Department of Water Affairs and Forestry

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KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY

TECHNICAL COMPONENT

WATER QUALITY REPORT

Coastal & Environmental Services

KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT

WATER QUALITY REPORT: FINAL

JUNE 2006

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KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT
WATER QUALITY REPORT: FINAL

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EXECUTIVE SUMMARY

The Reserve Determination process for the Kromme/Seekoei area was initiated in September 2003 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. Methods used were the updated methods of September 2003 for the water quality Reserve, as outlined in Palmer et al. (2004). The Ecoclassification manual of 2005 was used to design water quality ecospecs for each EWR site.

The results of the study are shown in the table below. Results indicated that water quality issues are mainly related to nutrient status and possible fluctuating temperature and oxygen levels downstream of dams. However, assessments are of low confidence due to poor historical monitoring and a small database of information being available for the assessment. The high impact of many in-stream dams, particularly on the Geelhoutboom, Swart and Seekoei River systems, together with intermittent rainfall, have resulted in very poor conditions in the study area. The system is also highly regulated by the Churchill and Impofu dams, with no or little environmental releases being made to maintain riverine and estuarine function.

WQSU and EWR site	Overall REC	PES: water quality	Recommended water quality category of the overall REC (quality ecospecs)	Confidence in water quality PES assessment
WQSU 1: EWR 1 - Melkhoutboskraal	C	B/C	B/C	Low
WQSU 2		C		Low
WQSU 3		B/C		Low
WQSU 4: EWR 2 – Krommeriviers Poort	D	B/C	B/C	Moderate
WQSU 5: EWR 3 – Dyke on Kromme River	D	C	C	Moderate
WQSU 6: EWR 7 – Diep River	C/D	B/C	B/C	Low
WQSU 7: EWR 4 – Geelhoutboom River	C/D	C/D	C/D	Low
WQSU 8: EWR 5 – Seekoei River	C	B/C	B/C	Very low
WQSU 9 + 10		B/C		Low
WQSU 11: EWR 6 – Swart River (upper section of the river)	B	A/B	A/B	Very low
WQSU 12 (lower section of the Swart River)		B/C		Low

The table shows that rivers are generally in a Fair condition in terms of water quality, with a hot spot occurring at EWR 4, i.e. the Geelhoutboom River.

In addition to assessing the present state of water quality conditions in the study area, an additional component of the quality Reserve process is normally to provide the water quality consequences of a range of predicted flow scenarios. The background to this step is as follows:

The EWR set during the Rivers specialist meeting (conducted in September 2004) have to be modelled (using a yield model) to assess the impact it would have on the yield of the system. If there is an impact on yield, or if there are any future development scenarios, then additional flow scenarios, called operational scenarios, are developed. These are then also modelled and the ecological consequences in terms of Ecological Categories evaluated for each of these scenarios.
However, the modelling results for the Reserve study indicated that, under present conditions, the EWR is being supplied at all the sites, therefore no impact on yield would exist to implement the EWR. Additional river flow and operational scenarios were therefore not assessed.

Recommendations included the following:

- It is recommended that monthly, or preferably bi-monthly monitoring be continued at all identified water quality monitoring points.
- Periphyton (chlorophyll-a) sampling should be conducted regularly at all EWR sites as a measurement of nutrient status, and monitoring of turbidity should be instituted.
- Temperature and dissolved oxygen should be measured when water samples are taken for analysis.
- It is also strongly recommended that DWAF Eastern Cape adopt the monitoring programme as required to conduct a water quality assessment for the Ecological Reserve. Unless the necessary list of variables is analysed (e.g. ALL required inorganic salts), confidence in the water quality assessments will continue to be low.
- A water quality manual should be developed which includes instructions on how all the available tools (e.g. methods of DWAF 2002 and the Ecoclassification manual's physico-chemical methods) must be used to conduct a water quality assessment in an EWR study.
- Further development is 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

ASPT	Average Score Per Taxon
D: RDM	Directorate: Resource Directed Measures
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Environmental Importance and Sensitivity
EWR	Ecological Water Requirements
ISP	Internal Strategic Perspective
MSL	Mean Sea Level
MV	Marginal vegetation
NMMM	Nelson Mandela Metropolitan Municipality
NWA	National Water Act
PES	Present Ecological State
Q-C	Flow-concentration
RC	Reference Condition
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
RU	Resource Unit
SI	Social Importance
SIC	Stones in Current
SOOC	Stones out of Current
SPATSIM	Spatial and Time Series Information Modelling
SRP	Soluble Reactive Phosphorous
TIN	Total Inorganic Nitrogen
TPC	Thresholds of Probable Concern
WMA	Water Management Area
WMS	Water Management System
WQSU	Water Quality Sub-Unit
WRSM90	Water Resources Simulation Model 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 and quality 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 (DWAF, 2003). 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 tasked with ensuring that methods, procedures and tools are developed for estimating the ecological requirements of water resources so that Reserve determinations take place before licensing can proceed.

The D: RDM identified the Kromme/Seekoei River catchments as requiring Comprehensive Reserve assessments before the compulsory licensing process can take place, due to the apparent highly stressed nature of the catchments, over-utilisation of water resources and water quality problems in the Kromme, Seekoei and Swart rivers. The requirements for the assessment of the Ecological Reserve (or Ecological Water Requirements (EWR)) for the Seekoei River are, *inter alia*, driven by the Kruisfontein resource-limited farmers requesting water allocations for additional irrigation. Once Reserve requirements are available, a planning study can be undertaken to determine the feasibility of the scheme. Other concerns include over-abstraction of well-fields by coastal towns in summer, and the impact of the many illegal small dams in the area.

The Reserve Determination process for the Kromme/Seekoei area was initiated in September 2003 and is made up of a number of studies. This report, DWAF report number RDM/WQR001/CON/1205, describes the process and results of the assessment conducted for the water quality component of the Ecological Reserve. This assessment was conducted to provide input to the Rivers specialist workshop of September 2004. 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 about flows and associated concentrations of water quality constituents, which describe both the present state of the system and conditions for the selected Ecological Reserve Categories.

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 of flows, the same is not true for the water quality component of a study. 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 Kromme/Seekoei catchment study area prescribed that water quality be assessed at a comprehensive level. 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. Although methods are currently being finalized in SPATSIM, this operating system was not available for use by the Kromme water quality team. As the methods can be used outside of the SPATSIM operating system, this was not perceived to be a stumbling block to completing present state water quality assessments.

The generic 8-step Ecological Reserve procedure (as taken from DWAF (2003a)) 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.

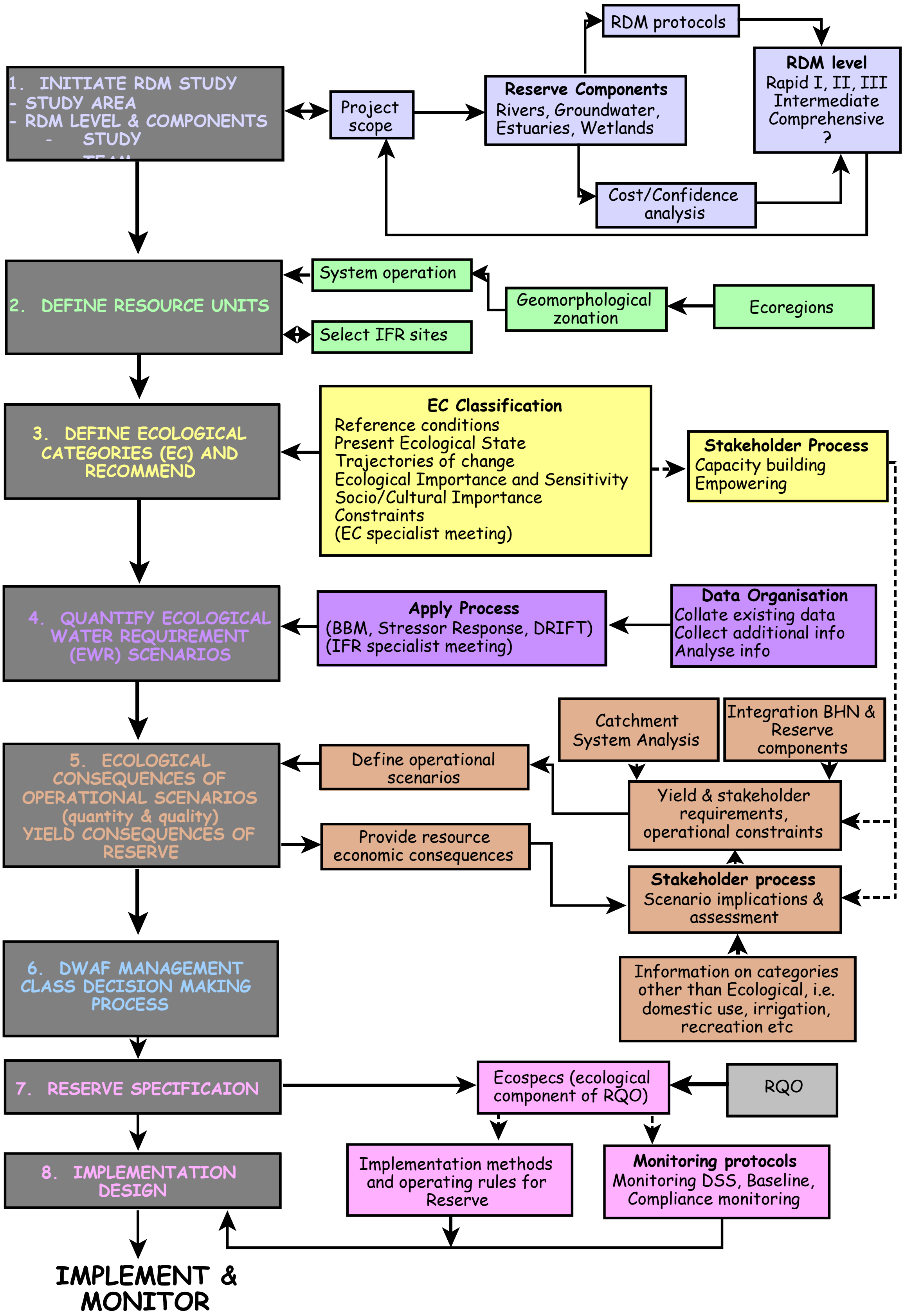


Figure 1-1 The 8-step Ecological Reserve procedure (DWAF, 2003a)

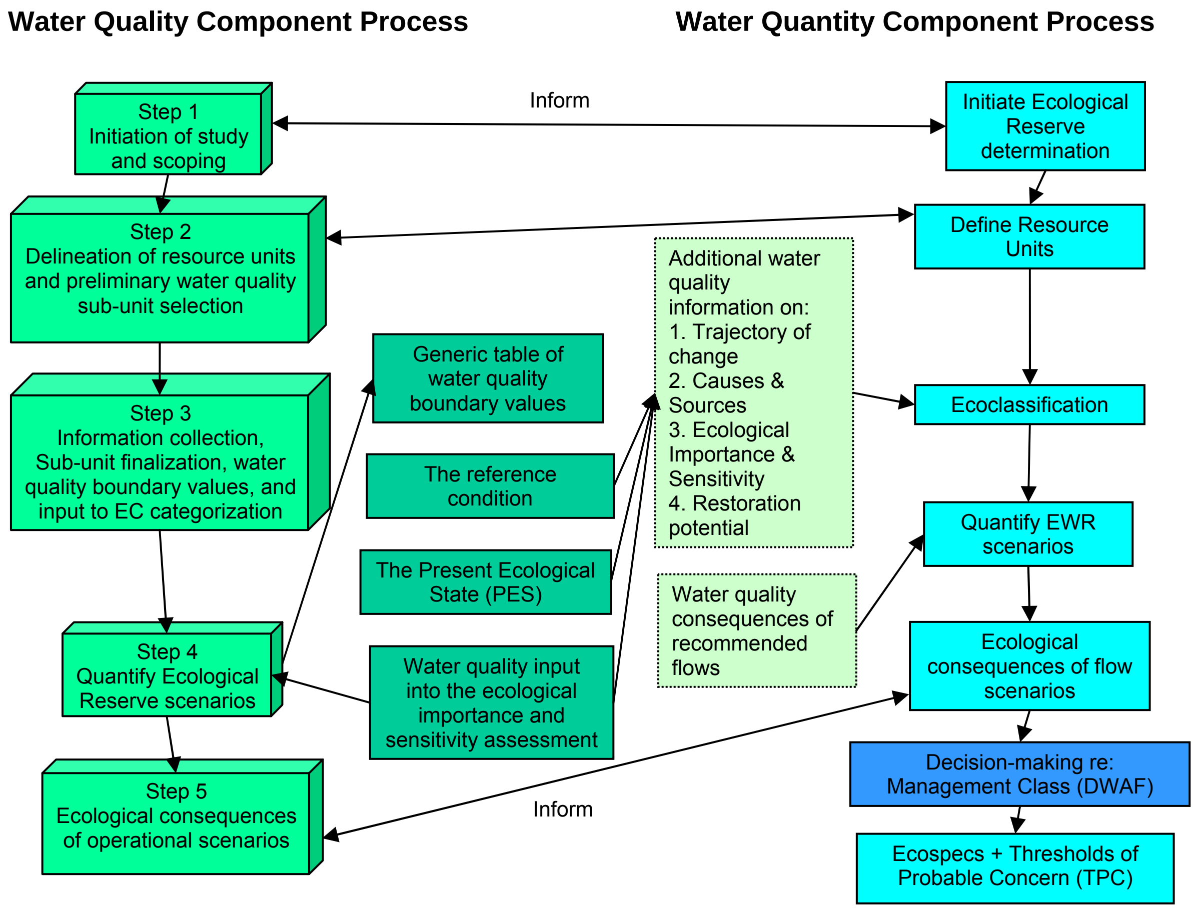


Figure 1-2 Flow diagram indicating the general approach for the water quality component of the Ecological Reserve determination study, as well as links between water quality and quantity

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-Unit (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 then 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 water quality 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 modelling) 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),
- Provide a present state assessment for water quality per WQSU,
- Provide a description of how flow-concentration modelling can be used to integrate water quality and water quantity during the EWR process, and
- Provide ecological specifications for water quality for each selected EWR site.

Note that an additional component of the quality Reserve process is normally to provide the water quality consequences of a range of predicted flow scenarios. The background to this step is as follows:

The EWR set during the Rivers specialist meeting (conducted in September 2004) have to be modelled (using a yield model) to assess the impact it would have on the yield of the system. If there is an impact on yield, or if there are any future development scenarios, then additional flow scenarios, called operational scenarios, are developed. These are then also modelled and the ecological consequences in terms of Ecological Categories evaluated for each of these scenarios.

However, the modelling results for the Reserve study (outlined in the Hydrology Report for the study, i.e. DWAF report no. RDM/HR0001/HR0007/CON/CES/1105) indicated that, under present conditions, the EWR is being supplied at all the sites, therefore no impact on yield would exist to implement the EWR. Additional river flow and operational scenarios were therefore not assessed.

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 – Ecological specifications for water quality per EWR site
Part 7 – Conclusions and recommendations
Part 8 – References

2 STUDY AREA

Background information on the study area is taken largely from the Internal Strategic Perspective (ISP) prepared for DWAF in 2003. The Kromme and Seekoei River catchments are situated in the Eastern Cape to the west of Jeffreys Bay in catchment area K90, in the Fish to Tsitsikamma Water Management Area (WMA 15). The Kromme/Seekoei area consists of seven quaternary catchments (K90A – G), as shown in Figure 2.1.

2.1 Kromme River

The Kromme River is located in a narrow valley between the Suuranys and Tsitsikamma mountains, is approximately 95 km long and drains a catchment area of 1 125 km^2. The Kromme River originates from its source in the Kromriverhoogte about 40 km to the west of the Formosa Nature Reserve. It runs in an easterly direction north of the Tsitsikamma and Kareedouw mountains and exits into the Indian Ocean at St Francis Bay. The Churchill and Impofu dams are situated about two-thirds down its length with a short stretch of river separating them. Another short stretch of river then leads into the estuary about 12 km from the mouth.

The largest tributary of the Kromme River system, the **Geelhoutboom River**, arises northwest of the N2 highway approximately 15 km from Humansdorp. It runs in a south-easterly direction for about 40 km before it flows into the Kromme Estuary from the north, approximately 9 km upstream of the mouth. Three small dams are located in the upper reaches of the river. Other medium-sized tributaries include the Dwars, Witels, Diep and Leeubos rivers.

The quality of water resources is variable across the region. The primary dune aquifers hold good quality water. The quality is good in the upper Kromme River, but becomes poorer downstream (DWAF, 2003).

2.2 Seekoei River

The Seekoei River flows in an easterly direction to the sea across a fertile coastal plain, is approximately 35 km long and drains a catchment area of 502 km^2. The Seekoei River arises in the Bakenberg Mountains about 40 km northwest of Humansdorp. It runs past Humansdorp to the south and exits into the sea at Beacon Bay. It has a 5 km estuary, which it shares with the Swart River coming in from the north.

The main tributary of the Seekoei is the **Swart River** which joins it approximately 1 km upstream of the mouth (Bickerton and Pierce, 1988). The Swart River originates from its source approximately 5 km north of the Seekoei River source also within the Bakenberg Mountains. It initially runs in an easterly direction for about 30 km to the north of Humansdorp, thereafter it flows due south and enters the Seekoei Estuary from the north.

Water quality problems are experienced in the Seekoei River due to salinisation (DWAF, 2003).

Land use in the Kromme/Seekoei study area (Figure 2-1) is predominantly grazing for livestock, with intensive cultivation of irrigated land along the main rivers as well as significant rain-fed farming. Cultivated lands are dependent on augmentary irrigation due to the low rainfall. The area is not rich in minerals and mining operations consist mainly of quarrying for building materials.

The bulk of surface water yield in the area is from dams, with several major dams constructed for urban supply and irrigation. The largest dams are the Churchill and Impofu dams on the Kromme River, which supply water *via* a transfer scheme to the Nelson Mandela Metropolitan Municipality (NMMM) and some coastal towns (DWAF, 2003). The various water storage and transfer systems that supply the NMMM are called the Algoa Water Supply System. According to the ISP the Kromme River catchment supplies approximately 48% of the water requirements for the rapidly growing NMMM.

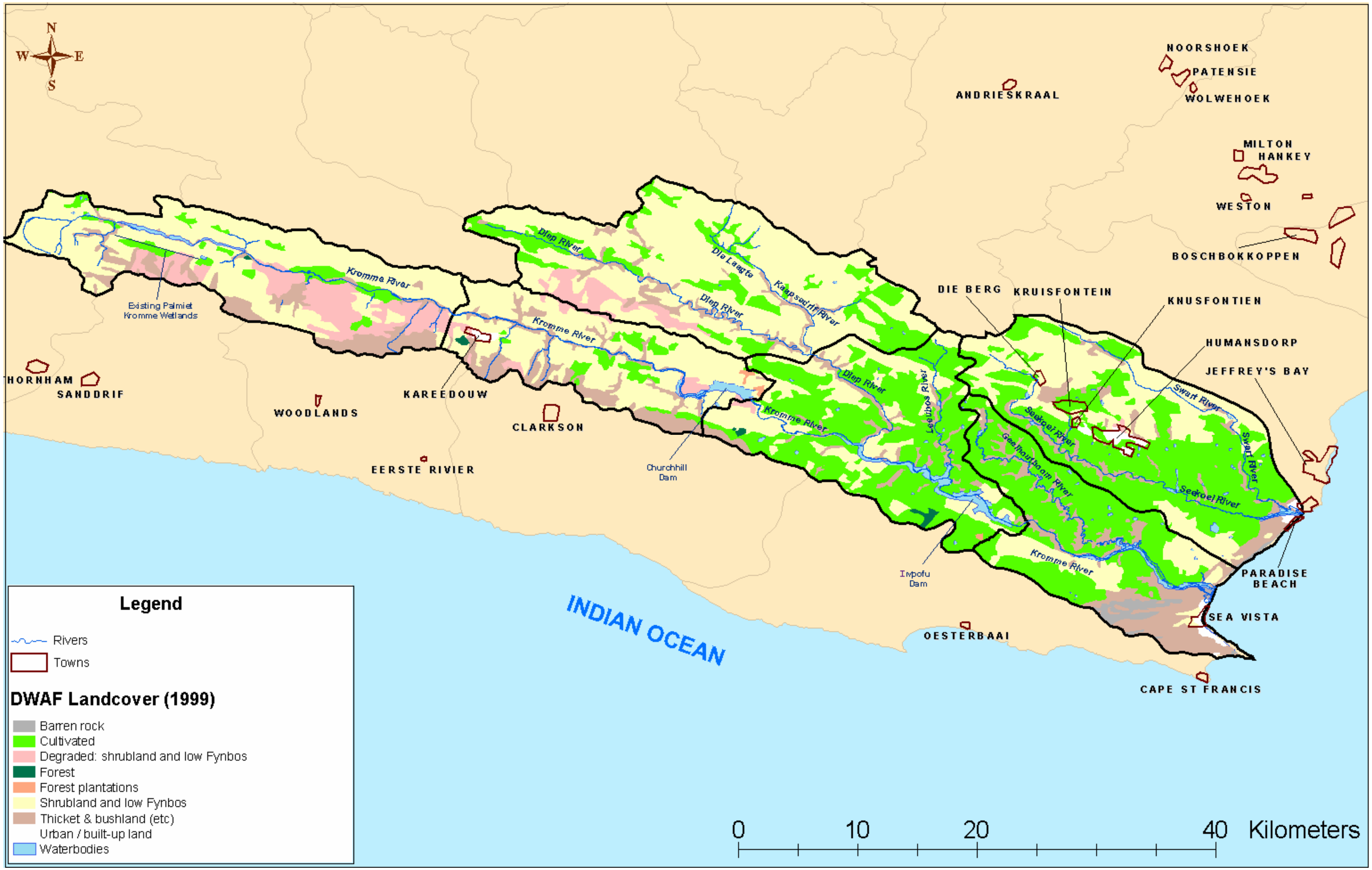


Figure 2-1 Land-use activities of the Kromme/Seekoei River catchments

2.3 General water quality monitoring status

As there are so few gauging stations and monitoring sites in the area, the confidence in the water balance calculations (Table 2-1) shown in the ISP can be described as varying from poor to fair (DWAF, 2003). Gauging stations and monitoring points for both water quality and quantity are shown in Table 2-1. Low sampling frequencies normally indicate groundwater sampling points.

Table 2-1 Monitoring points and gauging stations (flow and quality) and sampling frequency (n>2) in the study area

Monitoring Point	No. of samples	Begin date	End date
ZQMSFB1 3424BB00085 GOED GELOOF	20	05/05/94	07/05/03
ZQMHDP1 3424BB00086 ZWARTEBOSCH - RH1F	20	20/10/94	07/05/03
ZQMKWN1 3324CD00037 KAREEDOUW NORTH - KW1	20	19/10/94	07/05/03
ESSCHENBOSCH	2	13/02/95	13/02/95
WOLWEKRAAL	2	14/02/95	14/02/95
WOLWEKRAAL	2	14/02/95	14/02/95
WOLWEKRAAL-OOS	2	14/02/95	17/02/95
K9H001Q01 KROMME RIVER/CHURCHILL DAM ON KROMME RIVER: D/STREAM WEIR	8	18/04/95	22/06/99
K9H002Q01 KROMME RIVER/CHURCHILL DAM ON KROMME RIVER: LEFT PIPE	155	28/12/84	20/05/03
K9H003Q01 IMPOFU/ELANDSJAGT DAM ON KROMME RIVER: DOWNSTREAM	343	02/07/84	04/06/03
K9H004Q01 IMPOFU/ELANDSJAGT DAM ON KROMME RIVER: PIPEL TO TREAT	10	10/07/90	16/07/91
K9H006Q01 KROMME RIVER AT OSBOSCH/RIVERTIDE	13	20/09/97	17/04/03
K9R001Q01 KROMME RIVER/CHURCHILL DAM ON KROMME RIVER: NEAR DAM	71	15/05/68	25/06/96
K9R002Q01 IMPOFU/ELANDSJAGT DAM ON KROMME RIVER: NEAR DAM WALL	29	25/03/85	02/08/94
SUNNYSIDE	2	23/03/93	23/03/93
SUNNYSIDE PART OF MENTORSKRAAL	3	26/01/94	01/02/94
SUNNYSIDE PART OF MENTORSKRAAL	2	27/01/94	27/01/94
JEFFREYS BAY	4	28/01/94	30/01/94
ESSCHENBOSCH	2	13/02/95	13/02/95
KAREEDOUW AA	2	12/02/95	12/02/95
WOLWEKRAAL	2	14/02/95	14/02/95
ESSCHENBOSCH	2	14/02/95	14/02/95
MODDERFONTEIN	2	14/02/95	14/02/95
K9H007Q01 KRUISFONTEIN/HUMANSDORP	10	05/03/02	25/02/03

2.4 Study area and EWR sites

The study area was defined as follows:

- The Kromme River from below the Palmiet Wetlands to the estuary, including the estuary.
- The Geelhoutboom River, a tributary of the Kromme River.
- The Seekoei River, including the estuary, below Impofu Dam.
- The Swart River, a tributary of the Seekoei River.

Six EWR sites were selected, as shown on the study area map and Table 2-2:

- EWR 1: Melkhoutboskraal (Kromme River).
- EWR 2: Krommeriviers Poort (Kromme River).
- EWR 3: Dyke (Kromme River).
- EWR 4: Geelhoutboom River.
- EWR 5: Seekoei River.
- EWR 6: Swart River.

Table 2-2 EWR sites as located in the Kromme/Seekoei study area

EWR site	River	Latitude	Longitude	Quaternary	RU
EWR 1	Kromme	E 24º 15.680	S 33º 55.905	K90A	A
EWR 2	Kromme	E 24º 29.865	S 34º 00.822	K90D	B
EWR 3	Kromme	E 24º 43.6	S 34º 06.3	K90E	C
EWR 4	Geelhoutboom	E 24º 44.723	S 34º 05.411	K90E	E
EWR 5	Seekoei	S 33º 59.968	E 24º 42.113	K90F	F
EWR 6	Swart	S 34º 00.05	E 24º 50.83	K90F	H

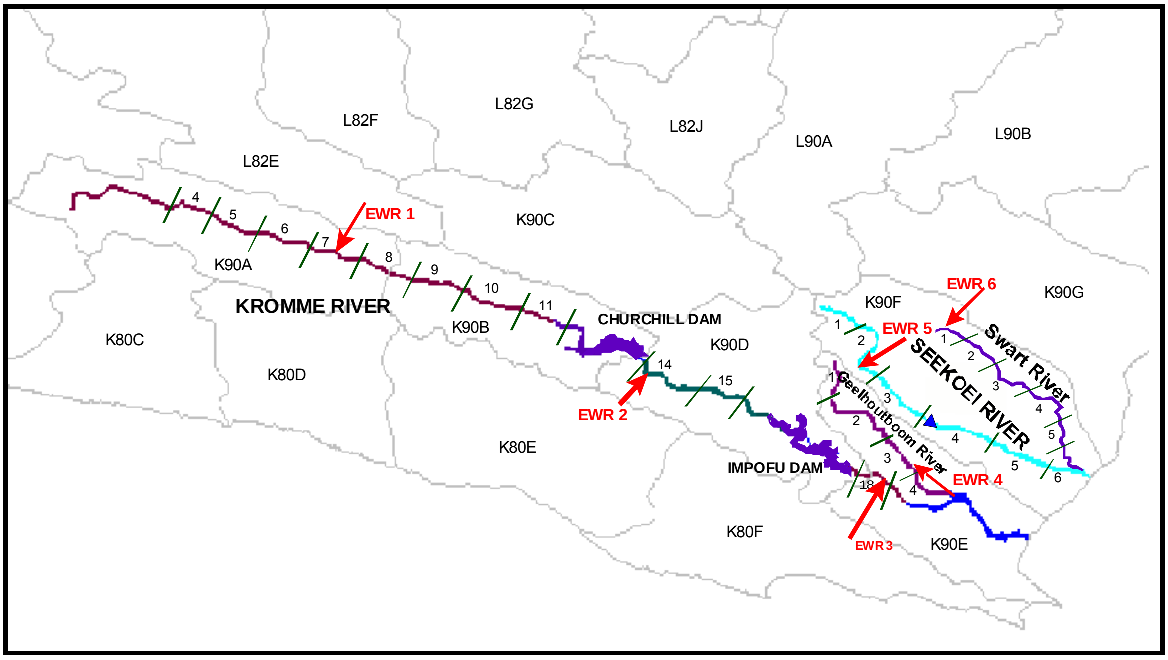


Figure 2-2 EWR sites as located in the Kromme/Seekoei study area

A subsequent study, conducted in March 2005, included a Rapid Level III study on the Diep River (a tributary of the Kromme River). EWR 7 is located at S 34º 01.322 and E 24º 35.557 in quaternary catchment K90D.

3 DELINEATION 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 3-1)
- Location of EWR sites (Table 2-2 and Table 3-1)
- A list of the DWAF monitoring stations in the study area (Table 2-1)
- Background information on water quality conditions in the study area (DWAF, 2003)
- Level 1 ecoregion boundaries (Figure 2-1) (http://www-dwaf.gov.za/IWQS/gis_data/ecoregions/get-ecoregions.htm)
- Possible point sources of pollution
- Major tributaries
- Information gained during the site survey of October 2003

The delineated Water Quality Sub-Units (WQSU), and their association to the resource units (RU), are shown in Table 3-1. The following points were noted about the study area, based on the field survey of October 2003:

- All catchments were very encroached with alien vegetation. There is widespread Black Wattle infestation in the Kromme River catchment particularly, with a Working-for-Water programme due to start clearing again in 2005 (Roux, Churchill Dam manager, *pers. comm.*).
- The Kromme River channel was almost covered by Palmiet in many sections (see Figure 3-2), while the Swart, Seekoei and Geelhoutboom rivers are also covered by papyrus.
- The streams are generally small (except for some sections of the Kromme River), and flow depends on good rains. The Geelhoutboom and Swart rivers seem particularly impacted by farm dams.
- Farmers in the Geelhoutboom and lower Kromme areas were aggressive and believe that DWAF is not fulfilling their function, particularly regarding water supply to the area *before* transfer to Port Elizabeth.
- There were tensions in the Kareedouw area regarding the municipality not fulfilling their functions in terms of waste treatment and disposal in low-cost housing areas.

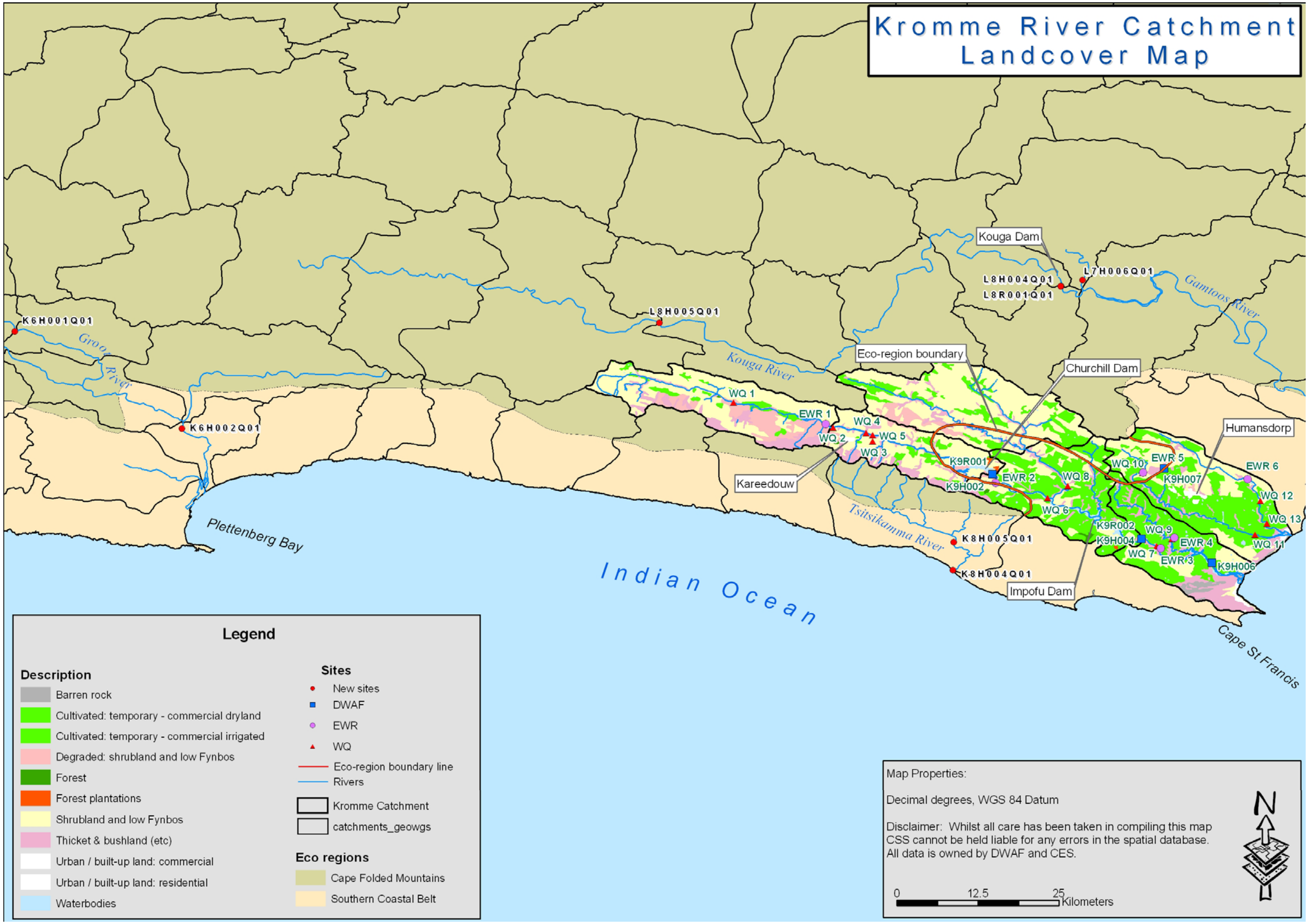


Figure 3-1 Map of the Kromme/Seekoei study area showing the position of water quality monitoring sties surveyed by the project team and DWAF, both regional and national monitoring programmes

Table 3-1 Water quality sub-units and descriptive information for the Kromme / Seekoei Reserve study area

RU	WQSU	Description and Map no.	Monitoring Points	Land-use Activities
KROMME RIVER				
A	1	From below Palmiet wetlands to below Melkhoutboskraal, just above Kareedouw town (Maps: 3324CC Witelsbos and 3324CD Kareedouw)	This stretch contains three WQ sites assessed in Oct '03, but two sites (Kammiesbos and Melkhoutboskraal) are monitored by EC DWAF. EC DWAF has a small database for the Melkhoutboskraal site.	This is mostly a wetland area fed by small streams. There is extensive farming in the area, e.g. Hendrikskraal (vegetables), Kammiesbos (cattle, pigs, goats etc.), Skaapdrift (sheep).
A	2	Kareedouw town to below the charcoal factory on the outskirts of the town (Map: 3324CD Kareedouw)	This stretch contains three WQ sites assessed in Oct '03, but two sites (Assegaaibos Station, and below the charcoal factory (i.e. just above Goedgenoeg farm)) are monitored by EC DWAF. EC DWAF has a small database for the Assegaaibos Station site.	Impacts in this area are six oxidation ponds related to the towns wastewater treatment facility, Woodline (factory producing creosote poles), a Nestlé factory in town, run-off from town and the low-cost housing areas of Uitkyk and Kagiso Heights, and the small-scale charcoal factory below Kareedouw.
A	3	From below the charcoal factory to the inlet of Churchill Dam (Map: 3324CD Kareedouw)	This stretch contains one WQ site assessed in Oct '03 at De Wilgen, but two other sites (Willowvale and Lemoenfontein) were checked for accessibility. EC DWAF continued monitoring one site at De Wilgen.	No significant tributaries are seen in this stretch. Land-use is primarily agriculture and grazing. The river is encroached with Palmiet.
B	4	Wall of Churchill Dam to the inlet of Impofu Dam (Map: 3424BA Kruisfontein)	The stretch contains one WQ site assessed in Oct '03 at Diepriviermond Farm. EC DWAF continued monitoring this site. DWAF-WMS sites K9R001, K9H001, K9H002.	This area is mostly inaccessible (Krommeriviers Poort) until Diepriviermond Farm (a large dairy farm in the area).
C	5	Wall of Impofu Dam to just above the estuary (Map: 3424BA Kruisfontein)	The stretch contains one WQ site assessed in Oct '03. EC DWAF continued monitoring this site. DWAF-WMS sites K9R002, K9H003, K9H004, K9H006.	Primary land-use is dairy farming. The river is wider and deeper in this section, with no habitat for fish or invertebrate monitoring.
KROMME RIVER TRIBUTARIES				
	6	Diep (Map: 3424BA Kruisfontein): This river was identified by Graham Devey of the Nelson Mandela Metropole laboratories as "good quality" and may act as a refugia area. As the river flows into Impofu Dam it has no impact on the Kromme River, but may be a useful reference site.	One WQ site was assessed in Oct '03 in the lower section of the river. Data were accessed from NMMM as they routinely monitor this system, and have a database for this river.	Primary land-use is cattle farming.

RU	WQSU	Description and Map no.	Monitoring Points	Land-use Activities
E	7	Geelhoutboom (Map: 3424BA Kruisfontein): The Geelhoutboom is a very small stream that flows only at times of good rains. There was some water in the channel at the time of the field survey, i.e. 22 October 2002, as it had rained a few days previously.	One WQ site was assessed in Oct '03. The site is downstream of the dam at Ebenezer, as an upstream site could not be found. EC DWAF continued monitoring this site.	Primary land-use is dairy farming. Below the road bridge there is a large illegal dam, which farmers are not allowed to use for abstraction (Meyer, pers. comm.).
SEEKOEI RIVER				
F	8	Upper section of the river to above Kruisfontein and Humansdorp (i.e. Orange Grove farm) (Map: 3424BA Kruisfontein)	One WQ site in this stretch was assessed in Oct '03. EC DWAF has a small database for this site. DWAF-WMS site K9H007.	This section of the river is mostly in game-farming area, and is above towns and townships. Some dairy farming is present along the lower section around Orange Grove Farm.
	9	Middle section of the river from the Kruisfontein discharge stream on Orange Grove Farm, to Geelhout Dam. This lower stretch of the Seekoei River was split by Geelhout Dam as inputs from Kruisfontein and Humansdorp would be trapped in the dam, resulting in water quality changes downstream of the dam (Map: 3424BA Kruisfontein and 3424BB Humansdorp).	One WQ site in this stretch was assessed in Oct '03, but it is above the Kruisfontein stream input, so will not be monitored in future. WQU 9 and 10 were combined, as there is no suitable site in WQU 9.	Primary land-use is dairy farming and urban areas (i.e. Humansdorp and Kruisfontein). Area is highly dammed.
	10	Below Geelhout Dam to above the estuary (Map: 3424BB Humansdorp)	There are two water quality sites assessed in Oct '03 in this stretch, i.e. on Soutvlei farm and around Lombardini. The Lombardini site is more accessible from the road, although very encroached by papyrus, and this one site was monitored by EC DWAF on a monthly basis.	This area has extensive dairy farms and some game farming, and is highly dammed. Due to the dams in the area and inconsistent rain, it is assumed that samples may not be taken at times, as there will not be water in the channel.
SWART RIVER				
H	11	This river is considered one sub-unit. There is very little water in the stream, with most of the small tributaries coming into the river being dammed.	Two water quality sites on this small river were assessed in Oct '03. One site is on the upper section of the stream under the road bridge on the R102, upstream of Swart River Dam and Jubilee Estates, and consists of a small stream and wetland (access difficult). The other site is downstream below Jubilee Estates and is a very small stream encroached by papyrus. This site is probably dry for much of the year, but is more accessible and this one site was monitored by EC DWAF when possible.	This area has extensive dairy farms, and is highly dammed. Due to the dams in the area and inconsistent rain, it is assumed that samples may not be taken at times, as there will not be water in the channel.

Figure 3-2 The Kromme River, showing infestation by Palmiet

4 WATER QUALITY PRESENT STATE ASSESSMENT

This section lists the results of the water quality assessment conducted for the Kromme/Seekoei 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, where possible.

Although the Kromme/Seekoei Ecological Reserve study was to be conducted at a Comprehensive level, the results of an 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. The water quality assessment conducted for this study is of low confidence as most of the analytical data used for the assessment was collected during the study on a monthly basis. Little data existed before the study was initiated, and DWAF in the Eastern Cape was not conducting regular and effective water quality monitoring in the Kromme/Seekoei catchment area.

4.1 Approach

Due to the paucity of water quality data and inadequate monitoring of these catchments by the national DWAF monitoring programme, an agreement was reached with EC DWAF for the collection of *monthly* samples at a number of monitoring points throughout the catchments of the study area. In many areas this was the only data available for a present state assessment. The amount of data available from the WMS database, particularly historical data describing Reference Condition, also suggested that it might be necessary to utilise adjacent catchments within the same ecoregion, as proxy sites. The sites considered are shown in Figure 3-1. The results of this consideration are discussed in Section 4.2.1.

As stated in Chapter 1, methods for undertaking the present ecological state assessment were based on a methods manual produced for DWAF (2002) and discussions held at a workshop in Grahamstown in July 2003 regarding water quality Reserve methods. These methods are published in Palmer et al. (2004) and can also be found on the Ninham Shand web-site (*http://projects.shands.co.za/Hydro/hydro/WQReserve/main.htm*).

4.2 Data collation

The following information was used to undertake the present state assessments for this study:

- Literature regarding water quality conditions in the catchment, and a field survey undertaken in October 2003 to verify the delineation of WQSUs and catchment land-use.
- The systems operation document circulated to study specialists and shown in the Hydrology Report for the study (DWAF report no. RDM/HR0001/HR0007/CON/CES/1105).
- Water quality data from selected DWAF and Nelson Mandela Metropolitan Municipality (NMMM) monitoring points in the catchment.
- Spot samples taken during the October field survey and subsequent samples (November 2003 to May 2004, where flow allowed) from identified sampling points. Samples were analysed at the NMMM laboratory in Port Elizabeth.
- Chlorophyll-*a* analyses were undertaken at selected points in the catchment as an indicator of algal abundance, during the field survey of October 2003 (n=1). Samples were analysed for phytoplankton and periphyton at the Coastal Research Group, Rhodes University. The results of these analyses can be seen in Froneman (2003). Although these results were

used in the water quality assessment, it must be cautioned that these were only single samples and results should be interpreted with due consideration.

- Biotic integrity data (macroinvertebrates (**ASPT values and boundary tables used to set categories**) and fish (**category *without impact of aliens* used**)) were sourced from relevant specialists of the Kromme and Seekoei Reserve study for the EWR sites. More detailed results of the macroinvertebrate and fish surveys can be found in the EWR Rivers report for the study, DWAF report number RDMEWR001/RR004/CON/CES/1105.

- The SALTBA23.exe version of the salt model (Jooste, 2004; RQS, DWAF) was used to generate PES categories for inorganic salts. The salt model returns classes (or categories) based on the data input. Although it is theoretically possible to extract the actual reconstituted inorganic salt values (Jooste, RQS, *pers. comm.*), this proved difficult and it was therefore not always possible to present these results.

Where water quality data, particularly inorganic salt (or appropriate ionic) data, were unavailable to undertake a present state assessment according to the method above, a method developed using electrical conductivity (EC) was included in the water quality assessment (DWAF, 2004). This method was developed in response to the recognition that EC is the most frequently monitored water quality parameter and may often be the only water quality data available. Note that the method has not been adequately tested and that these results therefore represent a low confidence assessment.

- Available data were screened for toxics, e.g. metals. Toxics are listed and assessed where data were available.

- No in-stream toxicity assessments were undertaken.

4.2.1 Data for reference conditions

Limited water quality data were available for the entire Kromme River catchment. Of particular concern was the paucity of Reference Condition (RC) data. Data from adjacent catchments were therefore evaluated for possible use to describe Reference Condition (see Figure 3-1). Site visits to these catchments were not undertaken and adequacy of the catchments as a proxy for water quality data was not ground-truthed.

L8H005Q01 in the Kouga River (Ecoregion Level I: Cape Folded Mountains) was assessed as a reference site for the upper Kromme River catchment (water WQSU 1 and 2, and incorporating EWR 1). Data from the lower Kouga catchment were not considered appropriate for RC due to unknown catchment land-use. Similarly, data from the Kouga Dam were not considered appropriate as reference condition.

L8H005Q01 was not used as a RC site for several reasons. The data record commenced in 1990 and therefore may not represent true reference condition. Data analysis revealed the site to be similar to the benchmark default values (with the exception of $MgSO_4$, NaCl and SRP). Therefore, due to the uncertainty of catchment condition, it was considered more appropriate to use either the default benchmark boundary values without adjustment or, where possible, data from the study catchment.

K8H005Q01 in the Tsitsikamma River (Ecoregion Level I: Southern Coastal Belt) was assessed as a reference site for the lower Kromme River catchment (WQSU 3 - 11, and incorporating EWR 2 - 6).

K8H005Q01 was rejected as a possible reference condition site as there was an insufficient data record. The data record commenced in 1995, no sample collection was undertaken in 1996, and monitoring was intermittent thereafter.

4.2.2 Trend of change assessment

An assessment of the trajectory of change was undertaken by plotting, where possible, a time series of the selected water quality variables. The selected statistical package (Statistica Version 6.1) then plotted a linear fit through the data points and an assessment of the trend of change was based on the slope of this linear fit.

4.3 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
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	5^{th} Percentile: 5.75 – 6.00 95^{th} Percentile:8.05 – 8.37
Good: 5.75 – 8.05 and 6.46 – 9.00	B	5^{th} Percentile: 6.00 – 6.24 95^{th} Percentile:8.37 – 8.69
Lower Good	B/C	5^{th} Percentile: 6.24 – 6.46 95^{th} Percentile:8.69 – 9.00
Upper Fair	C	5^{th} Percentile: 5.00 – 5.23 95^{th} Percentile:9.05 – 9.36
Fair: 5.00 -5.7 and 9.05 – 10.00	C/D	5^{th} Percentile: 5.23 – 5.46 95^{th} Percentile: 9.36 – 9.67
Lower Fair	D	5^{th} Percentile: 5.46 – 5.7 95^{th} Percentile: 8.56 – 10.00

Descriptive classification + allocated range from methods manual	Numerical classification	Value per category
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 (Average Score Per Taxon (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

4.4 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. These plots were also used to assess trends of change.
- Table 4-2 briefly shows the calculations needed for both RC and PES assessments (for Comprehensive Reserve studies).

Table 4-2 Calculations required for the PES assessment for water quality (Comprehensive Reserve methods)

Variable	Methodology
Inorganic salts	Individual salts put into computer salt model. If not available, use EC. 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 modelling – 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 data 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. Instream toxicity tests using 3 test organisms, *Daphnia*, fish and an algal test, may be undertaken

- 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/.

4.5 Results: Present Ecological State (PES) assessment

Results for the Present Ecological State (PES) assessments are presented in Tables 4-3 to 4-12. Results are presented on the basis of Resource Units (RU). The results of the water quality assessments for the Kromme River are presented first, followed by tributaries (Diep and Geelhoutboom rivers) and the other rivers in the study area (Seekoei and Swart rivers).

Note that Resource Units D and G refer to the estuaries of the Kromme and Seekoei Rivers respectively and as such, their water quality assessments are reported in the EWR Estuaries reports for the study (RDM/EWR001/ER0005/CON/CES/1105 and RDM/EWR001/ER0006/CON/CES/1105).

4.5.1 Resource Unit A: Kromme River: WQSU 1-3

This RU contains three WQSUs. The primary land-use in the RU is agriculture, being a mix of crops (vegetables) and grazing (cattle, sheep, pigs and goats). In the upper part of the RU, there are extensive wetlands and in many places the river is encroached with Palmiet. Impacts from Kareedouw were identified as the wastewater treatment works, a wood factory, a food product factory, a charcoal factory and run-off from low-cost housing areas and Kareedouw.

WQSU-1: Kromme River from below Palmiet wetlands to below Melkhoutboskraal (upstream Kareedouw)

EWR 1 is in this WQSU.

Table 4-3 shows the PES categories for WQSU-1. For all water quality variables assessed, the benchmark boundary values were used as there were no appropriate data which could be used for RC. A water quality monitoring site was instituted for the purposes of this study (WQ2 at Melkhoutboskraal) in the lower section of the WQSU and was used for the PES assessment. These data were of limited value as only four samples (February to May 2004) were collected and the small sample size (n=4) resulted in a low confidence assessment.

The increased SRP concentrations result in the assessment for this water quality variable being in a Poor category. This is reflected in the elevated periphyton chlorophyll-*a* concentrations and may also, in part, account for reduced macroinvertebrate and fish scores. Although there were no data available for inorganic salts, the low conductivity suggests that these may not be variables of concern in this WQSU.

A trend assessment could not be undertaken due to limited data. As land-use has not changed for some time, it is assumed that the current water quality conditions are unlikely to change.

Table 4-3 PES categories and overall site assessment for WQSU-1

RIVER	Kromme River	**Water Quality Monitoring Points**	
WQSU	1	**RC**	Default boundary tables
EWR SITE	EWR 1	**PES**	WQ2 (n=4)
Confidence assessment	Low, due to limited sample size (G-Power calculation was not undertaken)		
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	An assessment of inorganic salts could not be undertaken as the data from NMMM were not compatible with the salt model.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.24	D (Poor)
	TIN	0.105	A (Natural)
Physical Variables	pH (5^{th}-95^{th}%)	6.3-7.4	B/C (Lower Good) - A (Natural)
	Temperature	-	No data, but not considered a problem water quality variable as no thermal impacts expected and not below a dam.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	No data
	Electrical conductivity (mS/m)	29	A (Natural)
Response variables	Chl-a: periphyton	90.1	D (Poor)
	Chl-a: phytoplankton	0.255	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score	6.1 (mean of two surveys)	B/C (Lower Good)
	Fish community score	-	C (Upper Fair)
Toxics	Fluoride (mg/L)	0.08	A (Natural)
OVERALL SITE CLASSIFICATION		**B / C**	

WQSU-2: Kromme River from Kareedouw town to downstream of the charcoal factory on the outskirts of town

Table 4-4 shows the PES categories for WQSU-2. There was no appropriate data which could be used for RC within this WQSU and the default benchmark boundary tables were used. Two additional monitoring sites were instituted for the purposes of this study (WQ3: downstream of the town but upstream of the charcoal factory i.e. at Assegaaibos; and WQ4: downstream of both town and charcoal factory) and were used for the present state assessment. These data were of limited value as only four samples (February to May 2004) were collected.

Although limited data is available, WQ4 suggests an improvement in water quality from WQ3 (particularly for SRP and EC). However, the difference between the two sites is marginal and results from WQ3 (although positioned in the middle of the WQSU, this site is below most impacts) were used to reflect the PES for this WQSU as this site better represents the conditions of the entire WQSU.

The increased SRP concentrations result in the assessment for this water quality variable being in a Poor category. This is reflected in the elevated periphyton chlorophyll-*a* concentrations. Although there was no data available for inorganic salts, the conductivity suggests that these may not be variables of concern in this WQSU.

A trend assessment could not be undertaken due to limited data.

Table 4-4 PES categories and overall site assessment for WQSU-2

RIVER	Kromme River		**Water Quality Monitoring Points**	
WQSU	2		**RC**	Default boundary tables
EWR SITE	None		**PES**	WQ3 (n=4)
Confidence assessment	Low, due to limited sample size (G-power calculation was not undertaken)			
Water Quality Constituents			**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		-	An assessment of inorganic salts could not be undertaken as the data from NMMM were not compatible with the salt model.
	Na_2SO_4		-	
	$MgCl_2$		-	
	$CaCl_2$		-	
	NaCl		-	
	$CaSO_4$		-	
Nutrients (mg/L)	SRP		0.24	E/F (Poor)
	TIN		0.01	A (Natural)
Physical variables	pH (5^{th}-95^{th}%)		6.2-6.9	B (Good) – A (Natural)
	Temperature		-	No data, but not considered a problem water quality variable as there are no thermal impacts and not below a dam.
	Dissolved oxygen		-	
	Turbidity (NTU)		-	No data
	Electrical conductivity (mS/m)		42.7	A/B (Upper Good)
Response variable	Chl-a: periphyton		265.9	E/F (Poor)
	Chl-a: phytoplankton		0.253	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score		-	No data
	Fish community score		-	No data
Toxics	Fluoride (mg/L)		0.11	A (Natural)
OVERALL SITE CLASSIFICATION			**C**	

WQSU-3: Kromme River from downstream of the charcoal factory to the inlet of Churchill Dam

Table 4-5 shows the PES categories for WQSU-3. There was no appropriate data which could be used for RC within this WQSU and the default benchmark boundary tables were used for an assessment of all water quality variables. An additional monitoring site was instituted for the purposes of this study (WQ5 at De Wilgen, situated in the middle of the WQSU) and was used for the present state assessment. These data were of limited value as only four samples (February to May 2004) were collected.

The increased SRP concentrations resulted in the assessment for this water quality variable being in a Poor category. This is reflected in the elevated periphyton chlorophyll-*a* concentrations. Although there was no data available for inorganic salts, the low conductivity suggests that these may not be variables of concern in this WQSU.

A trend assessment could not be undertaken due to limited data.

Table 4-5 PES categories and overall site assessment for WQSU-3

RIVER	Kromme River	**Water Quality Monitoring Points**	
WQSU	3	**RC**	Default boundary tables
EWR SITE	None	**PES**	WQ5 (n=4)
Confidence assessment	Low, due to limited sample size (G-Power calculation was not undertaken)		
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	An assessment of inorganic salts could not be undertaken as the data from NMMM were not compatible with the salt model.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.12	D (Lower Fair)
	TIN	0.01	A (Natural)
Physical variables	pH (5^{th}-95^{th}%)	6.3-6.9	B (Good) – A (Natural)
	Temperature	-	No data, but not considered a problem water quality variable as there are no thermal impacts and not downstream of a dam.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	No data
	Electrical conductivity (mS/m)	27.3	A (Natural)
Response variable	Chl-a: periphyton	140.1	E/F (Poor)
	Chl-a: phytoplankton	0.279	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score	-	No data
	Fish community score	-	No data
Toxics	Fluoride (mg/L)	0.07	A (Natural)
OVERALL SITE CLASSIFICATION		**B/C**	

4.5.2 Resource Unit B: Kromme River: WQSU-4

WQSU-4: Churchill Dam wall to inlet of Impofu Dam

EWR 2 is in this WQSU.

Table 4-6 shows the PES categories for WQSU-4. Water quality data from the dam (K9R001Q01) was rejected for RC as these data were patchy and may have yielded unreliable results. Similarly, data from K9H002Q01 were also rejected for use as RC as the data record was considered too recent (sampling commenced in 1984) and was intermittent. Therefore, the default boundary tables and water quality data from K9H002Q01 (on the left outlet pipe at Churchill Dam) were used for present state assessment. Where there was sufficient data available, G-power was used to assign a confidence calculation to the assessment (listed where appropriate in Table 4-6).

While nutrients showed an increasing trend over time, this trend was also observed for CaCl, but not for any other water quality constituents assessed. In fact, both NaCl and MgCl showed a decreasing trend over the time period for which there was data available. Nutrients showed increased levels when compared to benchmark boundary values, resulting in an overall Good category, and the increased nutrients may be reflected in the increased periphyton chorophyll-*a* values recorded. Inorganic salt concentrations were in a Natural - Good category, and were not thought to be contributing to the reduced response variables, as shown by the fish and invertebrates.

Table 4-6 PES categories and overall site assessment for WQSU-4

RIVER	Kromme River	**Water Quality Monitoring Points**			
WQSU	4	**RC**	Default boundary tables		
EWR SITE	EWR 2	**PES**	K9H002Q01 (2000-2004) n=60		
Water Quality Constituents		**Value**	**Category / Comment**	**G-power**	**Confidence**
Inorganic salts (mg/L)	$MgSO_4$	18.9	A/B (Upper Good)	0.33	Low
	Na_2SO_4	0	A (Natural)	-	-
	$MgCl_2$	13.5	A (Natural)	0.07	Low
	$CaCl_2$	31.5	A/B (Upper Good)	0.56	Low
	NaCl	197	B (Good)	0.97	High
	$CaSO_4$	0	A (Natural)	-	-
Nutrients (mg/L)	SRP	0.017	B (Good)	0.09	low
	TIN	0.313	A/B (Upper Good)	0.27	low
Physical variables	pH (5^{th}-95^{th}%)	6.5-9.17	A (Natural) - C (Upper Fair)	0.99	high
	Temperature	-	No data. Operational rules indicate bottom releases to river and DO and temperature should therefore be monitored.		
	Dissolved oxygen	-			
	Turbidity (NTU)	-	No data		
Response variables	Chl-a: periphyton	140.1	D (Poor)	-	low
	Chl-a: phytoplankton	0.279	A (Natural)	-	low
	Biotic community composition: macroinvertebrate (ASPT) score	5.69 (mean of two surveys)	C		
	Fish community score	-	C (Upper Fair)		
Toxics	Fluoride (mg/L)	0.155	A (Natural)	0.28	low
OVERALL SITE CLASSIFICATION		**B/C**			

Note: where values of 0 are returned for inorganic salts, this is a reflection that concentrations of these inorganic salts were too low to be reconstituted by the model and does not reflect the absence of the inorganic salt.

Although there was no data available for dissolved oxygen and water temperature assessments, these may be water quality constituents of concern, due to the operating rules of Churchill Dam.

Overall confidence in the data assessment ranged from low (all but one of the inorganic salts and nutrients) to high (for NaCl and pH). Low confidence was assigned to the chlorphyll-*a* assessment as these were single samples and not considered to be truly representative of the prevailing water quality conditions.

4.5.3 Resource Unit C: Kromme River: WQSU-5

WQSU-5: Impofu Dam wall to immediately upstream of the Kromme Estuary

EWR 3 is in this WQSU.

Table 4-7 shows the PES categories for WQSU-5. The default boundary tables were used in the assessment of this RU and data from the monitoring point K9H003Q01 was used for the present state assessment; this monitoring point is downstream of Impofu Dam. Where there was sufficient data available, G-power was used to assign a confidence calculation to the assessment (listed where appropriate in Table 4-7).

There was no consistent pattern in trends for the various water quality constituents assessed. While there was an increasing trend for some variables ($MgSO_4$, SRP and F), a decreasing trend for others (e.g. TIN), other water quality constituents showed no trend (e.g. the remaining of the inorganic salts).

Of the inorganic salts, $MgSO_4$ and NaCl concentrations were elevated to such an extent that the resultant water quality categories ranged from Poor to Fair, while the remainder of the inorganic salts ranges from Upper Good to Natural. Despite the probable extensive use of fertilizers in this WQSU, nutrient levels remain within a Natural - Good level when compared to benchmark boundary values. It may be possible that nutrient levels are ameliorated in the dam and, as the monitoring point is immediately below the dam outlet, nutrient levels may not be representative of conditions at the EWR site. The below average water quality state is reflected in the reduced biotic response variable, namely a Poor macroinvertebrate score and a Fair fish score (Table 4-7).

Overall confidence in the data assessment ranged from low (for all but two of the inorganic salts) to high (for NaCl and pH). Low confidence was assigned to the chlorphyll-*a* assessment as these were single samples and not considered to be truly representative of the prevailing water quality conditions.

Although there was no data available for dissolved oxygen and water temperature, these may be water quality constituents of concern, when (and if) environmental releases are made from Impofu Dam. According to Mr Raimer of the NMMM, the environmental requirement of $2Mm^3/a$ that is prescribed for the Kromme Estuary, is not released from Impofu Dam. Some of the water that is released for the riparian users downstream of Impofu Dam, however, may reach the estuary, but these releases will probably decrease in future, as one of the main downstream riparian users (Gutsche) is currently constructing a pipeline to abstract water directly from Impofu Dam (Hydrology Report for the study, i.e. DWAF report no. RDM/HR0001/HR0007/CON/CES/1105).

Impofu Dam is a multiple release system, with outlets situated at 22%, 49.25%, 55.25%, 61.25% and 67.25% (about 45 m) relative to the top of the spillway. All releases are done from the bottom-most outlet, although releases have not been made for a long time. For dam safety, a small amount of water is allowed to trickle through the wall but these amounts are extremely low (flows shown on the DWAF website are between 0.001 m^3/s and 0.071 m^3/s for 2004).

Table 4-7 PES categories and overall site assessment for WQSU-5

RIVER	Kromme River	**Water Quality Monitoring Points**			
WQSU	5	**RC**	Default boundary tables		
EWR SITE	EWR 3	**PES**	K9H003Q01 (2000-2004) n=63		
Water Quality Constituents		**Value**	**Category / Comment**	**G-power**	**Confidence**
Inorganic salts (mg/L)	$MgSO_4$	51.8	E /F (Poor)	0.46	Low
	Na_2SO_4	0	A (Natural)	-	-
	$MgCl_2$	17.6	B (Upper Good)	0.06	Low
	$CaCl_2$	30.9	B (Upper Good)	0.67	Medium
	NaCl	459	C (Fair)	0.97	High
	$CaSO_4$	0	A (Natural)	-	-
Nutrients (mg/L)	SRP	0.017	B (Good)	0.06	low
	TIN	0.066	A (Natural)	0.08	low
Physical variables	pH (5th-95th%)	7.28-8.04	A (Natural) - A/B (Upper Good)	1	high
	Temperature	-	No data. Operational rules indicate bottom releases to river. Temperature and DO should therefore be monitored.		
	Dissolved oxygen	-			
	Turbidity (NTU)	-	No data		
Response variables	Chl-a: periphyton	-	No data (isolated patches of algae seen, November 2003).		
	Chl-a: phytoplankton	0.763	A (Natural)		
	Biotic community composition: macroinvertebrate (ASPT) score	4.42	E/F (Poor)		
	Fish community score	-	C (Upper Fair)		
Toxics	Fluoride (mg/L)	0.226	A (Natural)	0.09	low
OVERALL SITE CLASSIFICATION		**C**			

Note: where values of 0 are returned for inorganic salts, this is a reflection that concentrations of these inorganic salts are too low to be reconstituted by the model and does not reflect the absence of the inorganic salt.

4.5.4 Diep River: WQSU-6

The Diep River flows into Impofu Dam and has no direct impact on the Kromme River. It was thought that this river may act as a refugia area (it was identified by Devey, of NMMM, as providing good quality water to Impofu Dam) or possibly as a reference site. Due to this, the Diep River was assessed for water quality; this river was subsequently assessed in a Rapid level III Ecological Reserve assessment in March 2005. Table 4-8 shows the PES categories for WQSU-6.

There was no appropriate data which could be used for RC within this WQSU and the default benchmark boundary tables were used.

The NMMM monitor water quality in this river as it may affect the quality of water within Impofu Dam, which is used to supply drinking water to Port Elizabeth. Limited data were obtained from NMMM (Devey, NMMM, *pers. comm.*) and evaluated for possible use in the assessment. The data record obtained was monthly readings from January 2001 to June 2004. However, these data were of limited use as no nutrients are measured. These data were evaluated for trend assessment, but to ensure consistency within the current study it was decided to use data from the additional monitoring site instituted for purposes of this study (WQ6). However, it must be cautioned that this data were of limited value as only four samples (February to May 2004) were collected.

The elevated nutrient levels (i.e. increased SRP concentrations) were reflected in the increased periphyton chlorophyll-*a* concentrations, and electrical conductivity levels were also marginally increased (an Upper Good category). However, the macroinvertebrate response variables were in a Good category; there was no data available for fish.

Due to the limited data set, a trend assessment could not be undertaken.

Table 4-8 PES categories and overall site assessment for WQSU-6

RIVER	Diep River	**Water Quality Monitoring Points**	
WQSU	6	**RC**	Default boundary tables
EWR SITE	7	**PES**	WQ6 (n=4)
Confidence assessment	Low, due to limited sample size (G-Power calculation was not undertaken)		
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	An assessment of inorganic salts could not be undertaken as the data from NMMM were not compatible with the salt model.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.245	E/F (Poor)
	TIN	0.01	A (Natural)
Physical variables	pH (5^{th}-95^{th}%)	6.8-7.2	A (Natural)
	Temperature	-	No data, but not considered a problem water quality variable as not downstream of a dam, and thermal and dissolved oxygen impacts not expected.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	No data
	Electrical conductivity (mS/m)	40.7	A/B (Upper Good)
Response variable	Chl-a: periphyton	184.3	E/F (Poor)
	Chl-a: phytoplankton	0.913	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score	6.13 (Oct. 2003)	B (Good)
	Fish community score	-	No data
Toxics	Fluoride (mg/L)	0.07	A (Natural)
OVERALL SITE CLASSIFICATION		**B/C**	

4.5.5 Resource Unit E: Geelhoutboom River: WQSU-7

EWR 4 is in this WQSU.

The Geelhoutboom River is a small stream that flows only in times of good rains. For the duration of the study, only limited sampling was possible as there was little rain during the study period.

Table 4-9 shows the PES categories for WQSU-7. There was no appropriate data which could be used for RC within this WQSU and the default benchmark boundary tables were used. An additional monitoring site was instituted for the purposes of this study (WQ9) and was used for the present state assessment. These data were of limited value as only three samples (February to May 2004) were collected.

There was no data for an assessment of the inorganic salt variables, although the elevated conductivity (resulting in a Poor category) suggests that there may be water quality issues in this WQSU. Elevated SRP concentrations resulted in a Poor category and are possibly reflected in elevated periphyton chlorophyll-*a* concentrations (note: there was no data available for phytoplankton chlorophyll-*a* concentrations). The reduced water quality may, in part, be responsible for the reduced response variables, namely C and D categories for macroinvertebrates and fish respectively.

A trend assessment could not be undertaken due to limited data. As dairy farming is the main land-use in the area, and has been established for some time, it was assumed that the impact of dairy farming on water quality is stable.

Table 4-9 PES categories and overall site assessment for WQSU-7

RIVER	Geelhoutboom River	**Water Quality Monitoring Points**	
WQSU	7	**RC**	Default boundary tables
EWR SITE	EWR 4	**PES**	WQ9 (n=3)
Confidence assessment	Low, due to limited sample size (G-Power calculation was not undertaken)		
Water Quality Constituents		**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	An assessment of inorganic salts could not be undertaken as the data from NMMM were not compatible with the salt model.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.19	E/F (Poor)
	TIN	0.01	A (Natural)
Physical variables	pH (5^{th}-95^{th}%)	7.5-8.1	A (Natural) - A/B (Upper Good)
	Temperature	-	No data, but downstream of farm dams. Some impacts expected due to small size and low flows, although channel shaded.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	No data
	Electrical conductivity (mS/m)	330	E/F (Poor)
Response variables	Chl-a: periphyton	212.3	D (Poor)
	Chl-a: phytoplankton	-	No data
	Biotic community composition: macroinvertebrate (ASPT) score	5.65	C (note that PES was set as D by the invertebrate specialist – flow-related causes).
	Fish community score	-	D (Poor)
Toxics	Fluoride (mg/L)	0.08	A (Natural)
OVERALL SITE CLASSIFICATION		**C/D**	

4.5.6 Resource Unit F: Seekoei River: WQSU 8-10

WQSU-8: Upper section of the Seekoei River to upstream Kruisfontein and Humansdorp

EWR 5 is in this WQSU.

Table 4-10 shows the PES categories for WQSU-8.The DWAF monitoring point K9H007Q01 (at the lower end of the WQSU around Kruisfontein / Humansdorp) was used for the present state assessment in preference to the additional monitoring point (WQ10 at Bergplaas), due to sample size and length of data record (although it is still limited). The default boundary tables were used for reference condition.

A trend assessment could not be undertaken due to the limited data set (n=20) and the short time period over which data collection had taken place (2002 to 2004). Due to the predominant land-use in the WQSU being dairy farming, which has been established in the area for a long time, it is assumed that the impact of this land-use on water quality is relatively stable.

Inorganic salts were mostly in the Natural to Good categories, with the exception of NaCl, which was in a Fair category. As there were few data available for a high confidence inorganic salt assessment, electrical conductivity (EC) was assessed as a general indicator of water quality. The confidence assessment for EC was higher than that for the inorganic salts, and suggests that water quality is in a Good category. Although nutrient concentrations did not indicate that they could be contributing to a water quality problem, high periphyton chlorophyll-*a* levels suggest that nutrient loads may be a concern in this area.

Both the macroinvertebrate and fish response variables indicated a potential water quality problem, but given the limited data set it was not possible to attribute causes of concern to particular water quality constituents. Further studies to generate a larger water quality data set are required in order to ascertain the nature of the problem.

Table 4-10 PES categories and overall site assessment for WQSU-8

RIVER	Seekoei River	**Water Quality Monitoring Points**			
WQSU	8	**RC**	Default boundary tables		
EWR SITE	EWR 5	**PES**	K9H007Q01 (2002-2004) n=20		
Water Quality Constituents		**Value**	**Category / Comment**	**G-power**	**Confidence**
Inorganic salts (mg/L)	$MgSO_4$	27.9	B (Good)	0.07	low
	Na_2SO_4	0	A (Natural)	-	-
	$MgCl_2$	17.5	B (Upper Good)	0.09	low
	$CaCl_2$	18.3	A (Natural)	0.22	low
	NaCl	289	B (Upper Fair)	0.47	low
	$CaSO_4$	0	A (Natural)	-	-
Nutrients (mg/L)	SRP	0.02	B (Good)	0.095	low
	TIN	0.04	A (Natural)	0.08	low
Physical variables	pH (5^{th}-95^{th}%)	6.59-7.73	A (Natural)	0.99	high
	Temperature	-	No data. Significant impacts not expected as few farm dams in upper reaches.		
	Dissolved oxygen	-			
	Turbidity (NTU)	-	No data.		
	Electrical conductivity (mS/m)	41.6	B (Good)	0.74	medium
Response variables	Chl-a: periphyton	150.3	E/F (Poor)		
	Chl-a: phytoplankton	0.233	A (Natural)		
	Biotic community composition: macroinvertebrate (ASPT) score	4.32	E/F (note that PES was set as D by the invertebrate specialist – habitat-related due to cattle farming activities).		
	Fish community score	-	C (Upper Fair)		
Toxics	Fluoride (mg/L)	0.104	A (Natural)	0.18	low
OVERALL SITE CLASSIFICATION		**B/C**			

WQSU 9-10: Seekoei River from the Kruisfontein discharge stream on Orange Grove farm to the Seekoei Estuary (includes Geelhout Dam)

WQSU 9 extends from the Kruisfontein discharge stream on Orange Grove Farm to the inlet of Geelhout Dam; WSQU-10 extends from Geelhout Dam wall to the estuary. The main reason for separating this lower section of the Geelhoutboom River into two WQSUs was because of potential water quality changes as a result of Geelhout Dam. However, these two WQSUs were combined due to lack of suitable data and water quality monitoring sites in WQSU-9.

There was no appropriate data which could be used for RC within this WQSU and the default benchmark boundary tables were used. An additional monitoring site was instituted for the purpose of this study (WQ11 at Lombardini) and was used for the present state assessment. Due to many dams and little rain over the study period reducing the amount of instream water to sample, little water quality monitoring could be undertaken and only a single sample was taken.

A trend assessment could not be undertaken due to limited data.

Electrical conductivity and nutrient data suggests that water quality in this WQSU is in a Lower Good category. The increased nutrient concentrations were reflected in the high periphyton chlorophyll-*a* concentrations. No biotic response data was available to confirm the water quality assessment.

Table 4-11 PES categories and overall site assessment for WQSU 9-10

RIVER	Seekoei River		**Water Quality Monitoring Points**	
WQSU	9-10		**RC**	Default boundary tables
EWR SITE	None		**PES**	WQ11 (n=1)
Confidence assessment	Low, due to limited sample size (G-power calculation was not undertaken)			
Water Quality Constituents		**Value**	**Category / Comment**	
Inorganic salts (mg/L)	$MgSO_4$	-	An assessment of inorganic salts could not be undertaken as the data from NMMM were not compatible with the salt model.	
	Na_2SO_4	-		
	$MgCl_2$	-		
	$CaCl_2$	-		
	NaCl	-		
	$CaSO_4$	-		
Nutrients (mg/L)	SRP	0.65	E/F (Poor)	
	TIN	0.4	A/B (Upper Good)	
Physical variables	pH (5^{th}-95^{th}%)	8.2	A/B (Upper Good)	
	Temperature (°C)	20	Insufficient data to make adequate assessment	
	Dissolved oxygen	-	No data	
	Turbidity (NTU)	-	No data	
	Electrical conductivity (mS/m)	154.4	E/F (Poor)	
Response variables	Chl-a: periphyton	76.1	D (Lower Fair)	
	Chl-a: phytoplankton	0.87	A (Natural)	
	Biotic community composition: macroinvertebrate (ASPT) score	-	No data	
	Fish community score	-	No data	
Toxics	Fluoride (mg/L)	0.22	A (Natural)	
OVERALL SITE CLASSIFICATION		**B/C**		

4.5.7 Resource Unit H: Swart River: WQSU 11-12

WQSU-11: Upper section of the Swart River above Sunnyside Dam

EWR 6 is in WQSU-11.

This section of the river is upstream of all impacts, falls partly within a gorge area and covers only a small section of the Swart River. The only visible impact may be increased turbidity due to the construction of a pipeline for water abstraction for farming purposes. Water quality PES is therefore in an A/B category (expert judgement based on one site survey only), although it is acknowledged that impacts from irrigation return flows are possible. The biotic response categories are B for macroinvertebrates and C for fish respectively. However, confidence is very low as no data was available to substantiate the result.

WQSU-12: Swart River from below Sunnyside Dam to the estuary

Table 4-12 shows the PES categories for WQSU-12. A reliable present state assessment could not be undertaken for this RU as there was no data. Although an additional monitoring point had been instituted (WQ13), no samples were collected after the October 2003 field survey due to lack of water at the sites during the sampling period. Results presented here are from a single spot sample taken during the October 2003 field survey (WQ13) and results should be interpreted with caution. Only results from the most downstream site are presented.

The high electrical conductivity measurement, together with reduced macroinvertebrate and fish scores, suggest a persistent water quality problem. However, it was not possible to identify the cause/s in this study and further investigations are warranted.

A trend assessment could not be undertaken due to limited data.

Table 4-12 PES categories and overall site assessment for WQSU-12

RIVER	Swart River		**Water Quality Monitoring Points**	
WQSU	12		**RC**	Default boundary tables
EWR SITE	None		**PES**	WQ13 (n=1)
Confidence assessment	Low, due to limited sample size (G-Power calculation was not undertaken)			
Water Quality Constituents			**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		-	No data
	Na_2SO_4		-	
	$MgCl_2$		-	
	$CaCl_2$		-	
	NaCl		-	
	$CaSO_4$		-	
Nutrients (mg/L)	SRP		-	No data
	TIN		-	No data
Physical variables	pH		7.59	A (Natural)
	Temperature (°C)		20	Insufficient data to make adequate assessment
	Dissolved oxygen		-	No data
	Turbidity (NTU)		-	No data
	Electrical conductivity (mS/m)		422	E/F (Poor)
Response variables	Chl-a: periphyton		15.5	B/C (Lower Good)
	Chl-a: phytoplankton		3.623	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score		5.52	C (Upper Fair)
	Fish community score		-	C (Upper Fair)
Toxics	Fluoride (mg/L)		-	No data
OVERALL SITE CLASSIFICATION			**B/C**	

5 FLOW-CONCENTRATION MODELLING

5.1 Introduction: The need for water quality modelling

This 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 Kromme/Seekoei 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 instream chemical constituents, as well as the values of physical variables may vary significantly with changes in flow. In addition, the 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.

5.2 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 (2002) and Malan et al. (2003). At each EWR site, the available water quality data were assessed with regard to suitability for modelling. Both data from the DWAF chemical monitoring programme and data collected by the NMMU were examined. In order to satisfy the requirements for modelling, the data needs 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, 2002). Where possible, the data used for Q-C modelling were the same as those used in the water quality present state assessment for the Kromme/Seekoei system (Section 4).

Monthly mean flow values were correlated with median monthly concentration values for each variable (Malan and Day, 2002). *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* flow discharge values were used as is the convention in the field of hydrology. Subject to the availability of suitable water quality data, correlation of concentration and flow values were carried out separately for the Reference Condition (i.e. the least impacted state) as well as for the Present Ecological State. The water quality constituents that were examined included EC (electrical conductivity), SRP (soluble reactive phosphorus), TIN (total inorganic nitrogen) and any other chemical constituent considered be a problem (i.e. be present in high concentrations) at a 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 regression coefficient r^2. For each EWR site the median concentration and 95% confidence intervals of each chemical constituent were predicted using the appropriate regression relationship.

5.2.2 Production of concentration profiles

At each EWR site, the flow-concentration relationships that were generated in Section 5.2.1 were examined. Where an r^2 value greater than 6.5 was obtained, the data were suitable for production of concentration time-series as described in Malan (2004).

5.2.3 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 modelling. This is because 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.**
- It is important to note that **all predictions of water quality made in this report are made under the assumption that the present load of pollution will remain the same**.
- 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. Furthermore a method for predicting the overall effect on the biota of the combined water quality variables has not yet been developed.

5.3 Results

The availability of water quality data and the EWR sites for which modeling could be undertaken in the Kromme/Seekoei catchment area is summarised in Table 5-1. Unfortunately, due to the poor availability of water quality data modelling could only be carried out for EWR 3, and even for this site no data was available to describe the un-impacted condition, and thus the RC water quality condition could not be modelled.

Table 5-1 Sources of water quality data used for Q-C modelling and the EWR sites for which modelling could be carried out (u/s = upstream, d/s = downstream)

EWR Site	Water Quality Data		Comments
	RC	PES	
EWR 1 (Upper Kromme R. u/s Churchill Dam)	None	None	No suitable data available.
EWR 2 (Kromme R. between Churchill & Impofu dams)	None	None	No suitable data available (K9H002-Q01 is a pipeline, and therefore could not be used for modelling).
EWR 3 (Kromme R. d/s Impofu Dam, u/s estuary)	None	K9H003Q01 2000– 2004 (n=63)	Flow-concentration modelling carried out for EC, SRP and TIN for the PES. No data for the RC available.
EWR 4 (Geelhoutboom River)	None	None	No DWAF monitoring stations on this river. No modelling carried out.
EWR 5 (Seekoei River)	None	None	Only limited data collected at K9H007-Q01 (n=20 for the PES). No modelling carried out.
EWR 6 (Swart River)	None	None	No suitable data available.

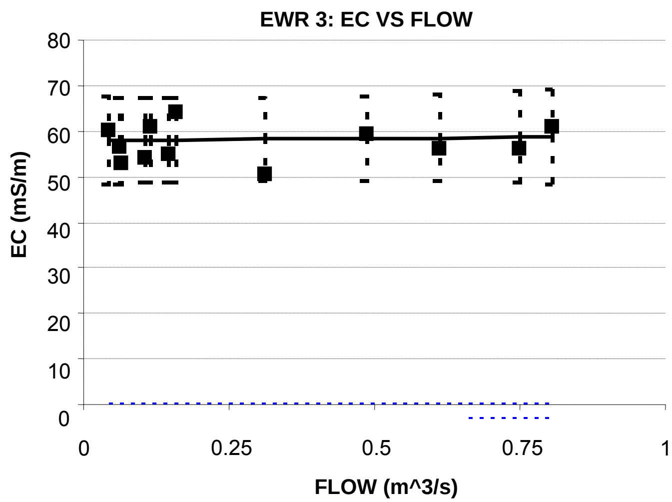
The flow concentration plots that were obtained for EWR 3 are shown in Figure 5-1. Also shown are the regression equations and the r^2 value for each water quality variable. A plot of monthly median electrical conductivity value against flow yielded an almost horizontal line indicating that flow does not have a marked effect on this variable at this site. The relationship that best described the correlation between this variable and flow was linear and a low r^2 (0.007) was obtained. In the case of the nutrients, SRP and TIN, a similar effect was noted to electrical conductivity, in that over the measured flow range there was no marked trend in concentration. The best fit for SRP was given by the power function r^2 = 0.043, and that for TIN was the power function r^2 = 0.013.

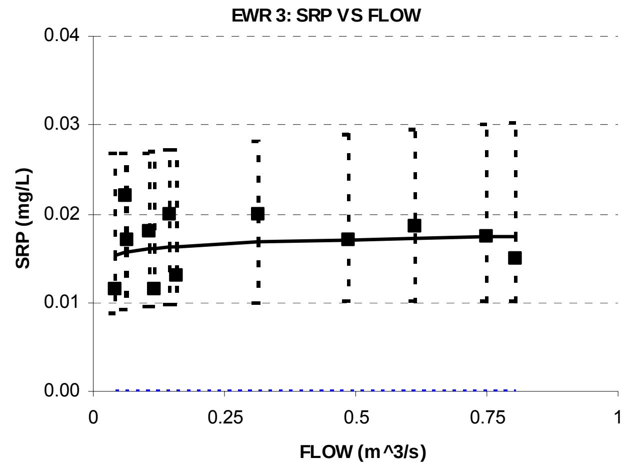
Frequently a *dilution effect* is seen when concentration is plotted against flow, especially for conservative constituents such as salts or electrical conductivity (Malan and Day, 2002). Concentration (or electrical conductivity) therefore usually decreases with increasing flow. The reason for the lack of such a dilution effect at EWR 3 is likely to be because the water quality monitoring site is just downstream of a dam (i.e. Impofu Dam). Almost all the water at EWR 3 therefore comes from the dam and there is very little incremental increase from surface runoff (and therefore other water sources with different water quality). Since mixing of water occurs within the dam, the water quality tends to be constant, whatever the flow passing EWR 3. This effect is most clearly shown for electrical conductivity (Figure 5-1), but also to a lesser extent for the nutrients.

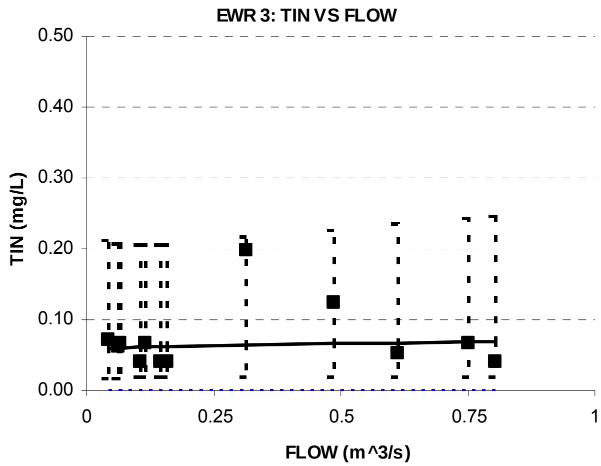
Electrical conductivity is largely independent of flow at EWR 3 and it can be predicted that, under the present loading of pollution in the system and the current operating scenario for the Impofu Dam, these constituents are unlikely to exceed the 95% confidence range. Note though that if there are extended periods of no-flow in this reach of the river, conductivity could rise above these levels due to evaporation.

Nutrients (unlike electrical conductivity) are non-conservative and the concentration of these substances is affected by many processes such as uptake by living organisms, chemical transformation etc. Periods of no-flow are likely to occur in this part of the Kromme River (Hughes, Rhodes University, *pers. comm.*), and intermittent bottom releases (which tend to be rich in sediments and thus nutrients) are made from Impofu Dam. Both these factors are likely to lead to an unpredictable relationship between flow and concentration, especially for non-conservative constituents. Under the present loading of pollution in the system and the current operating scenario for Impofu Dam, the concentration of nutrients in this river reach is not likely to exceed the upper 95% confidence interval. However, because of the caveats mentioned above, the confidence in this prediction is lower than for electrical conductivity.

Due to the low r^2 values obtained from flow-concentration modelling, the relationship between flow and concentration for electrical conductivity, TIN and SRP was considered to be too weak to continue with the generation of concentration time-series (and hence concentration profiles). Flow-concentration modelling was therefore of limited use in this study.







REGRESSION EQUATIONS
(Q = cumecs)

Electrical conductivity (mS/m):

EC = 1.102Q + 57.88
r^2 =0.007

Soluble Reactive Phosphorus (mg/L):

[SRP] = 0.018Q^0.043
r^2 =0.043

Total inorganic nitrogen (mg/L):

[TIN] = 0.07Q^0.055
r^2 =0.013

Figure 5-1 Q-C plots for EWR 3 showing the relationship of Electrical Conductivity (EC), Soluble Reactive Phosphorus (SRP) and Total Inorganic Nitrogen (TIN) with flow. The Present Ecological State (PES) ■ is shown, as well as the regression lines through the points. The 95% confidence interval for the PES is shown as dotted lines

6 ECOLOGICAL SPECIFICATIONS (ECOSPECS) FOR WATER QUALITY PER EWR SITE

6.1 Introduction

This section of the report lists, 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 95^{th} percentiles, i.e. values not to be exceeded more than 5% of the time, for inorganic salts, physical variables and toxics; and 50^{th} 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 6-1 is a summary of the output of the Kromme/Seekoei Reserve study (taken from the EWR Rivers Report for the study, DWAF report number RDMEWR001/RR004/CON/CES/1105, 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 6-1, the recommendation is that the PES, or Present Ecostatus, be maintained per EWR site, except for EWR 3 where an improvement is required.

Table 6-1 A summary of the output of the Kromme/Seekoei Reserve study

EWR sites	Driver PES	Instream PES	Present Ecostatus or PES	Ecostatus trend	EIS	SI	REC	Alternative EC
EWR 1	C	C	C	Stable	Moderate	Low	C	D
EWR 2	D/E	C/D	D	Stable	Moderate	Low	D	-
EWR 3	D/E	E	D/E	Stable	High	Low	D	-
EWR 4	C/D	D	C/D	Stable	Moderate	Moderate	C/D	-
EWR 5	C	D	C	Stable	Moderate	Low	C	
EWR 6	A/B	B/C	B	Stable	Moderate	Low	B	C
EWR 7	-	-	C/D	-	Moderate	-	C/D	D

EIS: Environmental Importance and Sensitivity
SI: Social Importance

6.2 Results

Results are expressed per EWR site. Ecospecs presented as narrative descriptions are taken from the Ecoclassification manual of Kleynhans et al. (2005). The ratings tables of Kleynhans et al. (2005) are the latest method for assessing water quality, but in terms of physico-chemistry only. This approach therefore does not include scores for response variables (i.e. chlorophyll-*a* levels, fish or invertebrate scores) explicitly in the tables. ***Although the Ecoclassification method was not used for the present state assessment, this manual was used to develop the water quality ecospecs for each EWR site.***

6.2.1 EWR 1: Melkhoutboskraal on the Kromme River

River	Kromme River	**DWAF Water Quality Monitoring points**		
WQSU	1	**RC**	No data	
EWR Site	1	**PES**	WQ2: continue monthly monitoring at site	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts *	$MgSO_4$	-	16 – 23 mg/L	N/A
	Na_2SO_4	-	20 – 33 mg/L	N/A
	$MgCl_2$	-	15 – 30 mg/L	N/A
	$CaCl_2$	-	21 – 57 mg/L	N/A
	NaCl	-	45 – 191 mg/L	N/A
Nutrients	SRP	D (0.24 mg/L)	**0.025 mg/L (C category)**	**Improvement needed**
	TIN	A (0.105 mg/L)	0.25 mg/L	N/A
Physical variables	pH (pH units)	A	6.5 to 8.0	N/A
	Temperature	No data, but no major impacts expected.	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)		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	D (90.1 mg/m²)	**21 mg/m² (C category)**	**Slight improvement**
	Chl-a: phytoplankton	A (0.255 µg/L)	< 10 µg/L (A category)	N/A
	Biotic community composition - macroinvertebrate	B/C	ASPT: 6(B/C category)	N/A
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
Toxics	Fluoride	A (80 µg/L)	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
	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

*: A quality ecospec of an A-B category has been allocated per inorganic salt. Due to the limited data, this recommendation is of low confidence.

- PES for water quality: B/C category
- Overall PES: C category
- Overall REC: C category
- Recommended water quality component of the REC: **B/C category**

6.2.2 EWR 2: Krommeriviers Poort on the Kromme River

River	Kromme River	**DWAF Water Quality Monitoring points**		
WQSU	4	**RC**	No data	
EWR Site	2	**PES**	K9H002Q01 (2000-2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	18.9 mg/L	23 mg/L (B category)	N/A
	Na_2SO_4	0	20 mg/L (A category)	N/A
	$MgCl_2$	13.5 mg/L	15 mg/L (A category)	N/A
	$CaCl_2$	31.5 mg/L	57 mg/L (B category)	N/A
	NaCl	197 mg/L	191 mg/L (B category)	N/A
Nutrients	SRP	B (0.017 mg/L)	0.015 mg/L (B category)	N/A
	TIN	A (0.313 mg/L)	0.25 mg/L (A category)	N/A
Physical variables	pH (pH units)	6.5-9.17 (A-C category)	**5.9-6.5 (5th percentile) 8.0-8.8 (95th percentile) (B category)**	**Slight improvement may be needed**
	Temperature	No data. Operational rules indicate bottom releases to river and DO and temperature issues may exist.	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)		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	D (140.1 mg/m²)	**84 mg/m² (D category)**	**Improvement needed**
	Chl-a: phytoplankton	A (0.255 µg/L)	< 10 µg/L (A category)	N/A
	Biotic community composition - macroinvertebrate	C (5.69)	ASPT: 6(B/C category)	N/A
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
Toxics	Fluoride	A (155 µg/L)	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
	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: B/C category
- Overall PES: D category
- Overall REC: D category

- Recommended water quality component of the REC: **B/C category**

6.2.3 EWR 3: Dyke on Kromme River

River	Kromme River	**DWAF Water Quality Monitoring points**		
WQSU	5	**RC**	No data	
EWR Site	3	**PES**	K9H003Q01 (2000-2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	51.8 mg/L (E/F category)	**37 mg/L (D category)**	**Improvement needed**
	Na_2SO_4	0	20 mg/L (A category)	N/A
	$MgCl_2$	17.6 mg/L	15 mg/L (A category)	N/A
	$CaCl_2$	30.9 mg/L	57 mg/L (B category)	N/A
	NaCl	459 mg/L (D category: Ecoclassification manual)	**389 mg/L (D category)**	**Improvement needed**
Nutrients	SRP	B (0.017 mg/L)	0.015 mg/L (B category)	N/A
	TIN	A (0.066 mg/L)	0.25 mg/L (A category)	N/A
Physical variables	pH (pH units)	7.28-8.04	6.5-8.0 (A category)	N/A
	Temperature	No data. Operational rules indicate bottom releases to river and DO and temperature issues may exist.	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)		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	- (Algal patches)	21 mg/m² (C category)	No information
	Chl-a: phytoplankton	A (0.763 µg/L)	< 10 µg/L (A category)	N/A
	Biotic community composition - macroinvertebrate	E/F (4.42)	**ASPT: 5.67(C category)**	**Improvement needed**
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
Toxics	Fluoride	A (226 µg/L)	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
	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: C category
- Overall PES: D/E category
- Overall REC: D category
- Recommended water quality component of the REC: **C category**

6.2.4 EWR 4: Geelhoutboom River

River	Geelhoutboom River	**DWAF Water Quality Monitoring points**		
WQSU	7	**RC**	No data	
EWR Site	4	**PES**	WQ9: continue monthly monitoring at site	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts *	$MgSO_4$	-	23 – 28 mg/L	No information
	Na_2SO_4	-	33 - 38 mg/L	No information
	$MgCl_2$	-	30 - 36 mg/L	No information
	$CaCl_2$	-	57 - 69 mg/L	No information
	NaCl	-	191 - 243mg/L	No information
Nutrients	SRP	E/F (0.19 mg/L)	**0.125 mg/L (D category)**	**Slight improvement needed**
	TIN	A (0.105 mg/L)	0.25 mg/L	N/A
Physical variables	pH (pH units)	A	6.5 to 8.0	N/A
	Temperature	No data, but downstream of farm dams. Some impacts expected due to small size and low flows, although channel shaded.	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)		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	D (212.3 mg/m²)	**21 mg/m² (C category)**	**Improvement needed**
	Chl-a: phytoplankton	-	< 10 µg/L (A category)	No information
	Biotic community composition - macroinvertebrate	C (5.65)	ASPT: 6(B/C category)	N/A
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
Toxics	Fluoride	A (80 µg/L)	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
	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

*: A quality ecospec of a B-C category has been allocated per inorganic salt, as the electrical conductivity data suggests salts are in a Poor state. Due to the limited data, this recommendation is of low confidence.

- PES for water quality: C/D category
- Overall PES: C/D category
- Overall REC: C/D category
- Recommended water quality component of the REC: **C/D category**

6.2.5 EWR 5: Seekoei River

River	Seekoei River	**DWAF Water Quality Monitoring points**		
WQSU	8	**RC**	No data	
EWR Site	5	**PES**	K9H007Q01 (2002-2004)	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts	$MgSO_4$	27.9 mg/L	23 mg/L (B category)	N/A
	Na_2SO_4	0	20 mg/L (A category)	N/A
	$MgCl_2$	17.5 mg/L	15 mg/L (A category)	N/A
	$CaCl_2$	18.3 mg/L	21 mg/L (A category)	N/A
	NaCl	289 mg/L	389 mg/L (D category)	N/A
Nutrients	SRP	B (0.02 mg/L)	0.025 mg/L (C category)	N/A
	TIN	A (0.04 mg/L)	0.25 mg/L (A category)	N/A
Physical variables	pH (pH units)	6.59-7.73	6.5-8.0	N/A
	Temperature	No data. Significant impacts not expected as few farm dams in upper reaches.	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)		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	E/F (150.3 mg/m²)	**84 mg/m² (D category)**	**Improvement needed**
	Chl-a: phytoplankton	A (0.233 µg/L)	< 10 µg/L (A category)	N/A
	Biotic community composition - macroinvertebrate	D (4.32) (habitat-related)	**ASPT: 5.34(C/D category)**	**Improvement needed**
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
Toxics	Fluoride	A (104 µg/L)	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
	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: B/C category
- Overall PES: C category
- Overall REC: C category
- Recommended water quality component of the REC: **B/C category**

6.2.6 EWR 6: Swart River

The information shown on the table below is what may be expected of an A/B category for river water quality. However, the PES of an A/B was based on specialist judgement only, as no data was collected for the site. Monitoring of water quality conditions should therefore be initiated for this site and the recommendations shown below verified.

River	Swart River	**DWAF Water Quality Monitoring Points**	
WQSU	11	**RC**	No data
EWR Site	6	**PES**	No data; expert judgement only
Water quality constituents		**Quality ecospecs**	
Inorganic salts	$MgSO_4$	16 - 23 mg/L (A - B category)	
	Na_2SO_4	20 – 33 mg/L (A – B category)	
	$MgCl_2$	15 – 30 mg/L (A – B category)	
	$CaCl_2$	21 - 57 mg/L (A – B category)	
	NaCl	45 - 191 mg/L (A - B category)	
Nutrients	SRP	Up to 0.025 mg/L (C category)	
	TIN	0.25 mg/L (A category)	
Physical variables	pH (pH units)	6.5-8.0	
	Temperature	Small change allowed. Natural temperature range, measured or estimated from air temperature. (Rating of 1, B category)	
	Dissolved oxygen	Small change allowed: 7 – 8 mg/L (Rating of 1, B category)	
	Turbidity (NTU)	Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff (Rating of 1, B category).	
Response variables	Chl-a: periphyton	Up to 21 mg/m² (C category)	
	Chl-a: phytoplankton	< 10 µg/L (A category)	
	Biotic community composition - macroinvertebrate	ASPT: 6.34(B category)	
	In-stream toxicity	In-stream toxicity should not occur	
Toxics	Fluoride	1500 µg/L (A category)	
	Al	20 µg/L (A category)	
	Ammonia	15 µg/L (A category)	
	As	20 µg/L (A category)	
	Atrazine	19 µg/L (A category)	
	Cd soft*	0.2 µg/L (A category)	
	Cd mod**	0.2 µg/L (A category)	
	Cd hard***	0.3 µg/L (A category)	
	Chorine (free)	0.4 µg/L (A category)	
	Cr(III)	24 µg/L (A category)	
	Cr(VI)	14 µg/L (A category)	
	Cu soft	0.5 µg/L (A category)	
	Cu mod	1.5 µg/L (A category)	
	Cu hard	2.4 µg/L (A category)	
	Cyanide	4 µg/L (A category)	

6.2.7 EWR 7: Diep River

River	Diep River	**DWAF Water Quality Monitoring points**		
WQSU	6	**RC**	No data	
EWR Site	7	**PES**	WQ6: continue monthly monitoring at site	
Water quality constituents		**Present state**	**Quality ecospecs**	**Improvements required**
Inorganic salts *	$MgSO_4$	-	16 – 23 mg/L	N/A
	Na_2SO_4	-	20 – 33 mg/L	N/A
	$MgCl_2$	-	15 – 30 mg/L	N/A
	$CaCl_2$	-	21 – 57 mg/L	N/A
	NaCl	-	45 – 191 mg/L	N/A
Nutrients	SRP	E/F (0.245 mg/L)	**0.125 mg/L (D category)**	**Improvement needed**
	TIN	A (0.105 mg/L)	0.25 mg/L	N/A
Physical variables	pH (pH units)	A	6.5 to 8.0	N/A
	Temperature	No data, but no major impacts expected.	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)		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	E/F (184.3 mg/m²)	**84 mg/m² (D category)**	**Improvement needed**
	Chl-a: phytoplankton	A (0.913 µg/L)	< 10 µg/L (A category)	N/A
	Biotic community composition - macroinvertebrate	B (6.13)	ASPT: 6.34(B category)	N/A
	In-stream toxicity	-	In-stream toxicity should not occur	N/A
Toxics	Fluoride	A (70 µg/L)	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
	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

*: A quality ecospec of an A-B category has been allocated per inorganic salt. Due to the limited data, this recommendation is of low confidence.

- PES for water quality: B/C category
- Overall PES: C/D category
- Overall REC: C/D category
- Recommended water quality component of the REC: **B/C category**

6.2.8 Concluding remarks

Although an attempt has been made to provide quality ecospecs for each EWR site assessed during the study, it must be noted that both the present state assessment and quality ecospecs were determined and designed based on very poor data records. Although some data was collected at most sites, which gives a preliminary indication of water quality, only continued monitoring and analysis of data can verify conditions at these sites. It is recommended that monitoring be continued at all sites on at least a monthly basis, although a two-weekly frequency would be preferred. Due to the large number of farm dams in many of the rivers in this study area, as well as the intermittent rainfall, little water flows at the lower end of the Geelhoutboom, Swart and Seekoei rivers. An assessment of the water quality state will therefore always be tenuous.

7 CONCLUSIONS AND RECOMMENDATIONS

This report has provided an assessment of water quality conditions for the Kromme/Seekoei Reserve study. Water quality is generally not the driver of the overall ecostatus of rivers in the study area, with riparian vegetation often being the determining parameter in assigning the overall ecostatus. The rivers are generally in a Fair condition in terms of water quality, with a hot spot occurring at EWR 4, i.e. the Geelhoutboom River. The current status is shown in Table 7-1, as well as the water quality categories used to design quality ecospecs.

Table 7-1 A summary of water quality status in the Kromme/Seekoei study area

WQSU and EWR site	Overall REC	PES: water quality	Recommended water quality category of the overall REC (quality ecospecs)	Confidence in PES assessment
WQSU 1: EWR 1 - Melkhoutboskraal	C	B/C	B/C	Low
WQSU 2		C		Low
WQSU 3		B/C		Low
WQSU 4: EWR 2 – Krommeriviers Poort	D	B/C	B/C	Moderate
WQSU 5: EWR 3 – Dyke on Kromme River	D	C	C	Moderate
WQSU 6: EWR 7 – Diep River	C/D	B/C	B/C	Low
WQSU 7: EWR 4 – Geelhoutboom River	C/D	C/D	C/D	Low
WQSU 8: EWR 5 – Seekoei River	C	B/C	B/C	Very low
WQSU 9 + 10		B/C		Low
WQSU 11: EWR 6 – Swart River (upper section of the river)	B	A/B	A/B	Very low
WQSU 12 (lower section of the Swart River)		B/C		Low

Water quality issues are mainly related to nutrient status and possible fluctuating temperature and oxygen levels downstream of dams. However, assessments of water quality status are of low confidence due to poor historical monitoring and a small database of information being available for the assessment. The high impact of many in-stream dams, particularly on the Geelhoutboom, Swart and Seekoei river systems, together with intermittent rainfall, have resulted in very poor conditions in the study area. The system is also highly regulated by the Churchill and Impofu dams, with no or little environmental releases being made to maintain riverine and estuarine function.

It is recommended that monthly, or preferably bi-monthly monitoring be continued at all identified water quality monitoring points. Periphyton (chlorophyll-a) sampling should also be conducted regularly at all EWR sites, and monitoring of turbidity should be instituted. Dissolved oxygen and temperature data should be collected. It is also strongly recommended that DWAF Eastern Cape Region adopt the monitoring programme as required (and requested) to conduct a water quality assessment for the Ecological Reserve. Unless the necessary list of variables is analysed (e.g. ALL required inorganic salts), confidence in the water quality assessments will continue to be low.

The assessment of water quality was conducted carrying out methods updated from the DWAF methods manual of 2002, while the ratings tables in the Ecoclassification manual of Kleynhans et al. (2005) was used to set quality ecospecs. 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.

8 REFERENCES

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APPENDIX A

ASSESSMENT OF AVAILABLE WATER QUALITY DATA FROM THE DWAF-WMS DATABASE

This assessment was conducted in January 2004, and covers all available data for surface waters of the Kromme/Seekoei catchment areas, where n>5.

Water Quality Sub-Unit	4
DWAF Monitoring Point	K9H001
Position	Kromme River: weir downstream of Churchill Dam
Grid Reference	34.0014S 24.49306E
Number of samples	8
Date of first sample	April 1995
Date of last sample	June 1999
Predominant sampling frequency	Ad hoc
Assessment	Poor data set for water quality assessment

Water Quality Sub-Unit	4
DWAF Monitoring Point	K9H002
Position	Kromme River: left pipe at Churchill Dam
Grid Reference	34.0014S 24.49306E
Number of samples	163
Date of first sample	December 1984
Date of last sample	October 2003
Predominant sampling frequency	Monthly or more frequent
Assessment	Suitable for present state assessment
Comments	Early data records may be appropriate for reference condition, undertake trend assessment to verify.

Water Quality Sub-Unit	5
DWAF Monitoring Point	K9H003
Position	Kromme River: downstream of Impofu Dam
Grid Reference	34.0919S 24.7E
Number of samples	356
Date of first sample	July 1984
Date of last sample	October 2003
Predominant sampling frequency	Monthly or more frequent
Assessment	Suitable for present state assessment
Comments	Early data records may be appropriate for reference condition, undertake trend assessment to verify.

Water Quality Sub-Unit	5
DWAF Monitoring Point	K9H004
Position	Impofu (Kromme River) pipeline to treatment works
Grid Reference	34.0919S 24.7E
Number of samples	15
Date of first sample	July 1990
Date of last sample	July 1991
Predominant sampling frequency	Ad hoc
Assessment	Poor data set for water quality assessment

Water Quality Sub-Unit	5
DWAF Monitoring Point	K9H006
Position	Kromme River at Osbosch/Rivertide
Grid Reference	34.1247S 24.79778E
Number of samples	15
Date of first sample	September 1997
Date of last sample	July 2003
Predominant sampling frequency	Ad hoc
Assessment	Poor data set for water quality assessment – may be suitable for the estuary Water Quality assessment.

Water Quality Sub-Unit	8
DWAF Monitoring Point	K9H007
Position	Upper Seekoei River around Kruisfontein/ Humansdorp
Grid Reference	33.9936S 24.73111E
Number of samples	16
Date of first sample	March 2002
Date of last sample	October 2003
Predominant sampling frequency	Monthly
Assessment	Data record too short for present state assessment

Water Quality Sub-Unit	4
DWAF Monitoring Point	K9R001
Position	Kromme River: Churchill Dam near dam wall
Grid Reference	34.0014S 24.49306E
Number of samples	71
Date of first sample	May 1968
Date of last sample	June 1996
Predominant sampling frequency	Monthly
Assessment	May be appropriate for reference condition assessment
Comments	Trend analysis must be undertaken

Water Quality Sub-Unit	5
DWAF Monitoring Point	K9R002
Position	Kromme River: Impofu Dam near dam wall
Grid Reference	34.0919S 24.7E
Number of samples	29
Date of first sample	March 1985
Date of last sample	August 1994
Predominant sampling frequency	From 1992, monthly. Prior to that, ad hoc
Assessment	Small sample size.