DEPARTMENT: WATER AFFAIRS AND FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES

OLIFANTS/DORING CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY

FINAL SUMMARY REPORT

FINAL
30 JUNE 2006

Prepared for:
Department of Water Affairs and Forestry
Directorate: Resource Directed Measures
P Bag X313
Pretoria
1200

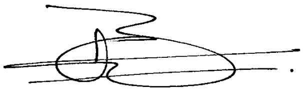
CONTACT PERSON:
Harrison Pienaar
Tel: 012-336 7197
Fax: 012-336 7575
Email: qin@dwaf.gov.za

Prepared by:
Southern Waters ER&C cc
PO Box 12414
Mill Street
8010

CONTACT PERSON:
Cate Brown
Tel: 021-465 3135
Fax: 021-465 3901
Email: cbrown@southernwaters.co.za

TITLE	Final Summary Report
PROJECT NUMBER	2002-376
COMPILERS	C. A. Brown, C. Pemberton and R. Magoba
STUDY NAME	Olifants Doring Catchment Ecological Water Requirements Study
REPORT STATUS	Final
DATE	30 JUNE 2006
DWAF REPORT No.	RDM/E000/MSR/01/CON/0606

APPROVED BY SOUTHERN WATERS ER & C cc



……………………………………..
DR. C.A. BROWN
PROJECT LEADER

APPROVED BY DEPARTMENT OF WATER AFFAIRS AND FORESTRY: CHIEF DIRECTORATE RESOURCE DIRECTED MEASURES

……………………………………..
MR H.H. PIENAAR
CHIEF DIRECTOR: RESOURCE DIRECTED MEASURES

OLIFANTS/DORING CATCHMENT
ECOLOGICAL WATER REQUIREMENTS STUDY

FINAL SUMMARY REPORT
EXECUTIVE SUMMARY

INTRODUCTION

This report forms part of a Comprehensive Assessment of the Ecological Water Requirements of the Olifants/Doring River Catchment, initiated and funded by the Department of Water Affairs and Forestry: Chief Directorate Resource Directed Measures (RDM).

Project duration was from July 2003 to June 2006.

STUDY AREA

The Olifants/Doring River falls within the Olifants-Doorn Water Management Area (WMA), which also includes the water resources of the Sandveld (Figure 0.1). The study area comprised the Olifants, Doorn and Kouebokkeveld as depicted in Figure 0.1.

Figure 0.1 The Olifants-Doorn WMA

This study concentrated on the mainstems of the Olifants and Doring Rivers, two important tributaries (Figure 0.2) and the estuary. There were six river-EWR sites distributed along the rivers, while the estuary formed a single focus area (Figure 0.3).

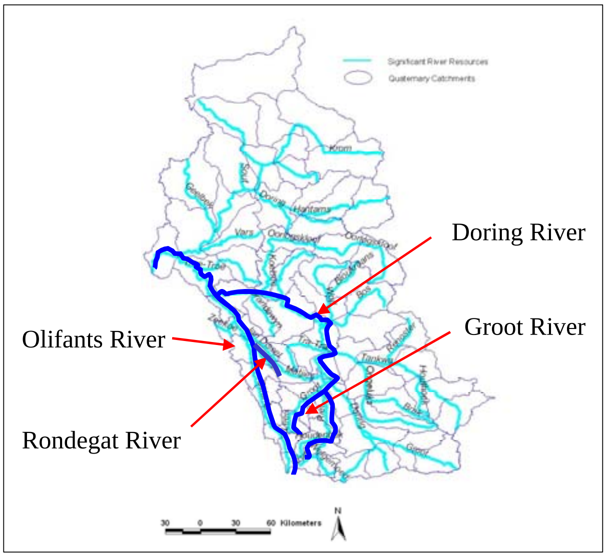


Figure 0.2 Map indicating the focus of the study on the Olifants and Doring Rivers, and important tributaries, the Rondegat and Groot Rivers

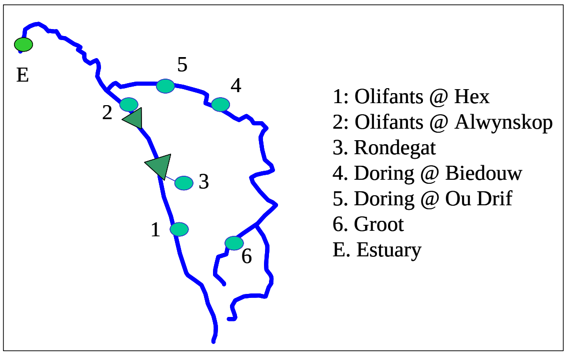


Figure 0.3 Schematic showing the relative locations of the six river-EWR sites and the estuary

RIVER: ECOLOGICAL WATER REQUIREMENTS DETERMINED FOR VARIOUS ECOLOGICAL CONDITIONS

The Olifants/Doring Catchment is essentially a tale of two distinctly different rivers. The Olifants River valley is more suitable for agriculture and hence more populated, and the river is fairly heavily impacted. The Doring River valley, on the other hand, is sparsely populated, and (at least in its middle and lower reaches) the river is relatively undisturbed compared with the Olifants River. The flow requirements for the lower Olifants River and estuary are largely supported by the contributions of the Doring River.

The Present Ecological Status (PES) of each of the EWR sites, plus the ecological categories (EWR-EC) for which EWRs were determined, are indicated in Table 0.1. The annual volume required to meet the EWRs, and the percentage nMAR that it represents is also provided (Table 0.1).

Table 0.1 The EWR for each EWR site. The volumes given exclude ≥ 1:2 year return period floods, to allow comparison with results from other Reserve studies

Site	Portion of the EWR	PES	EWR-EC	MCM a^{-1}	%nMAR
EWR SITE 1	TOTAL (Volume), excl. ≥1:2 year return period floods	D	D	88	26%
EWR SITE 2	TOTAL (Volume), excl. ≥1:2 year return period floods	E	D	*c.* 194[1]	38%
			Maintain PES (E)	48.3	9%
EWR SITE 3	TOTAL (Volume), excl. ≥1:2 year return period floods	B	B	*c.* 3	38%
			C	1.4	18%
EWR SITE 4	TOTAL (Volume), excl. ≥1:2 year return period floods	B	B	192	45%
			C	87	21%
EWR SITE 5	TOTAL (Volume), excl. ≥1:2 year return period floods	B	B	232	45%
			C	119	23%
EWR SITE 6	TOTAL (Volume), excl. ≥1:2 year return period floods	B/C	B/C	60	44%
			C	40	29%

ESTUARY: RESERVES SCENARIOS CONSIDERED

The PES for the Olifants Estuary is a C-category. It is, however, expected that the condition of the estuary is on a negative trajectory of change, because of the extremely low summer flows under the present state (< 1 m^3/s). As the catchment becomes more regulated, the water available at the estuary decreases and its ecological condition declines. Thus, in order to arrive at the EWR for the estuary, the implications for flow into the estuary of various water resource development : EWR combinations were considered as a range of scenarios loosely ordered in terms of increasing regulation of the catchment. Although numerous variations were considered, the estuarine team was only able to consider five scenarios, plus natural and present day. The short-list of the scenarios considered is provided below.

- Natural conditions – no developments in the catchment:
  - Scenario 0.
- Present day infrastructure with Clanwilliam Dam storing 121 MCM:
  - Scenario 1: Current operation of Clanwilliam Dam and Bulshoek Barrage, i.e., no EWR releases.
  - Scenario 2: EWR releases for maintaining a Category D river downstream of the Bulshoek Barrage (EWR Site 2).
- Additional development in the Olifants River:
  - Scenario 5: Clanwilliam Dam was raised by 15 m to store an additional 240 MCM, no or negligible EWR releases from Clanwilliam Dam.
  - Scenario 7: Clanwilliam Dam was raised by 15 m. EWR releases for maintaining a Category D river downstream of the Bulshoek Barrage (EWR Site 2).
- Raise Clanwilliam Dam by 15 m PLUS Brandewyn River Dam[2]. A 160 MCM dam was included on the Brandewyn River, with a diversion weir on the Doring River.
  - Scenario 17: No EWRs.

[1] Please see comments in body of the report.

[2] Water would be pumped from a five MCM weir on the Doring River into the Brandewyn River Dam at a maximum rate of 5m^3/s during April to October.

- Raise Clanwilliam Dam by 15 m PLUS Melkbosrug Dam on the Doring River, near the confluence with the Olifants River:
  - Scenario 10: No EWRs.

The estuarine specialists assessed the Scenarios in terms of their impact on future ecological condition of the estuary (Table 0.2). They recommended that, because of its regional importance, the condition of the estuary should be improved to a B-category and thus that Scenario 7 be selected. They also noted that Scenario 5 would stabilise the current negative trajectory and would maintain the estuary in a C-category.

Table 0.2 Summary of the expected estuarine ecological condition for each of the scenarios

No.	Description	EWR-EC	MCM a^{-1}	%nMAR[3]
0	Natural	A	1055	100
2	Present with EWRs	C	716	68
7	Clanwilliam Dam at 15 m, plus EWR releases	B	782	74
5	Clanwilliam Dam at 15 m, no EWR releases from Clanwilliam Dam	C	725	69
17	Clanwilliam Dam at 15 m plus Brandewyn River Dam, no EWRs	D	518	49
10	Clanwilliam Dam at 15 m plus Melkbosrug Dam, no EWRs	E	597	57

YIELD OF SCENARIOS CONSIDERED

The system yield associated with each of the scenarios considered for the estuary is given in Table 0.3.

Table 0.3 The implications for system yield for each of the scenarios, relative to present day

No.	Description	Change in system yield (MCM)	Direction
0	Natural	-324	Decrease
2	Present with EWRs	-72	
7	Clanwilliam Dam at 15 m, plus EWR releases	-15	
5	Clanwilliam Dam at 15 m, no EWR releases from Clanwilliam Dam	123	Increase
17	Clanwilliam Dam at 15 m plus Brandewyn River Dam, no EWRs	182	
10	Clanwilliam Dam at 15 m plus Melkbosrug Dam, no EWRs	273	

[3] Note: This includes requirements for inter-annual return period floods, e.g., 1:2, 1:5, 1:10 and 1:20.

SOCIOECONOMICS OF SCENARIOS CONSIDERED

The results of the socioeconomics study indicated that the value of developing water resources generally appears to far outweigh the environmental costs, with overall changes in value being increasing positive for Scenarios 2, 7, 5, 17 and 10 (in that order). Environmental costs were dominated by estuary fishery values and are lowest for Scenario 5, followed by Scenario 2 and Scenario 7.

KEY CONSIDERATIONS IN THE EVALUTION OF THE SCENARIOS

The evaluations done in this study indicate that:

a) there are some options for generating additional yield with relatively low environmental impact;
b) these options are focussed on the mainstem of the Olifants River, upstream of the confluence with the Doring River and on the headwater streams in the Kouebokkeveld;
c) The yield from the Clanwilliam Dam is dependent on the EWR requirements in the Olifants River upstream of the confluence with the Doring River (no EWR releases are currently made from the dam). EWR requirements for a D-category for the Olifants River downstream of Bulshoek Barrage to the confluence with the Doring River (EWR Site 2) will reduce the yield from Clanwilliam Dam to below that of the current yield;
d) the reach of the Olifants River downstream of Bulshoek Barrage, is significantly altered from natural and a D-category will be difficult, if not impossible, to achieve with flow alone. The specialists in this study recommended that a lower category (with a significantly lower EWR) be considered for this section of the river, e.g., an E-category;
e) even with lower EWRs at EWR Site 2 it is possible to maintain the Olifants Estuary in a C-category;
f) socioeconomic benefits derived *directly* from aquatic ecosystems in the Olifants-Doring catchment are highest for the estuary;
g) it is possible to create a more widely-optimum (from the perspective of the users and the ecosystems) configuration based on Scenario 5 (maximise Olifants), and some off-channel farm dams in the Kouebokkeveld;
h) while the projected impact of additional water use on GDP in the catchment favours Scenarios 17 and 10, it is worth considering that these projected figures exclude the considerable costs of infrastructure and management that would be associated with the schemes required to access this water. The financial benefits realised from exploring these options would be correspondingly lower with these figures included;
i) dams in the Doring River have been repeatedly rejected as economically and ecologically unviable.

RESERVE SCENARIO RECOMMENDED

The recommendations from the river and estuary specialists from an ecological (and pragmatic) perspective, taking account of the dichotomy brought about by human utilisation of the area, can be summarised as follows:

- Maintain the ecological integrity of the Doring River, and in so doing ensure sustainable utilisation of the Olifants estuary, i.e., no dams in the Doring or Groot Rivers.
- Maintain the ecological integrity of key tributaries on both the Olifants and Doring Rivers, thereby ensuring variability of flow, as well as provision of refuges and source areas.
- Undertake some river rehabilitation aimed at reducing non-flow related impacts in the mainstem Olifants River between the Olifants Gorge and Clanwilliam Dam, thereby improving overall river condition in this reach.

- Undertake some river rehabilitation aimed at reducing water quality impacts in the mainstem Olifants River downstream of the confluence with the Doring River. This would also improve the quality of water entering the estuary.
- Undertake minor estuary rehabilitation measures, mainly aimed at controlling over fishing.
- Keep Reserve releases from Clanwilliam Dam and Bulshoek Barrage to a minimum, so that water supply from Clanwilliam Dam and Bulshoek Barrage is maximised.

This could be achieved through the implementation of Scenario 5. The summary EWR data for Scenario 5 are provided in

Note:
Pursuing Scenario 5 (or similar) pre-supposes no major developments in the Doring River, as this water is required to maintain the Doring River in a good ecological condition (B-category) and maintain the C-category in the estuary.

Table 0.4 The summary EWR data for Scenario 5

Site	Portion of the EWR	EWR-EC	MCM a^{-1}	%nMAR
EWR SITE 1	TOTAL (Volume), excl. ≥1:2 year return period floods	D	88	26%
EWR SITE 2	TOTAL (Volume), excl. ≥1:2 year return period floods	Maintain PES (E)	48.3	9.3%
EWR SITE 3	TOTAL (Volume), excl. ≥1:2 year return period floods	B	*c.* 3	39%
EWR SITE 4	TOTAL (Volume), excl. ≥1:2 year return period floods	B	192	45%
EWR SITE 5	TOTAL (Volume), excl. ≥1:2 year return period floods	B	232	45%
EWR SITE 6	TOTAL (Volume), excl. ≥1:2 year return period floods	B/C	60	44%
ESTUARY	TOTAL (Volume), excl. ≥1:2 year return period floods[4]	C	*c.* 630	59%

[4] Estimated from relationships obtained for the EWR sites. The estuary flows are augmented by return flows from irrigation in the lower Olifants River valley.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY AND ABBREVIATIONS

AEC	Alternative Ecological Category.
Ca	Calcium (mg l^{-1}).
Cl	Chloride (mg $^{-1}$).
DEAT	Department of Environmental Affairs and Tourism.
DWAF	Department of Water Affairs and Forestry.
EC	Ecological Category.
ECOLOGICAL WATER REQUIREMENTS	Flow in a river, or into a wetland or coastal zone (which may be groundwater) that maintains the ecosystem in a negotiated Ecological Category.
EWR	Ecological Water Requirements.
GDP	Geographical Domestic Product.
GROUNDWATER	Water in a porous medium, beneath the soil surface, with a pressure greater than or equal to atmospheric pressure, and where all the voids are filled with water.
HDI	Historically-disadvantaged Individual.
HYDROLOGY	Science dealing with properties, distribution and circulation of water in the biosphere.
K	Potassium (mg l^{-1}).
MAR	Mean Annual Runoff.
MCM	Millions of Cubic Metres.
Mg	Magnesium (mg l^{-1}).
Mm^3	Millions of Cubic Metres.
MSL	Mean Sea Level.
Na	Sodium (mg l^{-1}).
nMAR	Naturalised Mean Annual Runoff.
NO_3-N	Nitrate nitrogen, as N (mg l^{-1}).
NH_4-N	Ammonium nitrogen, as N (mg l^{-1}).
NUTRIENT	An element whose scarcity can limit plant growth (e.g., compounds of nitrogen, phosphorus).
pdMAR	Present day Mean Annual Runoff.
PES	Present Ecological State.
pH	The negative log of the hydrogen ion activity; a measure of acidity ($pH<7$) or alkalinity ($pH>7$).
PMC	Project Management Committee.
PO_4-P	Orthophosphate, as P (mg l^{-1}).
REC	Recommended Ecological Category.
RDM	Resource Directed Measures.
RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of EWR.
RIPARIAN	Pertaining to the river bank.
TKN	Total (Kjeldahl) nitrogen, as N (mg l^{-1}).
ToR	Terms of Reference
TP	Total phosphorus, as P (mg l^{-1}).
SO_4	Sulphate (mg l^{-1}).
WMA	Water Management Area.

1 BACKGROUND

1.1 OBJECTIVES OF THE REPORT

This report is the Final Summary Report for the Comprehensive Assessment of the Ecological Water Requirements of the Olifants/Doring River Catchment. The objectives of the report are to:

- list the project reports that meet the various requirements of the Terms of Reference (ToR) for the study;
- outline the study area, study team and methods used;
- summarise the main results of the study;
- highlight the capacity building undertaken as part of the study;
- provide a synopsis of the contributions by Historically-disadvantaged Individuals (HDIs) to the study.

1.2 OVERVIEW OF THE STUDY AREA

1.2.1 Location

The Olifants/Doring River falls within the Olifants-Doorn Water Management Area (WMA), which also includes the water resources of the Sandveld (Figure 1.1). The study area comprised the Olifants, Doorn and Kouebokkeveld as depicted in Figure 1.1[5].

Figure 1.1 The Olifants-Doorn WMA

1.2.2 Climate

The area receives winter rainfall, which varies from *c*. 900 mm a^{-1} in the south-west to <100 mm a^{-1} in the north-west. Temperature is also varied (3°C in winter to 44°C in summer) and evaporation is high (*c*. 1500 mm a^{-1} in the south-west to 2200 mm a^{-1} in the north-west).

[5] I.e. it excludes the Sandveld.

1.2.3 Aquatic environments

The Olifants River is extremely important from a conservation perspective, primarily because of three attributes:

- it contains remnant populations of eight species of endemic fish, the highest number of endemic fish south of the Zambezi River; and
- its upper reaches flow through a unique gorge area, which is widely recognised for its aesthetic and recreational appeal;
- some unique and relatively undisturbed tributaries feed it.

Possible historical links with the Orange River also make the river important from a scientific point of view.

The Doring River is particularly important from a conservation point of view. It is inhabited by nine indigenous fish species, seven of which are endemic to the river system. Of these, the mainstem of the Doring River is most important for the larger species. The reaches upstream of the Tankwa River are vital breeding areas for the sawfin (*Barbus serra*), the Clanwilliam yellowfish (*Labeobarbus capensis*), and the Clanwilliam sandfish (*Labeo seeberi*). The latter two are classified as rare Red Data species, while the sawfin is regarded as vulnerable (Skelton, 1987). In addition, the Doring River is the only major river in the region that is not impounded; it flows through several unspoiled gorges; its ecological status is high down the full length of the river and as such it offers a unique wilderness experience to visitors to the area.

The water quality in the Doring River is a unique mixture of two distinct water chemistry systems, the one originating in the Karoo (turbid and saline), and the other in the Cedarberg Mountains (clear and fresh). Differences in these systems are largely based on the geological characteristics of their catchments, but are probably also influenced to some degree by land use.

A combination of habitat degradation and invasion by alien species have significantly contributed towards the decline in endemic fish populations in the Olifants/Doring River Basin, with the Clanwilliam Dam and Bulshoek Barrage having contributed significantly toward this reduction through:

- inundating significant spawning habitat;
- providing barriers to migration;
- providing a haven for alien fish species, which prey on the young of the indigenous species;
- affecting the timing and volume of flows in the downstream river, thereby reducing the quality and suitability of the available habitat for indigenous fish;
- reducing the frequency and duration of scouring floods resulting in palmiet encroachment into the active channel and reducing available riffle-spawning habitat for the indigenous fish species.

The unique fish community of the Olifants/Doring River system is greatly threatened by these impacts and management measures are urgently required to ensure that further utilisation of the catchment's rivers is sustainable (from Brown *et al*. 2003).

The Olifants Estuary is one of the largest, most diverse estuaries in South Africa. It also has a high functional importance in terms of its role as a nursery area for marine fishes on the West Coast. The estuary has been targeted as a 'Desired Protected Area' by the Resource Directed Measures Directorate in DWAF (DWAF 2004).

1.2.4 *Local economy*

The local economic output in the Olifants-Doring catchment is dominated by the agricultural sector, which contributes significantly more to the economy that is the national average for South Africa (Figure 1.2). The other significant sector in the catchment, trade, is dominated by tourism-related activities (Figure 1.2).

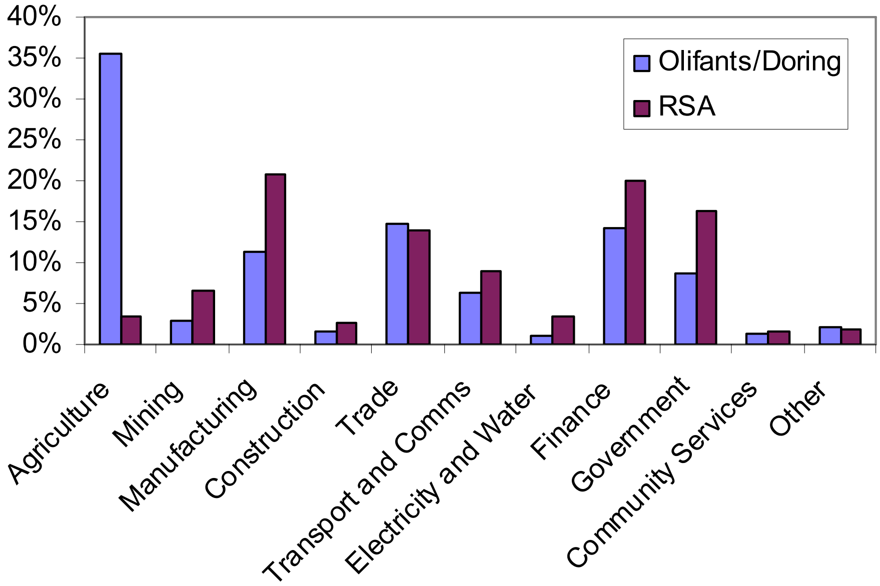


Figure 1.2 Sectoral contributions to the local (Olifants-Doorn WMA) economy relative to national averages

1.2.5 *Water resource developments and water supply*

The bulk of the water supply in the catchment is from Clanwilliam Dam and Bulshoek Barrage, with their associated 186 km of canal system. Together, these supply irrigation, municipalities, mines and some industry. Other significant water resource developments in the catchment include farms dams, in particular in the Kouebokkeveld, and groundwater developments, in particular those associated with the towns of Bitterfontein, Nuwerus, Calvinia and Citrusdal. Groundwater utlisation along the banks of the major rivers is also high.

Thus, while the resources of the Olifants River have largely been regulated with most of the water being used for irrigation, little development has taken place along the Doring River except for extensive riparian developments in the upper reaches (Kouebokkeveld). Smaller areas are being irrigated along the Tankwa River and the Middle Doring River (Brown *et al.* 2003).

The current available yield in the catchment has been estimated at 339 MCM a^{-1}, while the requirements/demands have been estimated at 373 MCM a^{-1}. Thus there is an estimated shortfall of around 34 MCM a^{-1} (ISP 2004).

Various water resource developments have been proposed to meet the shortfall, and possibly provide additional water in the catchment. These include:

- increasing the storage capacity of Clanwilliam Dam;
- various dams and barrages on the Groot and Doring Rivers;
- groundwater developments; and
- additional farm dams in the Kouebokkeveld.

The implications of various combinations of these on the flow regimes in the study rivers forms the focus of the scenarios discussed in Sections 6.1 and 5.

1.3 STUDY SITES

1.3.1 River – EWR sites

The study concentrated on the mainstems of the Olifants and Doring Rivers, and their important tributaries (Figure 1.3). The Olifants River was divided into seven broad resource units (RUs), and the Doring River into five broad RUs.

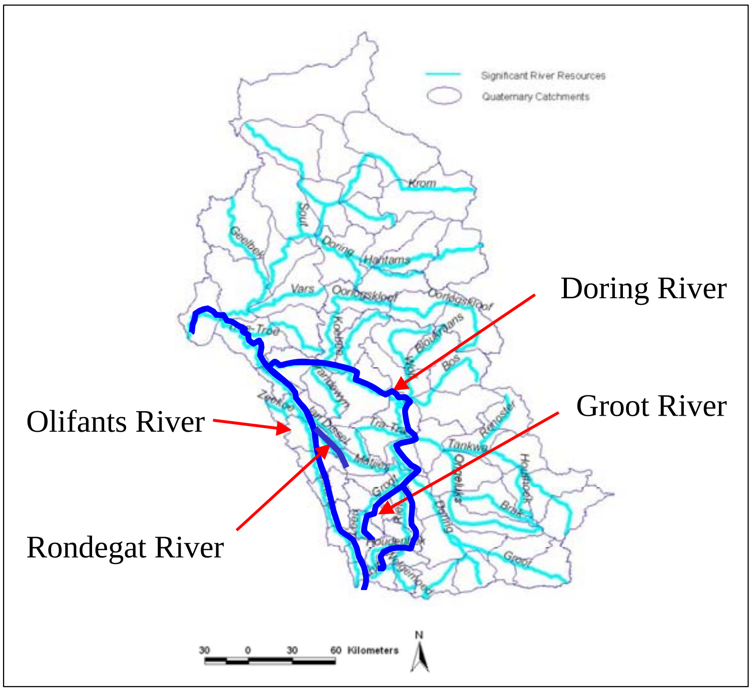


Figure 1.3 Map indicating the focus of the study on the Olifants and Doring Rivers, and important tributaries, the Rondegat and Groot Rivers

<u>*Olifants River*</u>

Olifants RU1: Kouebokkeveld (Olifants).
Olifants RU2: Olifants River Gorge.
Olifants RU3: Olifants River Gorge to Citrusdal.
Olifants RU4: Citrusdal to Clanwilliam Dam.
Olifants RU5: Clanwilliam Dam to Bulshoek Barrage.
Olifants RU6: Bulshoek Barrage to the confluence with the Doring River.
Olifants RU7: The confluence with the Doring River to the estuary.

<u>*Doring River*</u>

Doring RU1: Kouebokkeveld (Doring).
Doring RU2: Groot River Gorge.
Doring RU3: Groot/Doring River Confluence to Tankwa/Doring River Confluence.
Doring RU4: Tankwa/Doring River Confluence to Doringbos.
Doring RU5: Doringbos to Olifants/Doring River Confluence.

The two major tributaries selected were:

<u>*Rondegat River*</u>

The Rondegat River was included because EWR data generated there can be extrapolated to the Huis, Hex, Jan Dissels Rivers.

<u>*Groot River*</u>

The Groot River is included in the RUs delineated for the Doring River. It was also included because EWR data generated there could be extrapolated to the Riet, Matjies and upper Tra-Tra Rivers.

The total number of EWR sites for the study was limited to six, with two of these being on key tributaries. ***This equated to approximately two EWR sites per 200 km of river.*** This meant that EWR sites were selected only in high priority RUs, *viz*.:

Olifants RU4:	Citrusdal to Clanwilliam Dam.
Olifants RU6:	Bulshoek Barrage to the confluence with the Doring River.
Doring RU2:	Groot River Gorge.
Doring RU4:	Tankwa/Doring River Confluence to Doringbos.
Doring RU5:	Doringbos to Olifants/Doring River Confluence.
and:	Rondegat River.

The schematic in Figure 1.3 is extended in Figure 1.4 to illustrate the relative locations of the EWR sites, and additional detail in provided in Figure 1.5, and Table 1.1. The quaternary catchment in which each site is located is also provided in Table 1.1.

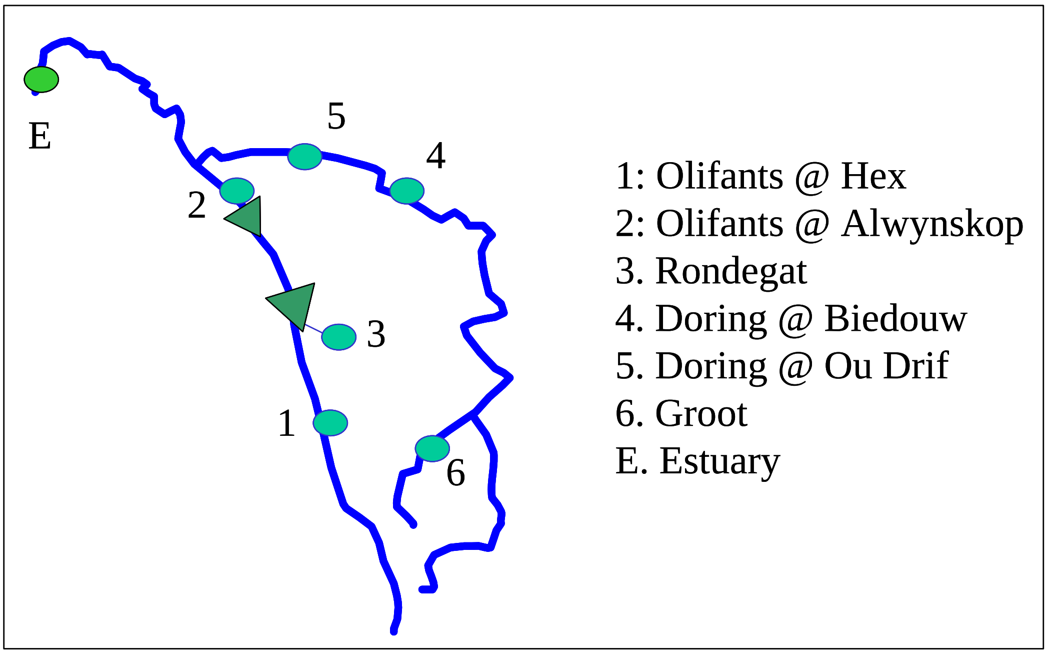


Figure 1.4 Schematic showing relative location of the six river EWR sites and the estuary

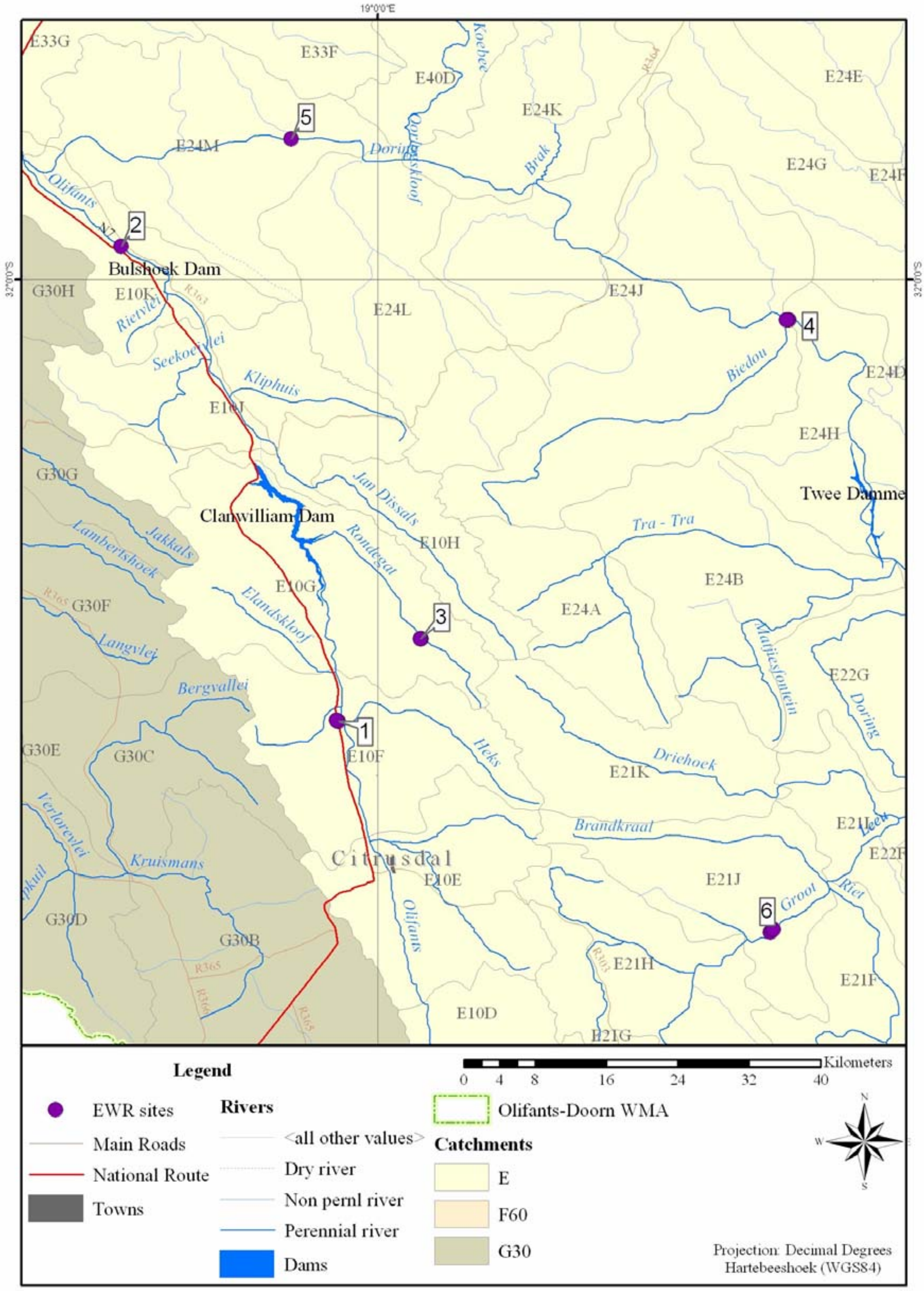


Figure 1.5 Map of the study area showing the location of the six EWR sites

Table 1.1 Details of each of the six river EWR sites selected

No.	River	Site Name	Quaternary catchment[6]	Description	Latitude	Longitude	nMAR[7]	pdMAR[8]
1	Olifants	Olifants at Hex River	E10F	N7 downstream of the confluence with the Hex River.	32°26.764 32°26.680	18°57.601 18°57.504	331.5	274.7
2	Olifants	Olifants at Alwynskop	E10K	Downstream of Bulshoek Barrage, just downstream of Cascade Pools.	31°57.974	18°44.463	519	Not known
3	Rondegat	Rondegat at Algeria	E10F - Incremental	Upstream of the Algeria staff accommodation, on the road between Algeria and Clanwilliam.	32°21.760 32°21.739	19°02.618 19°02.593	7.7	7.3
4	Doring	Doring at Biedou	E24J	On the Doring mainstem, immediately upstream of the confluence with the Biedou River.	32°02.410 32°02.416	19°24.896 19°24.783	420	320
5	Doring	Doring at Oudrif	E24M	At Oudrif.	31°51.446	18°54.754	511	401
6	Groot	Groot at Mount Cedar	E21J	Upstream of the bridge at Groot Rivier.	32°39.552 32°39.377	19°23.786 19°23.982	138	104

1.3.2 Estuary

The geographical boundaries of the Olifants River Estuary are as follows:

Downstream boundary:	Estuary mouth (31° 42.00'S; 18° 11.34'E).
Upstream boundary:	Extent of tidal influence, i.e. the causeway at Lutzville - about 36 km from the mouth (31° 33.80'S; 18° 19.78'E).
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank.

1.3.3 Groundwater

The study area comprised the whole of the Olifants/Doring catchment, with a total area of 49 054 km^2 and comprising 75 quaternary catchments.

1.3.4 Socio-economics

The study area for the socio-economics was coincident with the study areas for the river and estuarine studies.

[6] Site situated on mainstem unless otherwise stated.
[7] Natural Mean Annual Runoff.
[8] Present day mean Annual Runoff.

2 TERMS OF REFERENCE

The Terms of Reference (ToR) for this study are detailed in the Scope of Services presented in the Request for Proposals for the Olifants/Doring Reserve Determination, dated 28.11.2002, and subsequently updated at various intervals. Initially, the study had the following objectives:

Ecological Water Requirements	To determine the Ecological Water Requirements (EWR), for water quality and quantity, for various reaches of the Olifants and Doring Rivers, two key tributaries, and the Olifants estuary.
Wetlands:	None – removed from the study during negotiations.
Groundwater:	To review the importance of groundwater to current and potential users in the catchment, and to prepare a Terms of Reference for an appropriate level Groundwater EWR study.
Capacity Building:	To develop capacity in team members, and in particular persons from previously disadvantaged communities, and to train them in aspects of Ecological Reserve determinations.
System Analysis:	Provide realistic flow scenarios for evaluation in the estuary process, and report on overall implications for catchment yield.

These were expanded during the course of the study to include:

Socioeconomics:	Describe the social and economic implications of progressively increased water allocations to off-stream users, in order to facilitate the decision process required for classification.

2.1 PROJECT DURATION

Project duration was from July 2003 to June 2006[9].

2.2 PROJECT REPORTING

Table 2.1 provides a list of the Milestone Reports that were submitted to the Client in fulfillment of the ToRs of the project. The deadlines have been adjusted to reflect the latest agreed dates.

Table 2.1 The Milestone Reports submitted to the Client in fulfilment of the ToRs

Milestone Report		Due Date	Date submitted	Date accepted
Report 1:	Inception Report	October 2003	September 2003	December 2003
Report 2:	Delineation Report	March 2004	April 2004	May 2004
Report 3:	Groundwater ToR	May 2004	December 2003	March 2004
Report 4.1:	Riverine RDM Report (VOL 1).	March 2005	March 2005	June 2005
Report 4.2:	Riverine RDM Report (VOL 2).	March 2005	March 2005	May 2006
Report 5:	Estuarine RDM Report.	July 2005	July 2005	March 2006
Report 6:	Scenario Report	May 2005	July 2005	July 2005
Report 7:	Ecospecs and Monitoring Report (incl. WQ Reserve)	October 2005	December 2005[10]	March 2006
Report VO1:	Socio-economic Report.	December 2005	May 2006	June 2006
Report 8:	Final Summary Report.	May 2006	June 2006	June 2006
Scenario-creation database for the rivers (in electronic format).		May 2006	May 2006	June 2006

[9] The duration of the project was extended several times at the request of the Client, in order to align with other projects (such as the Groundwater Reserve for the Olifants-Doring Catchment).

[10] Please note that the submission of this report was delayed in order to first finalise Variation Order 3.

2.3 PROJECT REPORT NUMBERS

Milestone Report		Report No.
Report 1:	Inception Report	RDM/E00/IR/01/CON/1203
Report 2:	Delineation Report	RDM/E00/DR/01/CON/0504
Report 3:	Groundwater ToR	RDM/ToR/GWRR01/CON/0404
Report 4.1:	Riverine RDM Report (VOL 1)	RDM/V 1/SRR/01/CON/0505
Report 4.2:	Riverine RDM Report (VOL 2)	RDM/V 2/EWR/02/CON/0505
Report 5:	Estuarine RDM Report	RDM/E00/04/CON/0306
Report 6:	Scenario Report	RDM/SR/01/CON/0705
Report 7:	Riverine RDM Report (VOL 3). Ecospecs and Monitoring Report (incl. WQ Reserve)	RDM/E000/REMV3/01/CON/0506
Report VO1:	Socio-economic Report	RDM/E000/SEV1/01/CON/0606
Report 8:	Final Summary Report	RDM/E000/MSR/01/CON/0606
Scenario-creation DRIFT database for the rivers (in electronic format)		RDM/DDBS/01/CON/0606

3 STUDY TEAM AND METHODS

3.1 STUDY TEAM

The lead technical consultant for the project was Southern Waters Ecological Research and Consulting cc, with the following main sub-consultants:

- CSIR;
- DH Environmental Services;
- E.S.J. Dollar Consulting cc;
- Freshwater Consulting Group;
- GEOSS;
- Ninham Shand Consulting Services;
- Streamflow Solutions;
- Stellenbosch University;
- University of Cape Town;
- University of Port Elizabeth;
- A. Bok and Associates; and
- Anchor Environmental Consulting.

The members of the Southern Waters study team are listed in Table 3.1. The members of the SRK team, which undertook the Groundwater Reserve study are listed in Table 3.2.

Table 3.1 Members of the Southern Waters study team

Person	**Organisation**	**Reserve Component**	**Position on Team**
		MANAGEMENT	
C. Brown	Southern Waters	Management/ River Quantity	Project Leader/ River Task Leader
C. Pemberton	Southern Waters		Deputy PL/ Deputy RTL
R. Magoba	Southern Waters	Management	Assistance and review
A. Birkhead	Streamflow Solutions	River Quantity	Hydraulics engineer
I. du Plessis	SATMAP Solutions	River Quantity	Surveyor
G. Howard	Ninham Shand	River Quantity	Hydrologist
W. Kamish	Ninham Shand	River Quantity	Hydrologist
E. Dollar	CSIR	River Quantity	Geomorphologist
C. Boucher	Private	River Quantity	Botanist
J. Kereko	Univ. of Stellenbosch	River Quantity	Field Assistant: Botany data collection
G. Ractliffe	Freshwater CG	River Quantity	Invertebrates
B. Paxton	Univ. of Cape Town	River Quantity	Fish specialist
A. Bok	A. Bok and Assoc.	River Quantity	Supervisor: Fish specialist
L. Nzima	Living Landscapes Project	River Quantity	Field Assistants - Fish data collection
B. Fortuin	Living Landscapes Project	River Quantity	Field Assistants - Fish data collection
J. King	Southern Waters	River Quantity	Supervisor: Quality control
A. Sparks	Ninham Shand	River Quantity	System Analyst
W. Harding	Southern Waters	River Quality	WQ Task Leader
I. Morrison	Private	River Quality	WQ modelling
R. February	Southern Waters	River Quality	Deputy WQ TL

Person	Organisation	Reserve Component	Position on Team
S. Taljaard	CSIR	Estuary	Estuarine Task Leader (ETL)
L. van Niekerk	CSIR	Estuary	Deputy ETL
P. Huizinga	CSIR	Estuary	Supervisor: Quality control
G. Basson	Univ. of Stellenbosch	Estuary	Sedimentologist
J. Beck	Univ. of Stellenbosch	Estuary	Junior Sedimentologist
G. Bate	UPE	Estuary	Est. Microalgal specialist
J. Adams	UPE	Estuary	Est. Macrophyte specialist
T. Wooldridge	UPE	Estuary	Estuarine invertebrate ecologist
S. Lamberth	Private	Estuary	Estuarine fish ecologist
K. Hutchings	Univ. of Cape Town	Estuary	Junior Fish ecologist
J. Turpie	Anchor Consultants	Estuary/Socio-economics	Ornithologist/Resource eco.
A. Theron	CSIR	Estuary	Field and laboratory assistant
A. Adonis	CSIR	Estuary	Field and laboratory assistant
P. Smailes	UPE	Estuary	Research assistant
T. Bornman	UPE	Estuary	Research assistant
A. Rajkaran	UPE	Estuary	Research assistant
M. Thwala	UPE	Estuary	Research assistant
S. Deysel	UPE	Estuary	Research assistant
M. Vosloo	UPE	Estuary	Research assistant
I. Papadopolulos	UPE	Estuary	Research assistant
L. Atkinson	Univ. of Cape Town	Estuary	Research assistant
J. Conrad	Geoss	Groundwater	Groundwater Task Leader
Z. Munch	Geoss	GIS	GIS Task Leader
R. Robyntjies	Geoss	GIS	GIS
R. Townsend	Southern Waters	Logistics and financial control	
T. Tlou	Water for Africa	Socio-economics	Economics
W. Mullins	Water for Africa	Socio-economics	Economics
J. Goldin	Private	Socio-economics	Sociology
M. January	Private	Socio-economics	Sociology

Table 3.2 Members of the SRK groundwater study team

Person	Organisation	Position on team
M. Fortuin	SRK Consulting	Hydrogeologist
P. Rosewarne	SRK Consulting	Task Leader

3.2 CAPACITY BUILDING

Capacity building formed an integral part of the project, and opportunities for building capacity were incorporated into the river and estuarine determinations at all levels of seniority. Many of the recipients of training on this project have moved on to management or specialist advice positions in other projects.

3.2.1 River Ecosystem

River Team Leader: Mr Charles Pemberton[11] received on the job training in project management, coordination of the river quantity study team and workshop facilitation from Dr Cate Brown. He also

[11] On the basis of the experience he obtained during the two years on the Olifants-Doring project, Mr Pemberton was appointed Southern Waters' Project Manager on a major IFR Monitoring Programme in Lesotho.

developed skills in population and analysis of the DRIFT database, and towards the end of the project, took full responsibility for checking and running the DRIFT database. Mr Magoba took over Mr Pemberton's responsibilities in late 2005 and has received similar training since then.

Botanical laboratory and field assistant: Mr J. Kereko, a PhD student at the University of Stellenbosch, assisted Dr Charlie Boucher with the riverine botanical surveys and data analysis. Mr Kereko finished his PhD and left the university mid-way through the project to take up a position at the University of Natal.

Fish specialist: Mr Bruce Paxton[12] received advice and assistance in data gathering; review of the fish starter document, and assistance in the data interpretation at the EWR workshop from Dr Anton Bok.

Fish field assistants: Mr Londloza Nzima and Mr Bjorn Fortuin assisted Mr Paxton and Dr Bok with their field data collection. Both are from the Clanwilliam District and came to the project via the Living Landscapes Project in Clanwilliam. Mr Nzima and Mr Fortuin are also involved in an ongoing UCT-Southern Waters project on the indigenous fish of the Olifants/Doring River.

Macroinvertebrate data collection: Mr Rembu Magoba[13] received training in data gathering; for the macroinvertebrate component of the study. He also attended the workshop, and was involved in post-workshop population and review of the DRIFT database and the workshop reports.

Water quality data collection: Mr Rodney February assisted with water quality data collection during the initial field trips. He left Southern Waters in early 2004 to take up a position with The Table Mountain Fund[14], and has subsequently taken charge of the Aquatic Ecosystems Initiative at WWF. Mr Pemberton and Mr Magoba collected the water quality data and diatoms samples subsequent to Mr February's departure.

River Specialists: The biological specialists on the river team attended a one-day refresher workshop on DRIFT. This workshop concentrated on DRIFT Generic Lists and the format in which specialists were expected to provide their consequences at the workshop.

DRIFT workshop and scenario meeting: A workshop was held at DWAF: Belville Office wherein the following aspects of the study were explained:

- DRIFT Methodology, with particular focus on the DRIFT Database.
- DRIFT scenarios for each of the EWR sites that formed part of the riverine ecosystem.
- Implications for river management/rehabilitation in the Olifants/Doring basin.
- Future development options in the basin (see Section 6).

Scientific paper: C. Brown, C. Pemberton, A. Birkhead, A. Bok, C. Boucher, E. Dollar, W. Harding, W. Kamish, J. King, B. Paxton and S. Ractliffe. 2006. In support of water-resources planning – Highlighting key management issues using DRIFT: A case study. *Water SA Vol. 32 No. 2* April. 181-192.

[12] Mr Paxton is currently completing an MSc on the fish of the Olifants-Doring Rivers.

[13] Mr Magoba has an MSc in macroinvertebrate ecology and is currently reading a PhD. He is also using the experience he gained on the Olifants-Doring project as the Southern Waters' macroinvertebrate specialist on the environmental flow assessment for Metolong Dam in Lesotho. Towards the end of the study he also received training in Project Management and production of the final reports, and was involved in the compilation and review of several of the study reports that emerged in the latter part of the project (May 2005 onwards).

[14] Mr February was awarded this position on the basis of experience received at Southern Waters on this and other projects.

3.2.2 Estuarine Ecosystem

The main focus of the capacity building component for the estuary was fieldwork and data analysis, including:

- site selection;
- scientific sampling techniques;
- boating skills;
- species identification in the field;
- observational skills needed to identify the relationship between river inflows and abundance/species composition;
- analysis of samples collected.

The following students/assistants were part of the team:

- S. Deysel
- M. Vosloo
- M. Thwala
- J. Beck
- A. Rajkaran
- I. Papadopolus
- L. Atkinson
- A. Adonis.

The estuarine fish specialist, Dr S. Lamberth, also set up a Local Catch Monitoring Programme (for Marine and Coastal Management, DEAT) on the Olifants Estuary. He used the opportunity to employ local fishers from the Ebenhaesar Community in the field data collecting exercise.

3.3 CONTRIBUTIONS BY HISTORICALLY-DISADVANTAGED INDIVIDUALS

Table 3.3 lists the team members who qualify as Historically-Disadvantaged Individuals (HDIs).

Table 3.3 Team members who qualify as HDIs

Team member	**HDI Status**
Dr C. Brown (Project leadership)	White female
R. Townsend (Financial control)	White female
Dr J. King (Review)	White female
R. February (River WQ data collection)	Black male
W. Kamish (Hydrology)	Black male
J. Kereko (River botany assistance)	Black male
S. Mkosana (Survey assistance)	Black male
L. Nzima (River Fish field work)	Black male
B. Fortuin (River Fish field work)	Black male
G. Ractliffe (Macroinvertebrates)	White female
R. Magoba (Macroinvertebrates/DRIFT database/Project management)	Black male
E. Frazer (Macroinvertebrates)	Black female
Z. Munch (GIS)	White female
M. Robyntjies (GIS)	Black female
S. Taljaard (Estuarine task leadership)	White female
L. van Niekerk (Estuarine task leadership)	White female
A. Rajkaran (Estuarine field work)	Black female
A. Adonis (Estuarine field work)	Black male
Ebenezer fishers (Estuarine field work)	Black males
Prof J. Adams (Estuarine botany)	White female
J. Smailes (Estuarine botany)	White female
Dr J. Turpie (Estuarine birds and socio-economics)	White female
L. Atkinson (Estuarine birds)	White female
M. Thwala (Estuarine macroinvertebrates)	Black female

I. Papadopolulos (Estuarine macroinvertebrates)	Black female
J. Beck (Sediments)	White female
T. Tlou (Socio-economics)	Black male
Dr J. Goldin (Socio-economics)	White female
M. January (Socio-economics)	Black female

The **targets** for HDI contributions to the project, as stated in the Inception Report (which excluded the socioeconomics) were:
HDI component of hours worked: 51%.
HDI component of money invoiced: 45%.

The **actual** HDI contributions achieved in the project were:
HDI component of hours worked: 58% (Figure 3.1).
HDI component of money invoiced: 68% (Figure 3.2).

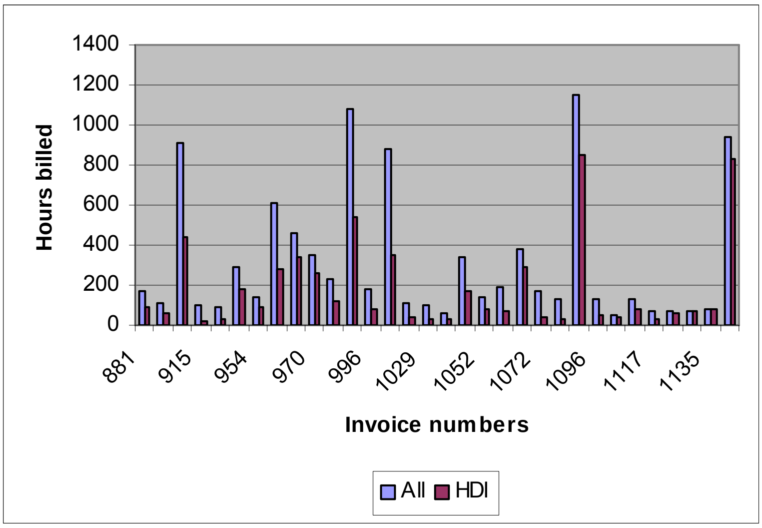


Figure 3.1 HDI involvement: hours billed

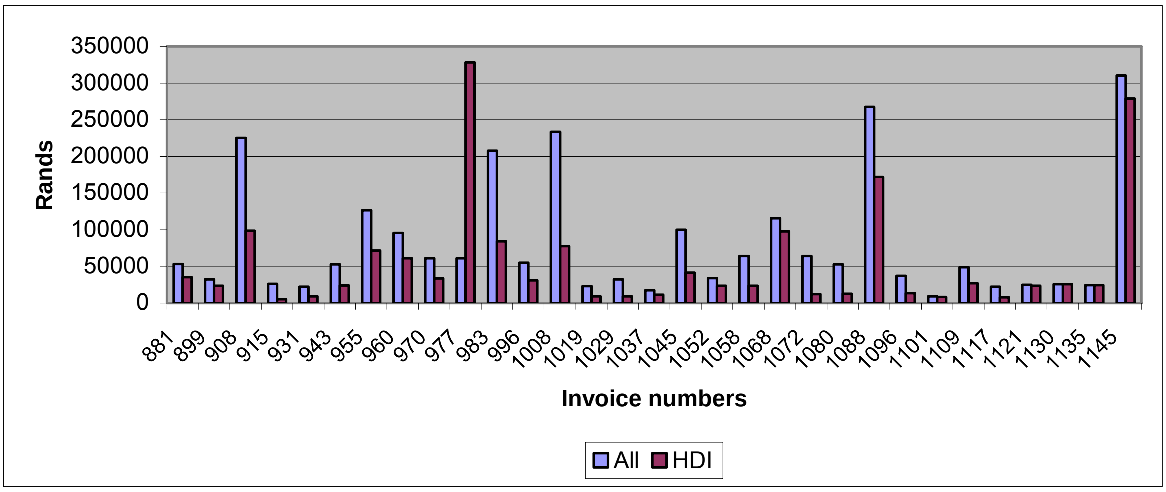


Figure 3.2 HDI involvement: Rands billed

3.4 METHODS

3.4.1 Riverine Ecosystem

The methodology used for the river EWR is called DRIFT (Downstream Response to Imposed Flow Transformations; King *et al*. 2003; Brown *et al*. 2006), and it is an interactive, holistic approach to advising on environmental flows for rivers. The main output was a matrix of ecological consequences for the study rivers, for a range of possible reductions (or additions) in flow, which was entered into the DRIFT Database. The database was then used to compile flow scenarios based on trade-offs between river condition and flow.

3.4.2 Estuarine Ecosystem

The methods that were applied in the determination of the recommended Ecological Category (EC) and the recommended Ecological Water Requirements (EWR) for the Olifants Estuary were those described in DWAF (2004).

3.4.3 Groundwater

A prioritisation of quaternary catchments was carried out using a risk-based approach, in conjunction with DWAF. This priority list was then used to determine the appropriate level of Groundwater Reserve determination for each quaternary.

3.4.4 Yield

The yield assessment used Pitman calibrations to generate natural and present day flow sequences at specified riverine sites in the Olifants and Doring Rivers (DWAF 1998a). The Water Resources Yield Model was used to assess the impacts of various future schemes and riverine environmental releases on the flow into the estuary and on water available for development.

3.4.5 Socio-economics

Economic values generated by out-of-stream uses and environmental flow were estimated using conventional and resource economics measures and evaluated in terms of their contribution to national income (GDP Value Added), and their contribution to local livelihoods and poverty reduction. Social measures included their contribution to human well-being, and considered factors such as health implications, contribution to basic human needs and the impact on social systems and fabric.

4 SUMMARY RESULTS – RIVER

4.1 INTRODUCTION

The Olifants-Doring Catchment is essentially a tale of two rivers reflected in their Present Ecological Status (PES; Table 4.1). The Olifants River valley is more suitable for agriculture and hence more populated. Consequently, the river is fairly heavily impacted. Upstream of the Clanwilliam Dam and Bulshoek Barrage, these impacts are both flow and non-flow related, with non-flow related impacts, such as cultivation of the riparian zone, dominating. The flow impacts are a result of over-abstraction in the dry summer months, resulting in the naturally perennial river system becoming seasonal and drying-up entirely at times. Downstream of the Clanwilliam Dam and Bulshoek Barrage to the confluence with the Doring River, the impacts on the river are strongly flow-related combined with other physical influences related to sediment trapped in the upstream impoundments. Downstream of the confluence, non-flow related impacts, such as cultivation of the riparian zone, again begin to dominate. Water quality impacts, mainly related to increased salinity concentrations, are most prevalent in the lower reaches of the Olifants River in the summer.

The Doring River valley, on the other hand, is sparsely populated, and (at least in its middle and lower reaches) the river is relatively undisturbed compared with the Olifants River. Flow impacts related to abstraction in the upper reaches, and resulting in an extended non-flow period for this naturally seasonal river system, dominate. The upper reaches of the Doring are, for all intents and purposes, the Groot River and it's tributaries. These rise on the plateau of the Kouebokkeveld before dropping steeply to their confluence with the Doring River. The sections of these rivers in the Kouebokkeveld are fairly impacted by flow and non-flow related agricultural activities, including numerous farms dams.

The flow requirements for the lower Olifants River and estuary are largely supported by the contributions of the Doring River.

Note: Determinations of EWRs necessiatate the use of several different models and programmes, and sometimes slightly different hydrology data. This means that the outputs from these tend to differ slightly, and thus some of the figures in the various tables provided here do not correspond exactly. This is to be expected and these do not represent errors.

4.2 RIVER FLOW - QUANTITY

4.2.1 Present Ecological Status Riverine, Recommended Ecological Category and Alternative Ecological Category

The Present Ecostatus, and the Recommended Ecological Category (REC) and Alternative Ecological Category (AEC) for which Reserves were presented in Report 4.2: Riverine RDM Report are indicated in Table 4.1. According to RDM Policy, which stipulates that the Ecological Category of a river should not be allowed to be lower than a D-category, the REC for EWR Site 2 should be a D. However, there was unanimous agreement from the specialists that attainment of a D-category at EWR Site 2 was unrealistic, and so no such recommendation was made. Instead a 'residual flow' was recommended to maintain the water quality and vegetation in EWR Reach 2.

Table 4.1 The Present Ecostatus, and the Recommended Ecological Category (REC) and Alternative Ecological Category (AEC) for which Reserves were determined

EWR Site	Present Ecostatus	REC	AEC
Site 1	D	D	None
Site 2	E	None	None
Site 3	B	B	C
Site 4	B/C	B	C
Site 5	B	B	C
Site 6	B/C	B/C	C

4.2.2 Ecological Water Requirements

The EWRs determined for EWR Sites 1, 3, 4, 5 and 6 are given in Table 4.2. The table gives the EWR averages excluding the requirements for the ≥ 1: 2 year return period floods. This 'lower' figure is the one routinely provided in Reserve determinations using the Desktop and other approved methods. It is provided here to facilitate comparison of the percentages nMAR with other studies.

The tables giving the distribution of flows for each EWR site, for the REC and including the requirements for the ≥ 1: 2 year return period floods, are presented in Table 4.3 – Table 4.8.

Table 4.2 The EWR for each EWR site. The volumes given exclude ≥ 1:2 year return period floods, to facilitate comparison with results from other Reserve studies

Site	Portion of the EWR	PES	REC	MCM a^{-1}	%nMAR
EWR SITE 1	TOTAL (Volume), excl. ≥1:2 year return period floods	D	D	88	26%
EWR SITE 2	TOTAL (Volume), excl. ≥1:2 year return period floods	E	D	*c.* 194[15]	38%
			Maintain PES (E)	48.3	9%
EWR SITE 3	TOTAL (Volume), excl. ≥1:2 year return period floods	B	B	*c.* 3	38%
			C	1.4	18%
EWR SITE 4	TOTAL (Volume), excl. ≥1:2 year return period floods	B	B	192	45%
			C	87	21%
EWR SITE 5	TOTAL (Volume), excl. ≥1:2 year return period floods	B	B	232	45%
			C	119	23%
EWR SITE 6	TOTAL (Volume), excl. ≥1:2 year return period floods	B/C	B/C	60	44%
			C	40	29%

[15] Please see comments in body of the report.

4.2.3 Key issues pertaining to the EWR sites

EWR SITE 1

- The Present Ecostatus at EWR Site 1 is a D-category, driven predominately by non-flow related issues, such as bulldozing of the channel, cultivation of the alluvial floodplains and encroachment of alien and other riparian vegetation.
- The Recommended Ecological Category (REC) is a D-category.
- Present day hydrology is reasonable with the notable exception of the summer months, when the naturally perennial Olifants River is pumped dry, sometimes for up to several weeks.
- There is some opportunity for further abstractions from the river while still maintaining a D-category river BUT only if some summer flows are reinstated.
- Opportunities for additional abstraction are limited by the fact that hydrology is presently supporting the D-category condition of the river, whereas other 'drivers' of river condition, such as geomorphology are in an E. If the hydrological regime is further restricted, this will result in the river falling to an E category.
- The most reliable way to increase the level of abstraction possible, and still maintain a D-category river, is to implement river restoration aimed at reversing some of the non-flow related geomorphological impacts.
- Only one scenario is presented, *viz*. maintain a D-category as this can best be made a C-category by restoration work addressing non-flow related issues.
- A dam in the upper reaches of the Olifants River, i.e., upstream of EWR Site 1 would negatively affect the hydrological and geomorphological condition of the system (with knock-on effects on other aspects of the river ecosystem) mainly through the reduction in variability of the large to medium sized floods, and through the reduction of sediment supply.

EWR SITE 2

- The Present Ecostatus is E-category with the deviations from natural, partially driven by flow-related issues. These are primarily attenuation of floods and severely-reduced dry season lowflows as a result of Clanwilliam Dam and Bulshoek Barrage.
- Additional impacts include reduced sediment supply, encroachment of reeds and palmiet, and cultivation of flood terraces.
- Recent repair work at Bulshoek Barrage has reduced the leaks from the dam, which were in the order of 1 cumec in the wet season (Francois van Heerden, DWAF, pers. comm.).
- Opportunities for improving the Present Ecostatus through releases from Clanwilliam Dam/Bulshoek Barrage are limited.
- At the EWR Workshop an EWR for maintaining a D-category (as per RDM Policy) was determined, however, there was unanimous agreement from the specialists that the risk of the EWR not supporting a D was extremely high as many of the impacts were related to the dam/barrage. Thus, maintenance of a D-category was deemed unrealistic.
- The EWR provided here is thus for 'maintenance of PES', *viz*. E-category.
- The EWR to support an E-category was estimated as 51.5 MCM per annum (i.e., 10% nMAR).

EWR SITE 3

- The Present Ecostatus is B-category, with the deviations from natural predominately driven by non-flow related issues, such as historic manipulation of the floodplain and invasion of alien vegetation into the riparian zone.
- The Recommended Ecological Category (REC) is a B-category.

Table 4.3 Water quantity for the REC (D) at EWR Site 1 (Olifants River at Hex). To be met at the Algeria bridge. MCM = million cubic metres[16]

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
nMAR = 331.5 MCM (estimated). pdMAR = 274.7														
EWR Ecostatus Category = D.														
MAINTENANCE														
CAPPING FLOWS	Not set												N/a	
LOW FLOWS Q m^3s^{-1}	3.3	0.9	0.1	0.1	0.1	0.1	0.6	2.0	4.5	6.0	6.0	4.0	67	20
FLOOD Class 1: 9[17]: m^3s^{-1}	1.5	3				1		3				1.5	3.3x10	10
FLOOD Class 2: 20: m^3s^{-1}									1				6.5x1	2
FLOOD Class 3: 36: m^3s^{-1}									1				12.4x1	4
FLOOD Class 4: 85: m^3s^{-1}									-				-	-
Inter-annual floods	Estimated annual volume (1:5; 1;10 and 1:20 year floods)[18]												45	14
MAINTENANCE TOTAL (Volume)	**Annual[19]**												**185.9**	**55**
	Long-term average[20]												**128.57**	**38.5**
DROUGHT														
LOW FLOWS m^3s^{-1}	0.39	0.01	0.01	0.01	0.01	0.01	0.01	0.37	1.87	1.69	2.23	1.48	21.4	6
FLOOD Peak[21] m^3s^{-1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL FLOWS (MCM)	***7.1***	***3.4***	***1.7***	***0.66***	***0.16***	***0.6***	***2.6***	***5.3***	***25.1***	***40.8***	***25.7***	***15.3***	**128.57**	**38.5**

[16] Values given are an ESTIMATE of the flows required. Actual volumes depend on climate.
[17] Daily average peak
[18] Volume of 1:2 year flood is *c*. 25 MCM per annum (i.e., 50 MCM per event).
[19] Calculated as the volume of water required to meet the full requirements.
[20] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[21] Daily average peak

Table 4.4 Water quantity for maintaining PES (E) at EWR Site 2 (Olifants River at Alwynskop). To be met at the pedestrian bridge at the confluence with the Doring River. MCM = million cubic metres[22]

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
nMAR = 519 MCM (estimated). pdMAR = unknown.														
PES Ecostatus Category = E.														
MAINTENANCE														
CAPPING FLOWS	Not set												N/a	
LOW FLOWS Q m^3s^{-1}	0.9	0.2	0.2	0.2	0.2	0.2	0.2	0.9	0.9	0.9	0.9	0.9	21.5	4
FLOOD Class 1[23] 10.5: m^3s^{-1}								1		1			3x2	1
FLOOD Class 2: 21 m^3s^{-1}													-	-
FLOOD Class 3: 42 m^3s^{-1}									1		1		12x2	5
FLOOD Class 4: 84.5 m^3s^{-1}													-	-
Inter-annual floods	Estimated annual volume (1:5; 1;10 and 1:20 year floods)												**Not available for this site.**	
MAINTENANCE TOTAL (Volume)	**Annual[24]**												**51.5**	**10**
	Long-term average												**Not available for this site.**	
DROUGHT														
LOW FLOWS m^3s^{-1}	0.9	0.2	0.2	0.2	0.2	0.2	0.2	0.9	0.9	0.9	0.9	0.9	21.5	4
FLOOD Peak m^3s^{-1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL FLOWS (MCM)	**Not available for this site.**													

[22] Values given are an ESTIMATE of the flows required. Actual volumes depend on climate.
[23] Daily average peak.
[24] Calculated as the volume of water required to meet the full requirements.

Table 4.5 Water quantity for REC (B) at EWR Site 3 (Rondegat River downstream of Algeria). To be met at the pedestrian bridge at Algeria. MCM = million cubic metres[25]

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
nMAR = 7.7 MCM. pdMAR = 7.3 MCM.														
EWR Ecostatus Category = B.														
MAINTENANCE														
CAPPING FLOWS	Not set												N/a	
LOW FLOWS Q m^3s^{-1}	0.07	0.06	0.04	0.04	0.02	0.02	0.02	0.02	0.04	0.09	0.09	0.12	1.64	21
FLOOD Class 1[26]: 0.32 m^3s^{-1}	0.5	1				1		1				0.5	0.05x4	3
FLOOD Class 2: 0.64 m^3s^{-1}								1	1		1		0.11x3	4
FLOOD Class 3: 1.28 m^3s^{-1}									1		1		0.22x2	1
FLOOD Class 4: 2.56 m^3s^{-1}									2				0.33x2	8
Inter-annual floods	Estimated annual volume (1:5; 1;10 and 1:20 year floods)												1.1	14
MAINTENANCE TOTAL (Volume)	**Annual[27]**												**4.83**	**63**
	Long-term average[28]												**4.06**	**53**
DROUGHT														
LOW FLOWS m^3s^{-1}	0.004	0	0	0.004	0.004	0	0	0	0.01	0.01	0.01	0.01	0.14	2
FLOOD Peak[29] m^3s^{-1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL FLOWS (MCM)	***0.22***	***0.22***	***0.14***	***0.11***	***0.07***	***0.06***	***0.07***	***0.15***	***0.32***	***0.93***	***1.05***	***0.64***	**4.06**	**53**

[25] Values given are an ESTIMATE of the flows required. Actual volumes depend on climate.
[26] Daily average peak
[27] Calculated as the volume of water required to meet the full requirements.
[28] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.
[29] Daily average peak

Table 4.6 Water quantity for REC (B) at EWR Site 4 on the Doring River upstream of the Biedou River, Western Cape

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
nMAR = 420 MCM. pdMAR =320 MCM														
EWR Ecostatus Category = B.														
MAINTENANCE														
CAPPING FLOWS	Not set	1 m^3s^{-1}	1 m^3s^{-1}	1 m^3s^{-1}	1 m^3s^{-1}	1 m^3s^{-1}	0 m^3s^{-1}	Not set					N/a	
LOW FLOWS Q m^3s^{-1} [30]	2.0	0.03	0	0	0	0	0.05	0.5	3.0	6.0	6.0	6.0	59.2	14
FLOOD Class 1[31]: 26 m^3s^{-1}	2	1				1		1				1	3.2x6	5
FLOOD Class 2: 52 m^3s^{-1}									1		1		11x2	5
FLOOD Class 3: 103 m^3s^{-1}									1		1		20.2x2	10
FLOOD Class 4: 209 m^3s^{-1}									1				45x1	11
FLOOD Class 5: 1:2 year													40	10
Inter-annual floods	Estimated annual volume (1:5; 1;10 and 1:20 year floods)												55	13
MAINTENANCE TOTAL (Volume)	**Annual[32]**												**277**	**66**
	Long-term average[33]												**199**	**47**
DROUGHT														
LOW FLOWS m^3s^{-1}	0.15	0.03	0	0	0	0	0	0.01	0.01	0.02	1.03	0.09	3.6	1
FLOOD Peak[34] m^3s^{-1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL FLOWS (MCM)	***6.75***	***3.88***	***1.26***	***6.28***	***1.96***	***0.91***	***13.19***	***25.22***	***39.32***	***39.05***	***36.71***	***24.74***	**199**	**47**

[30] Figures rounded-off to the nearest one decimal place.
[31] Daily average peak.
[32] Calculated as the volume of water required to meet the full requirements.
[33] Calculated using the historical flow sequence, and only ‘releasing’ requirements in response to ‘natural’ cues.
[34] Daily average peak.

Table 4.7 Water quantity for REC (B) at EWR Site 5 on the Doring River at Ou Drif, Western Cape

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 511 MCM. pdMAR = 401 MCM														
EWR Ecostatus Category = B.														
MAINTENANCE														
CAPPING FLOWS	Not set	1 m^3s^{-1}	1 m^3s^{-1}	1 m^3s^{-1}	1 m^3s^{-1}	1 m^3s^{-1}	0 m^3s^{-1}	Not set					N/a	
LOW FLOWS Q m^3s^{-1}[35]	2.29	0.03	0	0	0	0	0.05	0.82	5.00	8.30	8.00	6.00	78	15
FLOOD Class 1[36]: 35.05 m^3s^{-1}	2	1				1		1				1	4x6	6
FLOOD Class 2: 70.11 m^3s^{-1}									1		1		15x2	6
FLOOD Class 3: 140.22 m^3s^{-1}									1		1		27x2	10
FLOOD Class 4: 280 m^3s^{-1}									1				59x1	12
Inter-annual floods	Estimated annual volume (1:5; 1;10 and 1:20 year floods)												65	13
MAINTENANCE TOTAL (Volume)	**Annual[37]**												**310**	**61**
	Long-term average[38]												**234.39**	**46**
DROUGHT														
LOW FLOWS m^3s^{-1}	0.03	0.03	0	0	0	0	0	0	0	0.06	0.19	0.18	15	3
FLOOD Peak[39] m^3s^{-1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL FLOWS (MCM)	***6.7***	***1.9***	***1.0***	***18.2***	***24.4***	***52.1***	***47.7***	***44.9***	***21.1***	***8.9***	***4.3***	***3.2***	**234.39**	**46**

[35] Figures rounded-off to the nearest one decimal place.

[36] Daily average peak

[37] Calculated as the volume of water required to meet the full requirements.

[38] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

[39] Daily average peak

Table 4.8 Water quantity for REC (B/C) at EWR Site 6 on the Groot River at Mount Cedar, Western Cape

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
nMAR = 138 MCM. pdMAR = 104 MCM														
EWR Ecostatus Category = B/C.														
MAINTENANCE														
CAPPING FLOWS	Not set													
LOW FLOWS Q m^3s^{-1}	0.726	0.18	0.04	0.011	0.01	0.02	0.06	0.23	1.055	2.012	3.00	2.228	22	17
FLOOD Class 1[40]: 5.5 m^3s^{-1}	1					1		3				2	7x1	5
FLOOD Class 2: 11 m^3s^{-1}									2				2x2	3
FLOOD Class 3: 22 m^3s^{-1}									2				2x4	6
FLOOD Class 4: 44 m^3s^{-1}									2				2x11	16
Inter-annual floods	Estimated annual volume (1:5; 1;10 and 1:20 year floods)												16	12
MAINTENANCE TOTAL (Volume)	**Annual[41]**												**79**	**57**
	Long-term average[42]												**63**	**46**
DROUGHT														
LOW FLOWS m^3s^{-1}	0.04	0.01	0.001	0.001	0.001	0.001	0.001	0.01	0.04	0.15	0.42	0.54	3.2	2
FLOOD Peak m^3s^{-1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL FLOWS (MCM)	***2.699***	***2.085***	***0.725***	***0.296***	***0.127***	***0.261***	***0.764***	***5.756***	***8.713***	***13.148***	***17.681***	***11.168***	**63**	**46**

*Discrepancies relate to flood events occurring in some months and not in others.

[40] Daily average peak.
[41] Calculated as the volume of water required to meet the full requirements.
[42] Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

- There are NO gauging weirs on the Rondegat River and this affected the reliability of the hydrology. Nonetheless, it is unlikely that there are major alterations to flow regime, as all water abstraction is either run-of river or as a result of minor changes in landuse (in particular, forestry).
- Fish communities are in a pristine condition in the upper half of the Rondegat River, largely because of the absence of alien predators such as bass.
- Opportunities for improving the condition through flow manipulations are deemed to be limited.
- Two EWR Options are presented, *viz*. achieve a B-category and to achieve a C-category, as there is little opportunity for improvement to an A-category using flow.
- The EWR to support a B-category was estimated as 4.8 MCM per annum (i.e., 63% nMAR).
- The EWR to support a C-category was estimated as 2.0 MCM per annum (i.e., 26% nMAR).
- Given the conservation importance of this system (and other tributaries feeding the Olifants River[43]), the precautionary principle was applied.

EWR SITE 4

- The Present Ecostatus is B/C-category.
- The Recommended Ecological Category (REC) is a B-category.
- The EWR to support a B-category was estimated as 277 MCM per annum (i.e., 66% nMAR – incl. volume of inter-annual floods).
- The EWR to support a C-category was estimated as 136 MCM per annum (i.e., 33% nMAR – incl. volume of inter-annual floods).
- The flows recommended for BOTH scenarios provided here represents a slight INCREASE in dry season lowflow volumes as it seeks to reduce the length of the dry season back towards a more natural situation.
- At the time of this study, no data or models were available to assess the implications of flow changes on the unique water chemistry of the Doring River. It is thus, highly possible that the water quality implications of the changes in flow are underestimated.
- The invasion of biota into the Doring River, primarily *Nerium oleander*, is a major threat to the future ecostatus of this system.
- The physical presence (i.e., aside from influence on the flow regime) of a dam in the Doring or Groot River, i.e., upstream of EWR Site 4 or 5 would critically affect the geomorphological condition of the system (with knock-on effects on other aspects of the river ecosystem, e.g., geomorphology and water quality) mainly through the reduction in variability of the large to medium sized flood, and through the reduction of sediment supply/sediment transport capacity. It would also represent a barrier to fish and other fauna movement, and provide a safe haven for alien invaders, such as smallmouthed bass.

EWR SITE 5

- The Present Ecostatus is B-category.
- The Recommended Ecological Category (REC) is a B-category.
- The EWR to support a B-category was estimated as 310 MCM per annum (i.e., 61% nMAR – incl. volume of inter-annual floods).
- The EWR to support a C-category was estimated as 185 MCM per annum (i.e., 36% nMAR – incl. volume of inter-annual floods).
- The flows recommended for BOTH scenarios provided here represents a slight INCREASE in dry season lowflow volumes as it seeks to reduce the length of the dry season back towards a more natural situation.
- At the time of this study, no data or models were available to assess the implications of flow changes on the unique water chemistry of the Doring River. It is thus, highly possible that the water quality implications of the changes in flow are underestimated.

---

[43] See note re possible extrapolations of these data to other tributaries in Section 4.3.

- The invasion of biota into the Doring River, primarily *Nerium oleander*, is a major threat to the future ecostatus of this system.
- The physical presence (i.e., aside from influence on the flow regime) of a dam in the Doring or Groot River, i.e., upstream of EWR Site 5 would critically affect the geomorphological condition of the system (with knock-on effects on other aspects of the river ecosystem, e.g., geomorphology and water quality) mainly through the reduction in variability of the large to medium sized flood, and through the reduction of sediment supply/sediment transport capacity. It would also represent a barrier to fish, and other fauna, movement, and provide a safe haven for alien invaders, such as smallmouthed bass.

EWR SITE 6

- The Present Ecostatus is B/C-category.
- Detailed explanations of the ecosystem response to the different change levels presented here are provided as individual comments from specialists in the accompanying the DRIFT DATABASE (EWR Site 6), and are not detailed here.
- The Recommended Ecological Category (REC) is a B/C-category.
- The EWR to support a B/C-category was estimated as 79 MCM per annum (i.e., 57% nMAR – incl. volume of ≥ 1:5 return period floods). Long-term Average = 63 MCM (i.e., 46% nMAR).
- The EWR to support a C-category was estimated as 56 MCM per annum (i.e., 41% nMAR – incl. volume of inter-annual floods). Long-term Average = 53 (i.e., 38% nMAR).

4.3 EWRS FOR OTHER SITES

As part of two related initiatives, EWRs have been generated for a range of Ecological Conditions (e.g., Category B to D) 46 quaternary catchments in the Olifants Doring catchment (Brown *et al*. in prep[44]). Of these, 14 quaternaries used data generated from this study, and the remaining 32 were generated using the Desktop Model. These EWRs were generated partly to assist with testing the Water Resource Classification System, which is currently under development (DWAF 2005), and partly to assist the DWAF: Western Cape Region with implementation of the Reserve in that catchment.

44 BROWN, C.A., EWART-SMITH, J., CONRAD, J. and ROSSOUW, N. In prep. Development of the Water Resource Classification System (WRCS). Internal project report on Tasks 7.1 – 7.20. Ecological Considerations.

4.4 RIVER FLOW - QUALITY

EWR SITE		1	2	3	4	5	6
ECOSTATUS		D	D	B	B	B	B/C
Determinant		Recommended ranges					
Salts[45,46]	$MgSO_4$ (mg ℓ$^{-1}$)	<37	<37	<23	<23	<23	<23
	Na2SO_4 (mg ℓ$^{-1}$)	<51	<51	<33	<33	<33	<33
	$MgCl_2$ (mg ℓ$^{-1}$)	<51	<51	<30	<30	<30	<30
	$CaCl_2$ (mg ℓ$^{-1}$)	<105	<105	<57	<57	<57	<57
	NaCl (mg ℓ$^{-1}$)	<389	<389	<191	<191	<191	<191
Water temperature (^{o}C)		Not specified			Maximum daily mean = 40^{o}C. Spawning: Minimum = 19 ^{o}C, ideal = 25-28 ^{o}C (November to January).		
pH		6.5 – 9.0	6.5 – 9.0	5.2 – 7.0	6.5 – 8.5	6.5 – 8.5	6.0 – 8.5
EC (mS m^{-1})		<15	<25	<10	<20	<50	<15
Diss. oxygen (DO) (mg ℓ$^{-1}$)		> 6.0	> 6.0	> 6.0	> 6.0	> 6.0	> 6.0
Toxics[47]	Ammonia as NH_3 (mg ℓ$^{-1}$)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Nutrients	Nitrates as N (mg ℓ$^{-1}$)	<0.100	<0.100	<0.020	<0.020	<0.020	<0.050
	Phosphorus as PO_4-P (mg ℓ$^{-1}$)	<0.020	<0.015	<0.010	<0.020	<0.020	<0.020

[45] The data for salts, either individually or as Total Dissolved Solids, are not supported by the salinity-modelling component that was anticipated to become available from the WODRIS project.
[46] There are no locally relevant data available for salts or salinity tolerances of aquatic invertebrates.
[47] Specific data characterising effluents from wastewater treatment plants not yet received from RQS.

5 SUMMARY RESULTS - YIELD

The yield assessment provided an estimate of the consequences of the various estuarine scenarios (Section 6.1) for water availability (yield) within the catchment. A summary description of the scenarios and the change in water supply (wrt to current supply levels) is given in Table 5.1. This list is somewhat longer than that presented for the estuary, as the estuarine team could only assess five scenarios, whereas a greater selection was modelled and then the five chosen for the estuary selected. More detail describing the scenarios and the breakdown in supply to consumers and the estuary is included in Table 5.2.

Table 5.1 Description of the scenarios analysed and the change in water supply (wrt to current supply levels) and the average flow at the estuary

Scenario	Scenario ID[48]	Brief description	Key Flows	
			Change in supply wrt Present Day *(MCM a^{-1})*	*Estuary flows (MCM a^{-1})*
Natural	0*	Assume pre-development conditions	-324	1055
Present Day	1*	No change from present flows	0	716
	2*	EWR releases	-72	784
Maximize Olifants	5*	Raise CwD 15m	123	597
	6	Raise CwD 10m	99	622
	7	Raise CwD 15m and release EWR	-15	725
Dam Doring Headwaters	13	Dam on Groot R + EWRs d/s CWD & DO confluence	10	691
	14	Dam on Groot R without EWRs d/s CwD	147	565
	15	Dam on Groot R with reduced EWRs on Doring	155	556
	16	Off-channel farm dams u/s proposed GrootR Dam in Kouebokkeveld	140	577
Intermediate Doring	17*	Off-channel Brandewyn : No EWR d/s Brandewyn	182	518
	17B	Off-channel Brandewyn : EWR d/s Brandewyn	170	539
Maximize System	10*	No EWR d/s Doring confluence	273	422
	11	Meet EWR throughout system	50	640

Some of the water supplied to (and used by) the irrigators in the lower Olifants River is assumed to return to the main riverstem and increase the summer lowflows to the estuary.

The yield from the Clanwilliam Dam is highly dependent on the EWRs imposed on the dam, especially those applied downstream of Bulshoek Dam. These EWRs can reduce the yield from the dam below that of the current yield even if the Clanwilliam Dam is raised by 15 metres.

[48] Numbers are not sequential, as some scenarios were disgarded early on in the process as they did not differ significantly from other scenarios.

Table 5.2 Detailed breakdown of scenarios modelled and their impact on the supply to consumers and the impact on the estuary

Scenario	Scenario Number	Variant	Schemes: Dam capacity in MCM					Target EC for EWR Sites: Olifants (O)			Doring (D)				Olifants (O)	Key flows (MCM/a)								
			Additional Clanwilliam Dam capacity	Melkbosrug	Brandewyn	Groot	Farm dams in Kouebokkeveld	EWR Site 1 D/s Hex	Extrapolated D/s Clanwilliam Dam	EWR Site 2 D/s Bulshoek	EWR Site 3 Rondegat trib	EWR Site 4 U/s Biedou	EWR Site 5 Oudrif	EWR Site 6 Groot trib	Extrapolated D/s Doring Confluence	Supply to Upper Olifants and Doring	Lower Olifants and additional schemes before deducting return flows	System supply including new scenarios	Return flows	Nett supply (ie less return flows)	Evaporation (Exist + schemes)	**Estuary**	Total	**Increase in supply wrt Present day**
Natural	0*		None												-	0	0	0	0	0	0	**1055**	1055	**-324**
Present Day	1*		None												-	158	166	324	-18	306	33	**716**	1055	**0**
	2*	EWR releases	0	-	-	-		D	D	D	B	B	B	B/C	2+5	158	94	252	-9	243	30	**782**	1055	**-72**
Maximize supply from the Olifants River	5*	Raise CwD 15m	240	-	-	-		-	-	-	B	B	B	B/C	-	158	289	447	-31	416	42	**597**	1055	**123**
	6	Raise CwD 10m	143	-	-	-		-	-	-	B	B	B	B/C	-	158	265	423	-29	394	39	**622**	1055	**99**
	7	Raise CwD 15m and release EWR	240	-	-	-		D	D	D	B	B	B	B/C	2+5	158	151	309	-16	293	37	**725**	1055	**-15**
Dam upper reaches of the Doring	13	Groot + EWRs	240	-	-	159		D	D	-	B	B	B	B/C	2+5	158	176	334	-17	317	47	**691**	1055	**10**
	14	Groot without EWRs d/s CwD	240	-	-	159		D	-	-	B	B	B	B/C	-	158	313	471	-31	440	50	**565**	1055	**147**
	15	Groot with reduced EWRs on Doring	240	-	-	159		D	-	-	B	C	C	B/C	-	158	321	479	-31	448	51	**556**	1055	**155**
	16	Off-channel farm dams in Kouebokkeveld	240	-	-	-	50	D	-	-	B	C	C	B/C	-	158	306	464	-31	433	45	**577**	1055	**140**
Dam lower reaches of the Doring	17*	Off-channel Brandewyn : No EWR d/s Brandewyn	240	-	160	-		D	-	-	B	B	-	B/C	-	158	348	506	-31	475	62	**518**	1055	**182**
	17B	Off-channel Brandewyn : EWR d/s Brandewyn	240	-	160			D	-	-	B	B	B	B/C		158	336	494	-31	463	53	**539**	1055	**170**
	10*	No EWR d/s Doring confluence	240	470	-	-		-	-	-	-	-	-	-	-	158	439	597	-31	566	67	**422**	1055	**273**
Maximize supply from the system	11	Meet EWR throughout system	240	470	-	-		D	D	D	B	B	B	B/C	2+5	158	216	374	-17	357	58	**640**	1055	**50**

6 SUMMARY RESULTS - ESTUARY

The recommended EC (representing the level of protection recommended for a particular estuary) for the Olifants Estuary was set as **Category B** (largely natural with few modifications), as derived from its Present State and Ecological Importance. The Present State (Category C) of the estuary was calculated using an Estuarine Health Index, while the Ecological Importance ('Highly Important estuary') was determined by using an Estuarine Importance Rating Index.

According to the EC guidelines, the Olifants Estuary, which has been targeted as a Desired Protected Area, should be assigned a Category A or at least the Best Attainable State (BAS). However, at the specialist workshop (held on 25-27 July 2005 in Stellenbosch) it was concluded that with large dam developments already existing in the catchment (e.g. Clanwilliam Dam) it will be difficult to improve the Olifants Estuary to a Category A. The workshop therefore decided to recommend that the Olifants Estuary be improved to the minimum EC for a 'Highly Important estuary', namely a **Category B**.

The recommended EWR is defined as a run-off scenario that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended EC. To assist in the selection of such, simulated runoff scenarios are typically used. The selection of the simulated scenarios should preferably represent realistic future modifications in flow (e.g. incorporating future dam development or water abstraction strategies) and should be representative of a range of ECs. The Estuarine Health Index that was used to determine the Present Health Status of the estuary is also used in assessing the ecological consequences of the other simulated runoff scenarios.

6.1 SELECTION OF SCENARIOS FOR CONSIDERATION BY THE ESTUARINE TEAM

Seventeen possible scenarios involving different permutations of water resource developments and compliance to the EWR (quantity) for the river were identified. Each of these was modelled to produce the flows to the estuary likely to result from each (see Section 5). The modelling results were presented to and discussed with the Olifants Doring Project Management Committee (PMC; 1 February 2005 and 12 April 2005); representatives of DWAF Regional Office and several Water User Associations from the Olifants Doring catchment, and members of the PMC at a River Quantity Results Report Back and Scenario Discussion Meeting (1 April 2005) and the River and Estuarine Team Leaders (12 April 2005).

The main two criteria for selection of scenarios for presentation to the estuarine team were that the scenarios be realistic approximations of possible future inflows to the Olifants/Doring estuary and that they cover as wide a range as possible in terms of differences in both the Mean Annual Runoff (MAR), and the distribution of the flows reaching the estuary. The full range of scenarios considered was:

- Natural conditions – no developments in the catchment:
  - Scenario 0.
- Present day infrastructure with Clanwilliam Dam storing 121 MCM:
  - Scenario 1: Current operation of Clanwilliam, i.e., no EWR releases.
  - Scenario 2: EWR releases for maintaining a Category D river downstream of the Bulshoek Barrage (EWR Site 2).
- Additional development in the Olifants River:
  - Scenario 5: Clanwilliam Dam was raised by 15 m to store 362 MCM, no or negligible EWR releases from Clanwilliam Dam.
  - Scenario 6: Clanwilliam Dam was raised by 10 m to store 265 MCM, no or negligible EWR releases from Clanwilliam Dam.

- o Scenario 7: Clanwilliam Dam was raised by 15 m to store 362 MCM. EWR releases for maintaining a Category D river downstream of the Bulshoek Barrage (EWR Site 2).
- Raise Clanwilliam Dam by 15 m PLUS a dam of *c.* 160 MCM in the upper reaches of the Doring River:
  - o Scenario 13: With EWR releases for maintaining a Category D river downstream of the Bulshoek Barrage (EWR Site 2) and maintaining a Category B river in the Doring River (EWR Sites 4 and 5).
  - o Scenario 14: With EWR releases maintaining a Category B river in the Doring River only (EWR Sites, 4 and 5).
  - o Scenario 15: With EWR releases maintaining a Category C river in the Doring River only (EWR Sites, 4 and 5).
- Raise Clanwilliam Dam by 15 m PLUS increase off-channel storage in farm dams in the Kouebokkeveld:
  - o Scenario 16: Increase off-channel storage by 50 MCM and only allow water to be transferred to these dams during winter.
- Raise Clanwilliam Dam by 15 m PLUS Brandewyn River Dam[49], a 160 MCM dam was constructed on the Brandewyn River, with a diversion weir on the Doring River.
  - o Scenario 17: No EWRs.
- Raise Clanwilliam Dam by 15 m PLUS Melkbosrug Dam on the Doring River, near the confluence with the Olifants River:
  - o Scenario 10: No EWRs.
  - o Scenario 11: EWR releases maintaining a Category B river in remaining portion of the Doring River.

After due consideration of the inputs received from those consulted, the scenarios in Table 6.1 were agreed on.

6.2 ECOLOGICAL CONSEQUENCES OF DIFFERENT RUNOFF SCENARIOS ON OLIFANTS ESTUARY

A summary of the results from each of the simulated runoff scenarios is provided in Table 6.1.

Table 6.1 Summary of the expected estuarine ecological condition for each of the scenarios

No.	Description	EWR-EC	MCM a^{-1}	%nMAR[50]
0	Natural	A	1055	100
2	Present with EWRs	C	782	74
7	Clanwilliam Dam at 15 m, plus EWR releases	B	725	69
5	Clanwilliam Dam at 15 m, no EWR releases from Clanwilliam Dam	C	597	56
17	Clanwilliam Dam at 15 m plus Brandewyn River Dam, no EWRs	D	518	49
10	Clanwilliam Dam at 15 m plus Melkbosrug Dam, no EWRs	E	423.5	40

[49] Water would be pumped from a five MCM weir on the Doring River into the Brandewyn River Dam at a maximum rate of $5m^3$/s during April to October.

[50] Note: This **includes** requirements for inter-annual return period floods, e.g., 1:2, 1:5, 1:10 and 1:20.

The recommended EWR is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended category (in this case a Category B).

In the case of the Olifants Estuary, the recommended EWR is **Scenario 2** (i.e. the Present inflow scenario plus the Ecological Water Requirement releases of the River - MAR = 782 x 10^6 m^3) improving it to a Category B, the recommended EC (Table 6.2).

Table 6.2 Summary of the flow distribution for the recommended Ecological Flow Requirement (Scenario 2) for the Olifants Estuary

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	48.13	32.08	21.50	37.21	24.46	7.77	96.73	194.20	550.92	472.06	230.02	153.70
90%ile	28.90	9.60	7.24	3.64	3.76	3.85	9.62	80.90	151.71	159.08	126.25	65.58
80%ile	16.05	4.30	2.06	1.75	1.68	2.21	4.85	22.01	93.83	104.19	79.44	48.08
70%ile	12.84	2.93	1.68	1.55	1.38	1.81	3.07	11.18	57.99	78.10	66.22	34.22
60%ile	11.49	2.93	1.51	1.51	1.37	1.46	2.88	8.24	42.45	58.26	50.45	25.66
50%ile	10.11	2.93	1.50	1.51	1.34	1.42	2.84	6.19	37.99	51.82	47.54	22.18
40%ile	9.01	2.49	1.50	1.51	1.34	1.42	2.49	3.57	36.22	39.92	44.77	16.34
30%ile	8.32	1.51	1.50	1.51	1.34	1.42	1.76	3.42	24.20	30.79	33.23	14.73
20%ile	6.36	1.43	1.18	1.51	0.91	1.11	1.41	2.05	15.78	21.17	28.07	11.21
10%ile	4.02	0.83	0.58	0.99	0.85	1.00	1.28	1.15	7.44	9.49	17.41	9.66
1%ile	1.01	0.15	0.00	0.99	0.34	0.00	0.04	0.29	0.82	2.07	5.35	4.04

At the specialist workshop it was highlighted that a significant degree of the modification resulting in the Present State (Category C) is linked to non-flow related anthropogenic activities such as:

- nutrient inputs from agricultural activities; and
- over-exploitation of fish resources (gill net fisheries).

It was therefore concluded that should improved management and control of the above-mentioned activities be achieved, **Scenario 7** (raising of the Clanwilliam Dam by 15 m plus the EWR releases of the River - MAR = 725 x 10^6 m^3) might prove to be sufficient to achieve the recommended Category B. However, this will require cooperation and assistance from the Department of Agriculture and the Department of Environmental Affairs and Tourism (in particular Marine and Coastal Management) (i.e. cooperative governance).

Although the Present State of the Olifants Estuary currently falls within a Category C, the estuary is probably on a **negative trajectory of change**, because of the extremely low base flows that it currently receives (< 1 m^3/s), particularly during the summer months. It was therefore concluded that to maintain the estuary in the Present State (Category C) summer lowflows will need to be re-introduced. Scenario 5 showed that some of this increase in summer lowflows would be contributed by return flows as a result of increased irrigation. **Scenario 5** was selected as the EWR that would maintain the estuary in a Category C (Table 6.3).

A schematic of the consequences of different runoff scenarios is provided in Figure 6.1.

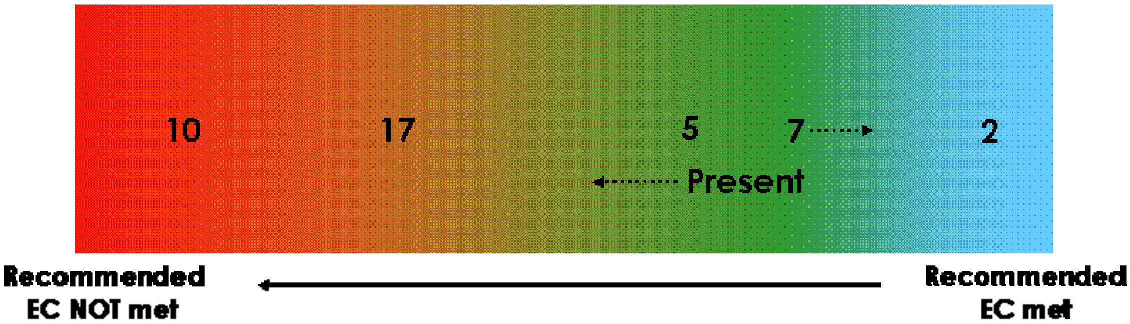


Figure 6.1 A schematic illustration of the consequences of different runoff scenarios

Table 6.3 Summary of the flow distribution of the Ecological Flow Requirement (Scenario 5) for the Olifants Estuary to maintain an Ecological Category C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	42.17	28.76	21.52	37.04	24.33	7.43	95.80	153.56	471.91	470.40	210.01	149.81
90%ile	23.61	7.85	7.27	3.66	3.84	4.07	9.43	66.69	112.14	150.96	116.78	65.34
80%ile	11.33	3.96	2.33	1.62	1.80	2.11	4.34	17.92	72.07	78.37	81.56	40.07
70%ile	7.85	2.16	1.64	1.53	1.46	1.73	2.24	8.84	44.03	53.49	52.19	30.07
60%ile	5.44	1.67	1.52	1.53	1.45	1.39	1.79	4.84	21.61	38.99	33.68	20.61
50%ile	4.36	1.42	1.52	1.53	1.41	1.32	1.23	2.33	14.39	22.60	27.35	13.96
40%ile	3.17	1.36	1.52	1.53	1.41	1.32	1.15	1.65	9.02	12.62	17.14	12.10
30%ile	2.00	1.36	1.52	1.53	1.41	1.32	1.15	0.90	5.01	8.22	11.91	8.78
20%ile	1.70	1.36	1.52	1.53	1.41	1.32	1.15	0.52	2.19	5.28	8.21	5.68
10%ile	1.43	1.36	1.52	1.24	0.95	0.70	0.80	0.43	0.84	2.91	3.92	3.28
1%ile	1.20	1.19	0.89	0.88	0.40	0.22	0.00	0.04	0.32	0.49	0.84	1.59

The consequences of maintaining the Olifants Estuary in a C-category are considered to be as follows:

- Excessive (or nuisance) macrophyte growth is likely to occur during the late summer months in the upper reaches, particularly if nutrient inputs from agricultural activities continue in the upper reaches. This will have potential negative impacts on water intake systems, recreational usage and aesthetics (i.e. 'loss of value').

- As the flow scenario for a C-category will result in a reduction of freshwater pulsing to the marine environment (e.g. inflows will be more regulated), this could result in a reduced cueing effect to estuarine dependent invertebrate and fish species.

- Also, more regulated inflow will reduce the variability in abiotic conditions, which in turn may result in changes in community composition (particularly in terms of invertebrates and fish), thus affecting biodiversity.

The above-mentioned are also likely to have a ripple effect on economic good and services provided by the adjacent marine environment, e.g. the marine fisheries. The Olifants Estuary is but one of a few large estuarine systems along the South African west coast where it is considered to play a crucial role in terms of biological functionality to sustain the important fisheries resource. However, the linkages between the estuary, the marine environment and the fisheries resource are still poorly understood. Some of the key aspects that require further research are highlighted later.

It is therefore strongly recommended that decisions regarding the future state of the Olifants Estuary, carefully consider potential impacts on all uses, both land-based and marine-based activities. This will require effective cooperative governance between the DWAF, Department of Agriculture and the DEAT (particularly Marine and Coastal Management).

7 SUMMARY RESULTS - GROUNDWATER

The ToR for the determination of the Groundwater Reserve, which contained the Scope of Work compiled in this study, were issued by DWAF: RDM Directorate in November 2004. The contract for that study was awarded to SRK Consultants in June 2005 and completed in March 2006.

8 SUMMARY RESULTS - SOCIOECONOMICS

8.1 DESCRIPTION OF THE AFFECTED COMMUNITIES

More than half of the population is concentrated in the lower and upper Olifants River zones (about 29 000 and 19 000 people, respectively). The dryland farming zone, Doring Rangelands and Kouebokkeveld zones each have about 9000 – 11 000 inhabitants, the Knersvlakte is very sparsely populated (<5000) and about 3500 people live in the vicinity of the estuary. The characteristics of these populations were described on the basis of Census 2001 data, for which Sub-place level data were adjusted on the basis of percentage area falling within each zone. Estimates of the rural and urban proportions thus differ slightly from the quarternary-based estimates.

Communities are predominantly rural in all the zones apart from the Lower Olifants zone, where most people are in towns (Table 8.1). The estuary zone only considers the largely rural population of the Ebenhaesar community. The rural population is decreasing partly because of a lack of economic stimulants, migration to urban areas and HIV/AIDS.

Table 8.1 Summary of population characteristics for each zone as % households

	Kouebokkeveld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants	Estuary
% rural	94	57	57	53	61	33	100
% poor	85	82	84	77	84	73	71
% without flush toilets	15	32	55	28	23	16	17
% in rent-free housing	84	40	33	38	41	33	0

Table 8.2 Summary of % individuals with a matric

	Kouebokkeveld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants	Estuary
% with matric education	9	13	13	17	15	18	23

Poverty levels are extremely high throughout the catchment, with more than 70% of households earning less than R38 500 per year in all areas. The eastern parts of the catchment, which are more sparsely populated, are characterised by high levels of poverty (over 80%). About 10% of the labour force is unemployed, which is lower than the national average, and about 2% of the employed are seasonal labourers. There is also a strong immigration of seasonal workers during the harvest and planting seasons.

Education levels are low throughout, being higher in the Lower and Upper Olifants zones and highest in Ebenhaesar. Very few (about 4%) are educated beyond matric, and those are mainly white. Educated young people tend to leave the area.

The majority of households have flush toilets, but significant proportions of households still rely on chemical or pit latrines or have no sanitation. Sanitation conditions are worst in the Knersvlakte area, but are relatively good in the main irrigation zones (Kouebokkeveld, Lower Olifants) and around the estuary.

Security of tenure is fairly low generally, with more than a third of households occupying rent-free dwellings (e.g. labourer cottages) in most zones, and as many as 84% in the Kouebokkeveld.

Community cohesion and organisational skills reflect the "social capital" within communities, and are indicated to some extent by the extent to which communities have developed forums, committees and associations such as Water User Associations (WUAs). Communities in most of the zones are relatively well organised in respect of water, with several WUAs, irrigation boards and committees, apart from the arid Knersvlakte zone.

The communities of the different zones have different relationships with water and aquatic resources. The Kouebokkeveld, Upper and Lower Olifants zones are important irrigation areas where economic activity and income is highly dependent on water supply. Other zones rely extensively on groundwater. The Lower Olifants zone is also interesting in that there is some saaidam agriculture. Tourism-related activities that depend to a certain extent on aquatic systems (e.g. hiking, scenic, fishing, rafting, birdwatching) occur in all the zones. Direct dependence on aquatic ecosystem resources is negligible, except in the case of the estuary, where up to 200 households in the Ebenhaesar community are involved in a gill net fishery.

8.2 VALUE OF AQUATIC ECOSYSTEMS AND IMPLICATIONS OF FLOW SCENARIOS[51]

A range of ecosystem goods and services provided by aquatic ecosystems were considered, and their importance in the Olifants Doring assessed. Of these, only those for which there was significant value and where this value was likely to be affected by the scenarios were considered in more detail, namely:

- Freshwater recreational fisheries are likely to be impacted under some of the scenarios, but this impact was negligible.
- The estuarine gill-net fishery at Ebenhaesar would be impacted to some extent, with losses of up to 20% estimated for the most developed scenario, Scenario 10 (Table 8.3).
- The recreational estuarine fishery would be similarly impacted, but the changes in fish abundance area unlikely to have a measurable impact on utility and hence recreational expenditure (Table 8.4.
- The nursery value of the estuary is most important from an economic perspective, contributing some R3.45 m to the value of West Coast fisheries. Losses of up to R0.76 m per year are expected in the most developed scenario, Scenario 10 (Table 8.4).
- The overall economic impact of the changes in ecosystem quality (in terms of GGP) is estimated to range from R40 000 under Scenario 5 to R270 000 under Scenario 17. Financially, these are considered negligible losses (Table 8.5).

Table 8.3 Estimated value of the estuarine gill net fishery under the different scenarios (R millions per annum)

Value	Range	Scenario					
		Present	**2**	7	5	17	10
Olifants gill-net fishery	Lower	0.491	0.436	0.436	0.478	0.403	0.417
	Upper	0.630	0.559	0.559	0.612	0.517	0.534

Table 8.4 Estimated change in value of the West Coast recreational and commercial fisheries under different flow scenarios (R millions)

	Scenario					
	Present	**2**	**7**	**5**	**17**	**10**

[51] See description of the scenarios in Section 5.

Recreational fisheries*	341.7	341.5	341.5	341.7	341.2	341.5
Commercial fisheries	305.0	304.9	304.9	305.0	304.7	304.9
Total fisheries value (lower bound)	646.7	646.6	646.6	646.7	646.4	646.6
Total fisheries value (upper bound) **	646.7	646.4	646.4	646.6	645.9	646.4
Change from present (lower bound)		- 0.07	- 0.08	- 0.01	- 0.28	- 0.07
Change from present (upper bound)		- 0.25	- 0.26	- 0.05	- 0.76	- 0.25
Nursery value (lower bound)	3.45	3.38	3.37	3.44	3.17	3.38
Nursery value (upper bound) **	3.45	3.20	3.19	3.40	2.69	3.20

*estimated maximum change assuming anglers respond to changes in catch rates
** upper bound estimates assume no change in recreational value

Table 8.5 Baseline values and values of fisheries under different scenarios (R millions)

	Present Day	Sc 2	Sc7	Sc5	Sc17	Sc10
Impact on Surplus Value	2.90	-0.13	-0.06	-0.03	-0.20	-0.13
Impact on GDP	3.97	-0.17	-0.07	-0.04	-0.27	-0.17
Low Income HH	0.41	-0.019	-0.008	-0.005	-0.031	-0.019
All Income HH	0.70	-0.031	-0.013	-0.007	-0.048	-0.0301

8.3 VALUE GENERATED BY WATER USE AND IMPLICATIONS OF SCENARIOS

The predicted economic losses and gains under the different scenarios due to changes in water use are orders of magnitude higher than those due to changes in ecosystem quality. Scenarios 2 and 7 result in losses of GDP from agriculture in the order of R14 to R300 million, whereas Scenarios 5, 17 and 10 result in gains of R1 – 2.5 billion (Table 8.6). There are expected social benefits, in the form of increased employment, associated with increased GDP.

Table 8.6 Values of irrigation, relative to present day, under different scenarios (R millions)

	Present Day	Sc 2	Sc7	Sc5	Sc17	Sc10
Impact on Surplus Value	R364.84	R-66.02	R-10.66	R+359.80	R+437.17	+R647.55
Impact on GDP	R1299.38	R-270.74	R-36.42	R+1231.78	R+1538.73	R+2265.91
Impact on Capital	R2796 .31	R-584.35	R-71.58	R+2637.56	R+3314.84	R+4870.75
Low Income HH	R199.60	R-36.84	R-5.01	R+192.73	R+237.77	R+350.04
All Income HH	R452.49	R-87.22	R-11.22	R+435.28	R+538.23	R+790.61

Table 8.7 Number of jobs, relative to present day, expected under different scenarios

Sector	Present Day	Sc 2	Sc7	Sc5	Sc17	Sc10
Irrigation	13 253	-4788	-756	+ 9976	+14 078	+20 274
Fisheries	124	-7	-4	-2	-12	-7
Nett	13 377	-4795	-760	+9974	+14 066	+20 267

8.4 SOCIAL IMPACTS OF SCENARIOS

Changes in the estuary fish stocks will have an impact on the wellbeing and nutritional security of fishing households in the Ebenhaesar community as *c.* 40% of these households obtain more than 75% of their income from fishing, and 64% of households eat fish at most meals. All the scenarios are expected to have a negative impact on the fishery, but this impact is negligible in the case of Scenario 5. In addition, changes in fish stocks are likely to have an impact on the community in Ebenhaesar.

Agriculture was seen as the main alternative to fishing in the Ebenhaesar community, which means that improved access to water for irrigation could make a difference to livelihood strategies of the poor households in this community. The degree of change will depend very much on social cohesion in the community and on the level of support that goes with improved water supply. These benefits are also true of the poor households in other affected zones, particularly the Lower Olifants zone, which would be the most likely to benefit from the development scenarios.

8.5 CONCLUSIONS

The predicted economic value of developing water resources generally outweighs the expected losses incurred as a result of reduced aquatic goods and services (as calculated here), with overall changes in value being increasingly positive for Scenarios 2, 7, 5, 17 and 10 (in that order). Resource losses are dominated by estuary fishery values and are lowest for Scenario 5, followed by Scenario 2 and Scenario 7. The range of error in estimation of environmental costs is also likely to be relatively greater than that for agricultural output. Furthermore, the environmental costs and benefits of the different scenarios did not include non-use values such as option and existence value. For example, if the area around the Olifants Estuary becomes developed, the quality of the estuary could have a very measurable impact on tourism expenditure and real estate value. The option and existence values of genetic diversity or are species such as the endemic fish species found in the catchment were not included in the study. The estimates also do not include external costs such as impacts of reduced water quality, which could have a significant impact on agricultural output. The choice of scenario should thus be driven by consideration of biodiversity impacts as well as the measurable economics impacts.

Finally, while the environmental costs are low in economic terms they may be considerable in terms of some people's livelihoods. None of the scenarios meets the Pareto criterion that a development should not make anyone worse off, but Scenario 5 is closest to this in that it has the smallest impact on the value of ecosystem goods and services. Under Scenario 5, the impacts on estuarine fisheries and nursery value are lowest, and thus so are the impacts on the livelihoods of small-scale fishers of Ebenhaeser, many of whom do not benefit from agriculture. This is a critical issue, since these households are very poor and thus extremely vulnerable. It is also very important to remember that DEAT is planning to eventually phase out the Ebenhaesar fishing licences, using an alternative livelihoods approach. In this respect, the provision of irrigation water to this community would provide a development opportunity.

9 CONCLUSIONS AND RECOMMENDATIONS

The primary scale for water resource management and planning is the river basin (catchment), which provides a practical, understandable spatial unit within which economic, social, and ecological trade-offs can be made (after DWAF 2005). The Olifants-Doring catchment is no exception.

The number of water resource development options that have been/currently are recommended for the catchment, many of which are captured in the scenarios considered in this study (e.g., Section 5, Figure 9.1), highlight the need for water for development in area. It is important, however, both from the perspective of protecting current uses (e.g., fisheries dependent on the Olifants Estuary) and the provisions for sustainable utilisation as laid out in the Water Act (DWAF 1998b), that the functioning of the aquatic ecosystems that provide the water is also considered when evaluating water resource options.

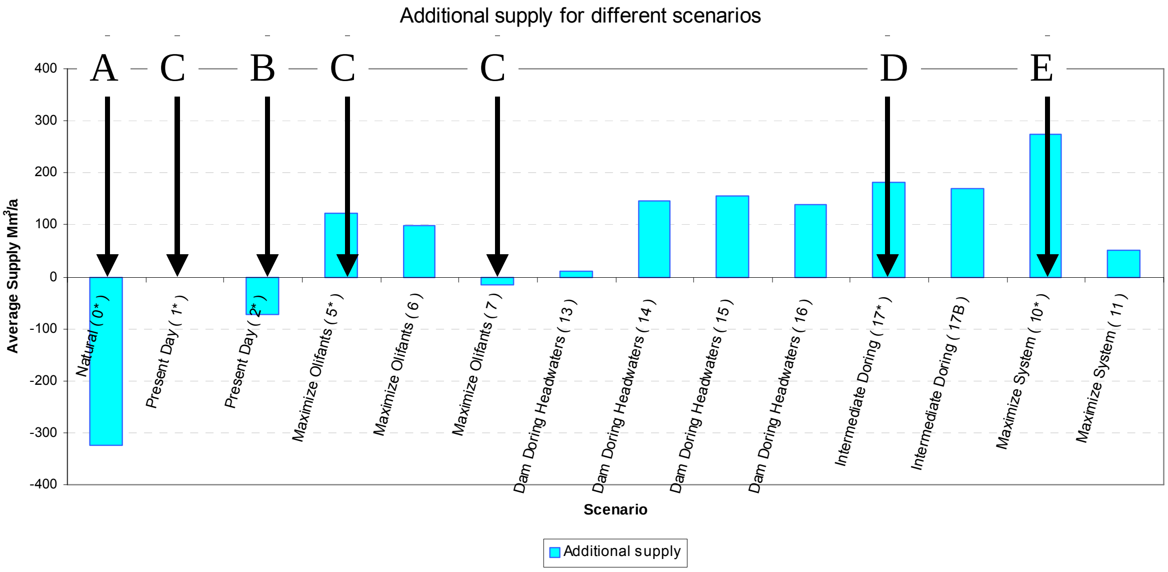


Figure 9.1 Schematic summarising the average additional supply for the different scenarios, plus the expected estuarine EC for those scenarios assessed by the estuarine team

A combination of natural attributes, geology and rainfall, and historic landuse, means that in that there are some options in Olifants/Doring catchment for generating additional yield with relatively low environmental impact. This is a rare opportunity to achieve a true balance between development and protection of the environment.

These options are focussed on the existing infrastructure on the Olifants River and on the headwater streams in the Kouebokkeveld.

No EWR releases are currently made from Clanwilliam Dam and Bulshoek Barrage and implementation of an EWR for D-category for the Olifants River downstream of Bulshoek Barrage to the confluence with the Doring River (EWR Site 2) would reduce the yield from Clanwilliam Dam to below that of the current yield. The reach of the Olifants River downstream of Bulshoek Barrage, is however, significantly altered from natural. It is currently in an E-category and an improvement to a D-category will be difficult to achieve, even with an EWR release. Thus, given the need for water in the catchment and the already impacted nature of the middle Olifants River, it makes little sense to implement an onerous EWR and the specialists in this study recommended that a lower category (with a significantly lower EWR) be considered for this section of the river, e.g., maintain an E-category. This recommendation is strengthened by the fact that, even with lower EWRs at EWR Site 2, it is possible to maintain the Olifants Estuary in a C-category provided the current contributions from the Doring River are maintained.

The Olifants estuary is considered to be extremely important both from an ecological and social perspective in that it supports both local and regional coastal fisheries. Indeed, socioeconomic benefits derived *directly* from aquatic ecosystems in the Olifants-Doring catchment are highest for the estuary. In recognition of this importance, the estuarine specialists recommended that the condition of the estuary be improved from the current C-category to a B-category. The EWR required to achieve a B-category would, however, mean a significant reduction in yield from the catchment. Moreover, an improvement in current estuary condition (albeit not to a B) can be achieved through lesser EWR combined with non-flow rehabilitation.

While it seems that the projected impact of additional water use on GDP in the catchment favours maximising yield from the catchment (Scenarios 17 and 10), it is worth considering that these projected figures exclude the considerable costs of infrastructure and management that would be associated with the schemes required to access this water. The financial benefits realised from exploring these options would be correspondingly lower with these figures included. It is worth noting that dams in the Doring River have been repeatedly rejected as economically and ecologically unviable.

Thus, of the scenarios considered, Scenario 5 offers the most economically and ecologically balanced configuration, based on maximising yield from the Clanwilliam Dam (possibly augmented by some off-channel farm dams in the Kouebokkeveld). Furthermore, under Scenario 5, the impacts on estuarine fisheries and nursery value are lowest, and thus so are the impacts on the livelihoods of small-scale fishers of Ebenhaeser, many of whom do not benefit from agriculture.

It is therefore recommended that Scenario 5, or some variation thereon, be explored as the most viable option for accessing additional yield from the system.

RECOMMENDED RESERVE SCENARIO CONFIGURATION

The recommendations from the river and estuary specialists from an ecological (and pragmatic) perspective, taking account of the dichotomy brought about by human utilisation of the area, can be summarised as follows:

- Maintain the ecological integrity of the Doring River, and in so doing ensure sustainable utilisation of the Olifants estuary, i.e., no dams in the Doring or Groot Rivers.
- Maintain the ecological integrity of key tributaries on both the Olifants and Doring Rivers, thereby ensuring variability of flow in the main stems, as well as provision of refuges and source areas.
- Undertake some river rehabilitation aimed at reducing non-flow related impacts in the mainstem Olifants River between the Olifants Gorge and Clanwilliam Dam, thereby improving overall river condition in this reach.
- Undertake some river rehabilitation aimed at reducing water quality impacts in the mainstem Olifants River downstream of the confluence with the Doring River. This would also improve the quality of water entering the estuary.
- Undertake estuary rehabilitation measures, mainly aimed at controlling over fishing.
- Keep Reserve releases from Clanwilliam Dam and Bulshoek Barrage to a minimum, so that water supply from Clanwilliam Dam and Bulshoek Barrage is maximised.

This could be achieved through the implementation of Scenario 5, or some variation thereon. The summary EWR data for Scenario 5 are provided in Table 9.1.

Table 9.1 The summary EWR data for Scenario 5[52]

Site	EWR-EC	MCM a^{-1}	%nMAR
EWR SITE 1	D	88	26%
EWR SITE 2	Maintain PES (E)	48.3	9.3%
EWR SITE 3	B	*c.* 3	39%
EWR SITE 4	B	192	45%
EWR SITE 5	B	232	45%
EWR SITE 6	B/C	60	44%
ESTUARY	C+	*c.* 630	59%

Note:
Pursuing Scenario 5 (or similar) pre-supposes:
- no major water resource developments in the Doring River (provision of the EWR alone in the Doring River will be insufficient to maintain the ecological integrity of the Doring River in a B-category and estuary in a C-category);
- implementation of non-flow rehabilitation on the Olifants River mainstem and estuary.

[52] The estimates differ slightly from those in the detailed reports and the tables in Section 4. This is because they were adjusted after running the data through the Desktop Model (see Appendix A).

10 REFERENCES

BROWN, C.A., W. HARDING and A. BOK. 2003. Western Cape Olifants/Doring River Irrigation Study (WODRIS - JA0385A). Riverine Study. Unpublished Southern Waters Report to ARCUS GIBB. 107 pp.

BROWN, C.A., C. PEMBERTON, A. GREYLING and J.M. KING. 2006. DRIFT User Manual. Biophysical Module for predicting overall river condition in small to medium sized rivers with relatively-predictable flow regimes. Water Research Commission. WRC Report No. 1404.05. 106 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1998a. Water Resources Evaluation (Hydrology) - Olifants Doring River Basin Study: Prepared by G. Howard. March 1998.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1998b. National Water Act. Act No. 36 of 1998. *Government Gazette*. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2004. Water resource protection and assessment policy implementation process. Resource directed measures for protection of water resource: Methodology for the Determination of the Ecological Water Requirements for Estuaries. Version 2. Pretoria.

DEPARTMENT: WATER AFFAIRS AND FORESTRY (DWAF): 2005: The development of a national water resource classification system. Inception report, Contract Report for Department: Water Affairs and Forestry, by ESJ Dollar Consulting cc, Cape Town, 277pp.

KING JM, BROWN CA and SABET H (2003) A scenario-based holistic approach to environmental flow assessments for regulated rivers. Rivers Res. Applic. **19** (5-6) 619-640.

SKELTON, P.H. 1977. *South African Red Data Book - fishes.* South African National Scientific Programmes Report No. 14, CSIR, Pretoria.

APPENDIX A

EWR SITE 1 – D-CATEGORY

EWR Tables

```
Desktop Version 2, Generated on 11/08/2006
        Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
        Total Runoff : Quaternaries E10F

        Annual Flows (Mill. cu. m or index values):
        MAR                =  331.551
        S.Dev.             =  148.479
        CV                 =    0.448
        Q75                =    1.376
        Q75/MMF            =    0.050
        BFI Index          =    0.313
        CV(JJA+JFM) Index =    2.398

        Ecological Category = D

        Total IFR          =   88.403 (26.66 %MAR)
        Maint. Lowflow     =   68.498 (20.66 %MAR)
        Drought Lowflow    =   21.563 ( 6.50 %MAR)
        Maint. Highflow    =   19.905 ( 6.00 %MAR)

        Monthly Distributions (Mill. cu. m.)
        Distribution Type : W.Cape(wet)
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	24.158	9.682	0.401	8.841	1.072	3.301	12.142
Nov	9.700	6.341	0.654	2.333	0.026	0.000	2.333
Dec	3.000	3.124	1.041	0.268	0.027	0.000	0.268
Jan	0.954	1.475	1.547	0.268	0.027	0.000	0.268
Feb	0.910	1.703	1.871	0.242	0.024	0.000	0.242
Mar	1.443	2.353	1.631	0.268	0.027	0.000	0.268
Apr	6.300	10.173	1.615	1.556	0.026	0.000	1.556
May	23.668	27.974	1.182	0.536	1.072	0.000	0.536
Jun	61.184	55.853	0.913	11.667	4.926	6.602	18.268
Jul	74.531	46.821	0.628	16.074	4.555	3.401	19.475
Aug	75.762	45.756	0.604	16.074	5.894	3.301	19.375
Sep	49.941	21.235	0.425	10.371	3.889	3.301	13.672

Rule Curves

Desktop Version 2, Generated on 11/08/2006
Summary of IFR rule curves (Desktop Version 2) for :
EWR Site 1
Total Runoff : Quaternaries E10F
Regional Type : W.Cape(wet)
Ecological Category = D

Data are given in m^3 * 10^6 monthly flow volume

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	22.500	22.500	22.313	21.889	20.988	19.212	16.050	11.188	5.317	1.534
Nov	4.638	4.638	4.597	4.504	4.307	3.919	3.228	2.165	0.882	0.055
Dec	0.495	0.495	0.490	0.477	0.447	0.391	0.301	0.185	0.079	0.030
Jan	0.495	0.495	0.490	0.477	0.447	0.366	0.267	0.185	0.079	0.030
Feb	0.448	0.448	0.443	0.431	0.287	0.208	0.158	0.079	0.020	0.000
Mar	0.533	0.533	0.528	0.518	0.496	0.327	0.218	0.178	0.059	0.000
Apr	3.092	3.092	3.065	3.003	2.821	2.020	1.277	0.832	0.346	0.045
May	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072
Jun	36.038	36.038	35.838	35.429	34.609	32.993	29.904	21.206	13.028	5.777
Jul	41.222	40.589	39.830	38.931	37.665	35.187	31.773	25.580	15.474	5.105
Aug	41.053	40.438	39.704	38.838	37.620	35.238	31.968	26.037	16.357	6.426
Sep	27.047	26.214	25.360	24.426	23.175	20.848	17.896	13.356	7.875	4.342

Reserve Flows without High Flows

Oct	17.578	17.578	17.431	17.100	16.395	15.006	12.532	8.728	4.134	1.175
Nov	4.638	4.638	4.597	4.504	4.307	3.919	3.228	2.165	0.882	0.055
Dec	0.495	0.495	0.490	0.477	0.447	0.391	0.301	0.185	0.079	0.030
Jan	0.495	0.495	0.490	0.477	0.447	0.366	0.267	0.185	0.079	0.030
Feb	0.448	0.448	0.443	0.431	0.287	0.208	0.158	0.079	0.020	0.000
Mar	0.533	0.533	0.528	0.518	0.496	0.327	0.218	0.178	0.059	0.000
Apr	3.092	3.092	3.065	3.003	2.821	2.020	1.277	0.832	0.346	0.045
May	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072
Jun	25.538	25.538	25.402	25.126	24.570	23.476	21.386	17.594	11.404	5.055
Jul	35.171	35.171	34.970	34.559	33.734	32.109	29.004	23.371	14.178	4.746
Aug	35.179	35.179	34.987	34.594	33.805	32.251	29.280	23.892	15.099	6.077
Sep	20.636	20.636	20.487	20.151	19.436	18.026	15.516	11.657	6.997	3.994

Natural Duration curves

Oct	37.947	32.096	27.433	24.641	21.859	20.889	18.662	16.513	13.949	9.197
Nov	17.414	13.266	10.464	9.148	8.385	7.088	6.405	4.970	4.109	2.762
Dec	5.138	3.673	2.901	2.465	2.188	1.732	1.554	1.307	0.931	0.445
Jan	2.029	1.049	0.881	0.752	0.515	0.366	0.267	0.208	0.119	0.059
Feb	2.396	1.059	0.634	0.445	0.287	0.208	0.158	0.079	0.020	0.000
Mar	4.673	2.396	1.247	0.673	0.505	0.327	0.218	0.178	0.059	0.000
Apr	17.810	7.593	5.930	4.237	2.821	2.020	1.277	0.832	0.346	0.079
May	58.697	29.938	24.592	17.959	15.533	11.672	8.276	5.217	2.604	1.277
Jun	135.719	87.734	65.974	53.816	43.550	40.036	30.185	21.206	13.028	5.960
Jul	141.253	104.692	91.971	75.586	68.973	55.044	47.639	36.194	24.245	11.999
Aug	131.957	101.218	84.794	74.220	70.231	61.885	48.748	40.986	30.819	19.820
Sep	74.943	68.161	58.945	52.183	45.946	41.006	37.155	33.016	27.878	14.405

EWR SITE 2 – E-CATEGORY

EWR Tables

```
Desktop Version 2, Generated on 11/08/2006
        Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
        Total Runoff : Quaternaries E10K

        Annual Flows (Mill. cu. m or index values):
        MAR              =  519.676
        S.Dev.           =  238.570
        CV               =    0.459
        Q75              =    2.246
        Q75/MMF          =    0.052
        BFI Index        =    0.314
        CV(JJA+JFM) Index =   2.369

        Ecological Category = E

        Total IFR         =   48.377 ( 9.31 %MAR)
        Maint. Lowflow    =   17.782 ( 3.42 %MAR)
        Drought Lowflow   =   17.782 ( 3.42 %MAR)
        Maint. Highflow   =   30.596 ( 5.89 %MAR)

        Monthly Distributions (Mill. cu. m.)
        Distribution Type : W.Cape(wet)
```

Month	Natural Flows Mean	SD	CV	Modified Flows (IFR) Low flows Maint.	Drought	High Flows Maint.	Total Flows Maint.
Oct	39.933	15.648	0.392	2.458	2.458	0.000	2.458
Nov	15.864	8.903	0.561	0.529	0.529	0.000	0.529
Dec	4.857	4.538	0.934	0.546	0.546	0.000	0.546
Jan	1.532	2.372	1.548	0.546	0.546	0.000	0.546
Feb	1.335	2.386	1.787	0.493	0.493	0.000	0.493
Mar	2.115	3.377	1.596	0.546	0.546	0.000	0.546
Apr	9.449	15.047	1.592	0.529	0.529	0.000	0.529
May	35.829	43.659	1.219	2.458	2.458	3.060	5.518
Jun	94.724	89.304	0.943	2.379	2.379	3.060	5.439
Jul	114.464	72.595	0.634	2.458	2.458	12.238	14.697
Aug	118.849	71.102	0.598	2.458	2.458	12.238	14.697
Sep	80.724	35.294	0.437	2.379	2.379	0.000	2.379

Rule Curves

Desktop Version 2, Generated on 11/08/2006
Summary of IFR rule curves (Desktop Version 2) for :
EWR Site 2
Total Runoff : Quaternaries E10K
Regional Type : W.Cape(wet)
Ecological Category = E

Data are given in m^3 * 10^6 monthly flow volume

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.901	4.901	4.880	4.831	4.726	4.521	4.155	3.592	2.912	2.474
Nov	1.054	1.054	1.049	1.039	1.016	0.972	0.893	0.772	0.626	0.532
Dec	1.013	1.013	1.008	0.995	0.965	0.909	0.819	0.704	0.598	0.549
Jan	1.013	1.013	1.008	0.995	0.892	0.639	0.550	0.385	0.198	0.132
Feb	0.915	0.915	0.910	0.672	0.506	0.374	0.231	0.121	0.044	0.011
Mar	1.089	1.089	1.084	1.024	0.815	0.506	0.374	0.220	0.077	0.000
Apr	1.054	1.054	1.049	1.039	1.016	0.972	0.893	0.772	0.626	0.099
May	9.464	9.464	9.405	9.270	8.984	8.420	7.416	5.872	4.008	2.213
Jun	10.083	10.083	10.034	9.935	9.736	9.343	8.593	7.232	5.010	2.731
Jul	27.167	24.889	22.861	21.067	19.398	16.172	14.764	12.211	8.044	3.769
Aug	27.167	24.889	22.861	21.067	19.398	16.172	14.764	12.211	8.044	3.769
Sep	4.743	4.743	4.722	4.675	4.574	4.375	4.021	3.476	2.818	2.394

Reserve Flows without High Flows

Oct	4.901	4.901	4.880	4.831	4.726	4.521	4.155	3.592	2.912	2.474
Nov	1.054	1.054	1.049	1.039	1.016	0.972	0.893	0.772	0.626	0.532
Dec	1.013	1.013	1.008	0.995	0.965	0.909	0.819	0.704	0.598	0.549
Jan	1.013	1.013	1.008	0.995	0.892	0.639	0.550	0.385	0.198	0.132
Feb	0.915	0.915	0.910	0.672	0.506	0.374	0.231	0.121	0.044	0.011
Mar	1.089	1.089	1.084	1.024	0.815	0.506	0.374	0.220	0.077	0.000
Apr	1.054	1.054	1.049	1.039	1.016	0.972	0.893	0.772	0.626	0.099
May	4.901	4.901	4.880	4.831	4.726	4.521	4.155	3.592	2.912	2.213
Jun	5.216	5.216	5.198	5.159	5.083	4.932	4.645	4.123	3.271	2.397
Jul	5.390	5.390	5.371	5.331	5.252	5.097	4.800	4.260	3.380	2.477
Aug	5.390	5.390	5.371	5.331	5.252	5.097	4.800	4.260	3.380	2.477
Sep	4.743	4.743	4.722	4.675	4.574	4.375	4.021	3.476	2.818	2.394

Natural Duration curves

Oct	61.089	54.340	45.764	40.733	37.155	33.577	30.825	27.324	22.976	16.381
Nov	30.528	21.357	17.295	16.084	13.981	12.077	10.558	8.906	7.431	5.218
Dec	8.345	6.154	4.844	4.216	3.556	3.027	2.697	2.367	1.728	1.068
Jan	3.149	1.640	1.299	1.178	0.892	0.639	0.550	0.385	0.198	0.132
Feb	3.677	1.574	1.013	0.672	0.506	0.374	0.231	0.121	0.044	0.011
Mar	6.341	3.479	1.883	1.024	0.815	0.506	0.374	0.220	0.077	0.000
Apr	23.614	13.475	9.082	7.112	4.448	3.005	1.772	1.310	0.749	0.099
May	91.606	47.052	34.976	27.280	23.537	16.811	11.879	8.026	4.404	2.213
Jun	225.618	137.150	101.789	77.889	69.445	58.821	43.309	33.919	20.124	9.369
Jul	212.562	162.086	143.326	119.679	97.397	85.155	71.525	54.748	35.680	17.427
Aug	218.353	154.765	127.363	116.750	110.222	91.133	77.591	62.069	48.682	32.256
Sep	129.994	112.303	91.859	82.259	73.386	66.417	62.784	48.792	44.498	21.335

EWR SITE 3 – B-CATEGORY

EWR Tables

```
Desktop Version 2, Generated on 11/08/2006
        Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
        Total Runoff : Quaternaries E10F

        Annual Flows (Mill. cu. m or index values):
        MAR                =    7.739
        S.Dev.             =    3.588
        CV                 =    0.464
        Q75                =    0.025
        Q75/MMF            =    0.039
        BFI Index          =    0.307
        CV(JJA+JFM) Index =     2.619

        Ecological Category = B

        Total IFR          =    3.056 (39.48 %MAR)
        Maint. Lowflow     =    1.790 (23.13 %MAR)
        Drought Lowflow    =    0.151 ( 1.95 %MAR)
        Maint. Highflow    =    1.266 (16.36 %MAR)

        Monthly Distributions (Mill. cu. m.)
        Distribution Type : W.Cape(wet)
```

Month	Natural Flows Mean	Natural Flows SD	Natural Flows CV	Modified Flows (IFR) Low flows Maint.	Modified Flows (IFR) Low flows Drought	High Flows Maint.	Total Flows Maint.
Oct	0.665	0.285	0.429	0.202	0.012	0.027	0.229
Nov	0.230	0.108	0.471	0.168	0.000	0.000	0.168
Dec	0.060	0.052	0.873	0.115	0.000	0.000	0.115
Jan	0.018	0.035	1.979	0.115	0.012	0.000	0.115
Feb	0.014	0.027	1.918	0.052	0.010	0.000	0.052
Mar	0.023	0.042	1.823	0.058	0.000	0.000	0.058
Apr	0.109	0.163	1.498	0.056	0.000	0.000	0.056
May	0.457	0.575	1.257	0.058	0.000	0.054	0.112
Jun	1.278	1.219	0.954	0.112	0.032	0.119	0.230
Jul	1.678	1.068	0.637	0.260	0.029	0.474	0.734
Aug	1.859	1.017	0.547	0.260	0.029	0.474	0.734
Sep	1.349	0.609	0.451	0.335	0.028	0.119	0.454

Rule Curves

Desktop Version 2, Generated on 11/08/2006
Summary of IFR rule curves (Desktop Version 2) for :
EWR Site 3
Total Runoff : Quaternaries E10F – Incremental (adjusted)
Regional Type : W.Cape(wet)
Ecological Category = B

Data are given in m^3 * 10^6 monthly flow volume

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.270	0.270	0.268	0.263	0.252	0.230	0.192	0.133	0.062	0.016
Nov	0.200	0.200	0.198	0.194	0.185	0.169	0.139	0.093	0.037	0.001
Dec	0.103	0.081	0.060	0.053	0.046	0.041	0.037	0.029	0.015	0.001
Jan	0.035	0.024	0.015	0.012	0.009	0.007	0.006	0.003	0.003	0.001
Feb	0.041	0.018	0.010	0.007	0.004	0.003	0.001	0.001	0.000	0.000
Mar	0.060	0.035	0.021	0.013	0.006	0.004	0.003	0.001	0.000	0.000
Apr	0.067	0.067	0.066	0.065	0.049	0.040	0.021	0.015	0.007	0.000
May	0.128	0.128	0.127	0.124	0.119	0.109	0.090	0.062	0.028	0.006
Jun	0.263	0.263	0.262	0.259	0.253	0.241	0.219	0.178	0.112	0.045
Jul	1.153	1.065	0.985	0.914	0.845	0.711	0.639	0.510	0.298	0.081
Aug	1.153	1.065	0.985	0.914	0.845	0.711	0.639	0.510	0.298	0.081
Sep	0.630	0.600	0.571	0.542	0.507	0.443	0.372	0.261	0.128	0.043

Reserve Flows without High Flows

Oct	0.241	0.241	0.239	0.234	0.224	0.205	0.171	0.118	0.054	0.013
Nov	0.200	0.200	0.198	0.194	0.185	0.169	0.139	0.093	0.037	0.001
Dec	0.103	0.081	0.060	0.053	0.046	0.041	0.037	0.029	0.015	0.001
Jan	0.035	0.024	0.015	0.012	0.009	0.007	0.006	0.003	0.003	0.001
Feb	0.041	0.018	0.010	0.007	0.004	0.003	0.001	0.001	0.000	0.000
Mar	0.060	0.035	0.021	0.013	0.006	0.004	0.003	0.001	0.000	0.000
Apr	0.067	0.067	0.066	0.065	0.049	0.040	0.021	0.015	0.007	0.000
May	0.069	0.069	0.068	0.067	0.064	0.058	0.048	0.032	0.013	0.000
Jun	0.133	0.133	0.133	0.131	0.129	0.123	0.113	0.094	0.064	0.032
Jul	0.310	0.310	0.308	0.304	0.297	0.282	0.253	0.202	0.117	0.031
Aug	0.310	0.310	0.308	0.304	0.297	0.282	0.253	0.202	0.117	0.031
Sep	0.400	0.400	0.396	0.389	0.373	0.342	0.286	0.200	0.097	0.030

Natural Duration curves

Oct	1.099	0.959	0.823	0.689	0.603	0.556	0.461	0.409	0.383	0.269
Nov	0.375	0.337	0.278	0.235	0.221	0.193	0.157	0.138	0.102	0.075
Dec	0.103	0.081	0.060	0.053	0.046	0.041	0.037	0.029	0.021	0.013
Jan	0.035	0.024	0.015	0.012	0.009	0.007	0.006	0.003	0.003	0.001
Feb	0.041	0.018	0.010	0.007	0.004	0.003	0.001	0.001	0.000	0.000
Mar	0.060	0.035	0.021	0.013	0.006	0.004	0.003	0.001	0.000	0.000
Apr	0.290	0.182	0.102	0.077	0.049	0.040	0.021	0.015	0.007	0.000
May	1.180	0.571	0.446	0.355	0.302	0.193	0.159	0.106	0.062	0.015
Jun	3.343	1.901	1.260	1.089	0.976	0.702	0.530	0.400	0.266	0.134
Jul	3.439	2.537	2.154	1.697	1.432	1.226	0.990	0.778	0.615	0.244
Aug	3.402	2.582	2.194	1.900	1.745	1.516	1.260	1.015	0.728	0.574
Sep	2.379	1.898	1.580	1.313	1.260	1.118	1.055	0.831	0.712	0.316

EWR SITE 4 – B-CATEGORY

EWR Tables

```
Desktop Version 2, Generated on 11/08/2006
    Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
    Total Runoff : Quaternaries E24J

    Annual Flows (Mill. cu. m or index values):
    MAR                =  421.470
    S.Dev.             =  337.317
    CV                 =    0.800
    Q75                =    2.373
    Q75/MMF            =    0.068
    BFI Index          =    0.307
    CV(JJA+JFM) Index =     2.619

    Ecological Category = B

    Total IFR          =  192.205 (45.60 %MAR)
    Maint. Lowflow     =   64.532 (15.31 %MAR)
    Drought Lowflow    =    3.705 ( 0.88 %MAR)
    Maint. Highflow    =  127.673 (30.29 %MAR)

    Monthly Distributions (Mill. cu. m.)
    Distribution Type : W.Cape(dry)
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	34.175	16.766	0.491	5.542	0.416	6.622	12.164
Nov	18.270	11.662	0.638	0.080	0.080	3.311	3.391
Dec	8.261	9.028	1.093	0.000	0.000	0.000	0.000
Jan	4.567	12.061	2.641	0.000	0.001	0.000	0.000
Feb	3.547	9.217	2.599	0.000	0.001	0.000	0.000
Mar	2.914	5.358	1.839	0.000	0.001	0.000	0.000
Apr	15.736	44.293	2.815	0.134	0.000	3.311	3.445
May	31.026	55.377	1.785	1.386	0.028	0.000	1.386
Jun	79.408	159.675	2.011	8.045	0.027	11.381	19.426
Jul	78.429	101.188	1.290	16.627	0.055	20.899	37.526
Aug	85.205	86.278	1.013	16.627	2.854	32.280	48.907
Sep	59.931	39.858	0.665	16.091	0.241	49.869	65.960

Rule Curves

Desktop Version 2, Generated on 11/08/2006
Summary of IFR rule curves (Desktop Version 2) for :
EWR Site 4:
Total Runoff : Quaternaries E24J
Regional Type : W.Cape(dry)
Ecological Category = B

Data are given in m^3 * 10^6 monthly flow volume

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	14.734	14.562	14.131	13.203	11.510	8.967	5.930	3.208	1.559	1.163
Nov	3.890	3.835	3.683	3.350	2.775	2.009	1.249	0.713	0.467	0.433
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jan	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Apr	3.959	3.913	3.799	3.433	2.131	1.648	1.218	0.766	0.459	0.031
May	1.790	1.773	1.734	1.653	1.500	1.250	0.899	0.501	0.172	0.039
Jun	23.407	23.194	22.713	21.717	19.862	16.806	12.492	7.525	3.279	1.304
Jul	62.071	56.511	51.618	47.052	42.306	34.347	28.407	18.153	10.313	3.369
Aug	89.155	78.323	69.141	60.826	46.023	39.495	30.279	19.669	10.598	6.380
Sep	123.436	82.889	65.366	59.340	49.240	43.823	37.429	22.715	10.546	5.636

Reserve Flows without High Flows

Oct	7.162	7.078	6.865	6.406	5.570	4.313	2.813	1.468	0.653	0.458
Nov	0.104	0.104	0.103	0.101	0.097	0.091	0.086	0.083	0.081	0.081
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jan	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Apr	0.173	0.171	0.166	0.154	0.132	0.100	0.062	0.027	0.006	0.001
May	1.790	1.773	1.734	1.653	1.500	1.250	0.899	0.501	0.172	0.039
Jun	10.393	10.295	10.070	9.606	8.741	7.317	5.306	2.991	1.012	0.092
Jul	21.480	21.326	21.009	20.391	19.244	17.253	14.081	9.610	4.418	0.709
Aug	21.497	21.320	20.916	20.082	18.526	15.965	12.348	8.185	4.626	2.971
Sep	20.788	20.589	20.132	19.184	17.410	14.491	10.397	5.756	1.918	0.370

Natural Duration curves

Oct	53.314	46.321	39.791	36.032	31.444	28.715	24.589	20.704	16.326	8.399
Nov	35.707	25.071	21.197	16.882	14.268	13.008	11.874	10.152	7.654	5.533
Dec	17.302	11.528	8.914	6.457	5.564	4.021	3.538	3.150	2.478	1.827
Jan	6.404	3.255	2.436	1.764	1.312	0.976	0.840	0.682	0.588	0.409
Feb	11.244	3.024	1.606	0.829	0.651	0.430	0.220	0.168	0.126	0.084
Mar	6.530	4.494	2.373	1.648	1.312	0.756	0.441	0.199	0.063	0.000
Apr	27.381	15.916	8.494	3.433	2.131	1.648	1.218	0.766	0.472	0.031
May	118.386	37.187	18.657	15.654	11.790	7.160	4.494	2.562	1.795	0.241
Jun	165.106	102.312	60.316	43.770	33.628	25.974	16.620	12.714	5.197	2.404
Jul	182.850	100.065	81.178	61.639	51.644	42.521	30.846	18.153	11.864	4.536
Aug	216.940	108.769	88.832	71.403	61.324	51.686	41.418	30.016	19.402	7.780
Sep	123.436	82.889	65.366	59.340	49.240	43.823	38.594	29.828	20.998	11.496

EWR SITE 5 – B-CATEGORY

EWR Tables

```
Desktop Version 2, Generated on 11/08/2006
      Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
      Total Runoff : Quaternaries E24M

      Annual Flows (Mill. cu. m or index values):
      MAR                =  509.621
      S.Dev.             =  418.927
      CV                 =    0.822
      Q75                =    3.229
      Q75/MMF            =    0.076
      BFI Index          =    0.282
      CV(JJA+JFM) Index =    3.544

      Ecological Category = B

      Total IFR          =  232.405 (45.60 %MAR)
      Maint. Lowflow     =   78.029 (15.31 %MAR)
      Drought Lowflow    =    4.480 ( 0.88 %MAR)
      Maint. Highflow    =  154.376 (30.29 %MAR)

      Monthly Distributions (Mill. cu. m.)
      Distribution Type : W.Cape(dry)
```

Month	Natural Flows Mean	Natural Flows SD	Natural Flows CV	Modified Flows (IFR) Low flows Maint.	Low flows Drought	High Flows Maint.	Total Flows Maint.
Oct	38.865	18.820	0.484	6.701	0.503	8.007	14.708
Nov	20.917	13.384	0.640	0.097	0.097	4.003	4.101
Dec	9.444	10.043	1.063	0.000	0.000	0.000	0.000
Jan	5.428	13.497	2.487	0.000	0.002	0.000	0.000
Feb	4.597	10.649	2.317	0.000	0.001	0.000	0.000
Mar	4.644	6.906	1.487	0.000	0.001	0.000	0.000
Apr	19.868	52.253	2.630	0.162	0.000	4.003	4.165
May	39.653	75.082	1.893	1.675	0.034	0.000	1.675
Jun	101.797	202.309	1.987	9.728	0.032	13.761	23.489
Jul	94.969	125.903	1.326	20.104	0.067	25.271	45.375
Aug	100.199	103.168	1.030	20.104	3.451	39.032	59.136
Sep	69.241	46.856	0.677	19.456	0.292	60.299	79.755

Rule Curves

Desktop Version 2, Generated on 11/08/2006
Summary of IFR rule curves (Desktop Version 2) for :
EWR Site 5:
Total Runoff : Quaternaries E24M
Regional Type : W.Cape(dry)
Ecological Category = B

Data are given in m^3 * 10^6 monthly flow volume

Month % Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%	
Oct	17.815	17.608	17.087	15.964	13.917	10.842	7.170	3.878	1.885	1.407
Nov	4.704	4.637	4.453	4.051	3.356	2.430	1.510	0.862	0.565	0.524
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jan	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002
Feb	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Apr	4.787	4.732	4.593	4.295	2.592	2.052	1.426	1.080	0.555	0.043
May	2.165	2.144	2.097	1.998	1.814	1.511	1.087	0.606	0.207	0.047
Jun	28.302	28.046	27.463	26.260	24.016	20.321	15.104	9.099	3.965	1.577
Jul	75.053	68.330	62.414	56.893	51.155	41.530	34.344	21.146	12.470	4.073
Aug	107.802	94.705	83.602	73.548	55.649	47.755	36.612	23.783	12.815	7.714
Sep	147.604	93.874	77.393	65.243	59.681	51.073	43.016	27.466	12.751	6.815

Reserve Flows without High Flows

Oct	8.660	8.558	8.301	7.746	6.735	5.215	3.401	1.775	0.790	0.554
Nov	0.126	0.126	0.125	0.122	0.117	0.111	0.104	0.100	0.098	0.097
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jan	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002
Feb	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Apr	0.209	0.207	0.200	0.186	0.160	0.121	0.074	0.033	0.007	0.001
May	2.165	2.144	2.097	1.998	1.814	1.511	1.087	0.606	0.207	0.047
Jun	12.567	12.448	12.176	11.615	10.570	8.847	6.416	3.617	1.224	0.111
Jul	25.973	25.786	25.403	24.656	23.269	20.861	17.026	11.619	5.341	0.857
Aug	25.994	25.779	25.290	24.282	22.401	19.304	14.931	9.897	5.594	3.592
Sep	25.136	24.895	24.343	23.196	21.051	17.522	12.571	6.960	2.320	0.447

Natural Duration curves

Oct	61.441	51.851	46.494	41.148	35.640	32.324	27.734	23.350	17.852	9.904
Nov	41.342	30.002	23.868	19.386	15.898	15.152	13.802	11.167	8.813	6.383
Dec	18.986	14.256	9.914	7.258	6.199	4.493	4.223	3.564	2.776	1.998
Jan	9.256	4.104	2.689	2.128	1.436	1.058	0.918	0.767	0.659	0.464
Feb	13.230	5.000	1.825	1.166	0.788	0.464	0.324	0.216	0.140	0.108
Mar	12.755	8.122	5.022	2.570	1.976	1.426	0.540	0.216	0.108	0.000
Apr	37.076	22.529	10.595	5.594	2.592	2.052	1.426	1.080	0.562	0.043
May	145.044	46.840	26.590	19.278	14.126	9.990	5.443	3.240	1.955	0.248
Jun	245.441	123.520	86.141	52.596	39.658	30.089	21.298	14.407	7.042	2.808
Jul	222.437	127.559	100.753	77.771	60.620	47.045	34.344	21.146	15.098	6.037
Aug	256.446	122.364	101.552	80.849	70.902	58.525	46.753	33.448	21.665	9.126
Sep	147.604	93.874	77.393	65.243	59.681	51.073	43.016	33.199	23.404	12.582

EWR SITE 6 – B/C-CATEGORY

EWR Tables

```
Desktop Version 2, Generated on 11/08/2006
   Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :
   Total Runoff : Quaternaries E21J

   Annual Flows (Mill. cu. m or index values):
   MAR                =  137.858
   S.Dev.             =   82.083
   CV                 =    0.595
   Q75                =    0.820
   Q75/MMF            =    0.071
   BFI Index          =    0.328
   CV(JJA+JFM) Index =    2.641

   Ecological Category = B/C

   Total IFR          =   60.331 (43.76 %MAR)
   Maint. Lowflow     =   25.331 (18.37 %MAR)
   Drought Lowflow    =    3.203 ( 2.32 %MAR)
   Maint. Highflow    =   35.000 (25.39 %MAR)

   Monthly Distributions (Mill. cu. m.)
   Distribution Type : W.Cape(wet)
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	16.399	7.698	0.469	1.945	0.107	1.000	2.945
Nov	7.971	3.808	0.478	0.467	0.026	0.000	0.467
Dec	2.901	1.903	0.656	0.107	0.003	0.000	0.107
Jan	1.033	1.612	1.560	0.029	0.003	0.000	0.029
Feb	0.677	1.318	1.949	0.024	0.002	0.000	0.024
Mar	0.552	0.783	1.419	0.054	0.003	0.000	0.054
Apr	1.627	2.801	1.722	0.156	0.003	1.000	1.156
May	6.713	10.664	1.589	0.616	0.027	1.000	1.616
Jun	18.513	23.490	1.269	2.735	0.104	2.000	4.735
Jul	24.703	22.882	0.926	5.389	0.402	15.000	20.389
Aug	30.860	24.692	0.800	8.035	1.125	11.000	19.035
Sep	25.910	14.823	0.572	5.775	1.400	4.000	9.775

Rule Curves

Desktop Version 2, Generated on 11/08/2006
Summary of IFR rule curves (Desktop Version 2) for :
EWR Site 6:
Total Runoff : Quaternaries E21J
Regional Type : W.Cape(wet)
Ecological Category = B/C

Data are given in m^3/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.320	1.320	1.309	1.284	1.231	1.126	0.940	0.654	0.308	0.085
Nov	0.224	0.224	0.222	0.217	0.208	0.190	0.158	0.109	0.050	0.011
Dec	0.049	0.049	0.049	0.047	0.044	0.039	0.029	0.017	0.006	0.001
Jan	0.014	0.014	0.013	0.013	0.012	0.011	0.008	0.005	0.002	0.001
Feb	0.012	0.012	0.012	0.012	0.011	0.010	0.008	0.005	0.002	0.001
Mar	0.025	0.025	0.025	0.024	0.023	0.021	0.018	0.012	0.005	0.000
Apr	0.506	0.506	0.502	0.359	0.255	0.207	0.164	0.097	0.055	0.012
May	0.703	0.703	0.698	0.684	0.656	0.601	0.500	0.352	0.169	0.029
Jun	2.188	2.188	2.175	2.147	2.091	1.981	1.771	1.390	0.768	0.130
Jul	12.485	11.443	9.730	8.523	7.381	6.687	4.556	3.125	1.807	0.706
Aug	11.067	10.302	9.607	8.973	8.349	7.142	6.430	5.121	3.035	0.875
Sep	5.768	5.379	5.029	4.705	4.359	3.743	3.202	2.369	1.364	0.717

Reserve Flows without High Flows

Oct	0.902	0.902	0.894	0.877	0.840	0.768	0.639	0.440	0.200	0.045
Nov	0.224	0.224	0.222	0.217	0.208	0.190	0.158	0.109	0.050	0.011
Dec	0.049	0.049	0.049	0.047	0.044	0.039	0.029	0.017	0.006	0.001
Jan	0.014	0.014	0.013	0.013	0.012	0.011	0.008	0.005	0.002	0.001
Feb	0.012	0.012	0.012	0.012	0.011	0.010	0.008	0.005	0.002	0.001
Mar	0.025	0.025	0.025	0.024	0.023	0.021	0.018	0.012	0.005	0.000
Apr	0.075	0.075	0.074	0.072	0.069	0.063	0.052	0.035	0.015	0.001
May	0.286	0.286	0.283	0.278	0.266	0.243	0.201	0.138	0.061	0.012
Jun	1.321	1.321	1.313	1.296	1.261	1.193	1.063	0.827	0.443	0.048
Jul	2.520	2.520	2.505	2.473	2.409	2.283	2.043	1.607	0.895	0.165
Aug	3.759	3.759	3.737	3.692	3.602	3.425	3.086	2.472	1.469	0.441
Sep	2.771	2.771	2.751	2.706	2.611	2.423	2.089	1.575	0.954	0.554

Natural Duration curves

Oct	10.224	8.134	7.087	6.080	5.539	5.150	4.556	3.897	3.173	1.878
Nov	5.231	4.367	3.528	2.999	2.725	2.463	2.299	1.940	1.466	1.192
Dec	2.090	1.483	1.207	1.007	0.842	0.748	0.689	0.624	0.436	0.306
Jan	0.718	0.447	0.324	0.265	0.218	0.177	0.153	0.135	0.112	0.053
Feb	0.743	0.261	0.182	0.124	0.091	0.065	0.039	0.033	0.026	0.020
Mar	0.524	0.377	0.206	0.177	0.088	0.053	0.047	0.029	0.012	0.000
Apr	1.557	0.791	0.602	0.359	0.255	0.207	0.164	0.097	0.055	0.012
May	8.811	2.755	2.201	1.519	1.160	0.824	0.500	0.424	0.230	0.029
Jun	18.533	8.473	6.478	5.650	4.732	3.570	2.585	1.484	0.906	0.414
Jul	22.196	12.008	9.730	8.523	7.381	6.687	4.556	3.125	1.807	0.706
Aug	23.756	15.716	13.867	11.478	9.359	7.846	6.457	5.121	3.408	1.436
Sep	19.494	13.217	11.793	9.610	8.704	7.682	6.271	5.565	4.014	2.445