study)

Water Quality Sub-Unit 15: Headwaters of the Molototsi River to upstream of the confluence with the Groot Letaba

The main land-use in the area is rural informal settlements e.g. Ka-Dzumeri (limited subsistence and cultivated agriculture, with livestock). The landscape is very dry. The headwater region of the Molototsi has some cultivated lands with formal settlements.

A water quality sample was taken in March 2004 (WQ Site 8 – east of Ka-Dzumeri). As this is the only data available for this section of the river, confidence in the assessment is very low and it is recommended that water quality monitoring be initiated.

Trend of change
A trend of change could not be calculated due to the limited data set (n=1).

Data confidence

The following confidences could not be generated using G-Power as there was only 1 data set, therefore confidence is **low** for all variables.

River	Molototsi River	**DWAF Water Quality Monitoring points**	
WQSU	15	**RC**	No reference condition data
EWR Site	**-**	**PES**	Field survey data. WQ Site 8: n=1
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		A
	Na_2SO_4		A
	$MgCl_2$		A
	$CaCl_2$		A
	NaCl		A
	$CaSO_4$		A
Nutrients (mg/L)	SRP	0.084	C/D
	TIN	0.088	A
Physical variables	pH (pH units)	7.33	A
	Temperature (º C)	No data	No impacts expected.
	Dissolved oxygen (mg/L)	No data	
	Turbidity (NTU)	1094 (n=1, March 2004)	Very high turbidity recorded – low confidence
Response variable	Chl-a: periphyton (mg/m^2)	Not sampled	-
	Biotic community composition - macroinvertebrate (ASPT) score	Giyani-Modjadji Bridge, ASPT: 5.8 Sekhiming Bridge, ASPT: 5.72 Dzumeri weir, ASPT: 5.7, 1999 survey (Angliss, 2004)	C
	In-stream toxicity	Not sampled	-
Toxics	Fluoride (µg/L)	219	A
Overall site classification			**B/C**

5. FLOW-CONCENTRATION MODELLING

The objective of this activity is to set up the tools required during the last step of the Ecological Reserve process, i.e. to assess the ecological consequences of various flow scenarios. The assessment of water quality conditions can be as simple as a qualitative statement based on expert judgement of the expected water quality behaviour under different flow regimes, or as complex as the application of a hydrodynamic river water quality model to simulate water quality changes under different flows. Malan and Day (2002a) reviewed a number of approaches for linking discharge, water quality and biotic responses in rivers. Their report described, in detail, two fairly simple approaches that could be used, namely a discharge-concentration modelling method and a time-series modelling method which is compatible with the flow-stressor response approach used in water quantity Reserve determinations. The selection of an assessment appropriate tool is a function of the confidence required by the client and the budget made available for this activity (DWAF, 2002).

Flow-concentration modelling was adopted for this study, and was used to provide information toward assessing water quality consequences of various flow scenarios. As limited flow-concentration modelling could be undertaken due to data constraints, additional sources of information were used to make predictions. These data and approaches are discussed in Section 6 of this report.

5.1 INTRODUCTION

Flow-concentration modeling is undertaken once all the relevant water quality data has been selected, manipulated and the PES assessment compiled. The results of the flow-concentration modeling provide input into determining both the water quality and overall ecological categories for the various flow scenarios as selected for evaluation by the hydrological and project management team.

In order for the flow-concentration modeling to be undertaken, the following must be provided by the water quality team:

- Monthly median values for each variable calculated over the same time period used for the PES and RC assessment (usually 3 or 5 years) at each EWR site.
- Sample size (n) and time period (e.g. 2000 – 2004)
- Variables required include:
    - TDS / Conductivity
    - salt ions (Na, SO_4, Cl, Mg etc.)
    - pH
    - nutrient variables
    - any constituents considered a potential water quality problem, e.g. fluoride

5.1.1 The need for water quality modelling

This section of the report describes the methods used and results obtained from water quality modelling carried out as part of the determination of the Ecological Reserve for the Letaba River system. The term *water quality modelling* is used to describe techniques employed to obtain quantitative predictions of what the concentration of chemical constituents in a given river reach would be under given conditions of flow (e.g. a proposed flow regime). The concentration of in-stream chemical constituents, as well as the values of physical variables, may vary significantly with changes in flow. In addition, aquatic biota respond not only to the hydraulic habitat and amount of water supplied, but also to the quality of that water. Thus it is important that the water quality conditions likely to occur under a proposed flow regime also be predicted and reported in a quantitative manner. This will ensure that in meeting the ecological Reserve with regard to *quantity* the water *quality* component of the Reserve is also attained.

5.1.2 Outline of the approach used

Water quality data for the Reference Condition (RC) and Present Ecological State (PES) at each EWR site were used to obtain flow-concentration relationships by plotting monthly median concentrations against monthly mean flow data and deriving the regression equation. These flow-concentration (Q-C) relationships were used to predict, for a given flow, what the expected in-stream concentration would be, and were used to set up a matrix of flows and associated predicted concentrations for identified water quality variables. The appropriate matrix was used to convert the flow time-series to a time-series of expected concentrations for different flow scenarios. From these time-series, concentration-exceedence curves were generated and the flow scenarios could then be compared with regard to the likely resultant changes in the concentrations of key water quality constituents.

5.2 METHODS AND DATA SOURCES USED

Water quality modelling was carried out in the following manner.

5.2.1 Flow-concentration modelling

Flow-concentration (Q-C) modelling was used to estimate the concentration of a particular chemical constituent that would be expected to occur in a river reach at a given flow. This technique is described in detail in Malan and Day (2002a, b) and Malan et al. (2003).

For each EWR site, present day (PES) water quality data was obtained from the nearest DWAF monitoring site. Reference Condition (RC) water quality was inferred from either historical data or from an un-impacted tributary using the procedure described in the Resource Directed Measures manual (DWAF, 1999). In order to satisfy the requirements for modelling the data need to be representative of the water quality at the EWR site under consideration, and consist of at least 60 data points collected during both the dry and wet seasons. Water quality data collected from a pipeline or from a dam are not suitable for use in modelling (Malan and Day, 2002a). Where possible, the data used for Q-C modelling were the same as those used in the water quality assessment (Section 4). Simulated flow data used in the water quantity determinations of the EWR as supplied by the hydrologist for the project, were also used. Monthly mean flows were calculated using data from the entire data-set.

Monthly mean flow values were correlated with median monthly concentration values for each water quality variable for which there were suitable data. Median water quality values were used since concentrations can range widely and a single extreme event can alter the mean significantly. It is therefore statistically correct to use median values. However, mean discharge values were used as is the convention in the field of hydrology. Correlation of concentration and flow values was carried out separately for the Reference Condition (i.e.

least impacted state) as well as for the Present Ecological State. The water quality constituents examined included EC (Electrical Conductivity), TP (Total Phosphorus), SRP (Soluble Reactive Phosphorus), and TIN (Total Inorganic Nitrogen). The selection of chemical constituents modelled depended on the availability of data at each site.

Graphs of concentration versus flow were plotted and a regression line drawn through the data points. The "best fit" was chosen by using the relationship (in Microsoft Excel) that yielded the highest value of the coefficient r^2. An r^2 value greater than or equal to 0.65 was used as the criterion for assessing the significance of the Q-C relationship. This value of 0.65 was chosen after consideration of the literature. Sites and variables for which the r^2 value was greater than 0.65 (and where concentration was inversely related to flow – Section 5.2.4) were used to make predictions of concentration under different flow regime. For each EWR site and for each recommended monthly flow, the median concentration and 95% confidence intervals of each chemical constituent could be predicted using the appropriate regression relationship.

The concentration of each water quality variable was predicted (where possible) for key months under the prescribed EWR base-flow regime. Predictions were made for base-flows, rather than total flow (which would include floods and any excess flow in the system). Therefore, in the case of EC and other chemical constituents which decrease in concentration with increased flow (Section 5.3.1), the predictions from Q-C modelling represent the *worst case scenario*.

5.2.2 Information that can be obtained using flow-concentration modelling

The following information can be obtained using flow-concentration (Q-C) modelling, depending on the availability and reliability of data at each EWR site:

- Flow-concentration relationships for the key water quality variables.
- Estimates of how many months of the year, under the proposed EWR base flow, the water quality Reserve would be attained with regard to the various water quality constituents (TDS, nutrients) as well as the likely assessment category (A, B, C etc.).
- In what month the worst water quality would be likely to occur and what concentrations could be expected.
- What flows, in the absence of pollution control, would be required to dilute pollutants in order to attain the water quality Reserve.

5.2.3 Production of concentration-exceedence curves

The software package TSOFT (Time Series Display and Analysis Software) (Hughes et al., 2000) was used to transform time-series of flow to time-series of concentration. This was carried out for each EWR site, and for each water quality variable where there was a good correlation between flow and concentration (r^2 = 0.65). The regression equation that had been derived at each site using Q-C modelling was used to convert time-series of flow to time-series of predicted concentration. A transformation matrix was set up such as that shown for electrical conductivity at EWR 2. This table shows, for given flow values, the corresponding predicted median EC value that could be expected under the current pollution loads. Because of the inherent inaccuracies in extrapolating to flows for which no observed EC values were available, the transformation matrix covered only up to the 1:10 year flood flows. Floods equal to or larger than this would be set at 11.05 mS/m, the corresponding EC value.

Additional justification for this step is the fact that EC levels decrease as flow is increased. Thus it is during periods of low flow, rather than during floods, that water quality problems resulting from high salinity are likely to occur.

EC was the most common water quality variable that was modelled in this way because it is a conservative water quality constituent and is often closely correlated with flow. In some cases, other constituents such as SRP that also showed a close relationship to flow, were also modelled.

A range of flow scenarios were examined, concentration-exceedence curves prepared and the consequent water quality implications assessed in Section 6. Flow scenarios were provided by the hydrologist of the project and were generated as part of an examination of the yield of the catchment. The flow time-series that were modelled were: natural flow, present-day flow, and flow scenarios 1, 2, 3, 4 and 6. Scenarios 5 and 7 were preliminary flow scenarios and not considered for ecological implications (Fsehazion, PD Naidoo & Associates, pers. com.). A description of the different flow scenarios considered was provided to the water quality team.

5.2.4 Production of summary statistics

The terms of reference for the Letaba Reserve study requires that median concentrations (where data permits) be predicted that will occur under each flow scenario. Summary statistics were therefore prepared by transforming flow values to concentration values (using the appropriate regression equation). Various statistics (e.g. the median, standard deviation etc) were calculated for each scenario in a spreadsheet package (EXCEL). Summary statistics were calculated for the entire time-series (under each scenario) as well as for the months of February and August, which represented wet and dry months respectively.

5.2.5 Assumptions and approximations in the approach

There are some important assumptions in the modelling method that need to be taken into account when interpreting the results.

- A low confidence is expressed in the quantitative predictions obtained using flow-concentration and time-series water quality modeling, as in-stream concentrations of chemical constituents are inherently variable and are affected by factors other than flow. The modelling method used is a very simple approach and is aimed at providing an *estimate* of predicted water quality.
- Use is made of monthly median values of concentrations and monthly average flow through which a trend-line is fitted. Unless there is measured water quality data for very low flows and very high flows, extrapolation to these conditions (as occurs when converting to concentration time-series) is likely to be inaccurate.
- It is important to note that all predictions of water quality made in this report are made under the assumption that the present loading of pollution will remain the same.
- Concentration exceedence (duration) curves can be used to compare and rank some of the water quality consequences that will arise from different flow scenarios. The results however are not sufficiently accurate to make exact quantitative predictions. Values given in this report are estimates.
- The water quality experienced by aquatic biota at a given site is composed of many different variables. The effect of altered flow on many of these variables (e.g.

dissolved oxygen, temperature) cannot be predicted using the simple modelling methods used in this project, and a way of combining the overall impact of the variables that can be predicted has not yet been developed.

- The modelling method is not suitable for chemical constituents that show an increase in concentration with increasing flow. This is because these pollutants often arise from diffuse sources in the surrounding catchment. It cannot automatically be assumed that if the flow in a river is decreased, the in-stream concentration of the pollutant will also decrease. This will depend on site-specific factors that require further investigation.

5.2.6 Water quality assessment categories

Modelling of individual salts was not carried out in this study because elevated salinity was generally not considered an issue. In the case of nutrients, the assessment method for the PES makes use of annual means (which may need to be benchmarked) whereas the modelling method uses monthly median values. This makes it difficult to compare the predicted category for TIN or SRP with the PES category.

The information provided in this section of the report (Section 5) was utilized by the water quality team at the scenario workshop to assess the consequences of manipulating flows (i.e. various flow scenarios) on water quality. These assessments are outlined in Section 6 of the report.

5.3 RESULTS

The water quality modelling results for the Letaba Reserve Determination Study are presented in the following manner. Firstly some general comments are given, followed by a description of the results for each individual EWR site. Some of the Q-C graphs and the exceedence curves that were obtained for EWR 2 are shown in the text as an illustration of the type of results that were obtained. For the rest of the sites the figures are given in the relevant appendices. This section of the report is completed with overall conclusions and comments.

5.3.1 General comments

Table 5.1 shows a summary of the DWAF monitoring stations that were used to provide water quality data used for modelling. Also shown is the time-period of data used and the extent of the water quality modelling that could be undertaken. There was no suitable monitoring station / adequate data for EWR 3 on the Groot Letaba River or EWR 7 on the Letaba River, and thus no flow-concentration modelling could be carried out for these sites. Suitable water quality data were available for EWR sites 1, 2, 4, 5 and 6 (although in the case of Site 5, not for the Reference Condition). Of the above five sites, time-series modelling could be carried out only at EWR Sites 2 and 6.

The Q-C plots for all EWR sites that could be modelled are shown in Appendix C, and the regression equations in Appendix D. As is to be expected from the dilution effect at high flows, and since EC is a conservative variable, EC decreased with increasing flow at all sites. Time-series modelling could only be carried out for this variable at EWR Sites 2 and 6. Total inorganic nitrogen (TIN) concentration was usually only weakly correlated with flow and thus in general the r^2 values obtained for this constituent were low, and no predictions of water quality could be made. The concentration of SRP either decreased with flow at some sites (e.g. EWR 2 – present day), showed little change with flow (e.g. EWR 2 – Reference Condition), or increased with flow (e.g. EWR 4 – present day). Predictions of SRP concentration could be made for this constituent only at EWR Site 2. At EWR Site 6, although the value of the regression coefficient r^2 for SRP was greater than 0.65, phosphate concentration increased with flow and therefore predictions could not be made using this modelling method. Increases in nutrients with increasing discharge have been attributed to the disturbance of benthic sediments at high flows, with the concomitant release of nutrients into the water column, as well as increased wash-off from banks during rainfall events (Malan and Day, 2002b).

Table 5.1: Sources of water quality data used for Q-C modelling in the Letaba system and the extent of modelling carried out at each site.

EWR Site	Water quality data	Comments	
	RC	PES	Comments – regression relationship
EWR 1 Groot Letaba River: upstream Tzaneen Dam	B8H014Q01 (1977 - 1979)	B8H014Q01 (1999 - 2004)	r^2 values for all variables <0.65. No time-series modelling done.
EWR 2 Letsitele River	B8H010Q01 (1975 – 1978)*	B8H010Q01 (1999 – 2004)*	Time-series modelling done for **EC** (PES and RC). Time-series modelling done for **SRP** (PES), but not for RC (concentration increased with flow).
EWR 3 Groot Letaba River at Die Eiland	-	-	No suitable water quality monitoring site. No Q-C or time-series modelling possible.
EWR 4 Letaba River at Letaba Ranch (downstream Molototsi, + upstream Klein Letaba confluence)	B8H008Q01 (1977 – 1979)*	B8H008Q01 (1999 – 2004)*	r^2 value > 0.65 obtained only for SRP at this site, but concentration increased with flow. Therefore no time-series modelling carried out.
EWR 5 Klein Letaba River (downstream confluence with Middel Letaba)	-	B8H033Q01 (1999 - 2003)	No reference condition data. Low r^2 values. No time-series modelling done.
EWR 6 Letaba River at Lonely Bull in the KNP	B8H028Q01* (1983 - 1987)	B8H028Q01* (2000 - 2004)	Time-series modelling done for **EC** only.
EWR 7 Letaba River below Letaba bridge in the KNP	-	-	No suitable water quality monitoring site. No Q-C or time-series modelling possible.

**Indicates that water quality data from a different time-period or DWAF monitoring station was used than in the Water Quality Assessment.*

Flow-concentration transformation matrices used to prepare concentration time-series are shown in Appendix E. The concentration-exceedence curves are shown under the results for each individual EWR site. In general, it was found that the flow scenarios that represented the lowest volumes were also predicted to exhibit the worst water quality (i.e. highest concentrations of SRP, TIN or highest values of EC).

5.3.2 Flow-concentration modelling results for individual EWR sites

EWR 1 (Appel on Groot Letaba River)

Flow-concentration relationships
Median monthly water quality data for the RC and PES used for modelling were derived from station B8H014Q01 (time period 1977-1979 and 1999-2003 respectively). This monitoring station is just upstream of the EWR site and thus should be representative of the water quality at the site. Flow-concentration plots were prepared for EC, TIN, SRP and TP (Appendix C). Electrical conductivity decreased with flow at this site (both for the RC and the PES), however, the regression coefficient was not high enough for further modelling to be carried out. Total inorganic nitrogen was found to decrease slightly with flow in the Reference Condition, but was largely independent of flow under present day conditions. Both SRP and TP decreased with flow under natural conditions but increase with flow under PES conditions. No time-series modelling could be carried out for this site.

EWR 2 (Letsitele Tank on Letsitele River)

Flow-concentration relationships
The data source used for water quality modelling at this site was B8H010Q01. This monitoring station is immediately upstream of the EWR site and therefore should be a good indicator of the water quality in the reach. For the assessment of water quality for the site (Section 4) the data period 2000-2004 was used. When these data were used for Q-C modeling, poor correlations were obtained for all water quality variables with flow. The time period was then extended slightly (1999-2004) to increase the number of data points and the data remodelled. Good r^2 values (i.e. = 0.65) were obtained for electrical conductivity and for SRP. The Q-C plot for electrical conductivity (EC) is shown in Figure 5.1. It can be seen that the PES concentration of EC is only slightly higher than that expected under natural conditions.

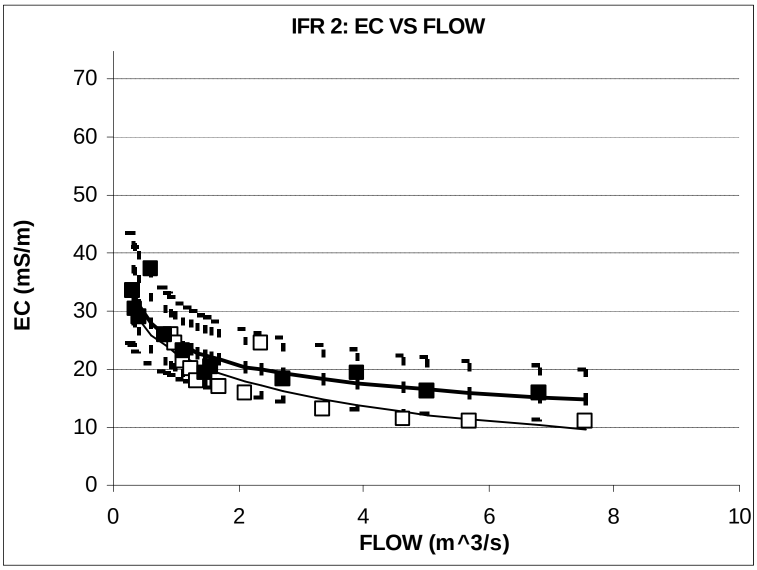


Figure 5.1: Q-C plot for EC at EWR 2. The Reference Condition (RC) □ and the Present Ecological State (PES) ■ are shown, as well as the regression lines through the points. The 95% confidence interval for the PES is shown as dotted lines.

Both EC and SRP decreased with flow (Appendix C) and the equations describing the relationships were used to make predictions of concentrations under the different flow scenarios.

Time-series modelling
A matrix of flow and corresponding electrical conductivity was prepared for the RC and for the PES (using the appropriate regression equations). The matrix for EC in the PES is shown in Table 5.2 as an example. The full set of matrices used in TSOFT for all sites and water quality variables is given in Appendix E. The flow range that was used to prepare the matrices was chosen after consideration of the flow time-series. The maximum flow corresponds roughly to the 1:10 year flood flow.

Table 5.2: Transformation matrix used to convert flow (m^3/s) to electrical conductivity (mS/m) for the PES at EWR 2.

Flow	EC	Flow	EC
0.01	78.11	13	13.01
1	24.70	14	12.77
2	20.77	15	12.55
3	18.77	17	12.16
5	16.52	18	11.99
6	15.78	20	11.68
8	14.69	21	11.54
9	14.26	22	11.40
10	13.89	24	11.16
11	13.56	25	11.05

Electrical conductivity (EC)
Exceedence curves of electrical conductivity values expected under the different flow scenarios are shown in Figure 5.2. The black line shows expected EC under natural (or reference) conditions. The expected EC conditions under present day flow (blue) appear to be slightly worse (i.e. EC values are higher) than under the other flow scenarios. There is very little difference between the other scenarios.

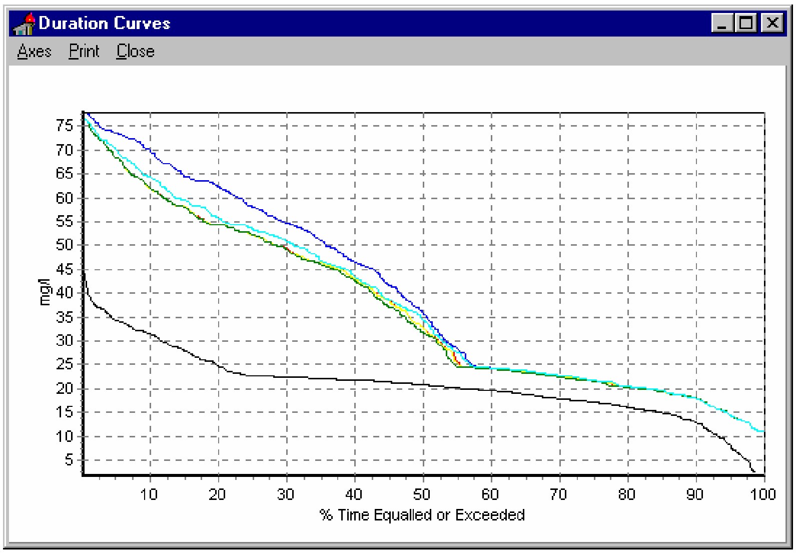


Figure 5.2: Exceedence curves for EC at EWR 2: Black = natural flow, blue = present day flow, red = scenario 1, yellow = scenario 2, green = scenario 3, pink = scenario 4, turquoise = scenario 6.

The summary statistics calculated for electrical conductivity (EC) at EWR 2 under the different flow regimes are shown in Table 5.3. The results confirm those obtained from preparation of exceedence curves using TSOFT, namely that under the different scenarios there is likely to be little marked difference in EC. The lowest EC values occur under the RC and the highest values under the present state. Periods of no-flow occur under present-day conditions and would not be conducive to improved water quality. The highest EC values would be expected during the driest period of the year (winter). Even in August, however, there is little difference between the scenarios, and these differences are not considered to be statistically significant.

Table 5.3: Summary statistics for predicted electrical conductivity (mS/m) values at EWR 2. Values are calculated for the entire time period and for February or August only.

ENTIRE YEAR	PRESENT	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 6	NATURAL
Median	25.91	25.53	25.52	25.47	25.75	25.75	20.39
95%ILE	46.91	37.46	37.46	37.46	38.94	38.94	25.93
SD	18.87	6.96	6.96	6.97	7.29	7.29	5.35
FEBRUARY ONLY	**PRESENT**	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**	**SCENARIO 4**	**SCENARIO 6**	**NATURAL**
Median	20.05	19.75	19.81	19.17	20.05	20.05	15.49
95%ILE	29.20	28.06	28.06	27.47	29.20	29.20	23.36
SD	5.89	5.51	5.51	5.29	5.89	5.89	7.22
AUGUST ONLY	**PRESENT**	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**	**SCENARIO 4**	**SCENARIO 6**	**NATURAL**
Median	31.42	29.24	29.24	29.24	29.24	29.24	22.13
95%ILE	138.90	40.86	40.86	40.86	40.86	40.86	26.35
SD	30.02	6.24	6.24	6.24	6.24	6.24	2.16

Soluble Reactive Phosphorus (SRP)

Exceedence curves of SRP concentrations expected under the different flow scenarios are shown in Figure 5.3. The expected SRP conditions under present day flow (black) appear to be slightly worse (i.e. concentrations are higher) than under the other flow scenarios. However, the concentration of SRP under all other flow scenarios are not likely to differ significantly.

The summary statistics for SRP under the different scenarios are shown in Table 5.4. Similar results can be seen as for EC in that best water quality conditions are expected under the RC. There is very little difference in the predicted water quality under the different scenarios, either when considered during the whole year, or during August when discharge is low.

Table 5.4: Summary statistics for predicted SRP concentrations (mg/L) values at EWR 2. Values were calculated for the entire time period and for February or August only.

	PRESENT	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 6	NATURAL
ENTIRE YEAR							
Median	0.13	0.13	0.13	0.13	0.13	0.13	0.01
95%ILE	0.48	0.30	0.30	0.30	0.32	0.32	0.02
SD	0.73	0.09	0.09	0.09	0.10	0.10	0.00
FEBRUARY ONLY							
Median	0.08	0.07	0.07	0.07	0.08	0.08	0.01
95%ILE	0.17	0.16	0.16	0.15	0.17	0.17	0.02
SD	0.05	0.04	0.04	0.04	0.05	0.05	0.00
AUGUST ONLY							
Median	0.20	0.17	0.17	0.17	0.17	0.17	0.01
95%ILE	5.00	0.36	0.36	0.36	0.36	0.36	0.01
SD	1.30	0.11	0.11	0.11	0.11	0.11	0.00

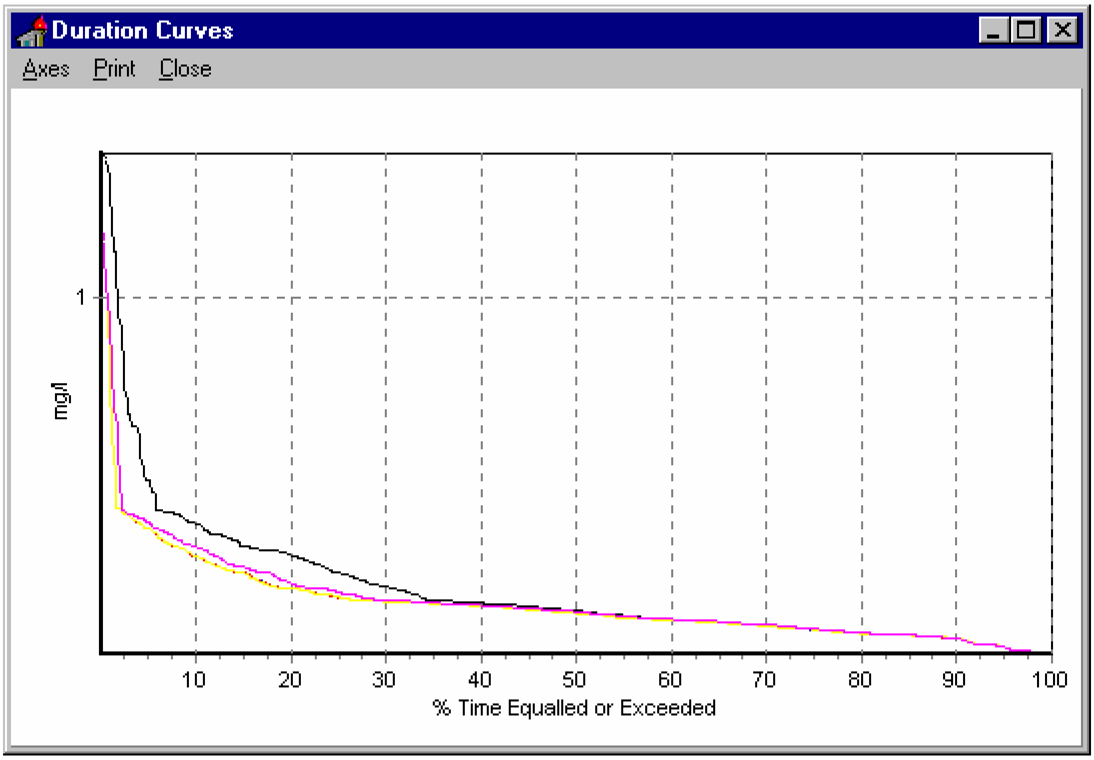


Figure 5.3: Exceedence curves for SRP at EWR 2: Black = present day flow, blue = scenario 1, red = scenario 2, yellow = scenario 3, green = scenario 4, pink = scenario 6.

EWR 3 (Die Eiland on the Groot Letaba River)

There was no DWAF water quality monitoring station that could be used for modelling of water quality data for this site. B8H017Q01 is close to the site but only a few samples have been collected that could be used to infer the PES (n = 15). B8H026Q01 has data only for a limited time-period. The monitoring stations B8H009Q01 and B8H025Q01 were also considered but these are upstream of the EWR site, with two tributaries entering the Groot Letaba River in between. Thus the water quality at these sites would not be representative of that at the EWR site.

EWR 4 (Letaba Ranch on the Groot Letaba River)

To infer the water quality at this site, the DWAF monitoring station B8H008Q01 was used. A slightly longer time-period was used for the Q-C modelling for the Reference Condition and the PES than was used in the assessment of water quality (Section 4). The reason for this was because the r^2 values obtained for all water quality variables were less than 0.65. An examination of the trend in water quality at the site with time indicated that it had not changed within the last six years or so, and thus data from the time period 1999-2004 (rather than 2000 -2004) was used. Despite this larger sample size the r^2 values were not improved substantially (Appendix D). Although SRP concentration was highly correlated with flow (r^2 = 0.746), concentration increases with flow. As this modelling method is not appropriate for predicting concentration where there is a positive relationship (Malan et al., 2003), no time-series modeling could be done for this site.

EWR 5 (Klein Letaba River)

To infer the water quality at this site, the DWAF monitoring station B8H033Q01 was used. This station is just upstream and should be representative of the water quality of EWR Site 5, however, no data were available to represent the Reference Condition at this site. As for the previous site, the r^2 values obtained for all water quality variables were less than 0.65. Collection of water quality data from B8H033Q01 by DWAF has been sporadic and increasing the time-period of data used would not have increased the sample size to any noticeable extent. Thus further time-series modeling could not be undertaken at this site.

EWR 6 (Lonely Bull on the Letaba River, Kruger National Park)

Flow-concentration relationships
The monitoring station B8H028Q01 was used as the data source for EWR 6 to infer both the RC and the PES. The Q-C plots for all water quality variables modelled at this site are shown in Appendix C. In general there was little difference between water quality for the RC and the PES for EC and SRP. For TIN the median monthly values calculated for the RC were higher than for the PES. It is therefore possible that the RC data (1983 – 1987) do not represent least-impacted conditions and that there has been an improvement in water quality since the above period (at least with regard to TIN). For this reason the RC for TIN was not modelled. Electrical conductivity for both the RC and the PES decreased with flow. A strong relationship between EC and flow was found at this site ($r^2 = 0.694$) and was used to make predictions of water quality under different flow scenarios. Neither of the nutrients satisfied the criteria and could be used for time-series modeling.

Time-series modelling
The exceedence curves for EC under the different proposed flow regimes are shown in Figure 5.4. The lowest EC would occur, as is to be expected, under the RC (black line). The worst water quality (highest EC) is predicted to occur under present day conditions (blue line), when under low flow conditions EC is likely to be above 80 mS/m thirty percent of the time. Under the other flow regimes EC above 80 mS/m is only likely to occur occasionally. Of the flow scenarios that were proposed, Scenario 3 (green line) appears to result in the best water quality.

The above results are supported by the summary statistics. Considering the entire time-series, a median EC of approximately 70 mS/m could be expected under present-day conditions (62 mS/m) under Scenario 3. It is during the driest months, however, that the most noticeable difference in EC can be predicted. Predicted EC in August (Table 5.5) is approximately 87 mS/m whereas under Scenario 3 it is 64 mS/m. Scenarios 1, 2, 4 and 6 do not differ greatly and because of the inherent error in predicting water quality, the differences are not considered to be statistically significant.

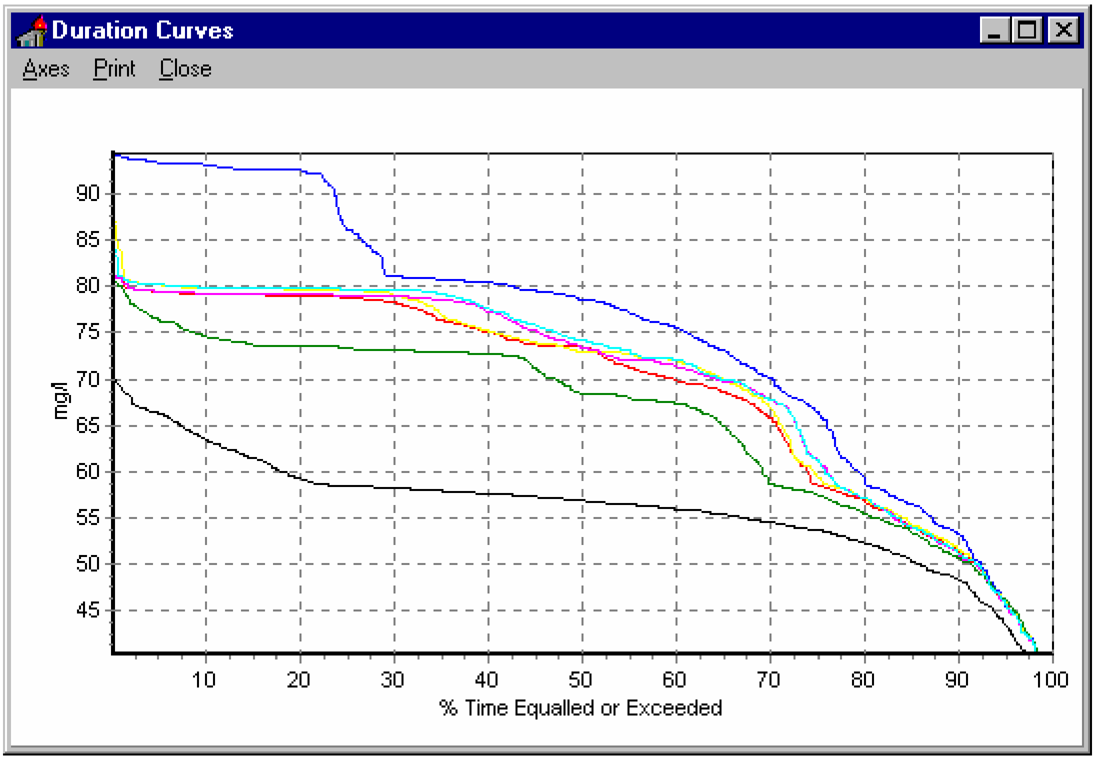


Figure 5.4: Exceedence curves for electrical conductivity at EWR 6: Black = natural flow, blue = present day flow, red = scenario 1, yellow = scenario 2, green = scenario 3, pink = scenario 4, turquoise = scenario 6.

Table 5.5: Summary statistics for predicted EC values (mS/m) values at EWR 6. Values were calculated for the entire time period and for February or August only.

ENTIRE YEAR	**PRESENT**	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**	**SCENARIO 4**	**SCENARIO 6**	**NATURAL**
Median	70.1	64.4	64.2	61.8	64.4	64.9	59.8
95%ILE	91.2	72.1	74.5	67.0	72.2	74.5	92.3
SD	14.5	8.5	9.1	6.8	8.8	9.5	21.5
FEBRUARY ONLY	**PRESENT**	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**	**SCENARIO 4**	**SCENARIO 6**	**NATURAL**
Median	57.3	51.1	51.3	50.9	50.8	51.0	34.5
95%ILE	75.2	57.8	58.0	59.0	56.4	56.6	67.0
SD	12.7	6.3	6.4	6.3	6.0	6.2	20.2
AUGUST ONLY	**PRESENT**	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**	**SCENARIO 4**	**SCENARIO 6**	**NATURAL**
Median	87.1	71.2	72.9	64.4	71.2	72.9	70.9
95%ILE	91.8	72.5	74.3	67.2	72.1	73.9	89.0
SD	7.4	1.7	1.8	1.7	1.3	1.4	9.8

5.4 CONCLUSIONS AND RECOMMENDATIONS

An important principle that needs to be remembered when considering water quality and the Ecological Water Requirements process is that the environmental flows that are recommended should be those that satisfy the requirements of the aquatic biota with regard to hydraulic habitat. Flows should not be recommended because they are required to dilute pollutants to a level acceptable to the biota. If they are, it should be stated clearly that this is a management decision and that the “extra” water required for dilution is not part of the Ecological Reserve.

Only at two sites was a strong enough correlation between concentration and flow present for selected variables for time-series modelling to be carried out. The results from this modelling show that at EWR 2 there is likely to be very little difference with regard to water quality between the scenarios. At EWR 6, however, implementation of Scenario 3 is likely to lead to improved water quality compared to present day, and is therefore the best of the recommended flow scenarios modelled.

6 WATER QUALITY CONSEQUENCES OF OPERATIONAL FLOW SCENARIOS

6.1 INTRODUCTION

Sections 5 and 6 of this report, i.e. flow-concentration modelling and the assessment of water quality consequences of operational flow scenarios, represent the steps of the EWR or Ecological Reserve process where the integration of water quality and quantity takes place. Flow-concentration modelling provides quantitative information to make predictions of water quality consequences. If lacking or minimal data can be modelled (such as in this study), qualitative predictions are made from available data and linking flow-duration curves (Appendix F) to knowledge of water quality conditions. An assessment is therefore made of how water quality conditions may change under selected flow scenarios.

As the Ecoclassification approach was in use by the time of the Letaba scenario workshop in May 2005, the ratings tables in the Physico-Chemical Driver Assessment Index section of the Kleynhans et al. (2005) report were used extensively. These tables are a further development of the benchmark tables presented in the water quality methods manual, and provide a direct link between the A-F water quality categories, boundary values or qualitative descriptions (e.g. for turbidity) per water quality variable, a description of deviation from RC and a PES rating of 0-5.

The integration between quality and quantity that occurs at this stage therefore provides the decision-maker with information on in-stream water quality conditions under a variety of operational flow scenarios. These operational scenarios account for operational constraints in the catchment, and normally include the recommended EWR. The decision-maker will then be in a position to determine whether quality source controls and/or dilution are required as part of water quality management to achieve the resource quality objectives.

6.2 APPROACH

The following approach was adopted by the water quality team during this phase:

- Limited flow-concentration modelling (Q-C) was available due to the lack of appropriate data and relationships between water quality variables and flow (Section 5 of this report).
- Flow-duration curves were provided to the water quality team. An example is shown in Figure 6.1 below. Further examples are shown in Appendix F. An explanation for the key to the figures is shown in Table 6.1.
- The water quality assessment conducted for the EWR sites (see PES tables in Section 4 of this report) was related to the 'Present (Day)' scenario (see Figure 6.1 and Table 6.1). This scenario was therefore used as the water quality baseline and conditions under all other scenarios compared to this assessment.
- Monthly flow-duration curves and ratings tables in Kleynhans et al. (2005) were used to provide qualitative water quality assessments under various flow scenarios at EWR sites where Q-C modelling could not be conducted. The rating tables shown in the text below therefore present an updated PES assessment of water quality conditions per EWR site using the Ecoclassification approach.

Note rank and %wt values on the ratings tables per variable and per EWR site. The importance and rating of these variables are dependent on river and river reach as different reaches of a river have different characteristics.

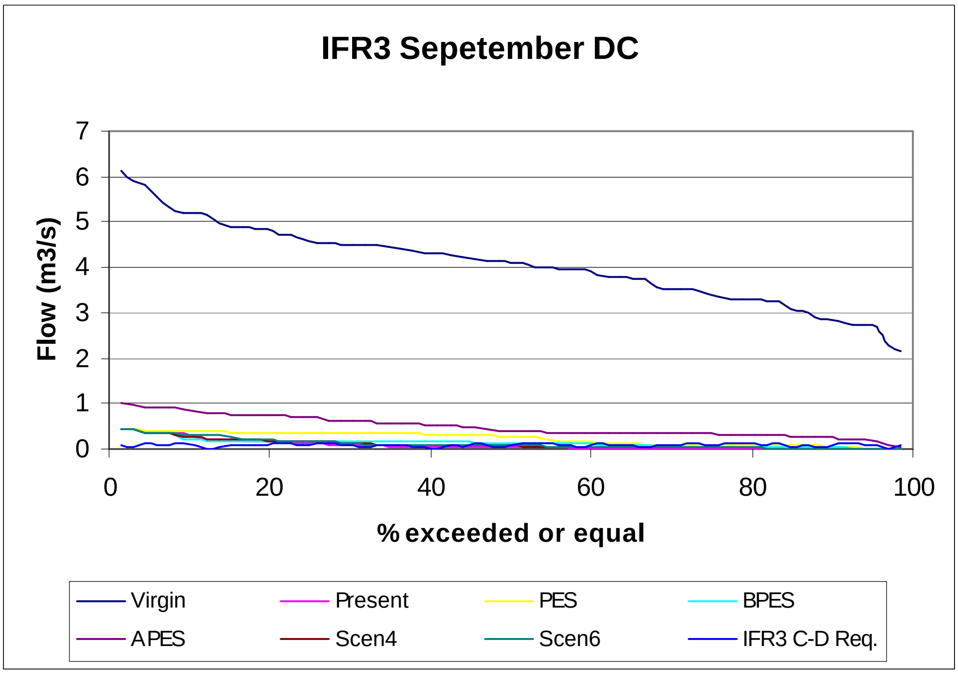


Figure 6.1: An example of a flow-duration curve provided to the water quality team by the project hydrologist.

Table 6.1: Descriptions of scenarios listed on flow-duration curves. The left column refers to the key on the graph, while the column on the right lists the interpretation of the description for purposes of evaluating flows and water quality implications.

Key on flow-duration curves	Description
Virgin	Natural / RC
Present	Present Day (i.e. the scenario without releases from dams e.g. no KNP allocation from Tzaneen Dam), but includes flood flows). This is the curve used as the baseline for the water quality PES assessment (although not the exact flows related to the present day hydrological record).
PES	Sc1
BPES	Sc2 Supply, i.e. a category below PES
Sc4	Sc4
Sc6	Sc6
IFR X Req.	Flow required to maintain the REC or ecostatus. Evaluation not required.

6.3 RESULTS

The results are presented per EWR site.

6.3.1 EWR 1 (Appel on Groot Letaba River)

<u>*Synopsis of assessment and available data*</u>
A present state water quality assessment was conducted for the upper stretch of the Groot Letaba River (WQSU 2) using data from B8H014Q01. Flow-concentration modelling was not conducted for this site. High and low flow duration curves were used to assess the various scenarios.

<u>Rating table</u>

Scenario: Present

SCORING GUIDELINES	EWR1	Scenario: Present					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.00	0.07	0.00		
SALTS	2	95	0.00	0.17	0.00		
NUTRIENTS	2	95	2.00	0.17	0.35		
TEMPERATURE	3	85	1.00	0.15	0.15		
TURBIDITY	4	50	1.00	0.09	0.09		
OXYGEN	3	85	1.00	0.15	0.15		
TOXICS	1	100	0.00	0.18	0.00		
TOTALS		550			0.75		
PHYSICO-CHEMICAL PERCENTAGE SCORE					85.09		
PHYSICO-CHEMICAL CATEGORY					B		

<u>*Description of flow and water quality conditions*</u>
All required flows are provided at the EWR site due to releases (also rainfall and spillages) from Ebenezer Dam, and there is no motivation to evaluate or request other flow scenarios. Low flows predominate downstream of the EWR site to Tzaneen Dam (about 10 kms) for most of the year due to irrigation abstractions and off-take for Tzaneen from Appel weir. Sub-surface flows and pools (near weirs) exist for some of the time.

An evaluation of water quality conditions under ‘Present (Day)’ and operational flow scenarios was conducted. Flow-duration curves were similar for the majority of the time. The ‘Present (Day)’ flows were marginally better from July - November, except for September (critical high flow month) where the ‘Present Day’ flow was lower than all other scenarios. During the critical low flow month (February) all scenarios were similar, except for Scenario 2, which was marginally higher for 70% of the time. In order to assess water quality, low flow curves were consulted to determine potential issues arising.

Potential water quality issues

Analysis of data, flow-duration curves and consultation with other specialists suggest the following potential water quality issues[1] at EWR 1:

- Nutrient elevation, particularly periphyton.
- Potential increases in oxygen, turbidity and temperature, which will be impacted more during low flows, although the conditions at Appel are relatively fast-flowing for most of the year.
- SRP may increase during high flows due to wash-off etc.

Impacts relate to the site being downstream of the Ebenezer Dam. However, the upstream section of river is considered to be in a relatively good state.

Water quality changes under operational flow scenarios

It is anticipated that water quality conditions will stay stable (i.e. as at present state) under all flow scenarios evaluated.

6.3.2 EWR 2 (Letsitele Tank on the Letsitele River)

Synopsis of assessment and available data

A present state water quality assessment was conducted for the Letsitele River (WQSU 8 and 9) using data from B8H010Q01. Flow-concentration modelling was conducted for EC and SRP. High and low flow duration curves were used to assess the various scenarios.

Rating tables

Due to the similarity in flow scenarios, scenarios were evaluated according to the following groupings.

Scenario: Present

SCORING GUIDELINES		EWR2	Scenario: Present				
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	3.00	0.17	0.51		
TEMPERATURE	3	85	2.00	0.15	0.30		
TURBIDITY	4	50	3.00	0.09	0.27		
OXYGEN	2	95	2.00	0.17	0.34		
TOXICS	1	100	0.50	0.18	0.09		
TOTALS		560			1.63		
PHYSICO-CHEMICAL PERCENTAGE SCORE					67.41		
PHYSICO-CHEMICAL CATEGORY					C		

[1] Potential issues provide motivation for rating scores.

Scenario: Sc6

SCORING GUIDELINES		EWR2	Scenario: Sc6				
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	2.50	0.17	0.42		
TEMPERATURE	3	85	1.50	0.15	0.23		
TURBIDITY	4	50	2.50	0.09	0.22		
OXYGEN	2	95	1.50	0.17	0.25		
TOXICS	1	100	0.50	0.18	0.09		
TOTALS		560			1.34		
PHYSICO-CHEMICAL PERCENTAGE SCORE					73.21		
PHYSICO-CHEMICAL CATEGORY					C		

<u>Description of flow and water quality conditions</u>
'Present (Day)' and Scenario 6 were evaluated against each other. As no dams or constraints exist within the system, only 'Present (Day)' flows and the most suitable requirements to be placed on the system were evaluated. Conditions would be expected to improve (60-80% of the time) under Scenario 6 during low flows (August – November).

<u>Potential water quality issues</u>
Analysis of data, flow-duration curves, time-series modelling and consultation with other specialists suggest the following potential water quality issues at EWR 3:

- Increased SRP with increased flow due to wash-off etc.
- Increased periphyton with decreased flow, which will also result in increased turbidity.

Based on the PES assessment for water quality (Section 4) and the time-series modeling (Section 5), EC and SRP are not expected to change with the different scenarios.

However, due to low flows much of the year, temperature and oxygen impacts are anticipated. Abstraction for agricultural purposes and solid waste pollution occurs. An improvement in a number of variables (e.g. periphyton and therefore overall nutrient status) was noted under Scenario 6 during the low flow period.

<u>Water quality changes under operational flow scenarios</u>
Water quality ratings are therefore considered higher (i.e. poorer) for 'Present (Day)' when compared to Sc6. However, the overall water quality category remains a C for both scenarios evaluated (Sc6 = 73.21% and 'Present (Day)' = 67.41%).

6.3.3 EWR 3 (Die Eiland on the Groot Letaba River)

Synopsis of assessment and available data
A present state water quality assessment was conducted for the Groot Letaba River (WQSU 4) using data from B8H009Q01. Flow-concentration modelling was not conducted for this site. High and low flow duration curves were used to assess the various scenarios. PES/Sc1 and Sc2 were evaluated against Sc4 (=Sc6) and 'Present (Day)', as can be seen by the groupings of the rating tables.

Description of flow and water quality conditions
Flow-duration curves were assessed to determine differences between the scenarios and water quality consequences. Flows were higher from Oct – Dec for Sc1 and Sc2, whilst Sc1 flows are higher than the other scenarios from Feb - March. From July - April the flows were comparable.

Potential water quality issues
Available data, flow-duration curves and consultation with other specialists suggest the following potential water quality issues at EWR 2:

- Increased SRP with increased flow due to wash-off etc.
- Increased periphyton with decreased flow, therefore modifying the nutrient status.
- Increased toxics with low flows.

Although no data was available for assessing temperature, a high impact is expected as low flows occur for approximately 4 months of the year and the river substrate is largely bedrock with little subsurface flow to provide cooling (Angliss, Letaba study invertebrate specialist, pers. comm.).

No data was available for turbidity. Although related to input from turbid tributaries, high turbidities are temporary. In-stream toxicity tests were conducted in which evidence of acute sub-lethal toxicity was identified – resulting in a high score for toxics. The use of biocides in the system was determined with the use of a short biocide survey – see Appendix G.

Rating tables

Scenario: Present, Sc4, Sc6

SCORING GUIDELINES	EWR3	Scenario: Present, Sc4, Sc6					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	4	40	0.00	0.07	0.00		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	2.00	0.17	0.33		
TEMPERATURE	2	95	2.00	0.17	0.33		
TURBIDITY	3	50	1.00	0.09	0.09		
OXYGEN	2	95	2.00	0.17	0.33		
TOXICS	1	100	3.00	0.18	0.53		
TOTALS		570			1.70		
PHYSICO-CHEMICAL PERCENTAGE SCORE					66.05		
PHYSICO-CHEMICAL CATEGORY					C		

Scenario: Sc1, Sc2

SCORING GUIDELINES	EWR3	Scenario: Sc1, Sc2					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	4	40	0.00	0.07	0.00		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	2.50	0.17	0.42		
TEMPERATURE	2	95	1.50	0.17	0.25		
TURBIDITY	3	50	1.00	0.09	0.09		
OXYGEN	2	95	1.50	0.17	0.25		
TOXICS	1	100	3.00	0.18	0.53		
TOTALS		570			1.61		
PHYSICO-CHEMICAL PERCENTAGE SCORE					67.72		
PHYSICO-CHEMICAL CATEGORY					C		

Water quality changes under operational flow scenarios

The physico-chemical percentage score was 67.72% for PES/Sc1 and Sc2, and 66.05% for Sc4 (=Sc6) and ‘Present (Day)’. Both these assessment represent a ‘C Category’, indicating that water quality is not expected to change significantly under any flow scenario.

6.3.4 EWR 4 (Letaba Ranch on the Groot Letaba River)

Synopsis of assessment and available data

A present state water quality assessment was conducted for the Groot Letaba River (WQSU 6) using data from B8H008Q01. Flow-concentration modelling was not conducted for this site. High and low flow duration curves were used to assess the various scenarios.

Rating tables

Scenario: Present

SCORING GUIDELINES	EWR4	Scenario: Present					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	4	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	2.00	0.17	0.33		
TEMPERATURE	2	95	3.00	0.17	0.50		
TURBIDITY	3	50	2.00	0.09	0.18		
OXYGEN	2	95	3.00	0.17	0.50		
TOXICS	1	100	1.50	0.18	0.26		
TOTALS		570			1.89		
PHYSICO-CHEMICAL PERCENTAGE SCORE					62.19		
PHYSICO-CHEMICAL CATEGORY					C		

Scenarios: PES/Sc1, Sc2

SCORING GUIDELINES	EWR4	Scenarios PES/Sc1, Sc2					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	4	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	1.00	0.17	0.17		
TEMPERATURE	2	95	2.00	0.17	0.33		
TURBIDITY	3	50	2.00	0.09	0.18		
OXYGEN	2	95	2.00	0.17	0.33		
TOXICS	1	100	0.50	0.18	0.09		
TOTALS		570			1.21		
PHYSICO-CHEMICAL PERCENTAGE SCORE					75.70		
PHYSICO-CHEMICAL CATEGORY					C		

Scenarios: Sc4, Sc6

SCORING GUIDELINES	EWR4	Scenarios Sc4, Sc6					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	4	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.08		
NUTRIENTS	2	95	1.50	0.17	0.25		
TEMPERATURE	2	95	2.50	0.17	0.42		
TURBIDITY	3	50	2.00	0.09	0.18		
OXYGEN	2	95	2.50	0.17	0.42		
TOXICS	1	100	1.00	0.18	0.18		
TOTALS		570			1.55		
PHYSICO-CHEMICAL PERCENTAGE SCORE					68.95		
PHYSICO-CHEMICAL CATEGORY					C		

Description of flow and water quality conditions

As can be seen from the grouping of the rating tables, ‘Present (Day)’ was evaluated against PES/Sc1 and Sc2, and Sc4 and Sc6. In terms of water quality, Sc1=Sc2 and Sc4=Sc6. The main difference between Sc1 and Sc4 is therefore decreased stress or increased flow between drought and maintenance flows. The ‘Present (Day)’ flows were significantly lower than the other scenarios for 60% of the time during high flows. During the low flows the various scenarios were comparable.

Potential water quality issues

Analysis of data, flow-duration curves and consultation with other specialists suggest the following potential water quality issues at EWR 4:

- Nutrient status. Increased flows will increase the SRP concentration.
- Toxics may be a problem due to wash-off from the agricultural area upstream (namely herbicides or pesticides).
- Temperature and oxygen variations at low flows

Large variations in oxygen and temperature are noted during low flows. Although turbidity increases are partly natural due to input from the Klein Letaba and Molototsi rivers, which are sandy-bed rivers, conditions are exacerbated compared to the natural state. Toxics are evident due to agricultural activities along the Groot Letaba River.

Water quality changes under operational flow scenarios

The overall category for the scenarios compared remain within a ‘Category C’, although water quality conditions were improved under Sc1 and 2 (75.70%), and Sc4 and Sc6 (68.95%), as compared to ‘Present (Day)’ (62.19%).

6.3.5 EWR 5 (Klein Letaba River)

Synopsis of assessment and available data
A present state water quality assessment was conducted for the Klein Letaba River (WQSU 13) using data from B8H033Q01. Flow-concentration modelling was not conducted for this site. High and low flow duration curves were used to assess the various scenarios.

Rating table

Scenarios: PES/Sc1, Sc2, Sc4, Sc6, Present

SCORING GUIDELINES		EWR5	Scenarios PES/Sc1, Sc2, Sc4, Sc6, Present				
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.09		
NUTRIENTS	2	95	2.50	0.17	0.43		
TEMPERATURE	3	85	1.00	0.15	0.15		
TURBIDITY	4	50	1.50	0.09	0.14		
OXYGEN	3	85	1.00	0.15	0.15		
TOXICS	1	100	0.00	0.18	0.00		
TOTALS		550			1.00		
PHYSICO-CHEMICAL PERCENTAGE SCORE					80.00		
PHYSICO-CHEMICAL CATEGORY					B (B/C)		

Description of flow and water quality conditions
The assessment indicated that Sc 1, Sc2, Sc6 and ‘Present (Day)’ should be evaluated against Sc4. Although ‘Present (Day)’ flows are frequently dissimilar to other scenarios, specifically in February and March, no regular pattern could be distinguished to separate this scenario from the others in terms of water quality. All scenarios were therefore evaluated together.

The scenarios do not show any consistent pattern over time, which is probably due to the use of generated data, as well as inconsistent flows in the Klein Letaba River and a dependence on flood events. Water is stored after flood events / rainfall, therefore few no-flow events occur. In addition, no spillages from Middel Letaba Dam are provided or managed for.

Potential water quality issues
Analysis of data, flow-duration curves and consultation with other specialists suggest the following potential water quality issues at EWR 5:

- Periphyton during low flows (Angliss, Letaba study invertebrate specialist, pers. comm.), which may increase the nutrient status.

Although the Klein Letaba River is a sandy bed river, turbidities are not very high due to the shallow nature of the system. Toxics are not expected to be significant due to the limited presence of commercial farming.

Water quality changes under operational flow scenarios
No changes in water quality are expected under any flow scenario.

6.3.6 EWR 6 (Lonely Bull on the Letaba River in the Kruger National Park)

Synopsis of assessment and available data
A present state water quality assessment was conducted for the Letaba River (WQSU 7) using data from B8H028Q01 (PES Table A (Section 4 of this report) and Site 16 for turbidity and periphyton). Flow-concentration modelling was conducted for EC.

Rating tables

Scenarios: PES/Sc1, Sc2, Sc4, Sc6

SCORING GUIDELINES	EWR6	Scenarios PES/Sc1, Sc2, Sc4, Sc6					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	1.00	0.17	0.17		
NUTRIENTS	2	95	2.00	0.17	0.35		
TEMPERATURE	3	85	2.00	0.15	0.31		
TURBIDITY	4	50	2.00	0.09	0.18		
OXYGEN	3	85	2.00	0.15	0.31		
TOXICS	1	100	0.50	0.18	0.09		
TOTALS		550			1.45		
PHYSICO-CHEMICAL PERCENTAGE SCORE					71.09		
PHYSICO-CHEMICAL CATEGORY					C		

Scenario: Present

SCORING GUIDELINES	EWR6	Scenario Present					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	2.00	0.17	0.35		
NUTRIENTS	2	95	3.00	0.17	0.52		
TEMPERATURE	3	85	2.00	0.15	0.31		
TURBIDITY	4	50	2.00	0.09	0.18		
OXYGEN	3	85	2.00	0.15	0.31		
TOXICS	1	100	0.50	0.18	0.09		
TOTALS		550			1.79		
PHYSICO-CHEMICAL PERCENTAGE SCORE					64.18		
PHYSICO-CHEMICAL CATEGORY					C		

Description of flow and water quality conditions
An evaluation of the scenarios PES/Sc1=Sc4, Sc2=Sc6 was conducted against ‘Present (Day)’. High and low flow duration curves were used to assess the various flow scenarios. Flow duration curves are similar for both EWR 6 and EWR 7.

The EC status from the time-series modelling showed that EC levels stay within the same category for all scenarios, except for ‘Present (Day)’ and ‘Natural’. Flows are similar for all scenarios, except for ‘Present (Day)’, therefore significant differences between the scenarios are unlikely. The low-flow duration curves suggest that the ‘Present (Day)’ scenario will result in poorer water quality.

Note that the PES water quality assessment for EWR 6/7 (Section 4) placed the sites in a B category. However, the evaluation conducted here assessed the sites separately as turbidity and periphyton scores are higher at EWR 6, with fish in a C and invertebrates in a D category.

Potential water quality issues
Analysis of data, flow-duration curves, time-series modelling and consultation with other specialists suggest the following potential water quality issues at EWR 6:

- Nutrient status. Increased flows will increase the SRP concentration and decreased flows will increase the periphyton levels. The potential for the latter is greater.
- Toxics may be a problem due to wash-off from the agricultural area upstream (namely herbicides or pesticides).
- Temperature increases during low flows.
- A drop in oxygen levels during low flows.

Large variations in turbidity, oxygen and temperature are noted during low flows. Although increases are partly natural due to input from the Klein Letaba and Molototsi rivers, which are sandy-bed rivers, conditions are exacerbated compared to the natural state.

Water quality changes under operational flow scenarios
Although water quality conditions are expected to improve under all flow scenarios evaluated, the overall category remains the same.

6.3.7 EWR 7 (Below Letaba Bridge on the Letaba River in the Kruger National Park)

Synopsis of assessment and available data
A present state water quality assessment was conducted for the Letaba River (WQSU 7) using data from B8H029Q01 (PES Table B and Site 16 for turbidity and periphyton; Section 4). Flow-concentration modelling was conducted for EC.

Rating tables

Scenario: PES/Sc1, 2, 4, 6

SCORING GUIDELINES	EWR7	Scenario: PES/Sc1, 2, 4, 6					
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	0.00	0.17	0.00		
NUTRIENTS	2	95	1.50	0.17	0.26		
TEMPERATURE	3	85	2.00	0.15	0.31		
TURBIDITY	4	50	0.50	0.09	0.05		
OXYGEN	3	85	2.00	0.15	0.31		
TOXICS	1	100	0.00	0.18	0.00		
TOTALS		550			0.96		
PHYSICO-CHEMICAL PERCENTAGE SCORE					80.82		
PHYSICO-CHEMICAL CATEGORY					B		

Scenario: Present

SCORING GUIDELINES	EWR 7: Scenario Present						
PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	5	40	0.50	0.07	0.04		
SALTS	2	95	0.50	0.17	0.09		
NUTRIENTS	2	95	2.50	0.17	0.43		
TEMPERATURE	3	85	2.00	0.15	0.31		
TURBIDITY	4	50	1.00	0.09	0.09		
OXYGEN	3	85	2.00	0.15	0.31		
TOXICS	1	100	0.00	0.18	0.00		
TOTALS		550			1.26		
PHYSICO-CHEMICAL PERCENTAGE SCORE					74.73		
PHYSICO-CHEMICAL CATEGORY					C		

Description of flow and water quality conditions

The flow scenarios PES/Sc1=Sc4, Sc2=Sc6 were evaluated against ‘Present (Day)’. High and low flow duration curves were used to assess the various scenarios. An assessment of the low and high flow duration curves suggest that the different scenarios are providing higher volumes of water when compared to ‘Present (Day)’. As a result, water quality ratings are slightly higher (poorer) under ‘Present (Day)’ conditions.

Conditions are similar to EWR 6, although turbidity and nutrient conditions are slightly improved due to the location of EWR 7 within the KNP.

Potential water quality issues

Analysis of data, flow duration curves, time-series modelling and consultation with other specialists suggest the following potential water quality issues at EWR 7:

- Increased peripyhyton during low flows.
- Increased SRP during high flow, but unlikely as no agriculture.
- Potentially increased turbidity during very high flows.
- Temperature increases during low flows.
- A drop in oxygen levels during low flows.

Large diurnal temperature differences suggest significant impacts during low flows. Although turbidity levels are related to input from tributaries, high turbidities are of a temporary nature.

Water quality changes under operational flow scenarios

Water quality conditions under all flow scenarios are expected to improve slightly as compared to the present state.

7. ECOLOGICAL SPECIFICATIONS (ECOSPECS) FOR WATER QUALITY PER EWR SITE

7.1 INTRODUCTION

This section of the report will list, per EWR site, the water quality objectives or ecological specifications (ecospecs) required in order to meet the water quality component of the Recommended Ecological Category (REC) for the constituents used in the assessment. Quality ecospecs will therefore be listed per EWR site based on the REC.

Quality ecospecs are related to attaining the recommended water quality category of the overall REC, and are presented as 95th percentiles, i.e. values not to be exceeded more than 5% of the time, for inorganic salts, physical variables and toxics; and 50th percentiles for nutrients, i.e. TIN and SRP. Biotic community composition (invertebrates) should not drop below the indicated values. Percentiles should be calculated within the framework of the current assessment method, i.e. using the PES monitoring point as shown on the table for the relevant EWR site, and the most recent 3 to 5 years of data, equivalent to a minimum of 60 data points. This approach is consistent with that to be used for the design of a monitoring programme for water quality. Present state categories per water quality constituent are shown as additional information.

Table 7.1 is a summary of the output of the Letaba Reserve study, and indicates the recommended future management of the system in terms of Ecological Water Requirements. Relevant to this section of the report is the PES and REC per EWR site. As can be seen from Table 7.1, the recommendation is that the PES be maintained per EWR site.

Table 7.1: A summary of the output of the Letaba Reserve study

EWR Site	PES	EIS		SI	Ecological Category		
		Natural	Present		REC	Alternatives	
1	**C**	Very High	Moderate	Low	**C**	N/A	D
2	**D**	Moderate	Moderate	Low	**D**	N/A	N/A
3	**C/D**	High	High	Moderate	**C/D**	C	D
4	**C/D**	High	High	High	**C/D**	N/A	D
5	**C**	High	Moderate	Moderate	**C**	D	N/A
6	**C**	Moderate	High	Low	**C**	D	B
7	**C**	Moderate	High	Low	**C**	D	B

EIS: Environmental Importance and Sensitivity
SI: Social Importance

Note the discrepancy in assessment results depending on the approach used for determining water quality category. Results of Section 4 follow the approach of the DWAF (2002) methods manual, while the ratings tables shown in Section 6 following the approach of Kleynhans et al. (2005). Although the latter approach is focused on a physico-chemical assessment only, and does not include scores for response variables (i.e. chlorophyll-a levels, fish or invertebrate scores) explicitly in the tables, tables do include qualitative assessments for variables such as turbidity. The Ecoclassification approach is therefore considered a more quantitative approach to assessing the physico-chemical state of water bodies. The results section displays both sets of assessment results.

7.2 RESULTS

Results are expressed per EWR site. Ecospecs presented as narrative descriptions are taken from the Ecoclassification manual of Kleynhans et al. (2005).

7.2.1 EWR 1 (Appel on the Groot Letaba River)

River	Groot Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	2	**RC**	B8H014Q01 (1977 – 1979)	
EWR Site	1	**PES**	B8H014Q01 (1999 - 2003)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	A	16 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	A	15 mg/L	N/A
	$CaCl_2$	A	21 mg/L	N/A
	NaCl	A	45 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	B-B/C (0.017)	**0.015 mg/L (B category)**	**Slight improvement**
	TIN	A (0.129)	0.25 mg/L	N/A
Physical variables	pH (pH units)	A	6.5 to 8.0	N/A
	Temperature	Impacts expected as Ebenezer Dam releases to river are bottom releases	Small change allowed. Natural temperature range, measured or estimated from air temperature. (Rating of 1, B category)	N/A
	Dissolved oxygen		Small change allowed: 7 – 8 mg/L (Rating of 1, B category)	N/A
	Turbidity (NTU)	Impacts rare	Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff (Rating of 1, B category).	N/A
Response variables	Chl-a: periphyton	C/D – D (60.54)	**21 mg/m² (C category)**	**Slight improvement**
	Chl-a: phytoplankton	-	15 µg/L (B category)	No information
	Biotic community composition - macroinvertebrate	C	ASPT: 5 (C category)	N/A
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
	Fluoride	A	1500 µg/l (A category)	N/A

River	Groot Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	2	**RC**	B8H014Q01 (1977 – 1979)	
EWR Site	1	**PES**	B8H014Q01 (1999 - 2003)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Toxics	Al	-	20 µg/l (A category)	No information
	Ammonia	-	15 µg/l (A category)	No information
	As	-	20 µg/l (A category)	No information
	Atrazine	-	19 µg/l (A category)	No information
	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

- PES for water quality (Methods Manual, Section 4): B category
- PES for water quality (Ecoclassification approach, Section 6): B category
- Overall PES: C category
- Overall REC: C category
- Recommended water quality component of the REC: **B category**

7.2.2 EWR 2 (Letsitele Tank on the Letsitele River)

River	Letsitele River	**DWAF Water Quality Monitoring points**		
WQSU	8 & 9	**RC**	B8H010Q01 (1975 – 1977)	
EWR Site	2	**PES**	B8H010Q01 (2000 - 2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	A	16 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	A	15 mg/L	N/A
	$CaCl_2$	A	21 mg/L	N/A
	NaCl	A	45 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	E/F (0.126)	**0.025 mg/L (C category)**	**Improvement required**
	TIN	B (0.624)	0.70 mg/L	N/A
Physical variables	pH (pH units)	A/B (7.62 + 8.33)	**5th percentile: 6.5 to 8.0 95th percentile: 6.5 to 8.0 (A category)**	**Slight improvement required**
	Temperature	Some impacts evident at low flows	Moderate (+ infrequent) change allowed. Vary by no more than 2°C (Rating of 2, C category).	N/A
	Dissolved oxygen		Moderate change allowed: 6 – 7 mg/L (Rating of 2, C category)	N/A
	Turbidity (NTU)	Turbidity assessed to be in a D category	Moderate change allowed. Catchment and land-use changes have resulted in high, but temporary, sediment loads turbidity during runoff events **(Rating of 2, C category)**	**Slight improvement required**
Response variables	Chl-a: periphyton	C upstream to E/F at Letsitele Tank	**21 mg/m² (C category)**	**Moderate improvement requited**
	Chl-a: phytoplankton	-	20 µg/L (C category)	No information
	Biotic community composition - macroinvertebrate	D (water quality related)	**ASPT: 5 (C category)**	**Moderate improvement requited**
	In-stream toxicity	-	In-stream toxicity may occur (Rating of 0.5, A/B category)	N/A
	Fluoride	A	1500 µg/l (A category)	N/A
	Al	-	20 µg/l (A category)	No information
	Ammonia	-	15 µg/l (A category)	No information
	As	-	20 µg/l (A category)	No information

River	Letsitele River	**DWAF Water Quality Monitoring points**		
WQSU	8 & 9	**RC**	B8H010Q01 (1975 – 1977)	
EWR Site	2	**PES**	B8H010Q01 (2000 - 2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Toxics	Atrazine	-	19 µg/l (A category)	No information
	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

- PES for water quality (Methods Manual, Section 4): C/D - D category
- PES for water quality (Ecoclassification approach, Section 6): C category
- Overall PES: D category
- Overall REC: D category
- Recommended water quality component of the REC: **C category**

7.2.3 EWR 3 (Die Eiland on the Groot Letaba River)

River	Groot Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	4	**RC**	B8H009Q01 (1976 – 1977)	
EWR Site	3	**PES**	B8H009Q01 (2000 - 2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	B	23 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	A	15 mg/L	N/A
	$CaCl_2$	A	21 mg/L	N/A
	NaCl	B	191 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	B (0.019)	0.015 mg/L	N/A
	TIN	A/B - B (0.416)	0.79 mg/L (B category)	N/A
Physical variables	pH (pH units)	A	5^{th} percentile: 6.5 to 8.0	N/A
	Temperature	Impacts expected due to low flows for 4 months of the year.	Moderate change allowed. Vary by no more than 2°C (Rating of 2, C category).	N/A
	Dissolved oxygen		Moderate change allowed: 6 – 7 mg/L (Rating of 2, C category)	
	Turbidity (NTU)	High turbidities temporary	Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff (Rating of 1, B category).	N/A
Response variables	Chl-a: periphyton	C – C/D: WQ Site 6: 45.77 WQ Site 7: 31.71	**21 mg/m² (C category)**	**Slight improvement required**
	Chl-a: phytoplankton	-	20 µg/L (C category)	No data
	Biotic community composition - macroinvertebrate	D (habitat + flow related)	**ASPT: 5 (C category)**	**Moderate improvement required**
	In-stream toxicity	Evidence of acute and sub-lethal toxicity	In-stream toxicity may occur **(Rating of 2, C category)**	**Improvements required**
	Fluoride	A	1500 µg/l (A category)	N/A
	Al	-	20 µg/l (A category)	No information
	Ammonia	-	15 µg/l (A category)	No information

River	Groot Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	4	**RC**	B8H009Q01 (1976 – 1977)	
EWR Site	3	**PES**	B8H009Q01 (2000 - 2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Toxics	As	-	20 µg/l (A category)	No information
	Atrazine	-	19 µg/l (A category)	No information
	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

- PES for water quality (Methods Manual, Section 4): C category
- PES for water quality (Ecoclassification approach, Section 6): C category
- Overall PES: C/D category
- Overall REC: C/D category
- Recommended water quality component of the REC: **C category**

7.2.4 EWR 4 (Letaba Ranch on the Groot Letaba River)

River	Groot Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	6	**RC**	B8H008Q01 (1977 – 1978)	
EWR Site	4	**PES**	B8H008Q01 (2000 – 2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	A	16 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	A	15 mg/L	N/A
	$CaCl_2$	A	21 mg/L	N/A
	NaCl	B	191 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	C – D (0.03)	**0.025 mg/L (C category)**	**Slight improvement required**
	TIN	A (0.107)	0.25 mg/L	N/A
Physical variables	pH (pH units)	B (7.75 + 8.54)	5th percentile: 5.9 – 6.5 95th percentile: 8.0 – 8.8	N/A
	Temperature	Impacts seen at low flows	Moderate change allowed. Vary by no more than 2°C **(Rating of 2, C category)**.	**Slight improvement required**
	Dissolved oxygen		Moderate change allowed: 6 – 7 mg/L **(Rating of 2, C category)**	**Slight improvement required**
	Turbidity (NTU)	Intermittent high levels recorded	Moderate change allowed. Catchment and land-use changes have resulted in high, but temporary, sediment loads turbidity during runoff events (Rating of 2, C category)	N/A
Response variables	Chl-a: periphyton	-	Small change allowed. 12 mg/m^2 (Rating of 1, B category)	No information
	Chl-a: phytoplankton	-	Small change allowed. 15 µg/L (Rating of 1, B category)	No information
	Biotic community composition - macroinvertebrate	D (flow-related)	**ASPT: 5 (C category)**	**Slight improvement required**
	In-stream toxicity	-	In-stream toxicity may occur (Rating of 1.5, B/C category)	No information
	Fluoride	A	1500 µg/l (A category)	N/A
	Al	-	20 µg/l (A category)	No information
	Ammonia	-	15 µg/l (A category)	No information
	As	-	20 µg/l (A category)	No information
	Atrazine	-	19 µg/l (A category)	No information

River	Groot Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	6	**RC**	B8H008Q01 (1977 – 1978)	
EWR Site	4	**PES**	B8H008Q01 (2000 – 2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Toxics	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

- PES for water quality (Methods Manual, Section 4): B/C category
- PES for water quality (Ecoclassification approach, Section 6): C category
- Overall PES: C/D category
- Overall REC: C/D category
- Recommended water quality component of the REC: **C category**

7.2.5 EWR 5 (Klein Letaba River)

River	Klein Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	13	**RC**	No reference condition data	
EWR Site	5	**PES**	B8H033Q01 (1999 – 2003)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	B	23 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	A	15 mg/L	N/A
	$CaCl_2$	A	21 mg/L	N/A
	NaCl	B	191 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	B/C (0.025)	0.025 mg/L	N/A
	TIN	A (0.0645)	0.25 mg/L	N/A
Physical variables	pH (pH units)	B/C (7.80 + 8.86)	5^{th} percentile: 5.9 – 6.5 95^{th} percentile: 8.0 – 8.8 **(Rating of 1, B category)**	**Sight improvement required**
	Temperature	No impacts expected	Natural temperature range, measured or estimated from air temperature (Rating of 1, B category)	N/A
	Dissolved oxygen		Small change allowed: 7-8 mg/L (Rating of 1, B category)	N/A
	Turbidity (NTU)	Turbidities generally not high.	Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff (Rating of 1.5, B/C category).	N/A
Response variables	Chl-a: periphyton	High benthic algae at times of low flow	**21 mg/m^2 (C category)**	**Probably moderate improvement required**
	Chl-a: phytoplankton	-	15 µg/L (B Category)	No information
	Biotic community composition - macroinvertebrate	D (flow-related)	**ASPT: 5 (C category)**	**Slight improvement required**
	In-stream toxicity	-	In-stream toxicity should not occur.	No information
	Fluoride	A	1500 µg/l (A category)	N/A
	Al	-	20 µg/l (A category)	No information

River	Klein Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	13	**RC**	No reference condition data	
EWR Site	5	**PES**	B8H033Q01 (1999 – 2003)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Toxics	Ammonia	-	15 µg/l (A category)	No information
	As	-	20 µg/l (A category)	No information
	Atrazine	-	19 µg/l (A category)	No information
	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

- PES for water quality (Methods Manual, Section 4): B/C - C category
- PES for water quality (Ecoclassification approach, Section 6): B – B/C category
- Overall PES: C category
- Overall REC: C category
- Recommended water quality component of the REC: **B/C category**

7.2.6 EWR 6 (Lonely Bull on the Letaba River in the Kruger National Park)

River	Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	7	**RC**	B8H028Q01 (1983 - 1987)	
EWR Site	6	**PES**	B8H028Q01 (2000 - 2004)	
Water Quality Constituents		**Present state**	**Ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	B	23 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	B	30 mg/L	N/A
	$CaCl_2$	B	57 mg/L	N/A
	NaCl	B	191 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	B/C (0.021)	0.025 mg/L (C category)	N/A
	TIN	A (0.0625)	0.25 mg/L	N/A
Physical variables	pH (pH units)	A/B (7.90 + 8.60)	5th percentile: 6.5 - 8.0 95th percentile: 8.0 – 8.8 (Rating of 1, B category)	N/A
	Temperature	Impacts expected at low flows	Moderate change allowed. Vary by no more than 2°C (Rating of 2, C category).	N/A
	Dissolved oxygen		Moderate change allowed: 6 – 7 mg/L (Rating of 2, C category)	N/A
	Turbidity (NTU)	High natural turbidity due to input of Klein Letaba and Molototsi rivers.	Moderate change allowed. Catchment and land-use changes have resulted in high, but temporary, sediment loads turbidity during runoff events (Rating of 2, C category)	N/A
Response variables	Chl-a: periphyton	E/F (Site 16: 85.38)	**21 mg/m^2 (C category)**	**Improvement required**
	Chl-a: phytoplankton	-	15 µg/L (B category)	No information
	Biotic community composition - macroinvertebrate	D (flow-related)	**ASPT: 5 (C category)**	**Slight improvement required**
	In-stream toxicity	-	In-stream toxicity may occur (Rating of 0.5, A/B category)	N/A
	Fluoride	A	1500 µg/l (A category)	N/A
	Al	-	20 µg/l (A category)	No information
	Ammonia	-	15 µg/l (A category)	No information

River	Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	7	**RC**	B8H028Q01 (1983 - 1987)	
EWR Site	6	**PES**	B8H028Q01 (2000 - 2004)	
Water Quality Constituents		**Present state**	**Ecospecs**	**Improvements required**
Toxics	As	-	20 µg/l (A category)	No information
	Atrazine	-	19 µg/l (A category)	No information
	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

- PES for water quality (Methods Manual, Section 4): B category
- PES for water quality (Ecoclassification approach, Section 6): C category
- Overall PES: C category
- Overall REC: C category
- Recommended water quality component of the REC: **B/C category**

7.2.7 EWR 7 (Below Letaba Bridge on the Letaba River in the Kruger National Park)

River	Letaba River	**DWAF Water Quality Monitoring points**		
WQSU	7	**RC**	B8H028Q01 (1983 - 1987)	
EWR Site	6	**PES**	B8H028Q01 (2000 - 2004)	
Water Quality Constituents		**Present state**	**Ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	B	23 mg/L	N/A
	Na_2SO_4	A	20 mg/L	N/A
	$MgCl_2$	B	30 mg/L	N/A
	$CaCl_2$	B	57 mg/L	N/A
	NaCl	B	191 mg/L	N/A
	$CaSO_4$	A	351 mg/L	N/A
Nutrients	SRP	B/C (0.021) *	0.025 mg/L (C category)	N/A
	TIN	A (0.0625)	0.25 mg/L	N/A
Physical variables	pH (pH units)	A/B (7.90 + 8.60)	5th percentile: 6.5 - 8.0 95th percentile: 8.0 – 8.8 (Rating of 1, B category)	N/A
	Temperature	Impacts expected at low flows	Moderate change allowed. Vary by no more than 2°C (Rating of 2, C category).	N/A
	Dissolved oxygen		Moderate change allowed: 6 – 7 mg/L (Rating of 2, C category)	N/A
	Turbidity (NTU)	Lower turbidity than EWR 6	Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff (Rating of 1, B category).	N/A
Response variables	Chl-a: periphyton	C (Site 17: 31.23)	21 mg/m^2 (C category)	N/A
	Chl-a: phytoplankton	-	15 µg/L (B category)	No information
	Biotic community composition - macroinvertebrate	D (flow-related)	**ASPT: 5 (C category)**	**Slight improvement required**
	In-stream toxicity	-	In-stream toxicity should not occur.	N/A
	Fluoride	A	1500 µg/l (A category)	N/A
	Al	-	20 µg/l (A category)	No information
	Ammonia	-	15 µg/l (A category)	No information
	As	-	20 µg/l (A category)	No information
	Atrazine	-	19 µg/l (A category)	No information

River	Letaba River	DWAF Water Quality Monitoring points		
WQSU	7	**RC**	B8H028Q01 (1983 - 1987)	
EWR Site	6	**PES**	B8H028Q01 (2000 - 2004)	
Water Quality Constituents		**Present state**	**Ecospecs**	**Improvements required**
Toxics	Cd soft*	-	0.2 µg/l (A category)	No information
	Cd mod**	-	0.2 µg/l (A category)	No information
	Cd hard***	-	0.3 µg/l (A category)	No information
	Chorine (free)	-	0.4 µg/l (A category)	No information
	Cr(III)	-	24 µg/l (A category)	No information
	Cr(VI)	-	14 µg/l (A category)	No information
	Cu soft*	-	0.5 µg/l (A category)	No information
	Cu mod**	-	1.5 µg/l (A category)	No information
	Cu hard***	-	2.4 µg/l (A category)	No information
	Cyanide	-	4 µg/l (A category)	No information

***** Although the same data record was used for assessing EWR sites 6 and 7, nutrient levels are expected to improve within the KNP and be lower at EWR 7.

- PES for water quality (Methods Manual, Section 4): B category
- PES for water quality (Ecoclassification approach, Section 6): C category
- Overall PES: C category
- Overall REC: C category
- Recommended water quality component of the REC: **B category**

8 CONCLUSIONS AND RECOMMENDATIONS

This report has provided as assessment of water quality conditions for the Letaba Reserve study. Water quality is generally not the driver of the overall ecostatus of rivers in the study area, as parameters such as flow and the status of the riparian vegetation are more instrumental in determining the health of the river. The river is generally in a Good - Fair condition in terms of water quality, with a hot spot occurring at EWR 2, i.e. Letsitele Tank. Current status is shown in Table 8.1, as well as the water quality category used to design quality ecospecs.

Table 8.1: A summary of water quality status in the Letaba River study area.

WQSU and EWR site	PES: water quality - using methods manual	PES: water quality Ecoclassification approach	Recommended water quality category of the overall REC (quality ecospecs)
Groot Letaba River			
WQSU 1	A/B		
WQSU 2: EWR 1	B	B	B
WQSU 3	B/C		
WQSU 4: EWR 3	C	C	C
WQSU 5	B		
WQSU 6: EWR 4	B/C	C	C
Letaba River			
WQSU 7: EWR 6 + 7	B	C	EWR 6: B/C EWR 7: B
Letsitele River			
WQSU 8 + 9: EWR 2	C/D	C	C
Middel Letaba River			
WQSU 10 + 11	B – B/C		
Klein Letaba River			
WQSU 13: EWR 5	B/C – C	B – B/C	B/C
WQSU 14	B		
Molototsi River			
WQSU 15	B/C		

Water quality issues are mainly related to nutrient status and fluctuating temperature and oxygen levels due to flow regulation in the catchment. In addition to being highly regulated, conditions in the Groot Letaba River (particularly from Die Eiland (EWR 3) down to Lonely Bull in the KNP (EWR 6)) are impacted by the citrus plantations in the area, resulting in elevated nutrient levels and instances of in-stream toxicity. It is recommended that water samples be taken for in-stream toxicity tests at regular intervals at The Junction (downstream of Craighead Estates and Letaba Estates) and Prieska weir (downstream of Nagude Estates). As spraying takes place throughout the year for various pests (Appendix G), sampling for in-stream toxicity should be taken quarterly. Conditions at other sites, particularly EWR 2, 4 and 6, should be tested in September and March to assess current state. Periphyton (chlorophyll-a) sampling should also be conducted regularly at all EWR sites, and monitoring of turbidity should be instituted.

Water quality consequences of operational flow scenarios were evaluated in Sections 5 and 6 of this report. Although flow scenarios do impact on water quality, impacts are generally not significant enough to change water quality status to another category. The only EWR site where flow scenarios would impact, and in fact improve water quality status, is EWR 7, where water quality status would improve from a current C to a B category.

The assessment of water quality was conducted carrying out methods updated from the DWAF methods manual of 2002, as well as the Ecoclassification approach as outlined in Kleynhans et al. (2005). Although the methods should be used together, i.e. the PES assessment using DWAF methods is used to populate the ratings tables in the Ecoclassification manual, there are no instructions in either manual as to how this procedure should take place. The Ecoclassification approach will also be using a model developed by Jooste of RQS, DWAF. A water quality manual should therefore be developed which includes instructions on how all these tools must be used to conduct a water quality assessment in an EWR study.

Further development is also required around the integration of water quality and quantity. Although flow-concentration modelling was used for this study, it was of little value as few constituents could be modelled.

9. REFERENCES

Angliss, M K (2004) A biomonitoring survey of selected sites in the Letaba and Luvuvhu River systems undertaken during 2003; including a review of the 1999 surveys. Report for the River Health Programme.

Consultburo (1998) The Groot Letaba Water Resource Development – Feasibility Study Report. Volume 5: Water quality and riparian vegetation. Annexure H – Water quality (1997). DWAF Report No. PBB810/00/0698. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (1996) South African water quality guidelines (second edition). Volume 1: Domestic use. Department of Water Affairs and Forestry, Pretoria.

DWAF (1999) Resource directed measures for protection of water resources. Institute for Water Quality studies, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (2002) Assessing water quality in ecological reserve determinations for rivers: Version 2, Draft 15.0, March 2002. Department of Water Affairs and Forestry, Pretoria.

Hughes, D A, Forsyth, D and Watkins, D A (2000) An integrated software package for the analysis and display of hydrological or water resource time series data. WRC Report No. 867/2/00, Water Research Commission, Pretoria.

IWR Source-to-Sea (2003). Prepared for the Department of Water Affairs and Forestry, Directorate: RDM. Proceedings of DWAF Ecological Reserve (Quantity) workshop, 8 and 9 April 2003, Delectus Manor, Pretoria.

Kleynhans, C J, Louw, M D, Thirion, C, Rossouw, N and Rowntree, K (2005) River Ecoclassification: Manual for Ecostatus Determination. First draft for training purposes.

Malan, H L and Day, J A (2002a) Development of numerical methods for predicting relationships between stream flow, water quality and biotic responses in rivers. WRC Report no. 956/1/02. Water Research Commission, Pretoria.

Malan, H L and Day, J A (2002b) Linking discharge, water quality and biotic responses in rivers: A Literature Review. WRC Report No. 956/2/02. Water Research Commission, Pretoria.

Malan, H, Bath, A, Day, J and Joubert, A (2003) A simple flow-concentration modelling method for integrating water quality and water quantity in rivers. Water SA 29 (3) 305-312.

Ninham Shand web-site: http://projects.shands.co.za/Hydro/hydro/WQReserve/main.htm.

Palmer, C G, Muller, W J and Hughes, D A (2004) Chapter 6: Water quality in the ecological Reserve. IN: *SPATSIM, an integrating framework for ecological Reserve and* *implementation: incorporating water quality and quantity components for rivers.* Hughes DA (Ed.) WRC Report No. 1160/1/04, Water Research Commission, Pretoria.

SRK (Steffen Robertson and Kirsten Inc.) 1989. Letaba Basin Study. Chapter 9: Water quality, Final Report. In: Steffen Robertson and Kirsten Inc. (1990). Water Resource Planning of the Letaba River Basin.

Water Research Commission. (2001) State of Rivers Report. Letaba and Luvuvhu River Systems. WRC Report No. TT 165/01. Water Research Commission, Pretoria.

APPENDIX A

PERIPHYTON BIOMASS AT SELECTED SITES IN THE LETABA RIVER CATCHMENT (Chlorophyll-a analysis)

PERIPHYTON BIOMASS AT SELECTED SITES IN THE LETABA RIVER CATCHMENT

Report by

PW Froneman

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Methodology

Periphyton biomass

To estimate the periphyton biomass, a fixed area (equivalent to 3.14 cm2) of submersed pebble collected from each site was gently scrapped using a scalpel. The scrapings were then washed into a beaker using distilled water. Contents of the beaker were then gently filtered through a GF/F filter and extracted in 90% acetone for 24h in the dark. Chl-a concentrations were then determined fluorometrically (Turner 10AU fluorometer) before and after acidification (Holm-Hansen and Riemann 1978). Results were expressed as were expressed as mg chl-a m-2. Three replicates were prepared at each station.

Results

The mean total periphyton biomass at the selected sites occupied along the length of the Letaba River was highly variable and ranged between 312 and 1065 mg chl-a m^{-2} (Figure 1). There were no distinct spatial patterns in the periphyton biomass evident (Figure 1). Biomass of the periphyton is shown in appendix 1.

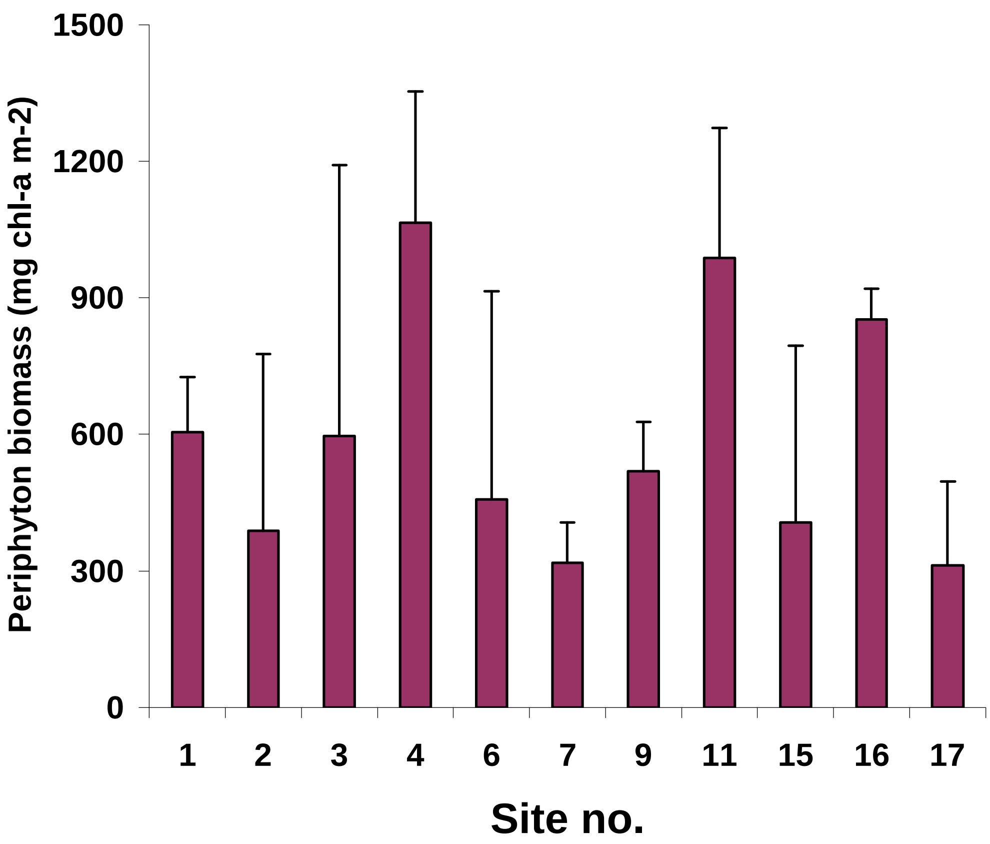


Figure 1. Periphyton biomass at selected sites occupied along the Letaba River. Error bars are standard deviation

Appendix 1

Site number	**Periphyton biomass (mg chl-a m^{-2})**
1	605.41 (± 121.08)
2	388.32 (± 152.86)
3	596.29 (± 138.41)
4	1065 (±289.49)
6	457.65 (±131.06)
7	317.06 (±89.25)
9	519.19 (± 108.55)
11	987.67 (±286.10)
15	406.78 (±389.90)
16	853.77 (±67.98)
17	312.34 (± 184.83)

Table 1: Periphyton biomass at selected sites occupied along the Letaba River. Values in brackets are standard deviation

References

HOLM-HANSEN O and RIEMANN B. (1978). Chlorophyll-a determination: improvements in methodology. Oikos **30,** 438-447

APPENDIX B

IN-STREAM TOXICITY RESULTS

ANALYTICAL RESULTS: RAND WATER **7-Jun-04**

QUALITY VARIABLE	METHOD NO	2004/266563	2004/266564
YOUR REFERENCE		**PRIESKA weir**	**LETSITELE downstream**
OUR REFERENCE		**2004/266563**	**2004/266564**
Daphnia pulex acute toxitcity test (% Survival)	1.1.2.04.1*	100	35
Poecilia reticulata acute toxicity test (% survival)	1.1.2.05.1*	100	80
Algael growth inhibition (%inhibition)	1.1.2.10.1*	69	68

Analyses commenced 2 June and was completed on 6 June 2004
Tel: 011 726 7027

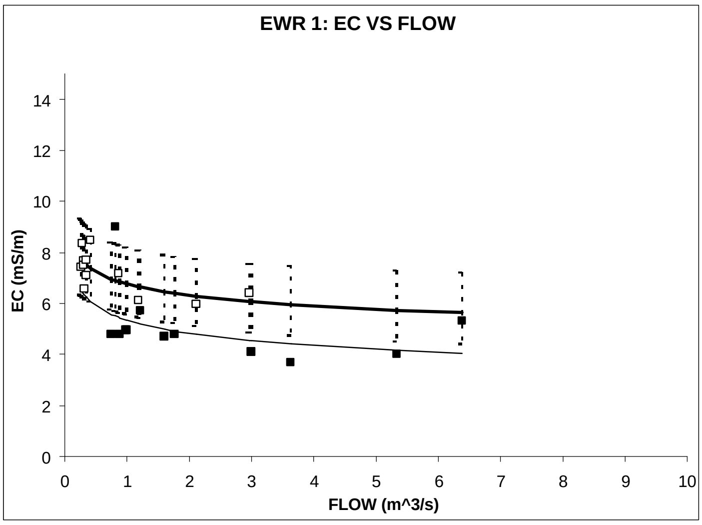
APPENDIX C

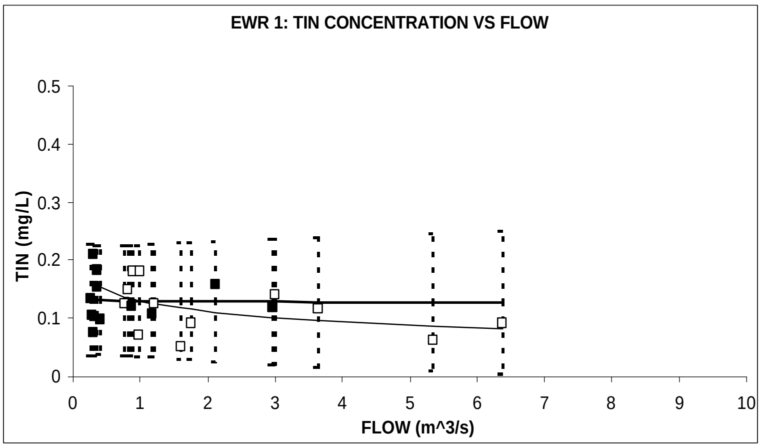
FLOW-CONCENTRATION PLOTS

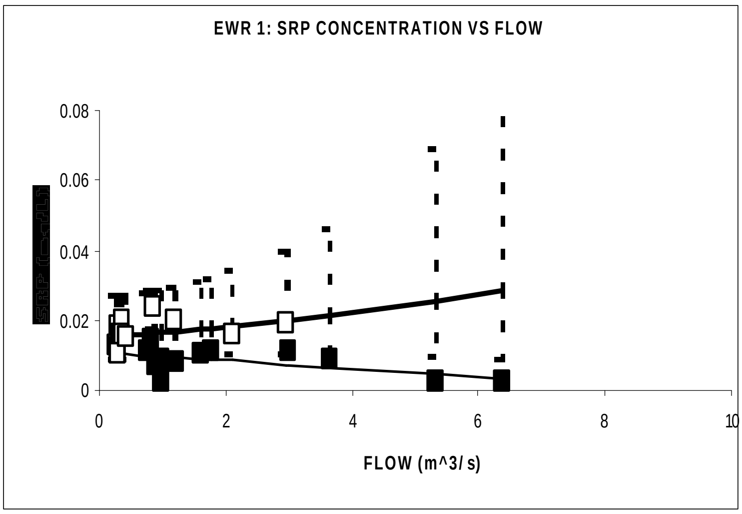
FLOW-CONCENTRATION OR Q-C PLOTS

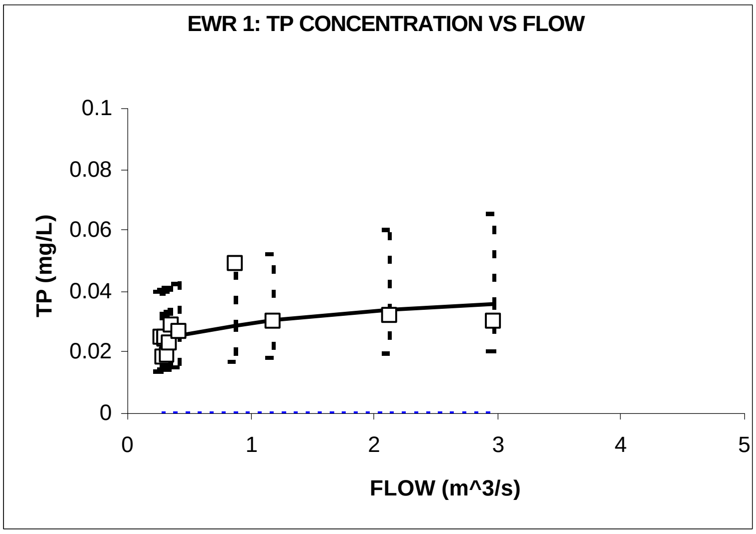
The Q-C plot for each constituent at each EWR site is shown for the Reference Condition (■) and the Present Ecological state (□). The 95% confidence interval for the Present Ecological State is shown as dotted error bars. The trendline for the Reference Condition and Present Ecological State is also shown. All flows given in m3/s, concentrations in mg/litre and electrical conductivity in mS/m

EWR 1

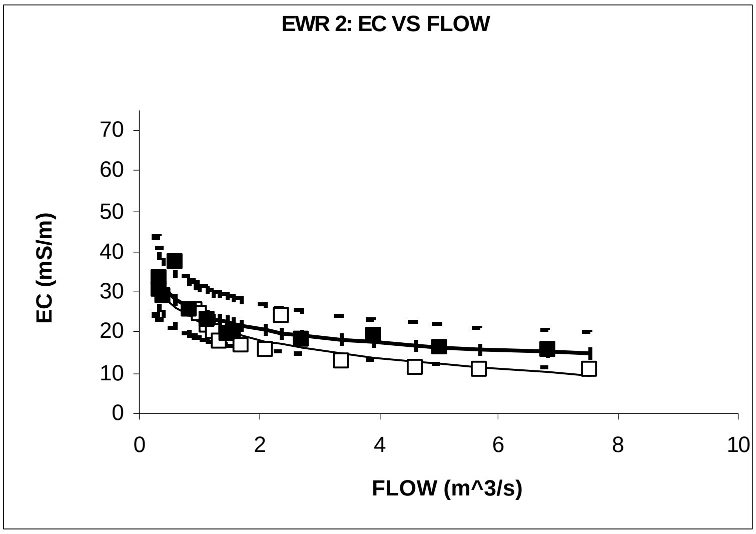


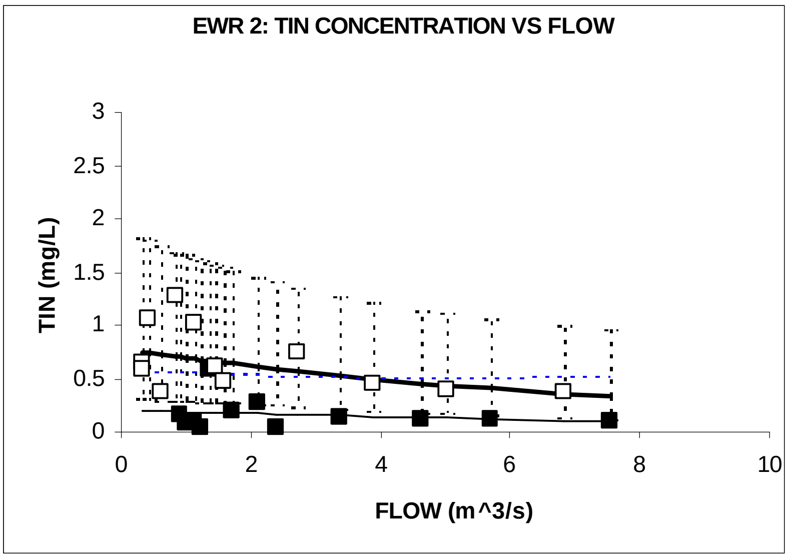


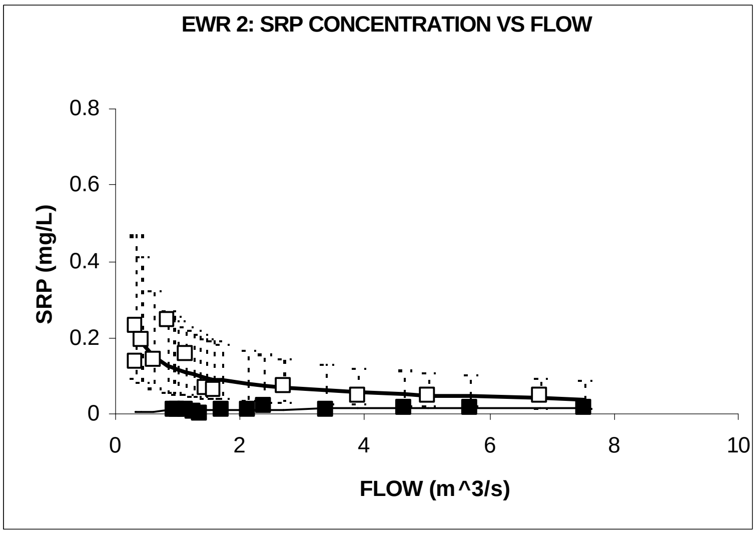



EWR 1: TP CONCENTRATION VS FLOW
TP (mg/L)
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
FLOW (m^3/s)

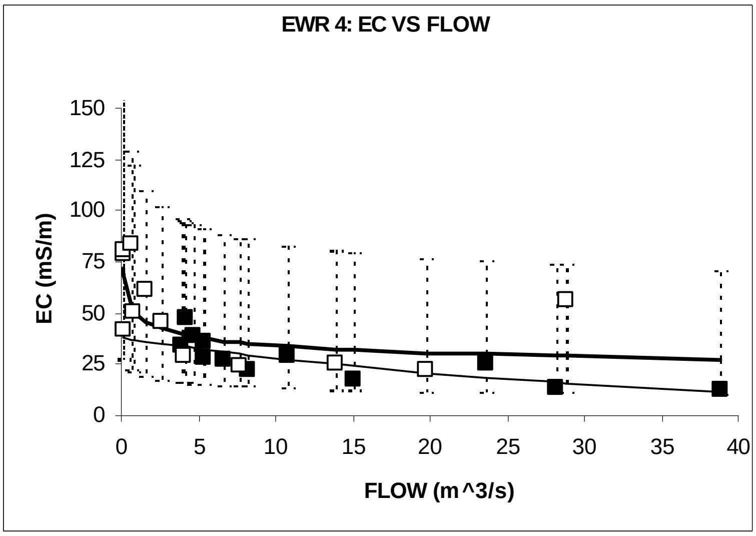
EWR 2

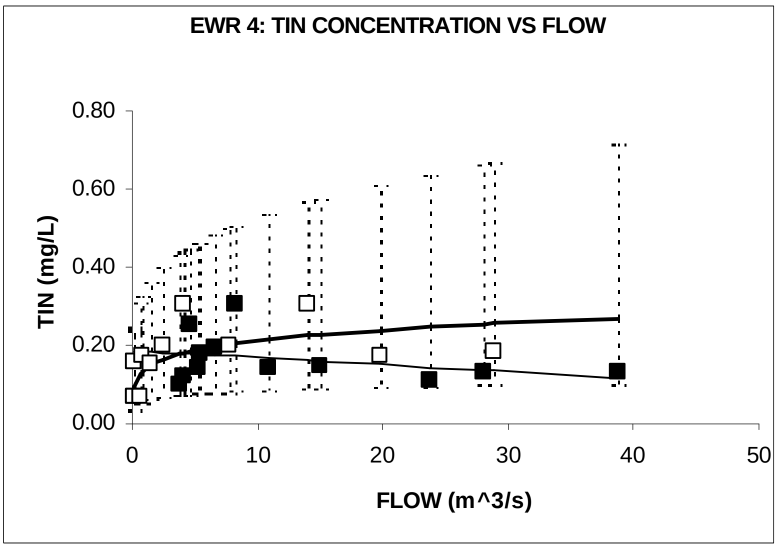

EWR 2: EC VS FLOW
EC (mS/m)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
FLOW (m^3/s)

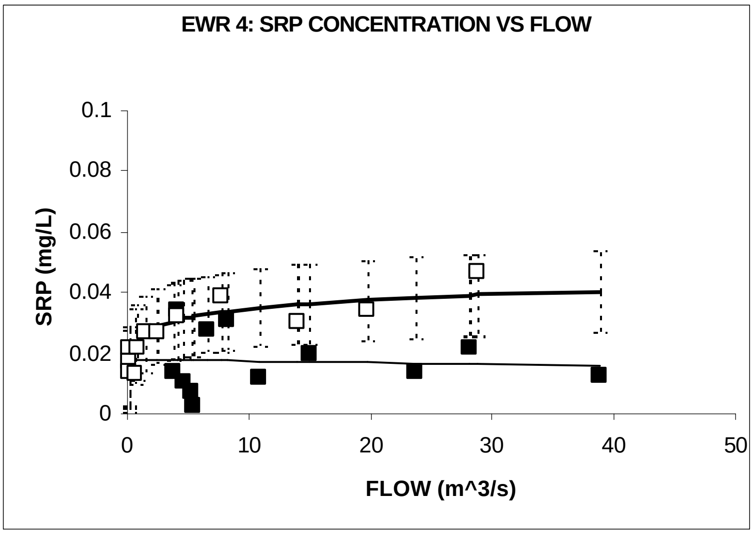

EWR 2: TIN CONCENTRATION VS FLOW
TIN (mg/L)
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
FLOW (m^3/s)


EWR 2: SRP CONCENTRATION VS FLOW
SRP (mg/L)
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
FLOW (m^3/s)

EWR 4

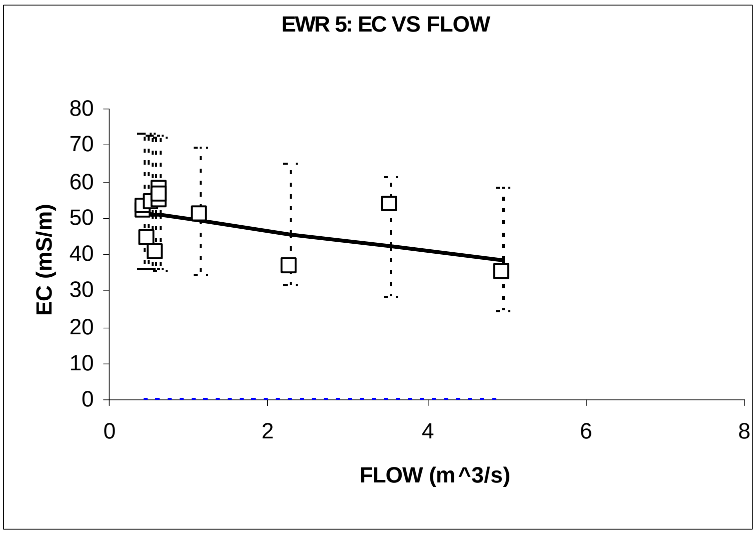

EWR 4: EC VS FLOW
EC (mS/m)
150
125
100
75
50
25
0
0
5
10
15
20
25
30
35
40
FLOW (m^3/s)


EWR 4: TIN CONCENTRATION VS FLOW
TIN (mg/L)
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
FLOW (m^3/s)

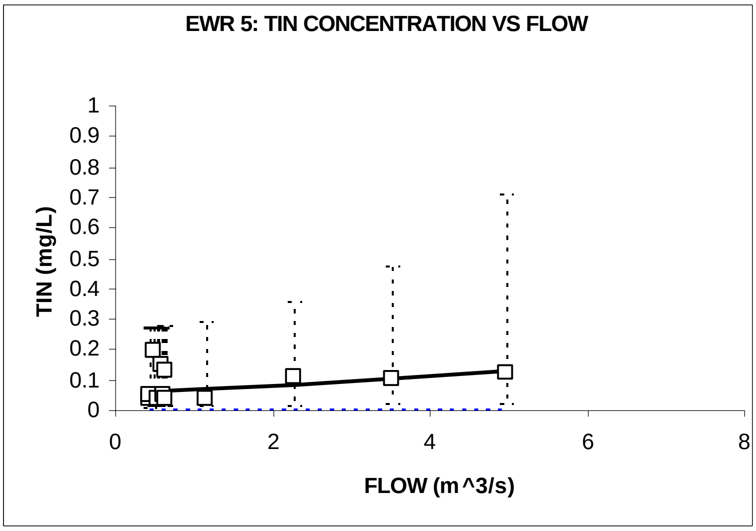


EWR 4: SRP CONCENTRATION VS FLOW
SRP (mg/L)
0.1
0.08
0.06
0.04
0.02
0
0
10
20
30
40
50
FLOW (m^3/s)

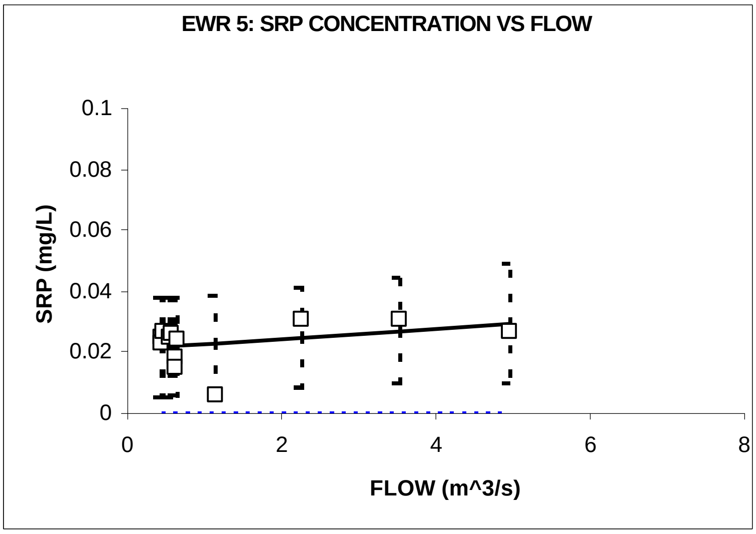
EWR 5



EWR 5: EC VS FLOW
EC (mS/m)
80
70
60
50
40
30
20
10
0
0
2
4
6
8
FLOW (m^3/s)

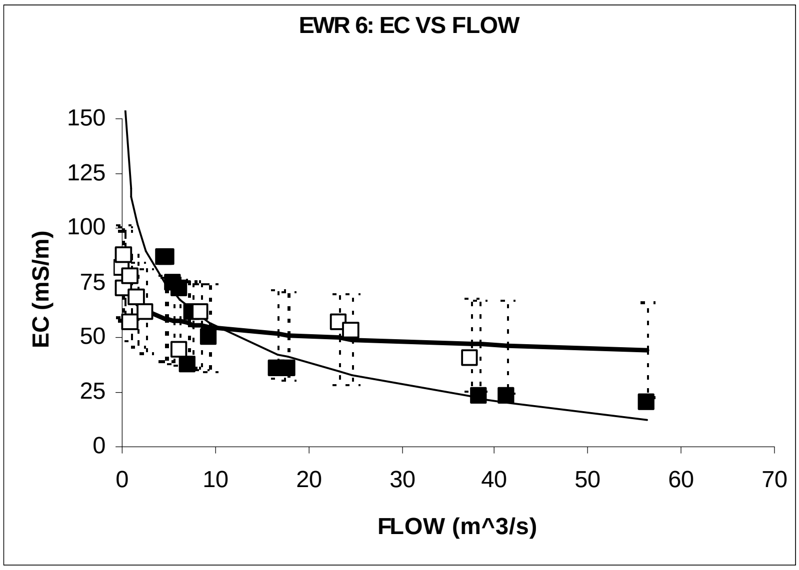


EWR 5: TIN CONCENTRATION VS FLOW
TIN (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
FLOW (m^3/s)

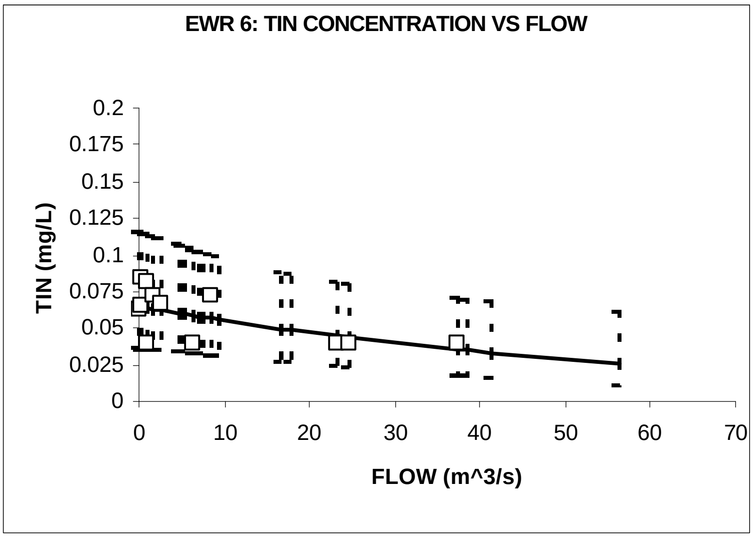


EWR 5: SRP CONCENTRATION VS FLOW
SRP (mg/L)
0.1
0.08
0.06
0.04
0.02
0
0
2
4
6
8
FLOW (m^3/s)

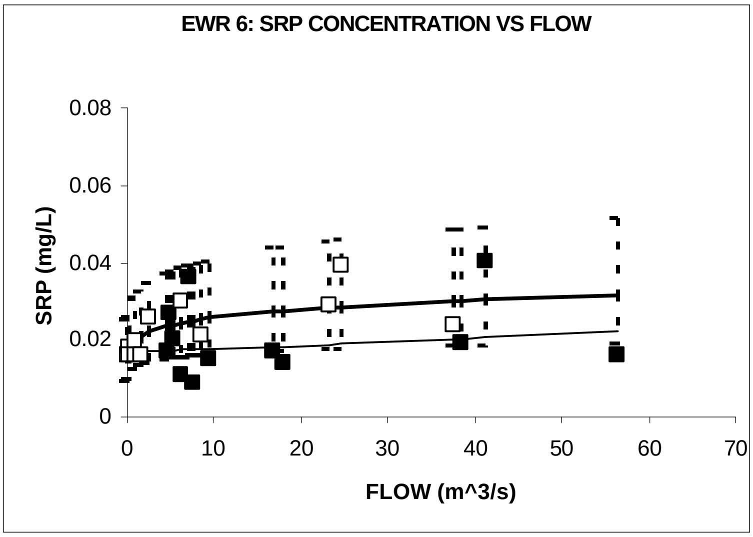
EWR 6



EWR 6: EC VS FLOW
EC (mS/m)
150
125
100
75
50
25
0
0
10
20
30
40
50
60
70
FLOW (m^3/s)



EWR 6: TIN CONCENTRATION VS FLOW
TIN (mg/L)
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
0
10
20
30
40
50
60
70
FLOW (m^3/s)


EWR 6: SRP CONCENTRATION VS FLOW
SRP (mg/L)
0.08
0.06
0.04
0.02
0
0
10
20
30
40
50
60
70
FLOW (m^3/s)

APPENDIX D

REGRESSION EQUATIONS AND COEFFICIENTS

REGRESSION EQUATIONS AND COEFFICIENTS

The equation that best describes the relationship between flow and concentration for each water quality constituent at each site is given below. The regression coefficient is also given. Flow (Q) in m^3/s and concentration [ ] in mg/L.

EWR 1				
	Constituent	**Equation**	**Regression coefficient (r2)**	**Correlation with Q**
Reference Condition	EC TIN SRP TP	$[EC] = 5.4Q^{-0.15}$ $[TIN] = -0.03LNQ+0.13$ $[SRP] = 0.01e^{(-0.2Q)}$ No data	0.246 0.0213 0.356	Decrease Slight decrease Decrease
Present Ecological State	EC TIN SRP TP	$[EC] = 6.8Q^{-0.1}$ $[TIN] = 0.12e^{(0.02Q)}$ $[SRP] = 0.02Q^{0.14}$ $[TP] = 0.03Q^{0.18}$	0.534 0.002 0.234 0.348	Decrease Little change with flow Increase Increase
EWR 2				
	Constituent	**Equation**	**Regression coefficient (r2)**	**Correlation with Q**
Reference Condition	EC TIN SRP	1.1.1 $[EC] = 23.1Q^{-0.4}$ $[TIN] = -0.01Q + 0.2$ $[SRP]=0.004LnQ+ 0.01$	0.796 0.043 0.283	Decrease Slight decrease Almost horizontal
Present Ecological State	EC TIN SRP	$[EC] = 24.7Q^{-0.3}$ $[TIN] = 0.8e^{-0.1Q}$ $[SRP] = 0.12Q^{-0.5}$	0.848 0.315 0.767	Decrease Decrease Decrease
EWR 3				
	Constituent	**Equation**	**Regression coefficient (r2)**	**Correlation with Q**
No suitable data, no Q-C modelling done.				
EWR 4				
	Constituent	**Equation**	**Regression coefficient (r2)**	**Correlation with Q**
Reference Condition	EC TIN SRP	$[EC] = 38.2e^{(-0.03Q)}$ $[TIN] = -0.002Q+0.19$ $[SRP] = Q+0.02$	0.721 0.108 0.004	Decrease Decrease Almost horizontal
Present Ecological State	EC TIN SRP	$[EC] = 49.4Q^{-0.2}$ $[TIN] = 0.14Q^{0.18}$ $[SRP] = 0.004LnQ+0.03$	0.451 0.509 0.746	Decrease Increase Increase
EWR 5				
	Constituent	**Equation**	**Regression coefficient (r2)**	**Correlation with Q**
Reference Condition	EC TIN SRP	No data “ “		
Present Ecological State	EC TIN SRP	$[EC] = 53e^{(-0.07Q)}$ $[TIN] = 0.06e^{(0.15Q)}$ $[SRP] = 0.002Q+0.02$	0.318 0.129 0.134	Decrease Increase Increase

EWR 6				
	Constituent	**Equation**	**Regression coefficient (r2)**	**Correlation with Q**
Reference Condition	EC TIN SRP	[EC] = -25LnQ+113 [SRP] = $0.02e^{(0.01Q)}$	0.812 - 0.038	Decrease - Increase
Present Ecological State	EC TIN SRP	[EC] = -5.8LnQ+67.9 [TIN] = $0.07e^{(-0.02Q)}$ [SRP] = $0.02Q^{0.11}$	0.694 0.427 0.620	Decrease Decrease Increase
EWR 7				
	Constituent	**Equation**	**Regression coefficient (r^2)**	**Correlation with Q**
No suitable data, no Q-C modelling done.				

SRP = SOLUBLE REACTIVE PHOSPHORUS, TP = TOTAL PHOSPHORUS, EC = ELECTRICAL CONDUCTIVITY, TIN = TOTAL INORGANIC NITROGEN.

APPENDIX E

FLOW-CONCENTRATION MATRICES

FLOW-CONCENTRATION MATRICES

The flow-concentration matrices used to produce the concentration time-series and excedence curves for each IFR site are shown below. Flow is given in m3/s and concentration in mg/L. PES = Present Ecological State, RC = Reference Condition, SRP = soluble reactive phosphorus, TDS = total dissolved solids, TIN = total inorganic nitrogen. *No difference between PES and RC, same data used.

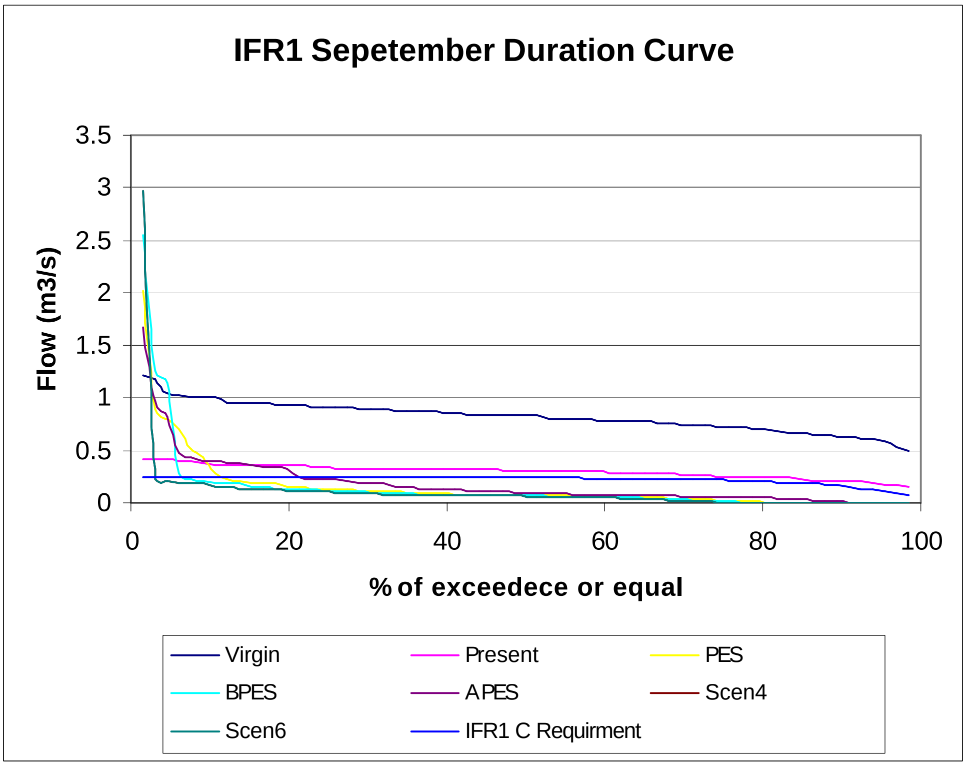
EWR 2 (Letsitsele River)							
Flow	**EC (PES)**	**Flow**	**EC (RC)**	**Flow**	**SRP (PES)**	**Flow**	**SRP (RC)**
0.01	78.11	0.01	53.06	0.01	1.44	0.01	0.00
1	24.70	1.00	22.80	0.1	0.42	0.50	0.01
2	20.77	2.00	18.25	0.5	0.17	1.00	0.01
3	18.77	3.00	15.58	1	0.12	2.00	0.01
5	16.52	5.00	12.23	2	0.08	3.00	0.01
6	15.78	6.00	11.03	3	0.07	4.00	0.01
8	14.69	8.00	9.14	5	0.05	5.00	0.02
9	14.26	9.00	8.36	6	0.05	6.00	0.02
10	13.89	10.00	7.67	8	0.04	8.00	0.02
11	13.56	11.00	7.05	9	0.04	9.00	0.02
13	13.01	13.00	5.95	10	0.03	10.00	0.02
14	12.77	14.00	5.46	11	0.03	11.00	0.02
15	12.55	15.00	5.01	13	0.03	12.00	0.02
17	12.16	17.00	4.19	14	0.03	13.00	0.02
18	11.99	18.00	3.81	15	0.03	14.00	0.02
20	11.68	20.00	3.12	17	0.03	15.00	0.02
21	11.54	21.00	2.80	18	0.03	17.00	0.02
22	11.40	22.00	2.49	20	0.02	20.00	0.02
24	11.16	24.00	1.92	21	0.02	21.00	0.02
25	11.05	25.00	1.65	25	0.02	25.00	0.02

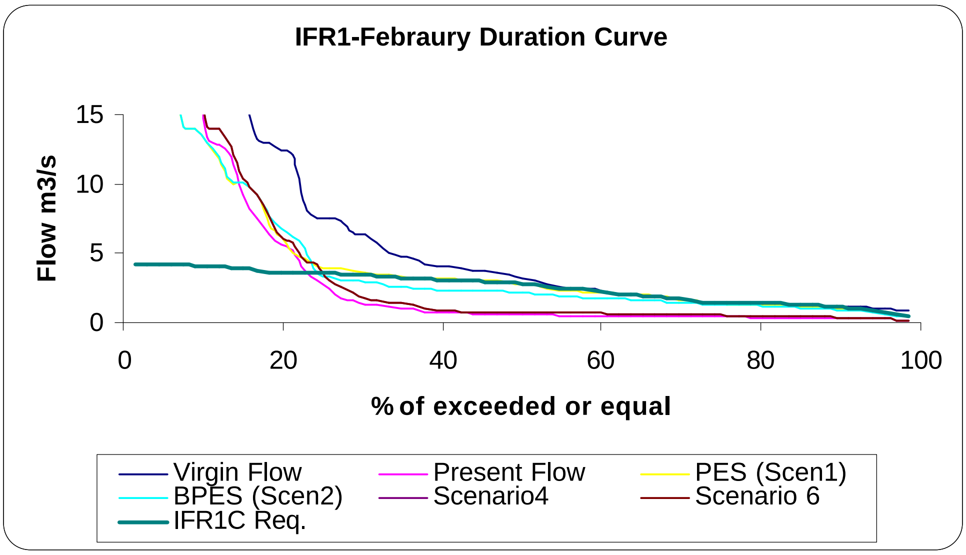
EWR 6 (Letaba River, KNP)			
Flow	**EC (PES)**	**Flow**	**EC (RC)***
0.01	94.56	0.01	94.56
0.1	81.23	0.1	81.23
5	58.58	5	58.58
10	54.57	10	54.57
15	52.22	15	52.22
20	50.55	20	50.55
25	49.26	25	49.26
10	54.57	10	54.57
20	50.55	20	50.55
30	48.21	30	48.21
35	47.31	35	47.31
40	46.54	40	46.54
50	45.25	50	45.25
60	44.19	60	44.19
70	43.30	70	43.30
80	42.53	80	42.53
90	41.85	90	41.85
100	41.24	100	41.24
110	40.68	110	40.68
120	40.18	120	40.18
130	39.72	130	39.72

APPENDIX F

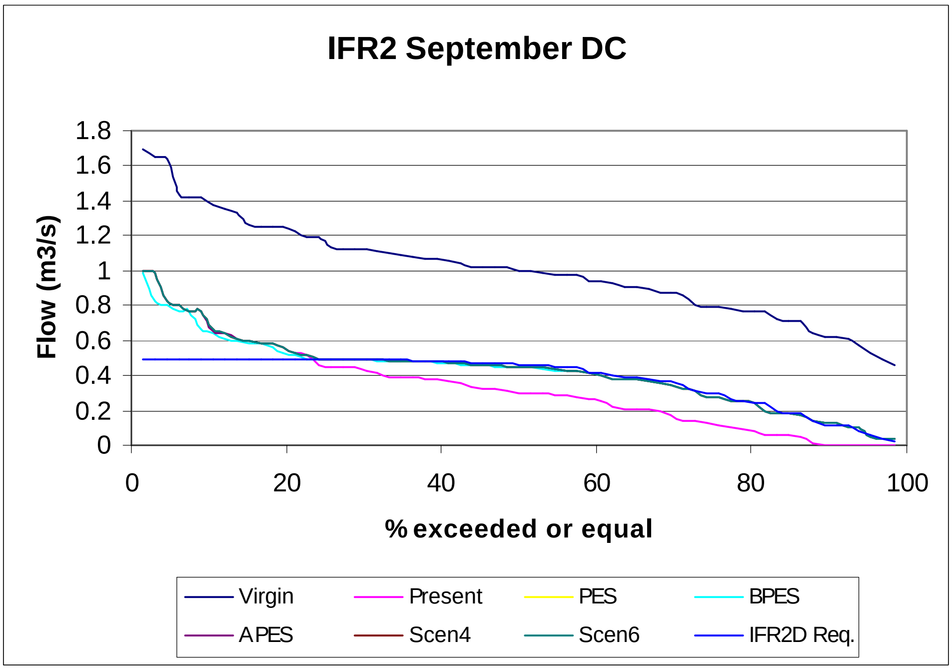
FLOW DURATION CURVES
(CRITICAL MONTHS)

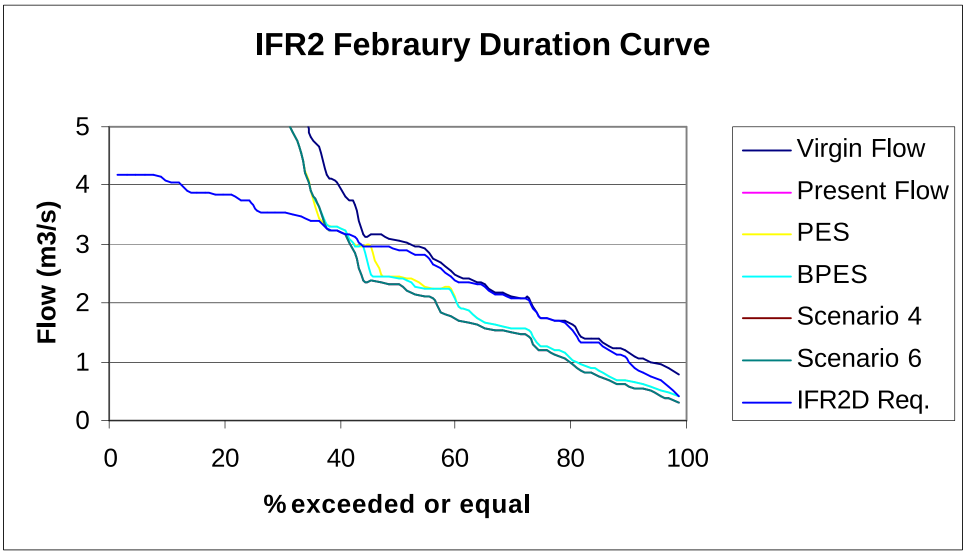
EWR SITE 1: BROEDERSTROOM (GROOT LETABA RIVER)
FLOW DURATION CURVES
Critical months: September (low flows); February (high flows)



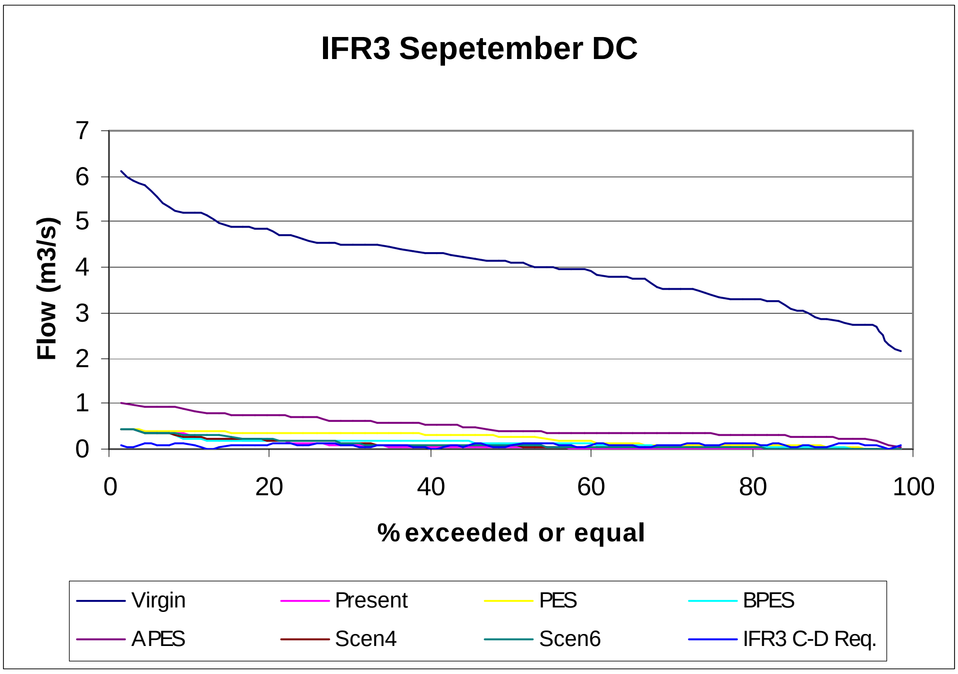


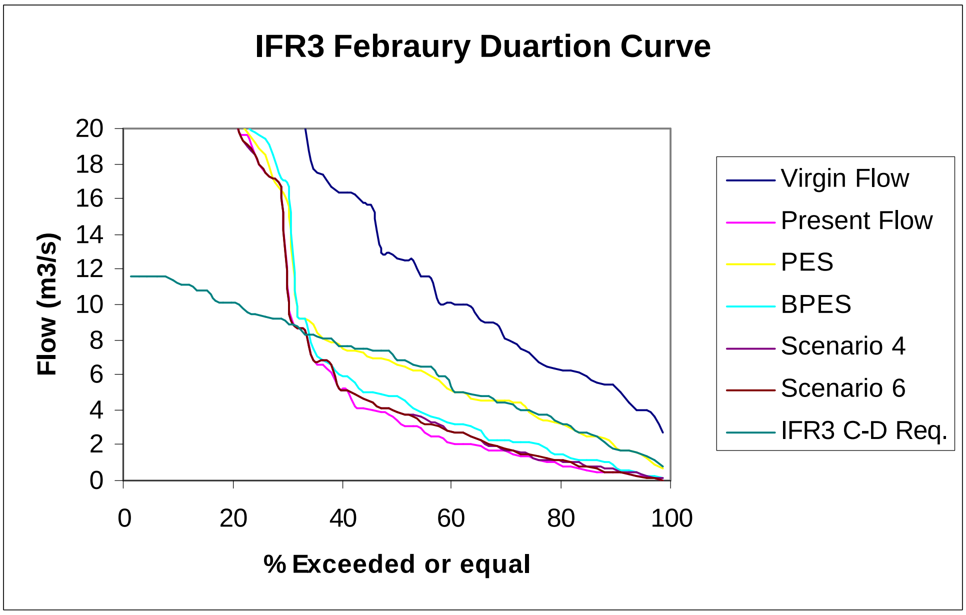
EWR SITE 2: LETSITELE RIVER
FLOW DURATION CURVES
Critical months: September (low flows); February (high flows)



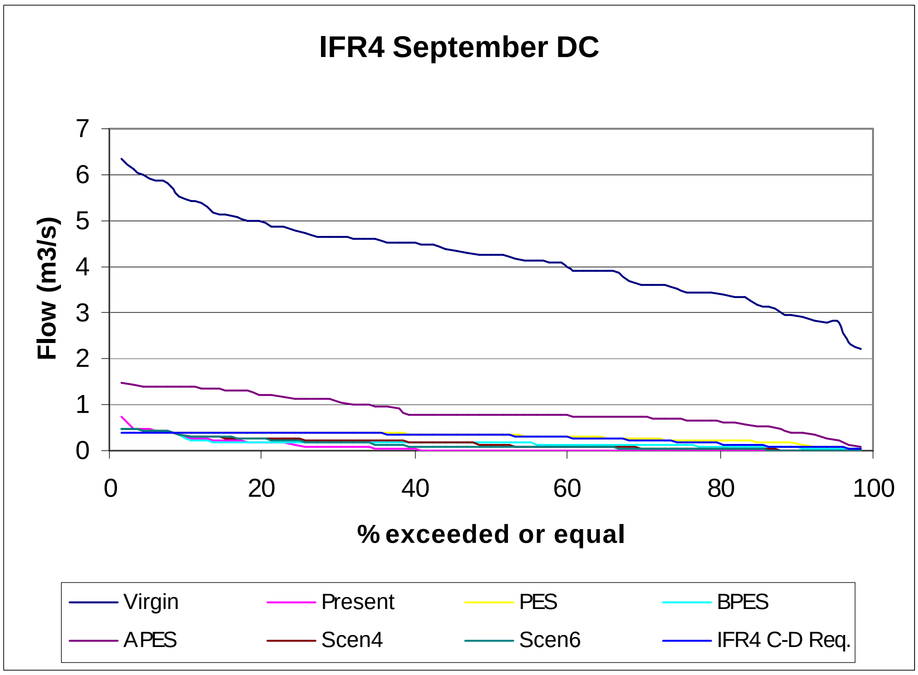


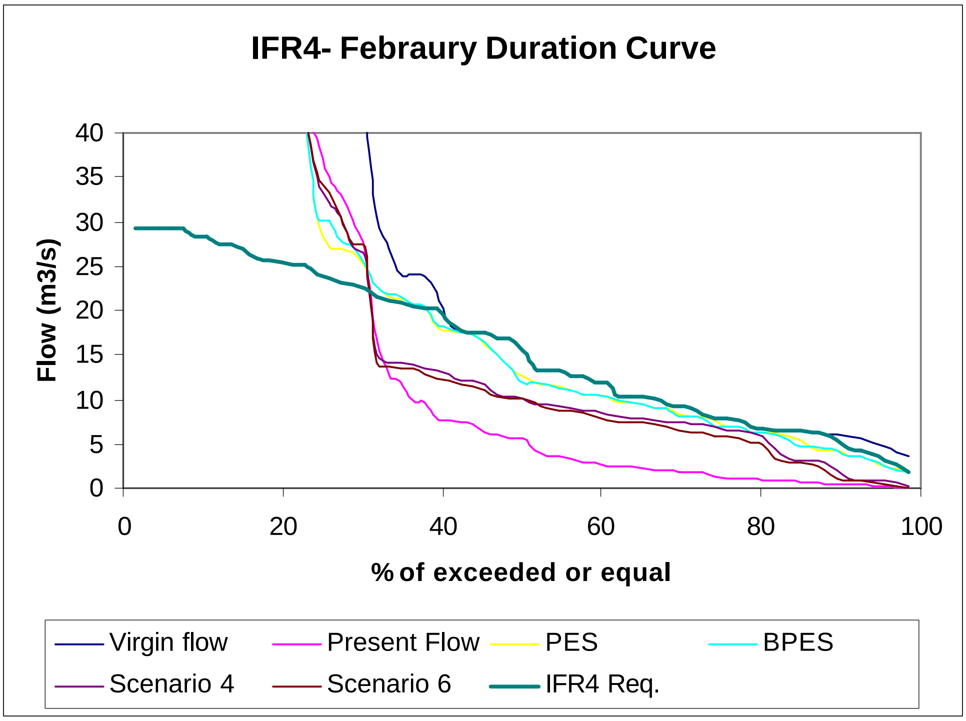
EWR SITE 3: GROOT LETABA RIVER
FLOW DURATION CURVES
Critical months: September (low flows); February (high flows)



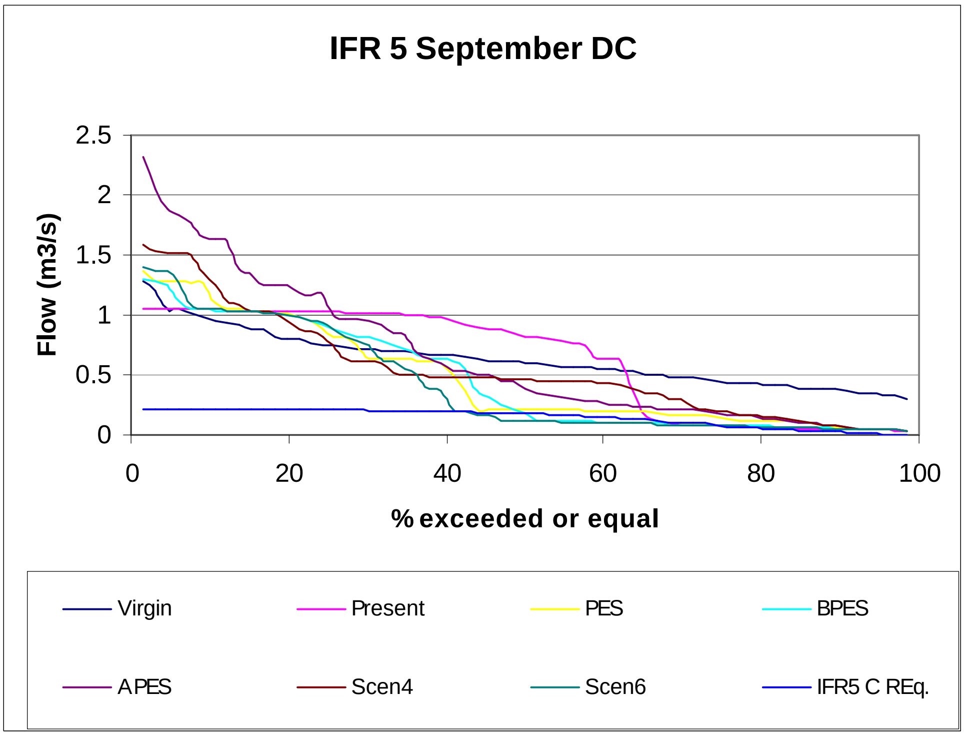


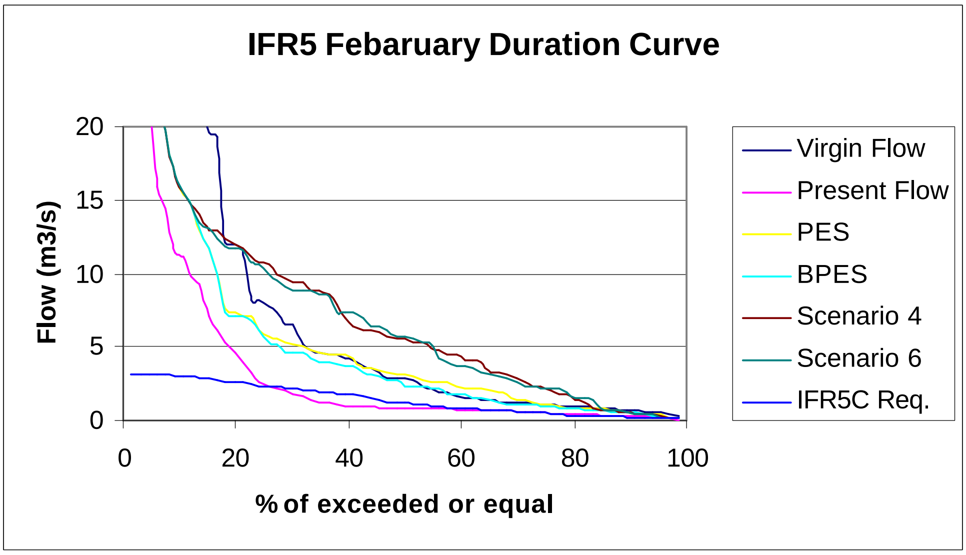
EWR SITE 4: GROOT LETABA RIVER
FLOW DURATION CURVES
Critical months: September (low flows); February (high flows)



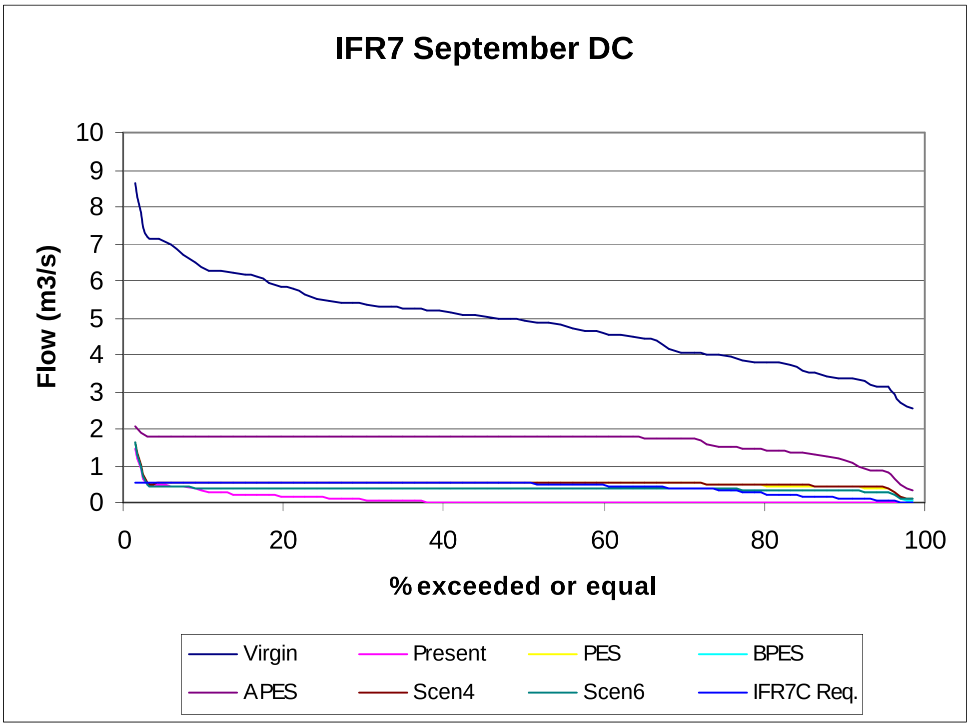


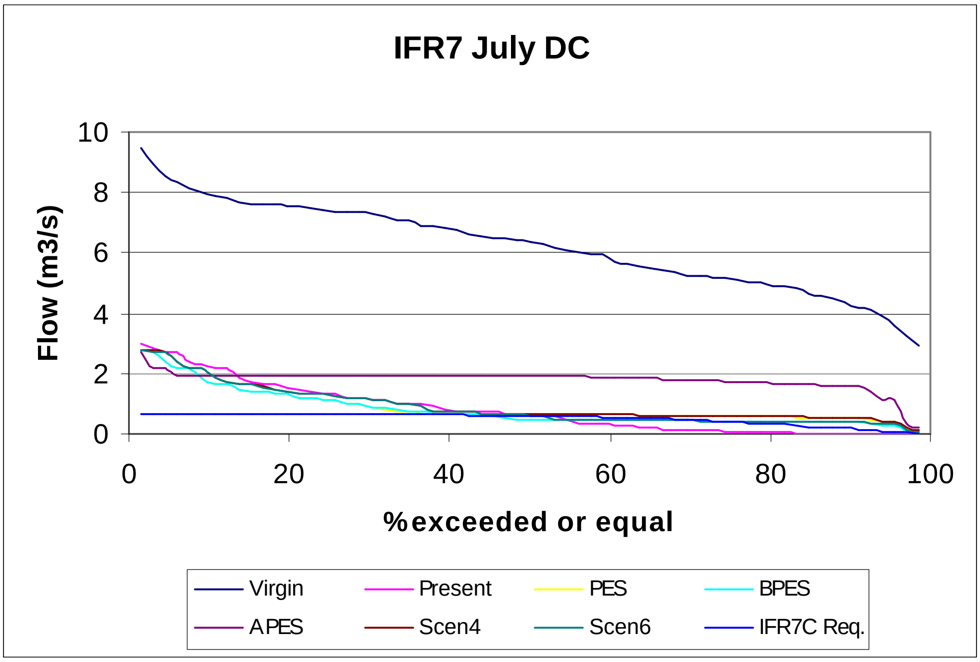
EWR SITE 5: KLEIN LETABA RIVER
FLOW DURATION CURVES
Critical months: September (low flows); February (high flows)





EWR SITE 6 & 7: LETABA RIVER
FLOW DURATION CURVES
Critical months: September (low flows); July (high flows)





APPENDIX G

BIOCIDE SPRAYING SURVEY

A number of organizations were identified in the Letaba catchment whom could provide information on the use of biocides and spraying regimes on the citrus plantations throughout the year. The following questionnaire was sent out to the following organizations:

- Nagude Estate: Voster family
- Letaba Estate
- Craighead Estate
- Mahela Boerdery, Letstitele: Anita Muller
- Agricultural Research Council (ARC): Mike Peel and Mike Danielle

BIOCIDE QUERIES

Dr Patsy Scherman and myself, Ms Deborah Vromans, of Coastal and Environmental Services, Grahamstown, are currently undertaking a water quality assessment of the Letaba River as part of a larger DWAF Letaba Reserve project. The study is in response to the National Water Act (1998), which stipulates the determination of the ecological Reserve of South African rivers. Patsy and myself represent the water quality sub-consultant team contracted by the Department of Water Affairs and Forestry (DWAF). The team leader is Dr Ralph Heath of Pulles, Howard and de Lange, Pretoria.

Water quality sampling at selected sites was conducted in December 2003. In addition to the sampling we need information from local farmers concerning biocide application, collection and disposal.

Hence we require the following information from you, please:

1. **QUERY 1: What is your spraying regime, namely during what months does spraying occur?**
ANSWER:

2. **QUERY 2: How/where is the biocide-containing waste collected and disposed of?**
ANSWER:

3. **QUERY 3: What type(s) of biocides do you use?**
ANSWER:

We appreciate your assistance with these queries. Please could you respond to myself or Patsy (if after 17/3/04), at fax: 046 – 622 6564, tel: 046 – 622 2364 or by e-mail: d.vromans@cesnet.co.za, or p.scherman@cesnet.co.za.

Yours sincerely

Ms D Vromans

cc. Dr Patsy Scherman
Dr Ralph Heath

The only reply was received from **Ms Anita Muller of Mahela Boerdery, Letstitele**. Her replies were as follows:

QUERY 1: What is your spraying regime, namely during what months does spraying occur?

Spraying begins in September for spring pest complex until October. Summer pest and disease control commences from October until February. Fuitfly control is from March until the end of August.

QUERY 2: How/where is the biocide-containing waste collected and disposed of?

All waste is collected in a sump at all filling points in orchards.

QUERY 3: What type(s) of biocides do you use?

- see attached list on the next page

MAHELA BOERDERY (EDMS) BPK.

Chemiese Toediening

Augustus	Formetanaat
September	Formetanaat Methidiathion Imidiachloprid
Oktober	Imidiachloprid Cypermethrin Glyphosate Mancozeb
November	Azoxystrobin Mancozeb Olie Glyphosate
Desember	Azoxystrobin Mancozeb Glyphosate Avermectin Olie Mercaptothion
Januarie	Mancozeb Avermectin Olie Mancozeb Mercaptothion
Februarie	Mancozeb Mercaptothion
Maart	Trichlorfon Proteienhidrolisaat Glyphosate Mercaptothion
April	Trichlorfon Proteienhidrolisaat Mercaptothion
Mei	Trichlorfon Proteienhidrolisaat Mercaptothion
Junie - Augustus	Trichlorfon Proteienhidrolisaat