

Resource Directed Measures

REPORT NO. RDM/ K10 – K30, K40E/00/CON/0407, volume 1

Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua (Groot Brak and other Water resources, excluding wetlands) catchment: Ecological Water Requirements Study

SUB-STUDY 2: REPORT NO. 4

RIVERINE RDM REPORT, VOLUME 1: ASSESSMENT



September 2008



**Department of Water Affairs and Forestry
Chief Directorate: Resource Directed Measures**

Published by

Department of Water Affairs and Forestry
Private Bag X313
PRETORIA, 0001
Republic of South Africa

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Fax: (012) 323 0321/ +27 12 323 0321

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This report should be cited as:

Department of Water Affairs and Forestry (DWAF), 2008. Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua (Groot Brak and other water resources, excluding wetlands) catchment: Ecological Water Requirements Study – Riverine RDM Report, volume 1: Assessment. Report No. RDM/ K10 – K30, K40E/00/CON/0407, volume 1. Pretoria.

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TITLE: Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua (Groot Brak and other water resources, excluding wetlands) catchment: Ecological Water Requirements Study – Riverine RDM Report, volume 1: Assessment

DATE: September 2008

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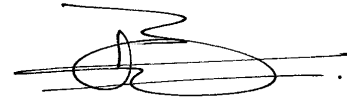
REPORT NO.: RDM/ K10 – K30, K40E/00/CON/0407, volume 1

PROJECT NO: WP 8927

FORMAT: MSWord and PDF

WEB ADDRESS: www.dwaf.gov.za

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**RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE
WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE
OUTENIQUA (GROOT BRAK AND OTHER WATER RESOURCES,
EXCLUDING WETLANDS) CATCHMENT: ECOLOGICAL WATER
REQUIREMENTS STUDY**

RIVERINE RDM REPORT, VOLUME 1: ASSESSMENT

INTRODUCTION

This Riverine RDM Report is the third in a series of nine project-related reports. The aims of the report are:

- to provide the overall Present Ecological Status of the river reaches represented by each of the EWR sites;
- to provide the information (data and literature reviews) on which the specialists based their EWR deliberations;
- to provide the hydrological information on which the deliberations were based;
- to explain the application of the DRIFT methodology in the study;
- to summarise the results obtained from the DRIFT Database for the sites for which an Intermediate Reserve Determination was done;
- to provide the results for the sites for which Rapid I/II determinations were done;
- to provide the Water Quality Reserve for the relevant reaches of the Groot Brak, Malgas, Kaaimans and Goukamma Rivers.

[Note: The hydrological data for some of the sites was updated during the course of the study. Since the EWRs are based on this hydrology, this meant that the EWRs also changed. For this reason, data on EWRs for the rivers in this study should be obtained from the Ecological input: Water Resource Classification Report (K10-K50, K60G) and the Main Study Report (K10-K50, K60G), as these contain the updated EWRs.]

THE STUDY AREA

The study area comprises part of the Outeniqua Coast and covers the coastal catchments between Klein Brak River, Goukamma River and Noetsie. The environmental flow work required for these catchments forms a separate (but parallel study, being undertaken by Coastal and Environmental Services (CES)). The area is bounded by the Outeniqua and Langeberg Mountains to the north and the Indian Ocean to the south.

LEVELS OF DETERMINATION

The following levels of EWR determination were applied:

- Intermediate Ecological Reserve on the Groot Brak River (one site; GB 1).

- Intermediate Ecological Reserve on the Malgas River (one site; Mal 1).
- Intermediate Ecological Reserve on the Kaaimans River (one site; Ka 1).
- Intermediate Ecological Reserve on the Goukamma River (one site; Gou 1).
- Rapid II Ecological Reserve determination for the Maalgate River.
- Rapid II Ecological Reserve determination for the Moeras River.
- Rapid II Ecological Reserve determination for the Gwaing River.
- Rapid II Ecological Reserve determination for the Swart River.
- Rapid II Ecological Reserve determination for the Silver River.
- Rapid I Ecological Reserve determination for the Noetsie River.
- Review of the Rapid III Ecological Reserve determination for the Moordkuil River.

The levels adopted were designed to provide the required level of scenario-based information necessary to make strategic recommendations with regard to water availability in the study area.

RECOMMENDED AND ALTERNATIVE CATEGORIES

The Recommended Ecological Categories (REC) and Alternative Ecological Categories (AEC) for which Reserve determinations were done for each of the study sites are provided in Table E.1.

Table E.1 Recommended Ecological Categories (REC) and Alternative Ecological Categories (AEC) for each of the study sites

River	EWR Site	Quat. Catchment	PES	EIS	REC	AEC 1	AEC 2	Level of determination
Groot Brak	GB 1	K20A	B/C	HIGH	B/C	C	B	Intermediate
Kaaimans	Ka 1	K30C	B	VERY HIGH	B	C	A/B	Intermediate
Malgas	Mal 1	K30B	C	HIGH	C	D	None	Intermediate
Goukamma	Gou 1	K40E	B/C	VERY HIGH	B/C	C	None	Intermediate
Gwaing	Gwa 1	K30B	E	HIGH	D	None	None	Rapid II
Maalgate	Maa 1 and Maa 2	K30A	D	HIGH	D	C	None	Rapid II
Moeras	Moe 1	K30A	D	HIGH	D	C	None	
	Moe 2		C	HIGH	C	D	None	
Swart	Sw 1	K30C	D	HIGH	D	None	None	Rapid II
Silver	Si 1	K30C	B	VERY HIGH	B	C	None	Rapid II
Noetsie	Noe 1	K60G	B	VERY HIGH	A/B	B	C	Rapid I
Moordkuil	Moo 1	K10F	D	HIGH	B/C	C	None	Review Rapid III

RECOMMENDED EWRs

The annual estimates of the Reserves for the REC for each EWR site are given in Table E.2.

Table E.2. The annual estimates of the Reserves for the REC for each EWR site

Method	River	Site	Portion of the EWR	PES	EIS	REC	Method/ Calculation Notation	MCMa ⁻¹	%nMAR	MCMa ⁻¹	%nMAR
								(incl. ≥1:2 year floods)		(excluding ≥1:2 year floods ¹)	
Intermediate (DRIFT)	Groot Brak	GB 1	MAINTENANCE TOTAL (Volume)	B/C	H	B/C	DRIFT Annual ²	10.1	54%	6.3	34%
							Long-term average ³	5.5	30%		
	Malgas	Mal 1	MAINTENANCE TOTAL (Volume)	C	H	C	DRIFT Annual	5.4	50%	3.8	35%
							Long-term average	3.5	31%		
	Kaaimans	Ka 1	MAINTENANCE TOTAL (Volume)	B	VH	B	DRIFT Annual	8.5	63%	6.5	48%
							Long-term average	6.7	50%		
	Goukamma	Gou 1	MAINTENANCE TOTAL (Volume)	B/C	VH	B/C	DRIFT Annual	14.1	53%	9.6	36%
							Long-term average	12.4	47%		
Rapid I/II (Desktop Model)	Gwaing	Gwa 1	MAINTENANCE TOTAL (Volume)	E	H	D	Calibrated Desktop			2.7	16%
	Maalgate	Maa 2	MAINTENANCE TOTAL (Volume)	D	H	D	Calibrated Desktop			5.6	16%
	Moeras	Moe 1	MAINTENANCE TOTAL (Volume)	D	H	D	Maa 2 site was used for the Reserve determination site (see Section 11.3)				
	Swart	Sw 1	MAINTENANCE TOTAL (Volume)	D	H	D	Calibrated Desktop			1.8	14%
	Silver	Si 1	MAINTENANCE TOTAL (Volume)	B	VH	B	Calibrated Desktop			3.2	40%
	Noetsie	Noe 1	MAINTENANCE TOTAL (Volume)	B	VH	A/B	Calibrated Desktop			3.8	60%
Review	Moordkuil	Moo 1	MAINTENANCE TOTAL (Volume)	D	H	B/C	Rapid III			8.9	26.2%

¹ For comparison with Desktop results.

² Calculated as the volume of water required to meet the full requirements.

³ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e., $\geq 1:2$ year return period⁴). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using the Desktop, the DRIFT volumes in Table E.2 are reported both including and excluding the volumes of the $\geq 1:2$ year return period flood. Similarly, DRIFT long-term averages include $\geq 1:2$ year return period floods, while the Desktop results do not. Thus, they are not directly comparable.

It is important to note that the Desktop requires specification of flood flows for a particular month. If the flood does not occur in the specified month, then the longterm average will exclude that flood, even if it occurs early in the following month. In reality, floods for EWRs are recommended for a suite of months. This makes the chances of the flood actually occurring higher, which makes the long-term average higher. This should be taken into consideration when modelling EWR requirements for water resource developments and/or management, and when reviewing these results. Also, the Desktop Model does not include floods with a return period of two years or greater, and these are required if these rivers are to be maintained in their target conditions.

REVIEW OF ECOLOGICAL RESERVE FOR THE MOORDKUIL RIVER

There are two main issues that arise with respect to the Ecological Reserve at this site:

1. The results obtained in the current (2007) study suggest that, the 26.22% nMAR previously recommended is about right for maintenance of a B/C category. Of the sites considered in this study, GB 1 is probably the closest to the Moordkuil site and would be the one used for calibration of the Desktop. Were this to be the case, the recommended Ecological Reserve for maintaining a B/C would be in the region of 27% nMAR.
2. The PES has declined in the six years separating the two studies. This decline appears to have been driven by non-flow related factors. Nonetheless, it points to a failure to maintain current condition, viz. a B/C in 2001. In this regard every effort should be made to restore the riverbanks, re-establish a buffer area, remove the alien invasives and regain a B/C category river.

With respect to Point 1 above, please note that these figures are exclusive of floods with a return period of two years or greater, but these are required if this river is to be maintained in a B/C Category.

With respect to Point 2 above, it may be tempting to suggest that the Reserve should be decreased to that required to maintain a D-Category⁵. It is the opinion of the specialists in this study (2007) that this would be counter-productive and damaging to efforts to implement

⁴ Previously all inter-annual floods were excluded in the reported volume, but recent studies have started to include floods with a 1:2 year return period, i.e., Komati Basin EWR Study.

⁵ The EWR for a D-Category was not determined as part of the Moordkuils EWR study, but is likely to be in the region of 17% nMAR.

the requirements of the Water Act in other catchments (and indeed in the rest of the Klein Brak Catchment).

WATER QUALITY

A summary of the water quality Present Ecological Status for each Water Quality Sub-Unit is provided In Table E.3.

Table E.3. Summary of water quality PES for each WQSU

River	WQSU	EWR site	Overall WQ PES ecostatus	Confidence
Groot Brak	1 & 2 3 4	- GB 1 -	A/B B B/C	Low for WQSU 1 – 3. Good for WQSU 4
Kaaimans	1 2	- Ka 1	A A	Good
Malgas	1 2 3	- Mal 1 -	A B D/E	Good for WQSU 1 and 2. Low for WQSU 3
Goukamma	1 2 3	- Gou 1 -	A A B	Medium for WQSU 1 and 2. Low for WQSU 3
Maalgate		-	C	Good
Moeras		No data	C	Low confidence. Deduced from landuse and SASS score (this study)
Swart		No data	A (upper) C (lower)	Low confidence. Deduced from landuse and SASS score (this study)
Silver		No data	A/B	Low-medium confidence. Deduced from landuse and SASS score (this study) and extrapolated from Kaaimans.
Noetsie		No data	Unknown	
Moordkuil	Upper reaches Lower reaches	- -	A B	Good

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GLOSSARY AND ABBREVIATIONS

% MAR	Percentage Mean Annual Runoff
1:10 year	1 in 10 year period
1:2 year	1 in 2 year period
1:20 year	1 in 20 year period
1:5 year	1 in 5 year period
AA	Floating aquatic zone
AEC	Alternative Ecological Category
AGES	Africa Geo-Environmental Services
AM	Rooted aquatic zone
ASPT	Average Score Per Taxon
Av. Flow depth	Average Flow Depth
Av. Velocity	Average Velocity
BD	Back dynamic zone
BKS	Barnard, Kruger and Stoffberg
c.	<i>circa</i> (approximately)
CES	Coastal and Environmental Services
CD: RDM	Chief Directorate: Resource Directed Measures
CL	Change Level (in DRIFT)
CSIR	Council for Scientific and Industrial Research
DRIFT	Downstream Response to Imposed Flow Transformations
DSLIF	Dry Season Lowflow
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
Eald	Elevation above local datum
Ecostatus	Ecological status
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirement
F	Fast
F.1	Fast Depth >0.1m
F.3	Fast Depth >0.3m
FBR	Fast Bedrock
FCS	Fast Coarse Sediment
FDCs	Flow Duration Curves
FFS	Fast Fine Sediment
GSM	Gravel, Sand and Mud
HI	Habitat Integrity
Hz	Horizontal
IFR	Instream Flow Requirement
Incl.	Including
LB	Left Bank
LD	Lower Dynamic
LHDA	Lesotho Highlands Development Authority
m ³ /s	Cubic meters per second
MAR	Mean Annual Runoff

Max	Maximum
MCA	Multi-criteria Analysis
MCM	Million Cubic Metres
MCM a ⁻¹	Million Cubic Metre per Annum
MRK	Mark (painted)
MOR	Mark on rock
MV-IC	Marginal Vegetation - In Current
nMAR	Natural Mean Annual Runoff
NWA	National Water Act
PBML	Potential Bed Material Load
PD MAR	Present Day Mean Annual Runoff
PD	Present Day
PES	Present Ecological Status
PIC	Peg In Concrete
PSP	Management Professional Service Provider
Q	Discharge
RB	Right Bank
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RHP	River Health Programme
RQS	Resource Quality Services
S	Slow
SASS5	South African Scoring System Version 5
SBR	Slow Bedrock
SCS	Slow Coarse Sediment
SD	Slow Deep
SFS	Slow Fine Sediment
Shands Format	see Brown <i>et al.</i> (2006a).
SIC	Stones In Current
SOOC	Stones Out Of Current
S-Pool	Stones in pool
S-Riffle	Stones in riffle
SS	Slow Shallow
TS	Tree-shrub zone
Vel.	Velocity
VG	Vegetation
VOL	Volume
WL	Low wetbank zone – fringing sedges
WQ	Water Quality
WR90 Format	Output from the WRSM2000 Model
WRC	Water Research Commission
WSLF	Wet Season lowflow
WU	Upper wetbank zone
$\omega = \gamma QS$	Stream Power.

11 INTRODUCTION

1.1. BACKGROUND

The National Water Act (NWA; Act No. 36 of 1998) is founded on the principle that National Government has overall responsibility for, and authority over, water resource management for the benefit of the public without seriously affecting the long-term functioning of the natural environment. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the Ecological Reserve.

In terms of the requirements of Chapter 3 of the NWA, the Department of Water Affairs and Forestry (DWAF) Chief Directorate: Resource Directed Measures (CD: RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which take priority over all other uses, are determined before licence applications can be processed.

The CD: RDM identified the following catchments for Reserve Determinations at various levels of detail to support the proposed compulsory licensing process:

- Groot Brak (K20A).
- Selected Water Resources in K10D and F, K30B, K30C, K40E and K60G.

The Technical Component of this study (Sub-study 2) was awarded to Southern Waters Ecological Research and Consulting, in conjunction with CSIR (estuaries) and AGES (groundwater). The project management component was awarded to BKS (Pty) Ltd in association with Londoloza Environmental Consultants (hereafter also referred to as the Management Professional Service Provider (PSP)).

The study is being conducted under the auspices of the DWAF's CD: RDM. The results of the study are intended to support water allocations planning, in accordance with the requirements of the NWA.

[Note: The hydrological data for some of the sites was updated during the course of the study. Since the EWRs are based on this hydrology, this meant that the EWRs also changed. For this reason, data on EWRs for the rivers in this study should be obtained from the Ecological input: Water Resource Classification Report (K10-K50, K60G) and the Main Study Report (K10-K50, K60G), as these contain the updated EWRs.]

1.2. OBJECTIVES OF THIS REPORT

This report provides the background data and deliberations for the River Ecological Water Requirements (EWRs) for the Moodkuils River in the Klein Brak catchment (K10D and F), Groot Brak catchment (K20A) and water resources in K30B, K30C, K40E and K60G.

The report has the following specific objectives:

- to provide the overall Present Ecological Status (PES) of the river reaches represented by each of the EWR sites;
- to provide the information (data and literature reviews) on which the specialists based their deliberations;
- to provide the hydrological information on which the deliberations were based;
- to explain the application of the DRIFT (an acronym for Downstream Response to Imposed Flow Transformations) methodology in the study;
- to summarise the results obtained from the DRIFT Database for the sites for which an Intermediate Reserve determination was done (see Section 1.3);
- to provide the results for the sites for which Rapid I/II determinations were done (see Section 1.3);
- to provide the Water Quality Reserve for the relevant reaches of the Groot Brak, Malgas, Kaaimans and Goukamma Rivers.



Figure 0.1 Quaternary catchments in the Outeniqua region

1.2.1 Layout of this report

This report is divided into several discrete sections. Each deals with one aspect of the riverine RDM information. The sections are as follows:

- Section 1: Provides a brief background to the project and an outline of the Riverine RDM reporting. Additional background to the project is available in the Inception Report.
- Section 2: Provides a general description of the study sites. Additional detail on the study area, delineation and the reasoning behind the selection of the study sites is provided in the Delineation Report.
- Section 3: Provides a brief summary of the methodology. Additional detail on DRIFT is available in various WRC reports.

- Section 4: Provides the detailed specialist reports.
- Section 5: Provides the ecoclassification, ecological importance and sensitivity, and the recommended and alternative ecological categories.
- Section 6: Provides results for EWR site GB 1 (Groot Brak River at Kleinplaas road).
- Section 7: Provides results for EWR site Mal 1 (Malgas River at Ou Brug).
- Section 8: Provides results for EWR site Ka 1 (Kaaimeans River at old road).
- Section 9: Provides results for EWR site Gou 1 (Goukamma River on old road).
- Section 10: Provides summary results for the Intermediate Reserve determination sites.
- Section 11: Provides results for the Rapid Reserve determination sites.
- Section 12: Provides summary results for the Rapid Reserve determination sites.
- Section 13: Provides the Water Quality Reserve for the relevant river reaches of the Groot Brak, Malgas, Kaaimeans and Goukamma Rivers.

Note: *Ecospecs are provided in a separate report (Riverine RDM Report, volume 2: Ecospecs and Monitoring; Report No. RDM/ K10 – K30, K40E/00/CON/0407, volume 2) in detail for each of the selected EWR for each EWR site.*

1.3. LEVELS OF EWR DETERMINATION

The following levels of EWR determination were applied (see Section 3 for method details):

- Intermediate Ecological Reserve on the Groot Brak River (one site; GB 1).
- Intermediate Ecological Reserve on the Malgas River (one site; Mal 1).
- Intermediate Ecological Reserve on the Kaaimeans River (one site; Ka 1).
- Intermediate Ecological Reserve on the Goukamma River (one site; Gou 1).
- Rapid II Ecological Reserve determination for the Maalgate River.
- Rapid II Ecological Reserve determination for the Moeras River.
- Rapid II Ecological Reserve determination for the Gwaing River.
- Rapid II Ecological Reserve determination for the Swart River.
- Rapid II Ecological Reserve determination for the Silver River.
- Rapid II Ecological Reserve determination for the Noetsie River.
- Review of the Rapid III Ecological Reserve determination for the Moordkuil River.

The levels adopted were designed to provide the required level of scenario-based information necessary to make strategic recommendations with regard to water availability in the study area.

Note: A Rapid II Ecological Reserve determination for the Varing River was later added to the study as part of a Variation Order.

2 LOCATION OF THE STUDY SITES

2.1 LOCATION OF STUDY SITES

The location of the study sites is provided in Table 2.1 and Figure 2.1. Details of the sites are provided in the Delineation Report (Report No. RDM/ K10-K30, K40E/00/ CON/0207).

Table 2.1 Location of the study sites

River	Quat. Catchment	Site Name	Description of location	Latitude	Longitude	Determination level in Contract (and actual)
Groot Brak	K20A	GB 1	@ Kleinplaas Road	33°58.621'	22°11.510'	Intermediate (Intermediate)
Maalgate	K30A	Maa 1	@ Sieben Schwaben	33°59.336'	22°19.865'	Rapid I/II (Rapid II)
	K30A	Maa 2	@ R102/DWAF gauging weir	34°00.395'	22°21.001'	
Moeras	K30A	Moe 1	@ Molendrif	33°57.437'	22°21.412'	
	K30A	Moe 2	@ R102	33°58.983'	22°20.672'	
Malgas	K30B	Mal 1	@ Ou Brug	33°56.251'	22°25.278'	Rapid III (Intermediate)
Gwaing	K30B	Gwa 1	@ R102	33°59.296'	22°25.063'	Rapid I/II (Rapid II)
Swart	K30C	Sw 1	@ old George-Knysna Road	33°58.047'	22°31.267'	Rapid I/II (Rapid II)
Kaaimans	K30C	Ka 1	@ old George-Knysna Road	33°58.263'	22°32.864'	Rapid III (Intermediate)
Silver	K30C	Si 1	@ old George-Knysna Road	33°57.897'	22°33.702'	Rapid I/II (Rapid II)
Goukamma/Homtini	K40E	Gou 1	@ old George-Knysna Road	33°56.845'	22°55.160'	Rapid III (Intermediate)
Noetsie	K60G	Noe 1	@ N2	34° 02.300'	23°09.400'	Rapid I/II (Rapid I)
Moordkuil	K10F	Moo 1	@ Road parallel to flood plain	34°02.023'	22°08.000'	Reviewed existing Rapid III
Varing	K20A	Var 2	Upstream of Kleinplaas Road	33°93.747'	22°24.226'	Rapid II
			Immediately upstream of Wolwedans Dam	33°57.467'	22°14.410'	Rapid II

Note: Favourable weather and flow conditions for hydraulic surveying meant that the determination levels could be upgraded at three of the sites (Table 2.1 – see also Section 1.3).

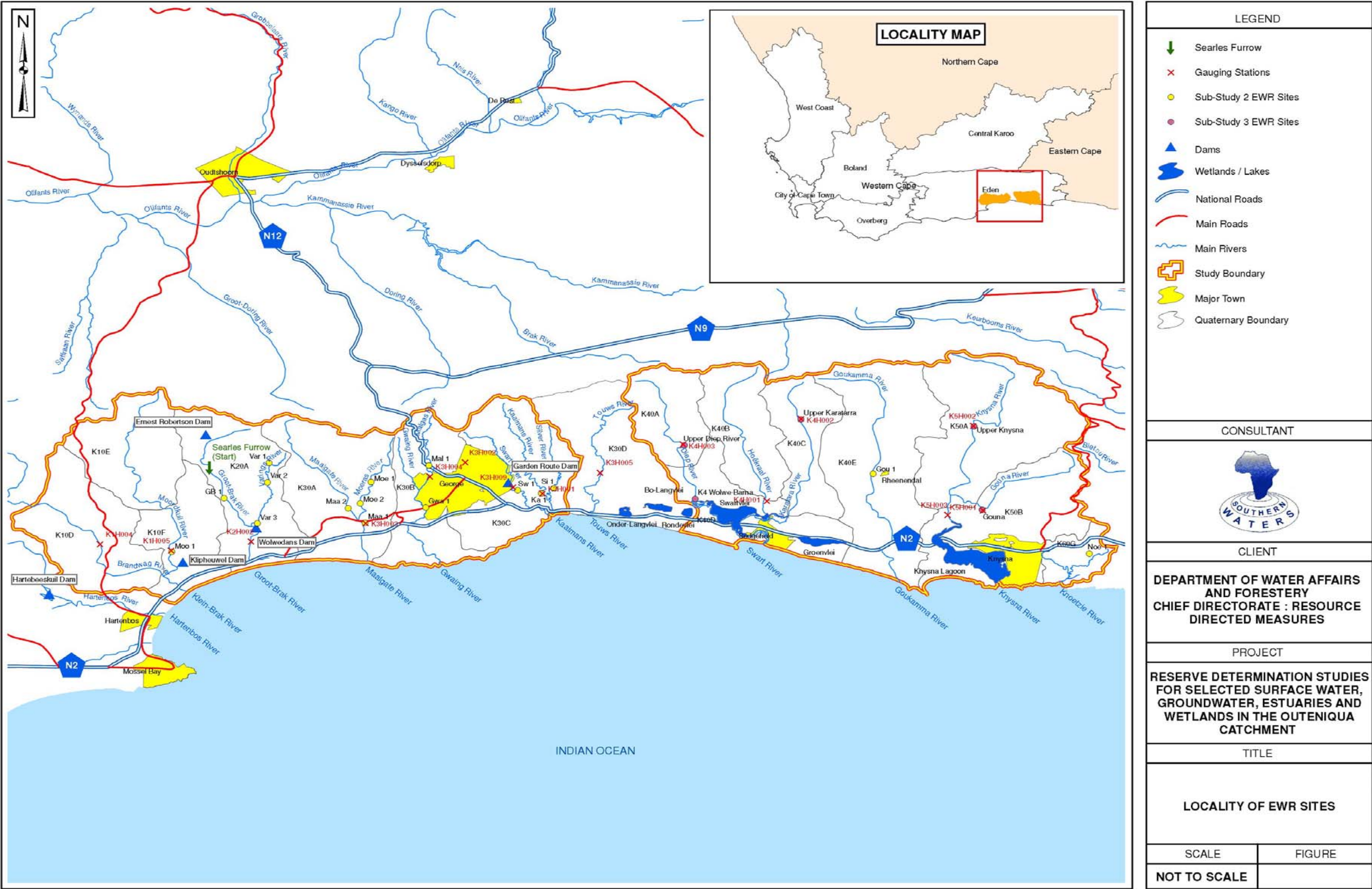


Figure 2.1 Map showing location of Sub-study 2 EWR sites and DWAF gauging weirs in the study area

3 SUMMARY OF METHODS

3.1 INTERMEDIATE METHOD

3.1.1 *Adjustments to DRIFT to cater for intermediate level determinations*

The differences between a DRIFT (an acronym for Downstream Response to Imposed Flow Transformations) application at the Comprehensive level and that at an Intermediate level are found in the intensity of data collection, the number of generic list items considered by the specialists at the workshop, the time provided for consideration of the consequences at the workshop, the number of components of the flow regime considered and the number of change levels considered. The following modifications were introduced (i.e., these represent reductions in time and effort relative to the Comprehensive level):

- ½ day field data collection;
- one hydraulic cross-section at each site;
- two hydraulic calibration points;
- ½ day consideration of the consequences for each site at the workshop⁶;
- a maximum of six generic list items per specialist⁷;
- consideration of the inter-annual floods as one flow component (instead of the four that would be considered in a comprehensive assessment, viz. 1:2, 1:5, 1:10 and 1:20), thereby reducing the total number of flow components to seven (from 10);
- fewer change levels for Class 1 floods (in some cases, e.g., Malgas River (Mal 1)).

3.1.2 *General explanation of DRIFT*

DRIFT is an interactive, holistic approach for advising on environmental flows for rivers. The DRIFT methodology can be used to provide flow scenarios and descriptive summaries of their consequences in terms of the condition of the river ecosystem, for examination and comparison by decision makers. In its totality, DRIFT consists of four modules (biophysical, subsistence use, scenario development and compensation economics). This report focuses on the results of the biophysical module, in which the river ecosystem is described and predictive capacity developed on how it would change with flow changes.

DRIFT is essentially a data-management tool, allowing data and knowledge to be used to their best advantage in a structured way. Within DRIFT, each specialist, to derive the links between river flow and river condition, uses component-specific methods. The central rationale of DRIFT is that different aspects of the flow regime of a river elicit different responses from the riverine ecosystem. Thus, removal of part or all of a particular element of the flow regime will affect the riverine ecosystem differently than will removal of some other element.

Furthermore:

- it is possible to identify and isolate these elements of the flow regime from the historical

⁶ This means that specialists are far more reliant on transfer of data from site to site.

⁷ This did not always apply as some specialists insisted on a greater number of generic list items.

hydrological record;

- it is possible to describe the probable biophysical consequences of partial or whole removal of a particular element of the flow regime, in isolation;
- once these biophysical consequences have been described, it is possible to combine them in various ways to describe the overall impact on river condition of a range of potential flow regimes; and
- once the potential changes in river condition have been described, it is possible to describe their socio-economic implications.

DRIFT GENERIC LISTS

DRIFT generic lists are the items within each discipline for which predictions are made. Generic list items are items that must be able to change in quantity, i.e., they are the end result of functional changes related to flow changes but are not an expression of the functional changes themselves. Items that change in quantity may be, e.g., an area of a riffle, or the extent of riffle embeddedness; change in abundance of a species/genus/family or community of species/genus/family; or a change in the concentration of a chemical determinant. These items are chosen by the relevant specialists in discussion with the other specialists to ensure that information required by other specialists is included in the list of generic items (see Brown *et al.*, 2006a for more detail).

In addition to the generic lists, DRIFT utilises five categories to assist in providing the consequences of flow change (King *et al.*, 2003), these are:

Direction of change:	For each consequence, the direction of the predicted change (if any) must be described (+ or -).
Severity and integrity ratings:	For each consequence, the severity of the predicted change must be described in terms of a range from 1 to 5 (Table 3.1). This should be described in terms of a movement towards or away from the natural condition.
Expression of uncertainty:	This is expressed through the range of severity ratings for each consequence (0 to 5) (Table 3.1).
Likelihood:	This is an expression of the probability that the predicted change will occur and is expressed as high (H), medium (M), or low (L).
Data source:	This expresses the quality of data supporting each consequence. The data quality are rated as high (H), medium (M), or low (L) according to the following criteria: • recommendation is supported by peer reviewed published studies that are directly applicable to the river in question; • recommendation is supported by at least two of the following: peer reviewed published studies; unpublished data on the same process; and direct observations in the study river; and • recommendations made on the basis of anecdotal information and 'gut-feel'.

Table 3.1 Severity ratings for each prediction of flow-related change. Severity ratings convert directly from integrity ratings by adding a + (towards natural) or a – (away from natural) (after King *et al.*, 2003)

Severity rating	Severity of change	Equivalent loss	Equivalent gain
0	None	No change	No change
1	Negligible	80-100% retained	1-25% gain
2	Low	60-79% retained	26-76% gain
3	Moderate	40-59% retained	68-250% gain
4	Severe	20-39% retained	251-500% gain
5	Critically severe	0-19% retained	> 501% gain

DRIFT SOLVER

The DRIFT biophysical database template is a site-specific framework designed to receive information from specialists and to use this to predict the ecological consequences of future (altered) flow regimes. Once populated, the database provides a permanent record of flow-related information provided by the specialists for that particular system, and the pathway used to develop the flow scenarios is transparent, from information provided by the specialists through to the final scenarios.

The flow scenarios are generated, and evaluated in terms of river condition, using multi-criteria analysis (MCA).

There is one scenario creation worksheet, called DRIFT-SOLVER, wherein, the predictive data, represented by the Integrity Ratings are combined in a range of permutations to create scenarios. Each scenario consists of a flow regime (one change level from each of the flow categories) together with its predicted ecosystem changes.

Integrity Ratings for each Component linked to the flow change levels are summed, taking into account their positive and negative values, to produce an Overall DRIFT Integrity Score for each scenario. The objective of SOLVER is to maximise the Overall DRIFT Integrity Score, and in doing so describe the distribution of flows, within an available volume of water, that would result in the least damage to the riverine ecosystem.

DRIFT CATEGORY

DRIFT-CATEGORY is the scenario evaluation component of the DRIFT Database. It uses the results from DRIFT SOLVER and displays the relationship between the volume of water remaining in the river and river condition. This is displayed in a plot where the volume of water is either shown as MCM (Million cubic metres) or as % PD MAR (Percentage Present Day Mean Annual Runoff). More detail on the DRIFT-CATEGORY plots is provided in the results for each EWR site.

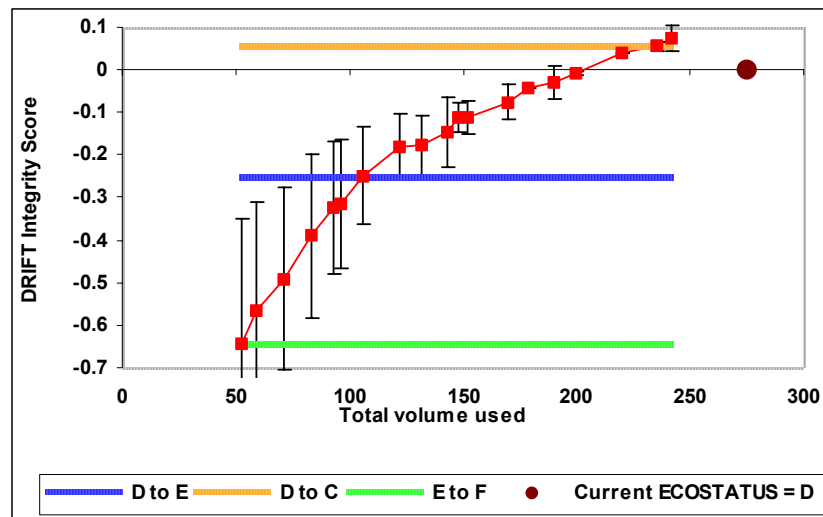


Figure 3.1 Example DRIFT Category plot

OBTAINING DATA AND CHECKING THE DRIFT SCENARIOS

The specialists provided their predictions on how the items on their generic lists are likely to change with the changes in flow during the River Workshop held in June 2007 in Wilderness. These were then entered into the DRIFT Database and used to generate the DRIFT scenarios presented in this report. The DRIFT scenarios for key sites were discussed with the specialists in a group session at the workshop, and adjusted if and where necessary.

3.2 RAPID I/II/III METHODS

The Rapid I, II and III methods differ from one another in terms of the effort allocated to data collection and analysis, with the level of detail increasing from I to III. In summary, the standard procedures for each are as follows:

- Rapid I: Usually done by one person. Site visit and a site-based habitat integrity, plus consideration of readily available information on the river, to set PES. Run Desktop for category based on habitat integrity.
- Rapid II: Similar to Rapid III, but without hydraulic information. A flow measurement is done during the site visit so that at least one point can be compared with the values generated by the Desktop.
- Rapid III: Usually done by a team of 3-4 people. Half-day site visit with fish and invertebrate specialists and a hydraulician. An EWR workshop, with same people plus a facilitator to guide the process, is then held to run the Desktop. The Desktop model is then verified and adjusted by using the hydraulics.

For this study, a couple of variations were applied, as follows:

- Rapid IIIs were upgraded to Intermediates (see Section 3.1).
- Rapid IIs: Full team consideration for the delineation, ecostatus assessments and Desktop adjustments. Plus, calibration of the Desktop using Intermediate data

generated for similar sites in the catchment (Table 3.2).

- Rapid Is: Vegetation and macroinvertebrate assessments for Ecostatus. Plus, full team calibration of the Desktop using Intermediate data generated for similar sites in adjacent catchments (Table 3.2).

Table 3.2 Actions making up the Rapid I and Rapid II Reserve assessments

ACTION	RAPID I	RAPID II
Site selection	Whole reach used	Facilitator selected sites
Specialist meeting	Half hour session for each site	Half hour session for each site
Report	Limited reporting – concentrating on ecostatus	Limited reporting – concentrating on ecostatus
Resource delineation	Desktop: map consultation	Desktop: map consultation
Habitat Integrity	Site based HI by botanist and macroinvertebrate ecologist	Site based Ecostatus assessment for geomorphology, water quality, vegetation, fish and macroinvertebrates by full team
Hydraulics	Flow measurement, comparison with DSS, expert system application	Flow measurement, comparison with DSS, expert system application
Hydrology	Present day and naturalised simulated monthly data	Present day and naturalised simulated monthly data
Geomorphology	None	Google Earth and maps, with longitudinal profiles
Fish	None	Selected surveys (one visit)
Aquatic invertebrates	SASS5	SASS5, plus other available (RHP) data. Calibrated with reference condition study
Riparian vegetation	Aerial assessment from helicopter	Field assessment by botanist
EWR assessment method	Desktop – calibrated using Intermediate level information from sites in nearby catchment	Desktop – calibrated using Intermediate level information from linked sites in the same catchment

3.3 EWR WORKSHOP

The EWR Workshop was held from 4th – 8th June 2007 at the Fairy Knowe Hotel in Wilderness. The agenda for the EWR Workshop is provided in Table 3.3.⁸ The following people attended the workshop proceedings:

EWR Facilitator: Dr Cate Brown
Hydraulics: Dr Andrew Birkhead
Water Quality: Dr Heather Malan
Vegetation: Dr Charlie Boucher
Macroinvertebrates: Mr Rembu Magoba
Fish: Mr Steven Lamberth
Management PSP: Mr Eugene Matthews
Management PSP: Ms Kirstin Botha
Management PSP: Ms Estelle van Niekerk
DWAF: Ms Barbara Weston
Study Manager: Ms Retha Stassen.

⁸ As with all workshop agendas, things did not go quite as planned and the team working late on several evenings.

Table 3.3 Agenda for the EWR Workshop

June 2007	Mon 4	Tues 5	Wed 6	Thurs 7	Fri 8
8:00 AM	Travel to Wilderness	Intermediate DRIFT - Background and procedures	EWR Malgas - Hydrology	EWR Goukamma - Hydrology	Charlie - presentation on Noetsie
8:15 AM			DRIFT Data Entry Malgas	DRIFT Data Entry Goukamma	Rapid I - Noetsie
8:30 AM		Finalisation of Generic Lists			
8:45 AM					
9:00 AM		EWR Kaaimans - Hydrology			
9:15 AM		DRIFT Data Entry Kaaimans			Completion of outstanding tasks
9:30 AM					
9:45 AM		TEA	TEA	TEA	TEA
10:00 AM		DRIFT Data Entry Kaaimans	DRIFT Data Entry Malgas	DRIFT Data Entry Goukamma	Hand over all specialist reports to Rembu Magoba
10:15 AM					Completion of outstanding tasks
10:30 AM					
10:45 AM					
11:00 AM					
11:15 AM					
11:30 AM					
11:45 AM					
12:00 PM					
12:15 PM					
12:30 PM					
12:45 PM					
1:00 PM	LUNCH	LUNCH	LUNCH	LUNCH	
1:15 PM					
1:30 PM	Introduction and welcome	DRIFT Data Entry Kaaimans	EWR Groot Brak - Hydrology	Rapid II Silver and Swart	Travel home
1:35 PM	Study area and levels of Reserve determination		DRIFT Data Entry Groot Brak		
1:50 PM	Workshop Programme - and procedures				
2:00 PM	ECOCCLASSIFICATION				
2:15 PM	Individual filling in of ECOSTATUS for Groot Brak				
2:30 PM					
2:45 PM					
3:00 PM					
3:15 PM	TEA	TEA	TEA	TEA	
3:30 PM	Individual filling in of ECOSTATUS for Malgas	DRIFT Data Entry Kaaimans/Presentation to observers on DRIFT Database and DRIFT Hydro (concurrent)	DRIFT Data Entry Groot Brak	Rapid II Moeras, Maalgate and Gwaing	
3:45 PM					
4:00 PM	Individual filling in of ECOSTATUS for Kaaimans				
4:15 PM					
4:30 PM	Individual filling in of ECOSTATUS for Goukamma				
4:45 PM					
5:00 PM	GROUP ECOSTATUS DISCUSSIONS FOR ALL SITES				
5:15 PM					
5:30 PM					
5:45 PM					
6:00 PM	Closure	Closure	Closure	Closure	

The geomorphologist, Dr Evan Dollar was not at the meeting as he has emigrated to England, however, he provided the consequences for the geomorphology generic list prior to the workshop. This is a normal occurrence, as the geomorphology consequences are determined on the basis of modelling, which needs to be done prior to the workshop (see Section 4.4).

4 SPECIALIST REPORTS

4.1 HYDROLOGY

4.1.1 Introduction

The data presented in this Section are generated from monthly data files provided by DWAF: Hydrological Services and those that were created as part of the *OUTENIQUA COAST WATER ASSESSMENT STUDY* (DWAF, 2007a).

As with all hydrological data the summaries provided in the section are designed for use to assess trends, and general principles. While every effort has been made to provide the best hydrological information on which to base the environmental flow determinations, it is essential that those using the data are aware of the inherent shortcomings thereof.

The daily hydrological data for the four sites at which Intermediate Reserve Determinations were generated by disaggregating the monthly data using nearby DWAF gauging weirs, as follows:

Groot Brak (GB 1):	Primary gauge: K1H009 on the Moordkuil River, K4H001 on the Hoëkraal River. Secondary gauge: K1H004 on the Brandwag River.
Kaaimans (Ka 1):	Primary gauge: K3H001 on the Kaaimans River at the site.
Malgas (Mal 1):	Primary gauge: K3H004 on the Malgas River, downstream of the site. Secondary gauge: K3H003 on the Maalgate River.
Goukamma (Gou 1):	Primary gauge: K4H001 on the Hoëkraal River at Eastbrook. Secondary gauge: K4H003 on the Diep River.

It is expected that the disaggregation of present day flows at the Kaaimans and Malgas Rivers are reasonably accurate, as they were based on observed records in the rivers of interest. However, for the Groot Brak and Goukamma Rivers because there are no gauging weirs in the catchment the records were disaggregated with observed records from nearby catchments, and this is likely to have yielded low confidence daily distributions. This is particularly true for the Groot Brak River, which has an impoundment upstream of the site and a flow diversion to Mossel Bay via the Searles Furrow. The expectation is that reductions in dry season lowflows and small dry season flood events will be under estimated, while the impact on the larger flood events may be over estimated, in the resultant present-day daily hydrological dataset.

Finally, the following flow data files were used:

- EWR Site GB 1: naturalised and present day monthly hydrology (WR90 Format);
naturalised and present day daily hydrology (Shands Format),
- EWR Site Ka 1: naturalised and present day monthly hydrology (WR90 Format);
naturalised and present day daily hydrology (Shands Format),
- EWR Site Mal 1: naturalised and present day monthly hydrology (WR90 Format);

- EWR Site Gou 1: naturalised and present day daily hydrology (Shands Format),
naturalised and present day monthly hydrology (WR90 Format);
naturalised and present day daily hydrology (Shands Format).

Monthly data are also available for the Rapid I/II sites. Present day and naturalised MAR for each site are provided at the end of this Section in Table 4.6.

4.1.2 DRIFT hydrological summary: Groot Brak River (GB 1)

MAR AND SEASONAL DISTRIBUTION

Please note that for the Groot Brak River (GB 1), the naturalised hydrological record was used as the basis for assessment, as opposed to the other sites where the present-day record was used. This is because there is a dam upstream of the GB 1 site and there was no suitable record to allow disaggregation of the present day record, and a diversion to Mossel Bay via Searles Furrow.

Present Day MAR = 10.16 MCM (54% of natural MAR)

Natural MAR = 18.74 MCM.

MAR AND SEASONAL DISTRIBUTION

Please see discussion in Section 4.1.3 re lowflow seasons.

Table 4.1 Monthly flows: GB1

Month	Nat (MCM)	PD (MCM)
Jan	1.433	0.719
Feb	0.983	0.448
Mar	1.632	0.888
Apr	2.110	1.245
May	1.362	0.783
Jun	0.687	0.311
Jul	0.882	0.371
Aug	1.597	0.894
Sep	1.552	0.861
Oct	2.442	1.384
Nov	2.270	1.355
Dec	1.795	0.902

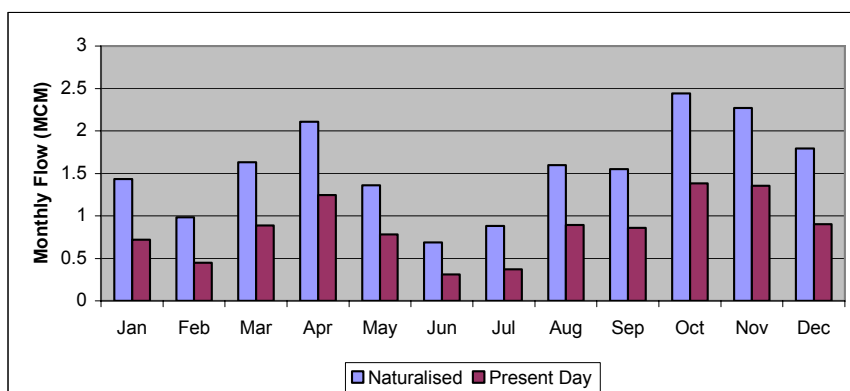


Figure 4.1 Monthly distribution of flow at Groot Brak River (GB 1) – present day and naturalised

SEASONS

The site showed a bi-modal distribution in rainfall, which leads to a similar distribution in runoff, as indicated in Figure 4.1.

The seasonal distribution was similar to that of the other sites, i.e., there were two wet seasons and two drier seasons, viz.:

- Wet season 1: March – May
- Wet season 2: August – November
- Dry season 1: June - July
- Dry season 2: December – February

The following division was applied (see explanation in Section 4.1.3):

- Summer: November – April
- Winter: May – October

It was decided to use summer and winter rather than wet or dry season because the lowflows do not differ appreciable in the two seasons (see explanation in Section 4.1.3).

The flow duration curves (FDCs) for the naturalised and present day records for these seasons are provided in Figure 4.2, Figure 4.3 and Table 4.2. These data are all the flows, i.e., including highflows and lowflows, and indicate the extent to which present day flows differ from naturalised.

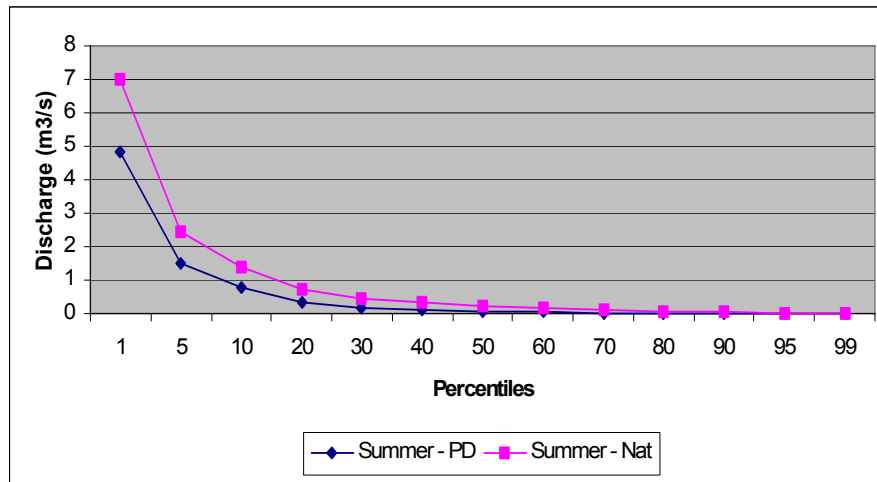


Figure 4.2 Flow duration curves for the full record for SUMMER at Groot Brak River (GB 1) – naturalised and present day

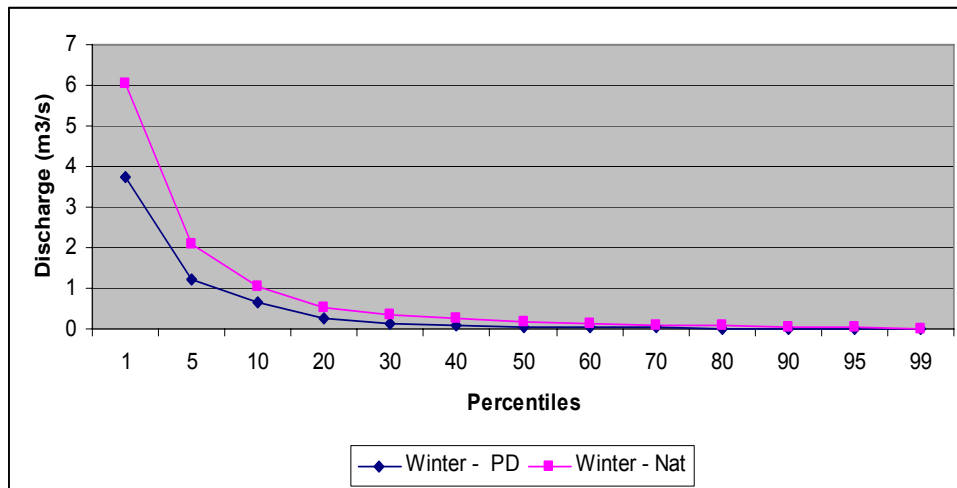


Figure 4.3 Flow duration curves for the full record for WINTER at Groot Brak River (GB 1) – naturalised and present day

Table 4.2 Monthly data: Duration curves for the FULL RECORD of summer and winter under naturalised and present day conditions at Groot Brak River (GB 1)

Percentiles		1	5	10	20	30	40	50	60	70	80	90	95	99	Volume (MCM)
Summer	PD	4.822	1.500	0.773	0.336	0.179	0.105	0.055	0.028	0.016	0.011	0.006	0.004	0.001	05.557
	NAT	6.980	2.457	1.375	0.719	0.462	0.321	0.227	0.152	0.094	0.056	0.030	0.019	0.003	10.222
Winter	PD	3.754	1.196	0.633	0.251	0.137	0.081	0.052	0.034	0.022	0.015	0.010	0.007	0.004	04.603
	NAT	6.046	2.099	1.062	0.539	0.342	0.247	0.181	0.138	0.105	0.077	0.051	0.035	0.016	08.521

LOWFLOW DISTRIBUTIONS

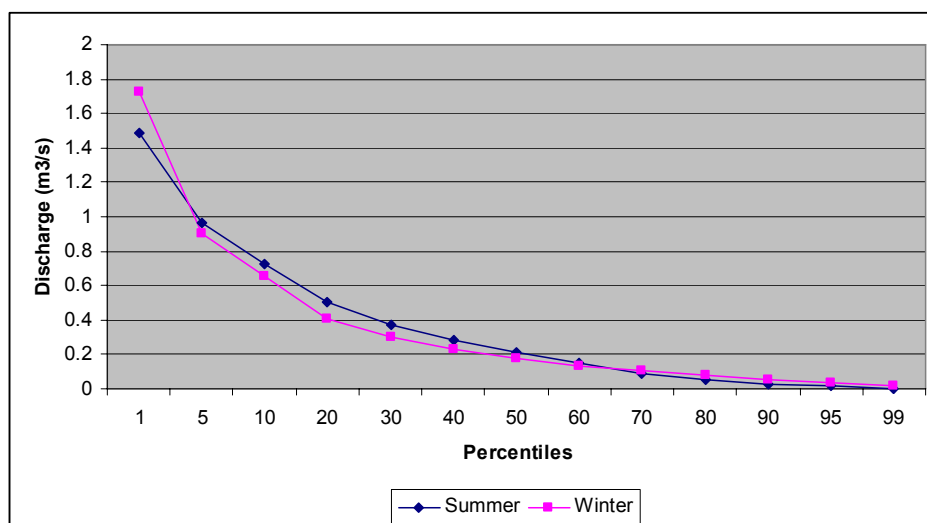


Figure 4.4 Lowflow FDCs at Groot Brak River (GB 1) - NATURALISED

INTRA-ANNUAL FLOODS – NATURALISED

Size classes for intra-annual floods (daily peak flow):

Class I = 0.75 – 1.25 m³/s

Class II = 1.26 – 2.50 m³/s

Class III = 2.51 – 5.00 m³/s

Class IV = 5.01 – 10.00 m³/s.

Monthly Distribution [#/annum]

Month	CI I	CI II	CI III	CI IV
Jan	0.27	0.50	0.27	0.12
Feb	0.50	0.35	0.15	0.12
Mar	0.38	0.35	0.31	0.27
Apr	0.35	0.58	0.31	0.23
May	0.12	0.27	0.23	0.04
Jun	0.08	0.12	0.12	0.08
Jul	0.19	0.12	0.04	0.15
Aug	0.23	0.23	0.12	0.19
Sep	0.23	0.15	0.35	0.12
Oct	0.42	0.54	0.31	0.27
Nov	0.38	0.31	0.23	0.15
Dec	0.54	0.38	0.38	0.12

Total of each class per annum 3.69 3.88 2.81 1.85

Note – There is no accurate Present Day record for the floods.

INTER-ANNUAL FLOODS - NATURALISED

Return period (in years)	Daily Peak (in cumecs)
2	11
5	22
10	40
20	64.

4.1.3 DRIFT hydrological summary: Kaaimans (Ka 1)

MAR AND SEASONAL DISTRIBUTION

Naturalised MAR = 13.46

Present Day MAR = 11.65 (i.e., 86% of natural)

Table 4.3 Monthly flows: Ka1

Monthly Flow [M.m3]	
Jan	0.802
Feb	0.737
Mar	1.083
Apr	1.124
May	0.936
Jun	0.618
Jul	0.633
Aug	1.086
Sep	1.088
Oct	1.400
Nov	1.219
Dec	0.913

The site showed a bi-modal distribution in rainfall, which leads to a similar distribution in runoff, as indicated in Figure 4.5.

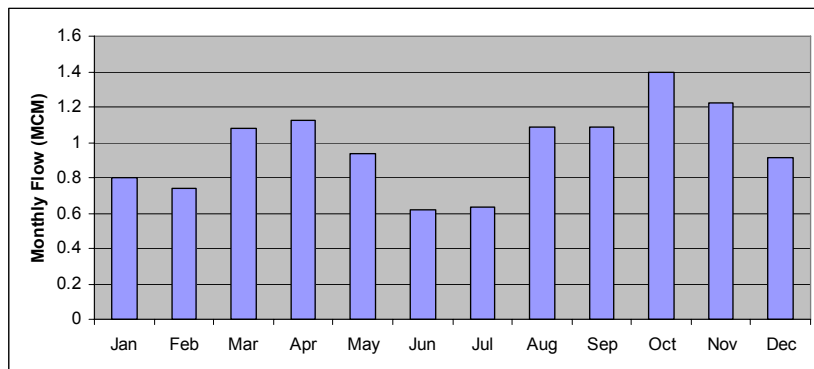


Figure 4.5 Monthly distribution of flow at Kaaimans River (Ka 1) – present day

This made it difficult to select a wet and a dry season. In fact, there are two wet seasons and two drier seasons, viz.:

Wet season 1: March – May
Wet season 2: August – November
Dry season 1: June – July
Dry season 2: December – February.

However, once the highflows had been separated from the lowflows, there was very little intra-annual difference between the lowflows, i.e., all months showed a similar distribution (Figure 4.6 and Figure 4.7). For this reason, the record was divided into:

Summer: November – April
Winter: May – October.

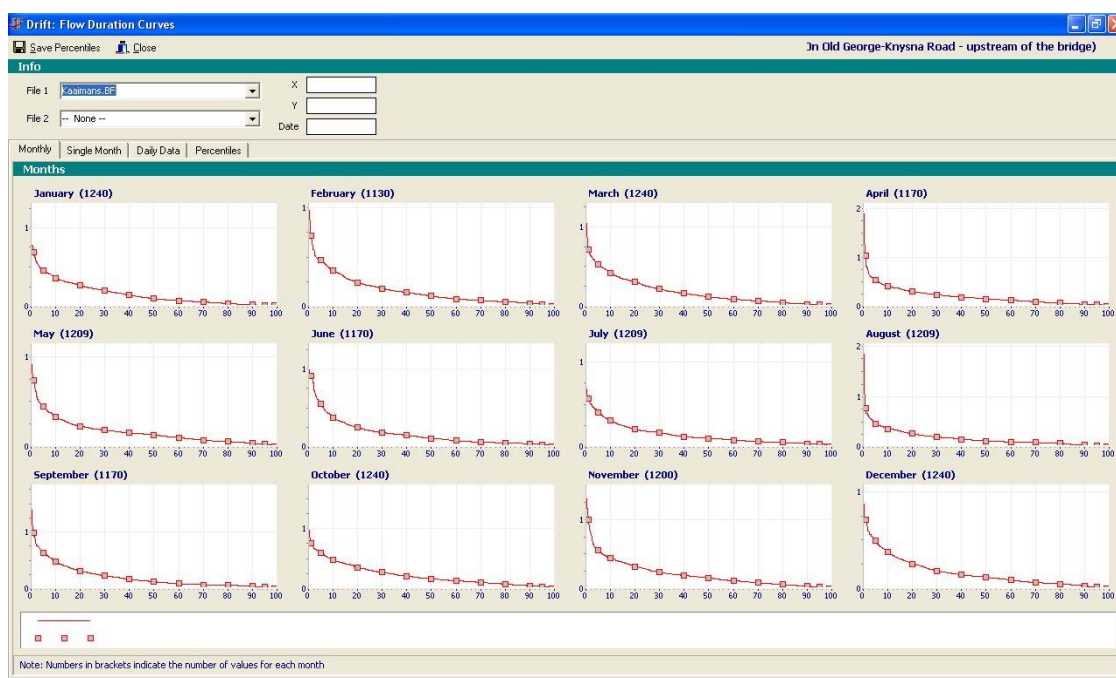


Figure 4.6 Lowflow monthly FDCs for Kaaimans River (Ka 1) – individual months

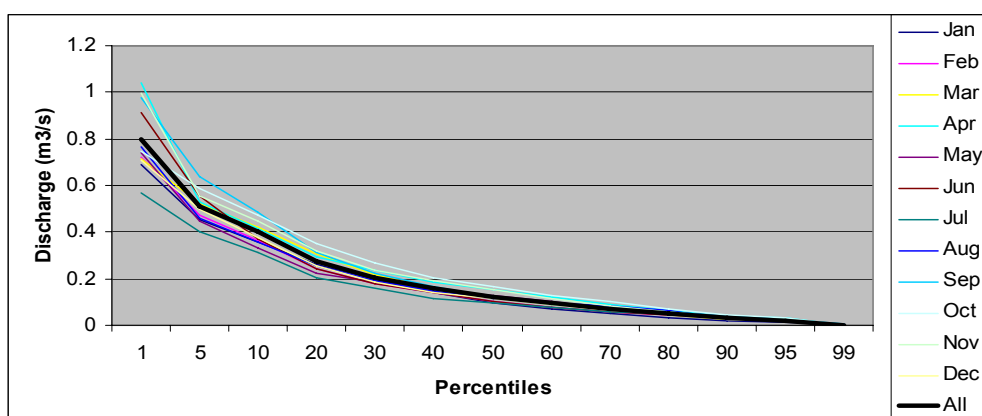


Figure 4.7 Lowflow monthly FDCs for Kaaimans River (Ka 1) – all months

LOWFLOW DISTRIBUTIONS

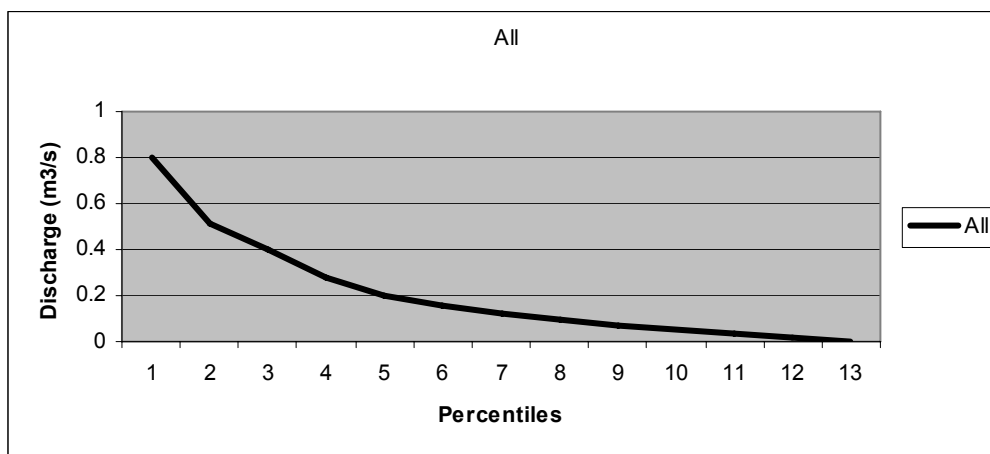


Figure 4.8 Lowflow FDC for Kaaimans River (Ka 1) – all years and months combined (0 – 0.8 m³ s⁻¹)

INTRA-ANNUAL FLOODS

Size classes for intra-annual floods (daily peak flow):

Class I = 0.80 – 1.60 m³/s

Class II = 1.61 – 3.20 m³/s

Class III = 3.21 – 6.30 m³/s

Class IV = 6.31 – 12.60 m³/s.

Monthly Distribution [#/annum]

Month	CI I	CI II	CI III	CI IV
Jan	0.42	0.38	0.10	0.08
Feb	0.35	0.30	0.30	0.05
Mar	0.57	0.33	0.28	0.08
Apr	0.56	0.31	0.08	0.18
May	0.21	0.18	0.13	0.03
Jun	0.23	0.13	0.15	0.00
Jul	0.21	0.13	0.10	0.05
Aug	0.33	0.10	0.18	0.08
Sep	0.28	0.23	0.13	0.10
Oct	0.50	0.33	0.23	0.08
Nov	0.35	0.23	0.28	0.08
Dec	0.38	0.35	0.23	0.08
Total of each class per annum	4.40	2.98	2.17	0.86

INTER-ANNUAL FLOODS

Return period (in years)	Daily Peak (in cumecs)
2	14
5	28
10	34
20	37.

NATURALISED FLOWS

There was little difference between naturalised and present day flows at Ka 1 (Figure 4.9).

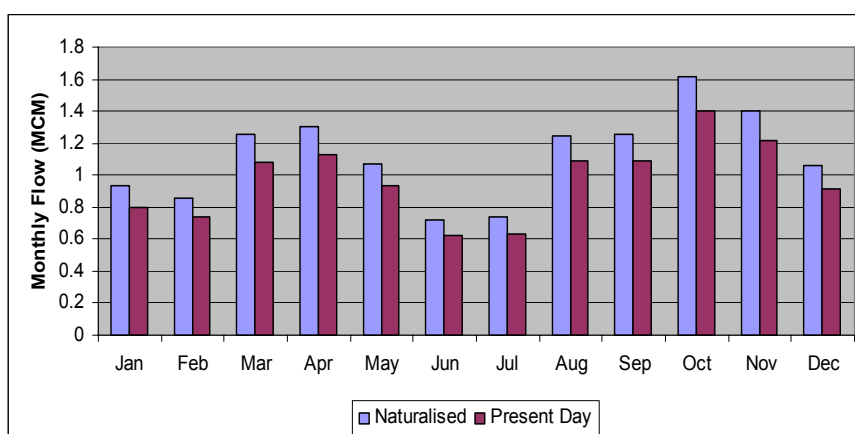


Figure 4.9 Monthly distribution of flow at for Kaaimans River (Ka 1) – present day and naturalised

4.1.4 DRIFT hydrological summary: Malgas River (Mal 1)

MAR AND SEASONAL DISTRIBUTION

Natural MAR = 10.86 MCM.

Present Day MAR 8 MCM (74% of natural MAR).

Table 4.4 Monthly flows : Mal 1

Jan	0.437
Feb	0.446
Mar	0.730
Apr	0.729
May	0.588
Jun	0.363
Jul	0.370
Aug	0.688
Sep	0.644
Oct	0.857
Nov	0.743
Dec	0.507

SEASONS

The site showed a bi-modal distribution in rainfall, which leads to a similar distribution in runoff, as indicated in Figure 4.10.

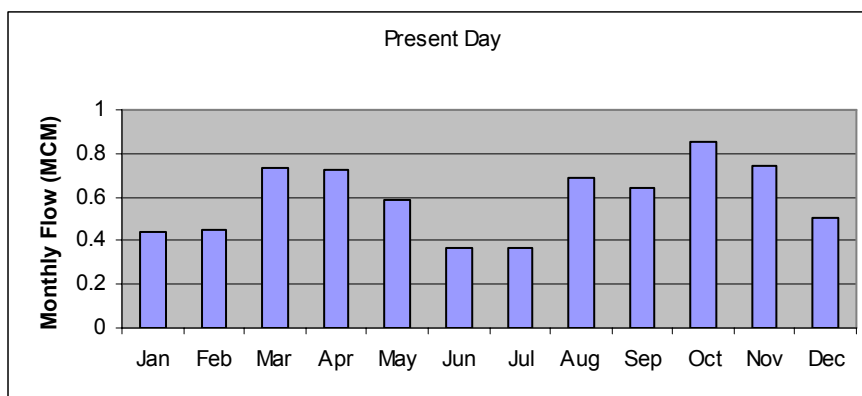


Figure 4.10 Monthly distribution of flow at Malgas River (Mal 1) – present day

As was the case for the Kaaimans River (Ka 1), it was difficult to select a wet and a dry season (Figure 4.11). In fact, there were two wet seasons and two drier seasons, viz.:

- Wet season 1: March – May
- Wet season 2: August – November
- Dry season 1: June – July
- Dry season 2: December – February.

The following division was applied (Figure 4.12):

- Summer: November – April
- Winter: May-October.

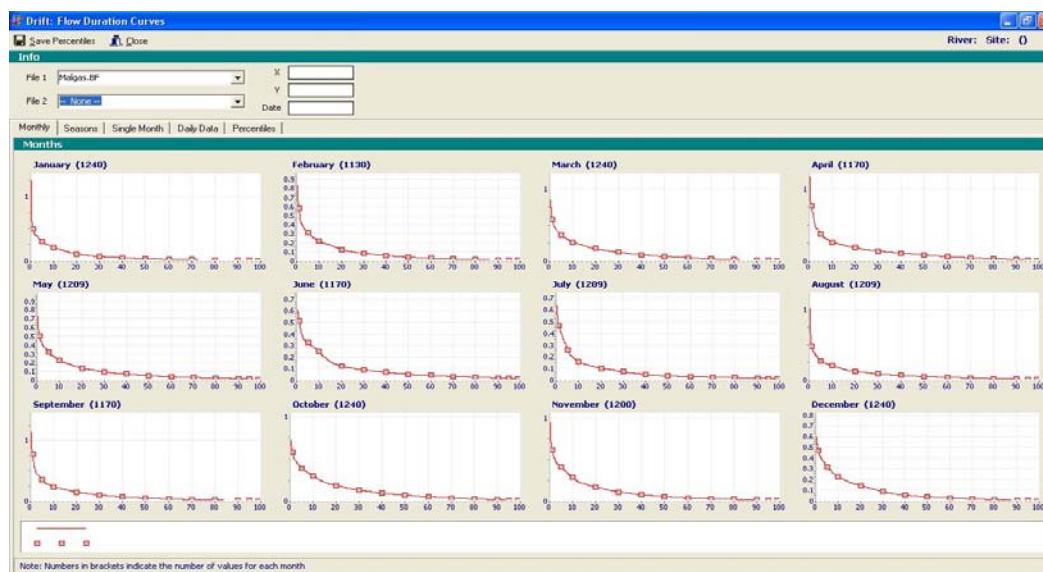


Figure 4.11 Lowflow monthly FDCs for Malgas River (Mal 1) – individual months

LOWFLOW DISTRIBUTIONS

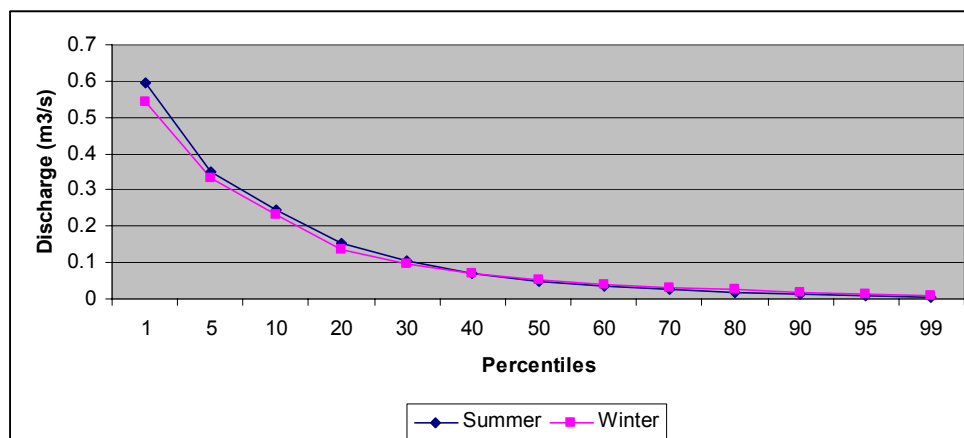


Figure 4.12 Lowflow FDCs for Malgas River (Mal 1)

INTRA-ANNUAL FLOODS

Size classes for intra-annual floods (daily peak flow):

Class I = 0.75 – 1.25 m³/s

Class II = 1.26 – 2.50 m³/s

Class III = 2.56 – 5.00 m³/s

Class IV = 5.01 – 10.00 m³/s.

Month	CI I	CI II	CI III	CI IV
Jan	0.57	0.28	0.15	0.00
Feb	0.55	0.33	0.28	0.03
Mar	0.60	0.65	0.25	0.10
Apr	0.74	0.18	0.15	0.21
May	0.28	0.23	0.08	0.03
Jun	0.28	0.21	0.10	0.00
Jul	0.21	0.18	0.05	0.13
Aug	0.33	0.13	0.18	0.08
Sep	0.41	0.10	0.26	0.05
Oct	0.82	0.33	0.17	0.13
Nov	0.53	0.40	0.20	0.08
Dec	0.53	0.20	0.15	0.08
Total of each class per annum	5.86	3.20	2.02	0.89

INTER-ANNUAL FLOODS

Return period (in years)	Daily Peak (in cumecs)
2	11
5	23

10 26
20 34.

NATURALISED FLOWS

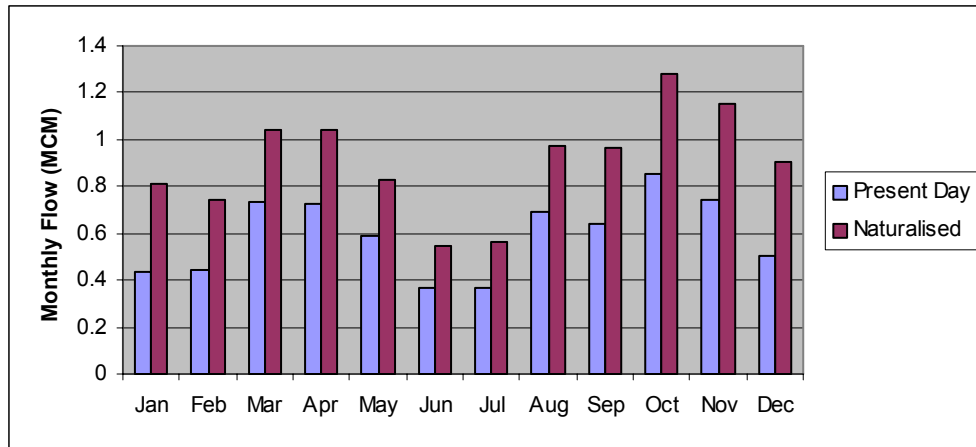


Figure 4.13 Monthly distribution of flow at Malgas River (Mal 1) – present day and naturalised

4.1.5 DRIFT hydrological summary: Goukamma River (Gou 1)

MAR AND SEASONAL DISTRIBUTION

Naturalised MAR = 26.6 MCM

Present Day MAR = 23.1 MCM (i.e., 86% of natural).

Table 4.5 Monthly flows: Gou 1

Month	MCM
Jan	1.256
Feb	1.108
Mar	1.854
Apr	2.131
May	2.030
Jun	1.486
Jul	1.522
Aug	2.236
Sep	2.294
Oct	2.990
Nov	2.568
Dec	1.679

SEASONS

The site showed a bi-modal distribution in rainfall, which leads to a similar distribution in runoff, as indicated in Figure 4.14.

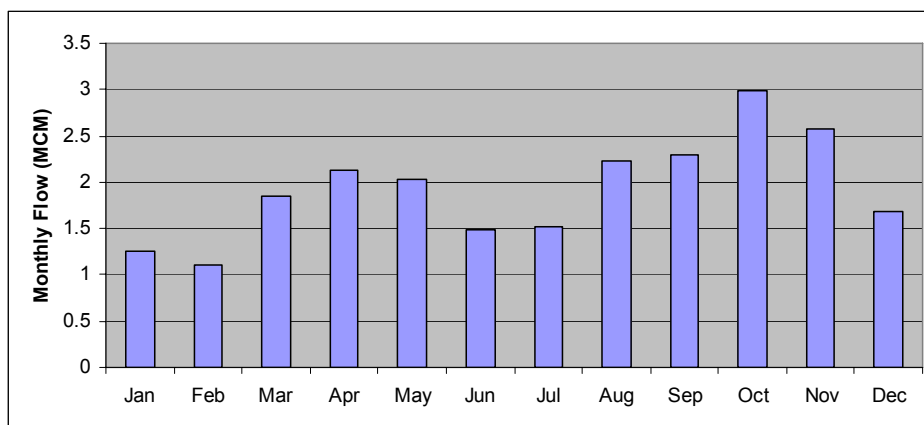


Figure 4.14 Monthly distribution of flow at Goukamma River (Gou 1) – present day

The seasonal distribution was similar to that of the Kaaimans (Ka 1) and Malgas (Mal 1) River sites, i.e., there were two wet seasons and two drier seasons, viz.:

Wet season 1: March – May
Wet season 2: August – November
Dry season 1: June – July
Dry season 2: December – February.

The following division was applied (Figure 4.15):

Summer: November – April
Winter: May–October.

LOWFLOW DISTRIBUTIONS

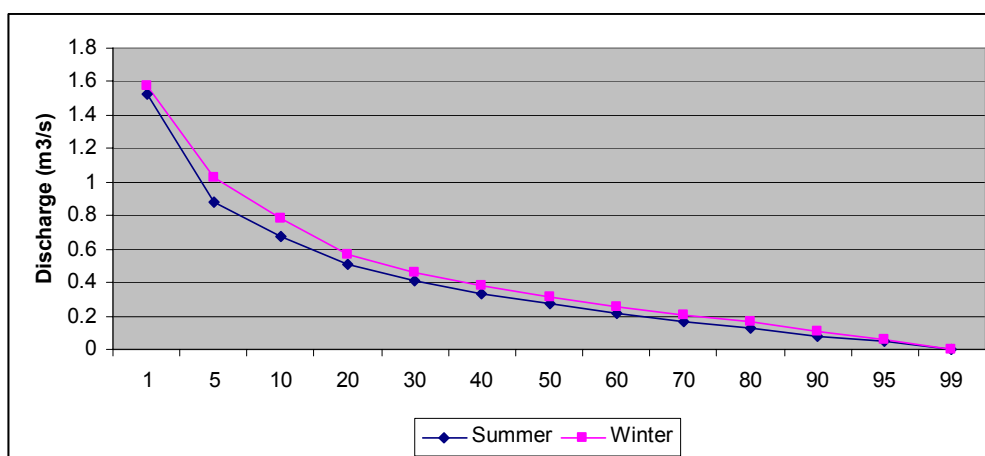


Figure 4.15 Lowflow FDCs for Goukamma River (Gou 1)

INTRA-ANNUAL FLOODS

Size classes for intra-annual floods (daily peak flow):

Class I = 1.24 – 2.59 m³/s

Class II = 2.60 – 5.18 m³/s

Class III = 5.19 – 10.35 m³/s

Class IV = 10.36 – 20.07 m³/s.

Monthly Distribution [#/annum]				
Month	CI I	CI II	CI III	CI IV
Jan	0.54	0.17	0.12	0.02
Feb	0.68	0.12	0.17	0.07
Mar	0.71	0.29	0.15	0.10
Apr	0.37	0.22	0.12	0.10
May	0.29	0.12	0.10	0.05
Jun	0.23	0.15	0.10	0.05
Jul	0.33	0.08	0.03	0.08
Aug	0.35	0.20	0.10	0.13
Sep	0.35	0.23	0.10	0.05
Oct	0.57	0.38	0.10	0.25
Nov	0.45	0.15	0.17	0.15
Dec	0.38	0.28	0.08	0.08
Total of each class per annum	5.24	2.38	1.33	1.12

Note – that these are average frequencies for the whole record since 1961. The record was disaggregated with the observed data from the weir and it is apparent from that record that the Class 1 floods HAVE REDUCED IN FREQUENCY over the last 20 years or so. For the last 10 years, their frequency has been about 5 per annum.

INTER-ANNUAL FLOODS

Return period (in years)	Daily Peak (in cumecs)
2	23
5	50
10	67
20	100

NATURALISED FLOWS

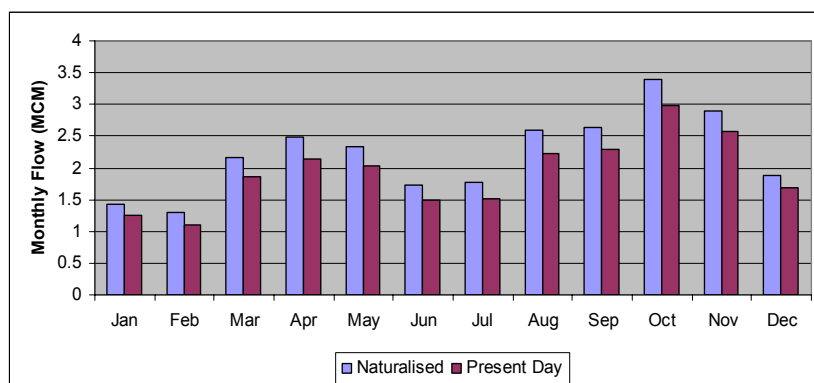


Figure 4.16 Monthly distribution of flow at Goukamma River (Gou 1) – present day and naturalised

4.1.6 Hydrological summaries for the Rapid sites

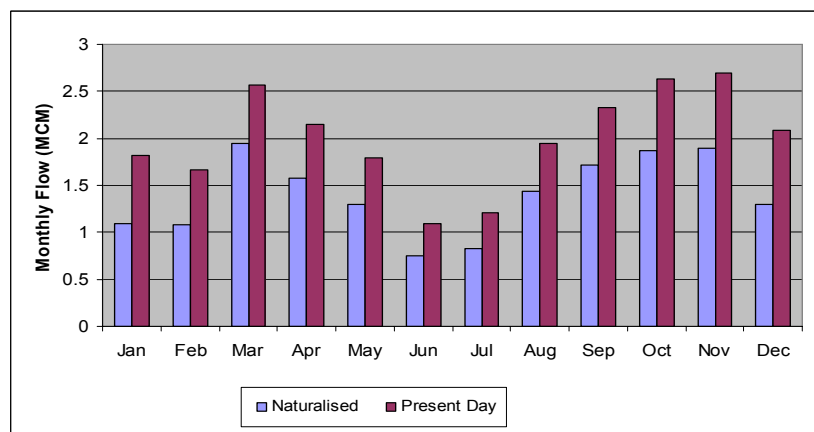


Figure 4.17 Present Day and Naturalised Monthly Flow – Gwaing River (Gwa 1)

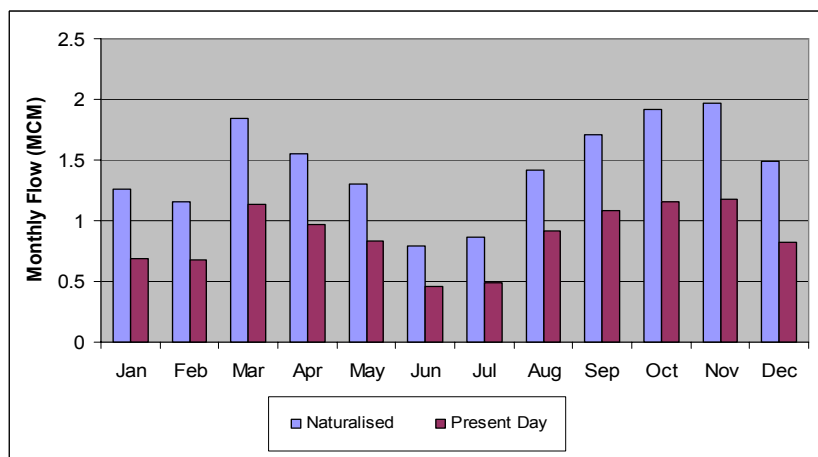


Figure 4.18 Present Day and Naturalised Monthly Flow – Maalgate River (Maa 1)

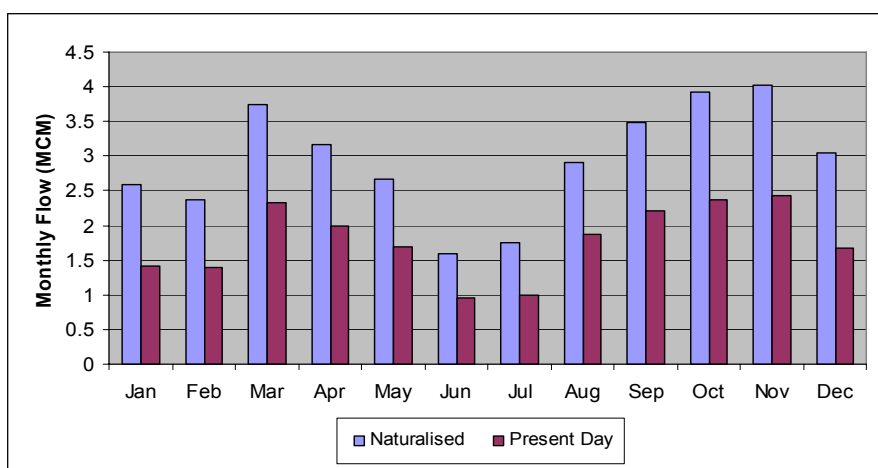


Figure 4.19 Present Day and Naturalised Monthly Flow – Maalgate River (Maa 2)

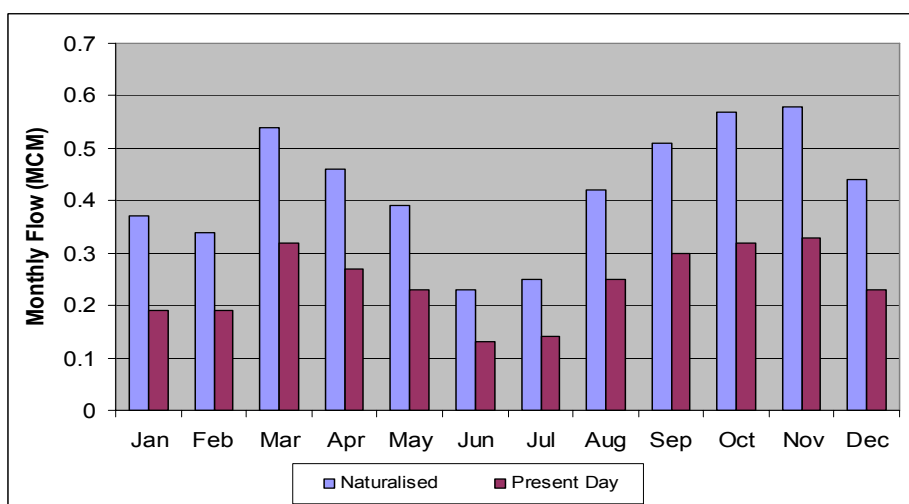


Figure 4.20 Present Day and Naturalised Monthly Flow – Moeras River (Moe 1)

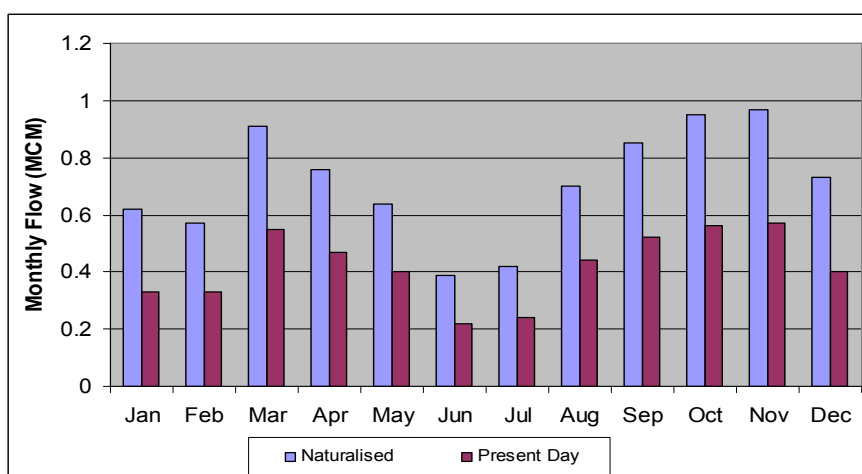


Figure 4.21 Present Day and Naturalised Monthly Flow – Moeras River (Moe 2)

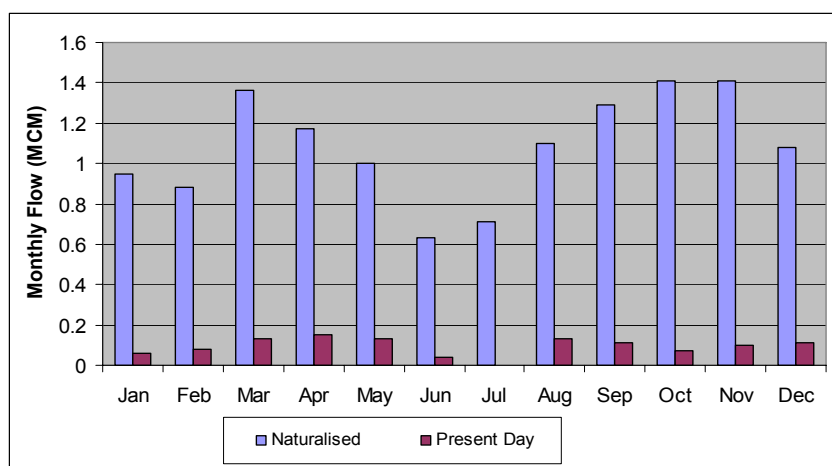


Figure 4.22 Present Day and Naturalised Monthly Flow – Swart River (Sw 1)

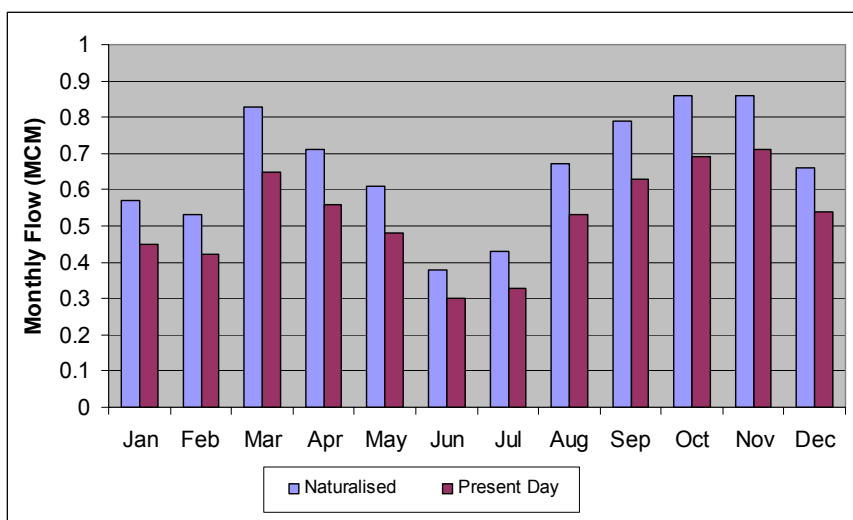


Figure 4.23 Present Day and Naturalised Monthly Flow – Silver River (Si 1)

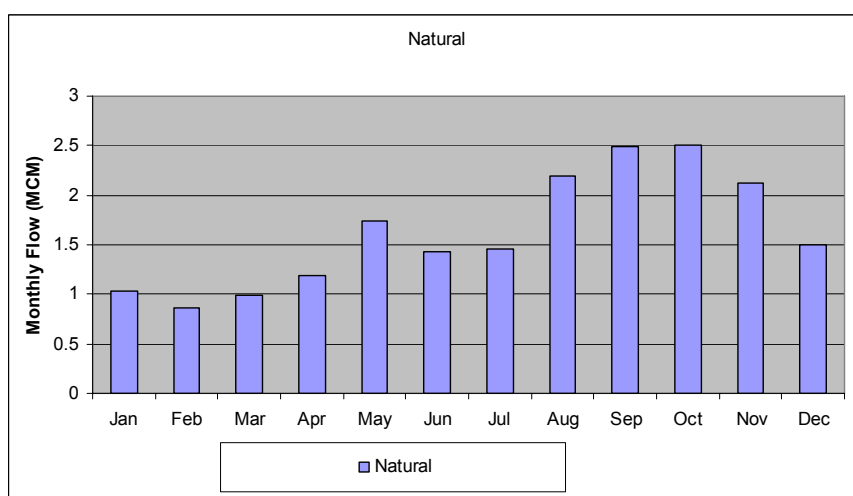


Figure 4.24 Naturalised Monthly Flow – Noetsie River (Noe 1)

Table 4.6 Summary of nMAR and pdMAR for all study sites

River	EWR Site	NMAR (MCM)	pdMAR (MCM)	pdMAR as % nMAR
Groot Brak	GB 1	18.74	10.16	54
Maalgate	Maa 2	35.26	21.32	60
Moeras	Moe 1	5.11	2.89	57
	Moe 2	8.53	5.03	59
Malgas	Mal 1	10.86	8.00	84
Gwaing	Gwa 1	16.80	24.02	143
Swart	Sw 1	12.99	1.11	9
Kaaimans	Ka 1	13.46	11.65	86
Silver	Si 1	7.90	6.28	79
Goukamma	Gou 1	26.60	23.10	86
Noetsie	Noe 1	6.40	unknown	unknown
Moordkuil	Moo 1	34.01	unknown	unknown

4.2 HYDRAULICS

4.2.1 Introduction

The role of hydraulics and the procedures for generating hydraulic information for EWR studies have been documented for various levels of determination (DWAF, 1999), with subsequent periodic updates (Birkhead, 2002 and Jordanova *et al.*, 2004). This section provides the hydraulic information (methods, modelling and results) for the sites on the Groot Brak (GB 1), Kaaimans (Ka 1), Malgas (Mal 1) and Goukamma (Gou 1) Rivers, i.e., those sites for which Intermediate Reserve Determinations were done.

The application of holistic methods for ecological flow determinations (Tharme, 1996) requires water requirements to be expressed as discharge rates (including their temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling of sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments, to be the most useful:

- depth (maximum and average);
- velocity (average);
- wetted perimeter, and;
- width of the water surface.

4.2.2 Methods

The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (Rowlston *et al.*, 2000; Birkhead, 2002 for descriptions of procedures for deriving hydraulic information for use in ecological flow requirements, or Ecological Reserves in South Africa). Once the rating

relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (Section 4.2.5).

The cross-sectional profile plots and look-up tables comprise the “standard hydraulic data” used in EWR determinations. Ecologists use these standard hydraulic data with the aid of site assessments, photographs and video exposure, to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat, e.g., hydraulic, substratum and cover attributes for fish). For this reason, a procedure has been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (see Jordanova *et al.* (2004) for a detailed explanation of the method). The probability distribution model of Lamouroux *et al.* (1995) is used to predict frequency-velocity distributions as a function of average depth and average velocity (derived from the cross-section) and the “dominant” substratum size (taken as the d_{84}). The substratum characteristics for each of the EWR sites are provided in Table 4.9.

The habitat-types for fish are defined in terms of depth and depth-averaged velocity, and for invertebrates in terms of depth-averaged velocity and substratum size (fine or coarse with a 16mm (coarse gravel) threshold). The probability distribution of habitat types predicted for the run and riffle at the site assume that depth, velocity and substratum are independent variables.

4.2.3 Data collection

Fixed stations were installed at the EWR sites using local datums (Table 4.8). Two cross-sections were surveyed at the Groot Brak River (GB 1, bedrock step and pool), and one cross-section each at the remaining river sites on the Kaaimans River (Ka 1, bedrock step), Malgas River (Mal 1, boulder bed) and Goukamma River (Gou 1, cobble riffle). The measured discharges and flow depths are provided in Table 4.7, together with the dates when the data were collected.

Photographs of the low-flow channels where the cross-sections were surveyed are provided in Figure 4.25 to Figure 4.28 for the four EWR sites for which Intermediate Reserve Determinations were undertaken.

Table 4.7 Hydraulic data collected at the EWR sites

River	Site no.	Date	Discharge Q (m ³ /s)	Max. flow depth y (m)	
				Cross-section A	Cross-section B
Groot Brak	GB 1	21/3/2007	0.21	0.34	0.81
		21/4/2007	0.052	0.26	0.71
Kaaibmans	Ka 1	22/3/2007	0.12	0.42	
		21/4/2007	0.066	0.34	
Malgas	Mal 1	20/3/2007	0.18		
		21/3/2007	0.14	0.43	
		21/4/2007	0.068	0.38	
Goukamma	Gou 1	19/3/2007	0.48	0.35	
		22/3/2007	0.29	0.29	
		21/4/2007	0.21	0.21	

Table 4.8 Fixed survey stations at the EWR sites

River	Site no.	Station	Co-ordinates (local datum)		Hz (decimal degrees) rel. to cross-section (0°)	Eald (m)
			X (m)	Y (m)		
Groot Brak	GB 1	RBBM1(MOR)	NA	NA	Setup	100.00
		LBBM2(PIC)			180.00	100.61
Kaaibmans	Ka 1	RBBM1(MOR)	NA	NA	Setup	100.00
		RBBM2(MOR)			240.32	101.58
Malgas	Mal 1	LBBM1(PIC)	NA	NA	Setup	100.00
		LBBM2(MOR)			17.62	99.87
		LBBM3(MOR)			177.40	100.29
Goukamma	Gou 1	LBBM1(MOR)	NA	NA	Setup	100.00
		LBBM2(MOR)			175.89	100.35
		LBBM3(MOR)			150.61	105.28

RB: Right Bank

LB: Left Bank

Eald: Elevation above local datum

PIC: Peg in concrete

MOR: Mark on rock (painted)

Hz: Horizontal

Table 4.9 Substratum characteristics at the EWR sites

River	Site no.	Cross-section	d_{84} (m)	Substratum composition (%)		
				< 16 mm	> 16 mm	Bedrock
Groot Brak	GB 1	A	0.15 ⁹	20(0.26 m)	40(0.26 m)	40(0.26 m)
				70(2 m)	12(2 m)	18(2 m)
Malgas	Mal 1	A	0.30	20(0.43 m)	80(0.43 m)	0
				50 (2 m)	50(2 m)	0
Kaaimans	Ka 1	A	0.05 ¹	20	30	50 ¹⁰
Goukamma	Gou 1	A	0.20	20(0.21 m)	80(0.21 m)	0(0.21 m)
				35(2 m)	60(2 m)	5(2 m)

(x) max. flow depth in metres



Figure 4.25 View of the bedrock step (cross-section A) at site GB 1 on the Groot Brak River for a discharge of 0.052 m³/s (maximum depth of 0.26 m), showing the substratum composition of the bed (boulder/cobble)

⁹ difficult to define: bedrock step with cobble/gravel

¹⁰ takes account of in-channel step & left bank bedrock



Figure 4.26 View of the bedrock step at EWR site Ka 1 on the Kaaimans River (Ka 1) for a discharge of $0.066 \text{ m}^3/\text{s}$ (maximum depth of 0.34 m), showing the substratum composition of the bed (bedrock and cobble)



Figure 4.27 View across the river at the Malgas River (Mal 1) taken from the left bank for a discharge of $0.068 \text{ m}^3/\text{s}$ (maximum depth of 0.38 m), showing the substratum composition of the bed (boulder/cobble)



Figure 4.28 View across the cobble bed river at the EWR site (Gou 1) on the Goukamma River (Gou 1) taken from the left bank for a discharge of 0.21 m³/s (maximum depth of 0.21 m), showing the substratum composition of the bed (boulder/cobble).

4.2.4 Modelling

The observed rating data at the EWR sites have been extended using Manning's resistance relationship. The surveyed water surface and regional (1:50000 topographical) channel slopes are given in Table 4.10 and Table 4.11, and these have been used in conjunction with estimates of Manning's resistance coefficient (Table 4.12) to synthesize rating data for discharges higher than those measured. Continuous rating functions of the form given by Equation A1 have been fitted to the measured and modelled data, and these are plotted in Figure 4.34 to Figure 4.37 for the relevant cross-sections.

$$Q = ayb + c$$

Equation A1

where y is the flow depth (m), Q is the discharge (m³/s), and a , b and c are regression coefficients, listed in Table 4.13.

Use of the rating function (equation A1 with coefficients provided in Table 4.13) may result in modelled conditions at low-flows (lower than that measured – refer to Table 4.7) where the implied resistance coefficient is unrealistically low. To address this, a resistance computation is preferable when the implied resistance coefficients (using the rating function, i.e., equation A1) are less than specified (estimated) values. This is the case for the stage-discharge computations at the EWR sites on the Groot Brak and Kaaimans Rivers for depth (maximum) ranges of 0.08 m to 0.26 m and 0.22 m to 0.28 m, respectively. For these depth ranges, the modelled lookup data in Table 4.15 and Table 4.18 is preferable to the use of equation 1.

Table 4.10 Regional 1:50 000 channel slope

River	Site no.	Channel slope
Groot Brak	GB 1	0.013
Kaaimans	Ka 1	0.011
Malgas	Mal 1	0.013
Goukamma	Gou 1	0.010

Table 4.11 Surveyed water surface slopes

River	Site no.	Discharge (m ³ /s)	Cross-section	Water surface slope ¹¹
Groot Brak	GB 1	0.052 0.21	A	0.012(10), 0.011(78) 0.007(17) ¹²
Kaaimans	Ka 1	0.066 0.12	A	0.005(101) 0.0038(18)
Malgas	Mal 1	0.068 0.14	A	0.029(31) 0.023(10)
Goukamma	Gou 1	0.21 0.24	A	0.010(26), 0.003(107) 0.011(17)

(x) distance over which slope surveyed (m)

Table 4.12 Hydraulic data used to extend the measured rating data

River	Site no.	Cross-section	Discharge (m ³ /s)	Manning's resistance n^{13}	Max. flow depth y (m)	Energy slope S	Ave. velocity v (m/s)
Groot Brak	GB 1	A	0.052	0.164	0.26	0.012	1.76
			0.21	0.077	0.34	0.012	
			54	0.05	2.0	0.011	
			222	0.45	3.0	0.011	
Kaaimans	Ka 1	A	0.066	0.055	0.34	0.0038	0.30
			0.12	0.060	0.42	0.0038	
			14	0.045	1.5	0.0050	
			238	0.035	4.0	0.0050	
Malgas	Mal 1	A	0.068	0.43	0.38	0.029	0.12
			0.14	0.30	0.43	0.023	
			5.8	0.10	1.0	0.025	
			71	0.045	2.0	0.020	
			236	0.045	3.5	0.015	
Goukamma	Gou 1	A	0.21	0.077	0.21	0.010	0.30
			0.29	0.073	0.24	0.011	
			0.48	0.076	0.27	0.011	
			57	0.038	2.0	0.0030	
			318	0.040	4.0	0.0030	

Italic – modelled
¹¹ used to extend the measured rating data using Manning's resistance equation

¹² include backup along pools

¹³ determined by calibration of measured rating data.

Table 4.13 Regression coefficients in Equation A1

River	Site no.	Discharge Q (m ³ /s)	Cross-section	Rating coefficients ¹⁴			
				a	b	c relative to	
						bed	local datum
Groot Brak	GB 1	all	A - step	0.576	0.311	0.005	98.76
		all	B – run/pool	0.539	0.312	0.500	98.71
Kaaimans	Ka 1	<12.5	A	0.740	0.270	0.000	99.41
		>12.5		0.620	0.340	0.000	99.41
Malgas	Mal 1	<34.8	A	0.684	0.216	0.000	98.49
		>34.8		0.162	0.541	0.367	98.85
Goukamma	Gou 1	<0.27	A	0.337	0.292	0.000	99.32
		>0.27		0.390	0.404	0.000	99.32

4.2.5 Results

CROSS-SECTIONAL PROFILES

The cross-section profiles for the sites are provided in Figure 4.29 to Figure 4.33.

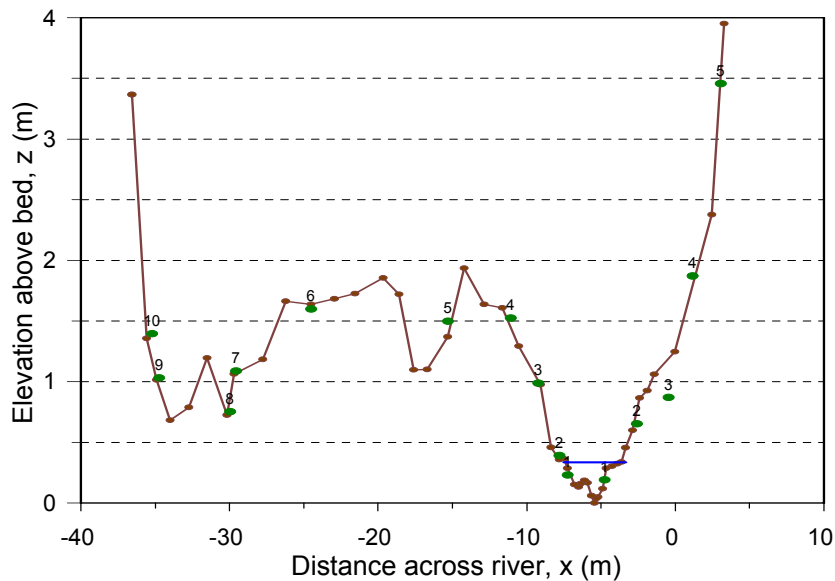


Figure 4.29 Cross-sectional profile through the step on the Groot Brak River (GB 1), showing the water level surveyed on 21/3/2007 ($Q = 0.21 \text{ m}^3\text{s}^{-1}$; numbers indicate vegetation zones)

¹⁴ determined by regressing modelled data and measured rating data.

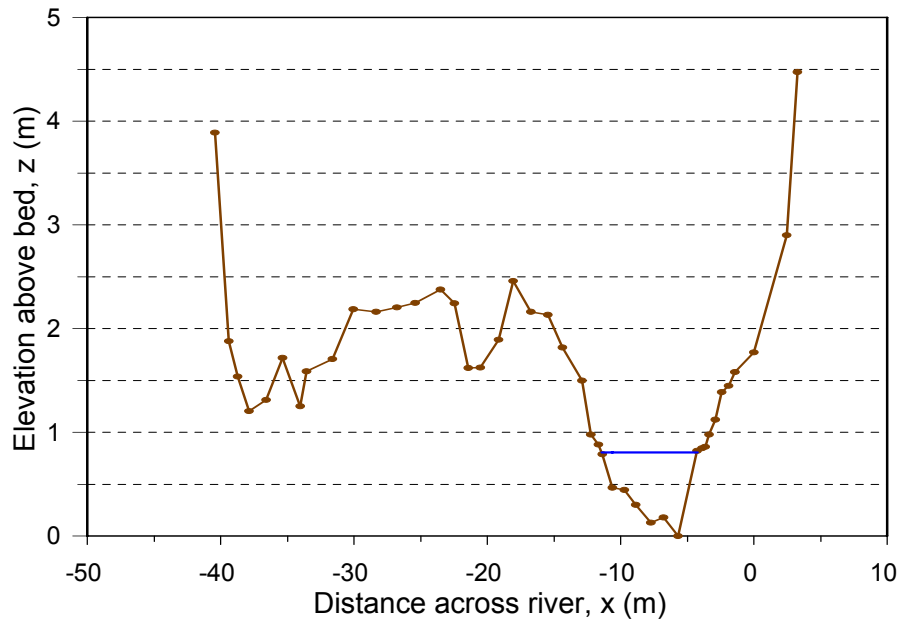


Figure 4.30 Cross-sectional profile through the pool on the Groot Brak River (GB 1), showing the water level surveyed on 21/3/2007 ($Q = 0.21 \text{ m}^3\text{s}^{-1}$)

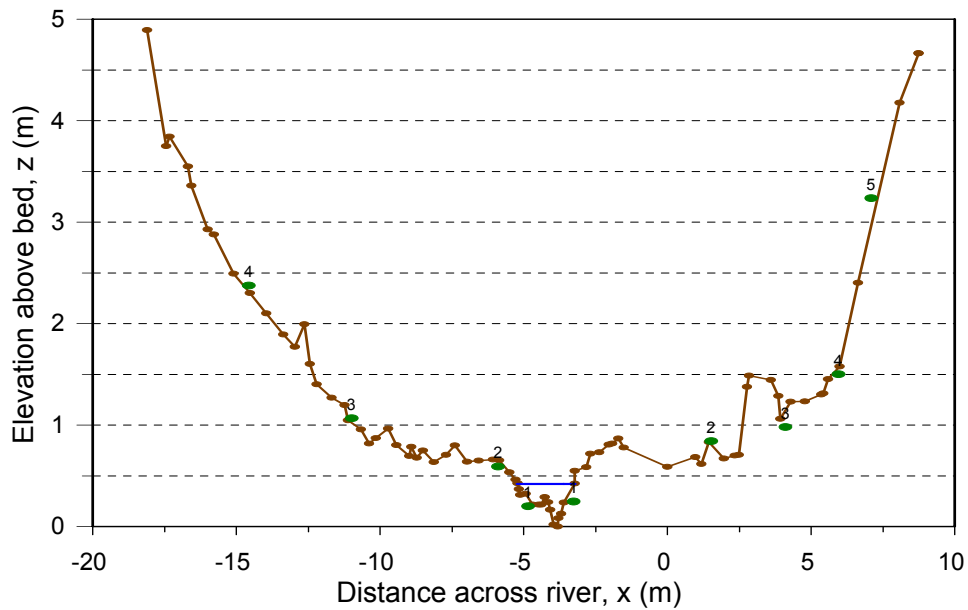


Figure 4.31 Cross-sectional profile through the step on the Kaaimans River (Ka 1), showing the water level surveyed on 22/3/2007 ($Q = 0.12 \text{ m}^3\text{s}^{-1}$; numbers indicate vegetation zones)

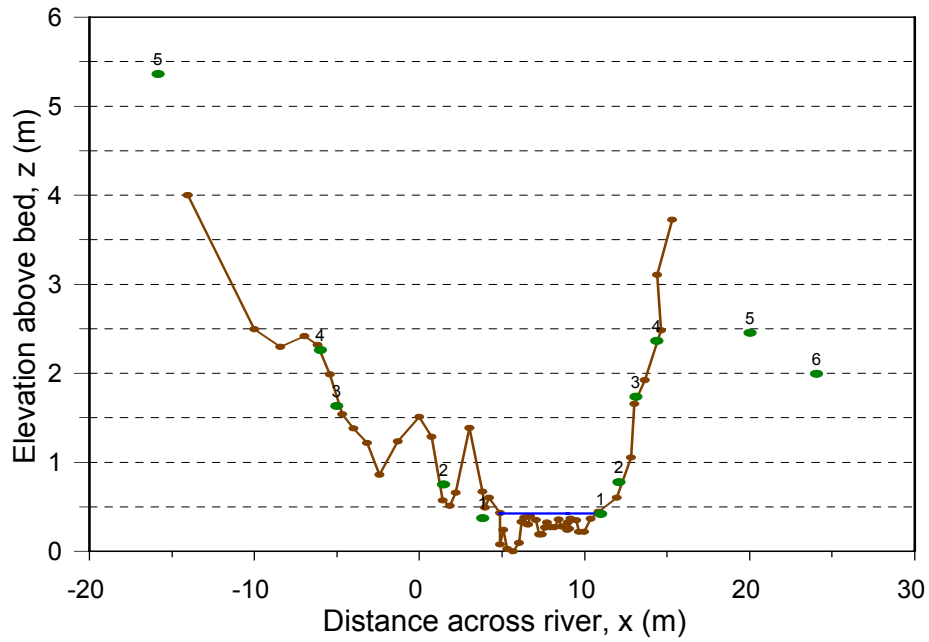


Figure 4.32 Cross-sectional profile through the boulder/cobble bed on the Malgas River (Mal 1), showing the water level surveyed on 21/3/2007 ($Q = 0.14 \text{ m}^3\text{s}^{-1}$; numbers indicate vegetation zones)

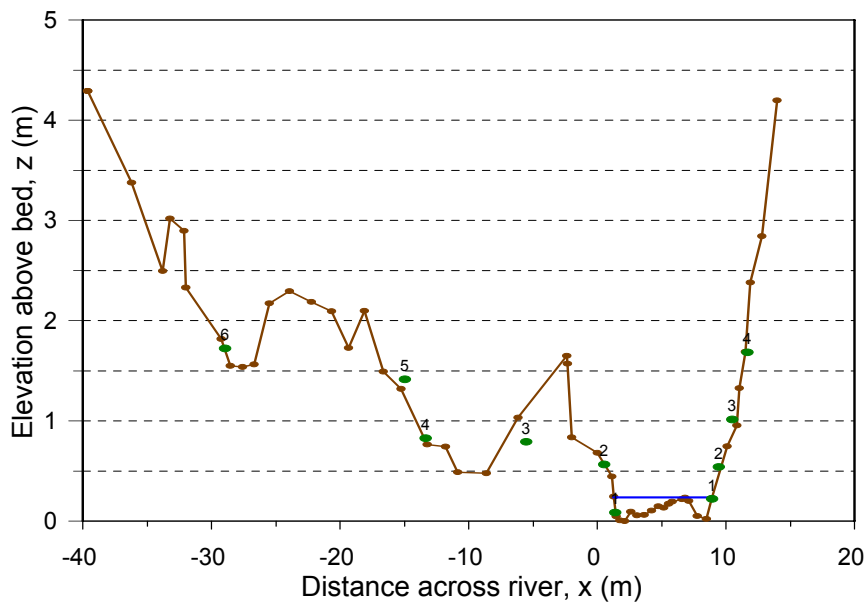


Figure 4.33 Cross-sectional profile through the riffle on the Goukamma River (Gou 1), showing the water level surveyed on 22/3/2007 ($Q = 0.29 \text{ m}^3\text{s}^{-1}$; numbers indicate vegetation zones)

RATING DATA AND FUNCTIONS

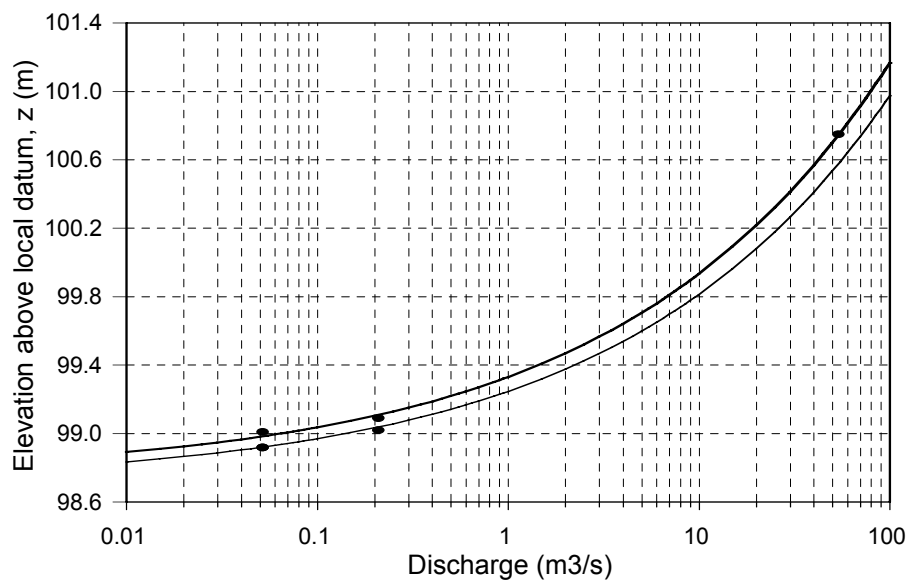


Figure 4.34 Measured and modelled rating data and functions for the cross-sectional profiles through the step (upstream) and pool (downstream) at EWR Site GB 1 on the Groot Brak River (GB 1)

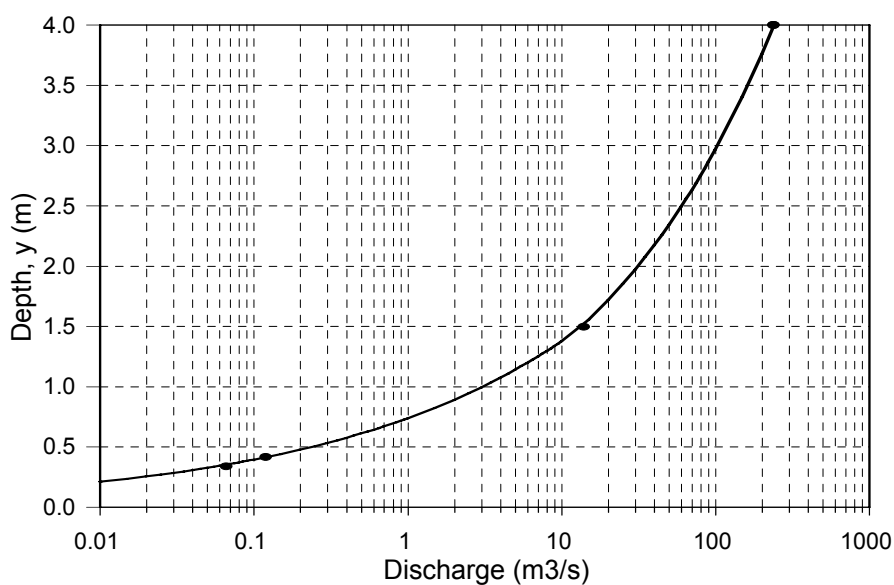


Figure 4.35 Measured and modelled rating data and functions for the cross-sectional profile through the step at EWR Site Ka 1 on the Kaaimans River

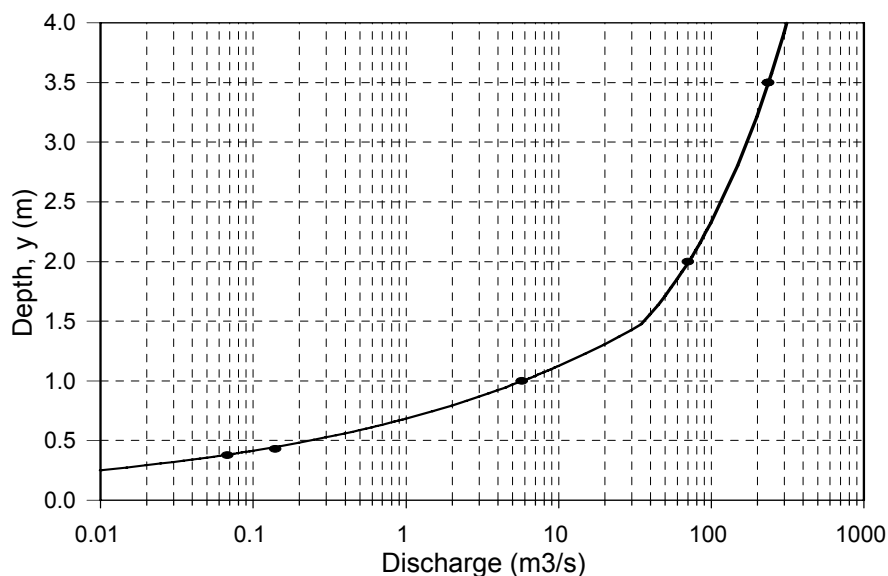


Figure 4.36 Measured and modelled rating data and functions for the cross-sectional profile through the boulder bed at the EWR Site Mal 1 on the Malgas River

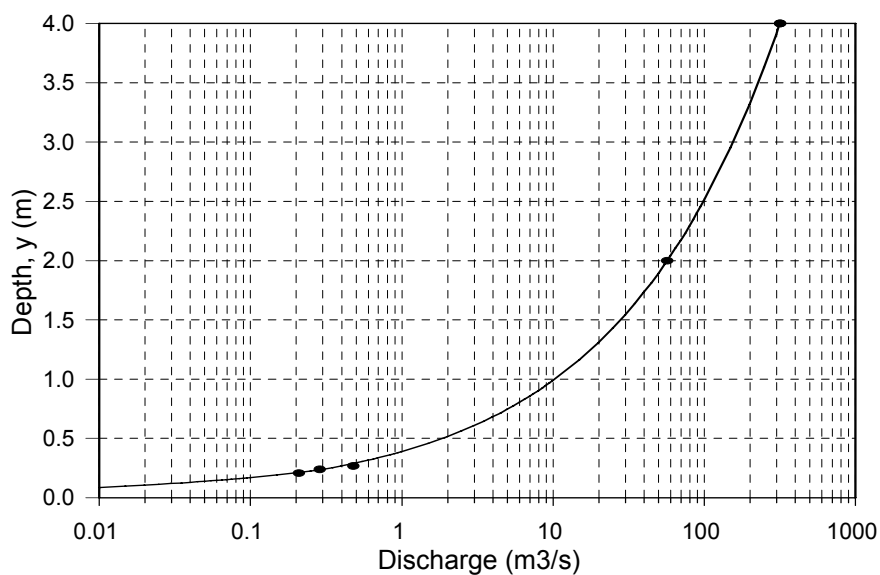


Figure 4.37 Measured and modelled rating data and functions for the cross-sectional profile through the cobble riffle at EWR Site Gou 1 on the Goukamma River (Gou 1)

CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS

The estimated confidence in the characterisations of the hydraulic relationships is provided in Table 4.14. “Site character” refers to the suitability of the site for hydraulic modelling, “available data” refers to the range of measured rating data, and the final column refers to the confidence in the hydraulic characterisations with reference to natural flows or the present state.

Table 4.14 Confidence in the hydraulic characterisations

Site no.	Site character	Available data	Reference to natural/present state	
			Low flows	High flows
GB 1	1	2	2	1
Ka 1	1	2	3	1
Mal 1	2	2	2	2
Gou 1	3	2	3	2

Confidence rating: 0 = none, 1 = low, 2 = low/medium, 3 = medium, 4 = medium/high, 5

TABULATED MODELLED HYDRAULIC DATA

The hydraulic data in tabulated form are provided in Table 4.15 to Table 4.18.

Table 4.15 Tabulated hydraulic data for EWR Site GB 1 on the Groot Brak River (bedrock step with gravels and cobbles)

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types (%)					Invertebrate Habitat Types (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.02	0.01	0.000	0.10	0.10	0.01	0.02	100	0	0	0	0	40	0	20	0	0	40	0
0.04	0.02	0.000	0.30	0.30	0.02	0.08	100	0	0	0	0	40	0	20	0	0	40	0
0.06	0.03	0.001	0.50	0.50	0.04	0.14	100	0	0	0	0	40	0	20	0	0	40	0
0.08	0.04	0.001	0.60	0.60	0.06	0.20	100	0	0	0	0	40	0	20	0	0	40	0
0.10	0.05	0.003	0.80	0.80	0.07	0.24	100	0	0	0	0	40	0	20	0	0	40	0
0.12	0.06	0.004	0.90	0.90	0.08	0.28	98	0	2	0	0	40	1	20	0	0	40	1
0.14	0.06	0.006	1.10	1.20	0.08	0.29	98	0	2	1	0	39	1	20	0	0	39	1
0.16	0.07	0.009	1.50	1.50	0.09	0.31	97	0	3	1	0	39	2	19	1	0	39	2
0.18	0.07	0.013	1.90	2.00	0.10	0.33	96	0	4	1	0	39	2	19	1	0	39	2
0.20	0.08	0.019	2.20	2.30	0.11	0.37	94	0	6	2	0	38	3	19	1	0	38	3
0.22	0.10	0.028	2.30	2.40	0.13	0.44	91	0	9	4	0	37	4	18	2	0	37	4
0.24	0.11	0.039	2.40	2.50	0.15	0.50	89	0	11	6	0	34	5	17	2	4	34	5
0.26	0.13	0.052	2.50	2.60	0.16	0.56	85	0	15	9	0	32	6	16	3	8	32	6
0.28	0.14	0.093	2.60	2.70	0.25	0.82	66	0	34	26	0	23	12	12	6	11	24	12
0.30	0.15	0.12	2.80	3.00	0.28	0.89	61	0	39	31	0	21	13	11	7	13	21	14
0.32	0.15	0.14	3.30	3.40	0.30	0.94	57	0	43	30	2	19	14	10	8	14	19	15
0.34	0.14	0.18	3.80	3.90	0.32	1.00	53	0	47	29	4	17	15	10	9	17	18	15
0.36	0.16	0.21	3.90	4.10	0.34	1.04	50	0	50	31	6	15	15	9	9	20	16	16
0.38	0.16	0.25	4.40	4.50	0.35	1.08	47	0	53	31	7	14	16	8	9	22	15	16
0.40	0.18	0.30	4.60	4.70	0.37	1.12	45	0	55	35	9	13	16	8	10	25	13	16
0.42	0.19	0.35	4.70	4.90	0.39	1.14	42	0	58	41	11	11	16	7	10	27	12	16
0.44	0.20	0.41	4.90	5.00	0.41	1.18	39	0	61	46	15	10	16	6	10	30	11	17

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types (%)					Invertebrate Habitat Types (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.46	0.22	0.47	5.00	5.20	0.43	1.20	37	0	63	53	19	9	16	6	10	32	10	17
0.48	0.23	0.54	5.10	5.30	0.45	1.24	34	0	66	56	25	8	16	5	10	35	9	17
0.50	0.25	0.61	5.20	5.40	0.47	1.28	31	0	68	60	28	7	16	5	10	37	8	17
0.52	0.26	0.70	5.30	5.50	0.50	1.31	29	1	71	63	31	7	16	4	10	39	7	16
0.54	0.28	0.79	5.40	5.60	0.52	1.33	26	2	72	66	32	6	15	4	10	42	6	17
0.56	0.29	0.89	5.50	5.70	0.55	1.36	24	2	74	68	34	5	15	3	10	44	6	16
0.58	0.31	0.99	5.60	5.80	0.58	1.36	21	3	76	71	36	5	15	3	10	46	5	16
0.60	0.32	1.11	5.70	5.90	0.60	1.40	19	3	78	73	40	4	15	3	10	47	5	16
0.62	0.34	1.23	5.70	6.00	0.63	1.43	17	3	79	74	46	4	15	3	10	48	4	16
0.64	0.36	1.37	5.80	6.10	0.66	1.49	15	4	81	76	53	3	15	2	10	49	4	16
0.66	0.37	1.51	5.90	6.10	0.69	1.52	13	5	82	77	57	3	15	2	10	51	4	16
0.68	0.39	1.67	5.90	6.20	0.72	1.56	11	5	83	79	60	3	14	2	10	52	3	16
0.70	0.39	1.83	6.30	6.60	0.75	1.60	10	5	85	77	62	3	15	2	11	50	3	16
0.72	0.39	2.00	6.60	6.90	0.79	1.63	9	5	86	75	61	2	15	2	11	49	3	17
0.74	0.38	2.19	7.00	7.30	0.81	1.70	9	4	87	71	60	2	16	2	12	48	3	17
0.76	0.38	2.39	7.40	7.80	0.84	1.75	8	4	88	70	59	2	16	2	13	45	3	19
0.78	0.38	2.60	7.90	8.30	0.87	1.79	8	4	88	67	57	2	17	2	14	43	3	19
0.80	0.38	2.82	8.20	8.60	0.90	1.81	7	4	89	69	57	2	18	2	15	41	3	20
0.82	0.39	3.05	8.50	8.90	0.92	1.88	6	4	90	71	56	2	18	2	15	40	2	21
0.84	0.40	3.30	8.70	9.20	0.95	1.93	5	4	91	73	55	2	18	2	16	39	2	21
0.86	0.41	3.56	9.00	9.50	0.97	1.97	5	4	91	76	56	2	19	2	17	38	2	21
0.88	0.41	3.84	9.30	9.80	1.00	2.02	5	4	91	76	55	2	19	2	17	36	2	22
0.90	0.42	4.13	9.70	10.30	1.02	2.09	5	4	92	76	53	2	19	2	18	35	2	23

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types (%)					Invertebrate Habitat Types (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.92	0.42	4.43	10.10	10.70	1.05	2.13	4	4	92	76	52	2	19	2	19	33	2	23
0.94	0.42	4.75	10.50	11.10	1.07	2.16	4	4	92	77	51	2	20	2	20	32	2	23
0.96	0.43	5.08	10.80	11.40	1.09	2.20	4	4	92	78	51	2	20	2	20	31	2	23
0.98	0.44	5.43	11.00	11.70	1.12	2.25	4	4	92	79	52	2	20	2	21	31	2	23
1.00	0.45	5.80	11.40	12.10	1.14	2.27	4	3	93	80	53	1	20	2	21	30	2	24
1.02	0.45	6.18	11.80	12.50	1.16	2.37	4	3	93	79	53	1	20	2	22	29	2	24
1.04	0.46	6.58	12.10	12.80	1.18	2.40	4	3	93	80	55	1	20	2	23	28	2	24
1.06	0.47	7.00	12.50	13.20	1.20	2.47	4	3	93	79	56	1	20	2	23	27	2	25
1.08	0.47	7.44	13.00	13.80	1.23	2.50	4	3	93	79	57	1	20	2	24	26	2	25
1.10	0.46	7.89	13.80	14.50	1.25	2.54	4	3	94	77	57	1	20	2	25	25	2	25
1.12	0.43	8.36	15.50	16.30	1.26	2.52	4	2	94	72	51	1	20	2	28	22	2	25
1.14	0.42	8.86	16.40	17.20	1.27	2.56	4	2	94	71	51	1	20	2	30	21	2	25
1.16	0.42	9.37	17.20	18.10	1.28	2.64	4	2	94	69	49	1	20	2	31	20	2	24
1.18	0.42	9.90	18.10	18.90	1.30	2.60	4	2	94	72	48	1	20	2	32	19	2	24
1.20	0.43	10.45	18.80	19.70	1.30	2.61	4	2	94	74	50	1	20	2	33	18	2	24

SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1m, F.3=Fast Depth>0.3m; SCS=Slow Coarse Sediment, FCS=Fast Coarse Sediment, SCS=Slow Fine Sediment, FFS=Fast Fine Sediment; VEG = vegetation in water; SBR=Slow Bedrock, FBR=Fast Bedrock, Shaded = measured 21/3/2007(0.21m³/s) & 21/4/2007 (0.052m³/s)

Table 4.16 Tabulated hydraulic data for EWR Site Ka 1 on the Kaaimans River (bedrock step)

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁵ (%)					Invertebrate Habitat Types ¹⁶ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.02	0.01	0.000	0.10	0.20	0.00	0.00	100	0	0	0	0	30	0	20	0	0	50	0
0.04	0.03	0.000	0.20	0.20	0.00	0.02	100	0	0	0	0	30	0	20	0	0	50	0
0.06	0.04	0.000	0.20	0.30	0.01	0.04	100	0	0	0	0	30	0	20	0	0	50	0
0.08	0.06	0.000	0.20	0.30	0.02	0.08	100	0	0	0	0	30	0	20	0	0	50	0
0.10	0.06	0.001	0.30	0.40	0.04	0.13	100	0	0	0	0	30	0	20	0	0	50	0
0.12	0.07	0.001	0.30	0.40	0.05	0.19	100	0	0	0	0	30	0	20	0	0	50	0
0.14	0.08	0.002	0.40	0.50	0.07	0.25	99	0	1	0	0	30	0	20	0	0	49	1
0.16	0.09	0.003	0.40	0.60	0.09	0.31	97	0	3	2	0	29	1	19	1	0	48	2
0.18	0.10	0.005	0.40	0.60	0.12	0.39	94	0	6	3	0	28	2	19	1	0	47	3
0.20	0.11	0.008	0.50	0.70	0.15	0.46	91	0	9	5	0	27	3	18	2	0	46	4
0.22	0.08	0.009	0.90	1.10	0.14	0.42	93	0	7	3	0	28	2	19	1	0	46	4
0.24	0.09	0.013	1.00	1.20	0.15	0.48	91	0	9	4	0	27	3	18	2	0	45	5
0.26	0.09	0.017	1.10	1.40	0.16	0.51	88	0	12	4	0	27	3	18	2	0	44	6
0.28	0.10	0.023	1.30	1.60	0.18	0.54	86	0	14	5	0	25	4	17	3	2	42	7
0.30	0.11	0.031	1.40	1.70	0.20	0.57	81	0	19	7	0	23	5	15	3	7	38	9
0.32	0.11	0.038	1.60	1.90	0.21	0.61	77	0	23	9	2	21	6	14	4	10	35	10
0.34	0.12	0.056	1.80	2.10	0.26	0.69	65	0	35	20	3	17	9	11	6	13	28	16
0.36	0.14	0.069	1.80	2.10	0.27	0.74	59	0	41	25	4	14	10	9	6	22	23	16

¹⁵ SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1 m, F.3=Fast Depth>0.3 m.

¹⁶ SCS=Slow Fine Sediment, FFS=Fast Fine Sediment; VEG = vegetation in water; SBR=Slow Bedrock, FBR=Fast Bedrock, Shaded = measured 22/3/2007(0.12m³/s) & 21/4/2007 (0.066m³/s).

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁵ (%)					Invertebrate Habitat Types ¹⁶ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.38	0.16	0.085	1.90	2.20	0.29	0.75	56	0	44	30	5	12	9	8	6	30	19	16
0.40	0.17	0.10	1.90	2.30	0.31	0.78	51	0	49	37	7	9	9	6	6	38	16	15
0.42	0.19	0.12	2.00	2.40	0.33	0.81	47	0	53	42	8	8	9	5	6	46	13	14
0.44	0.20	0.15	2.00	2.40	0.36	0.85	43	0	57	49	11	6	8	4	5	53	10	13
0.46	0.22	0.17	2.10	2.50	0.38	0.90	38	0	62	54	12	5	8	3	5	60	8	13
0.48	0.23	0.20	2.10	2.60	0.41	0.92	35	0	65	57	14	3	6	2	4	67	6	11
0.50	0.25	0.23	2.20	2.70	0.44	0.97	31	0	68	60	16	3	6	2	4	73	4	9
0.52	0.26	0.27	2.20	2.70	0.47	1.03	27	1	72	64	22	2	5	1	3	79	3	8
0.54	0.27	0.31	2.30	2.80	0.50	1.07	23	2	75	66	29	1	3	1	2	84	2	6
0.56	0.27	0.36	2.40	3.00	0.53	1.09	21	2	77	66	35	1	3	1	2	86	2	6
0.58	0.26	0.41	2.70	3.30	0.56	1.15	19	2	79	62	37	1	4	1	3	83	2	7
0.60	0.25	0.46	3.10	3.60	0.59	1.21	17	2	81	58	37	1	5	1	3	80	2	8
0.62	0.24	0.52	3.50	4.10	0.62	1.25	16	2	83	52	39	1	6	1	4	78	2	9
0.64	0.23	0.58	4.10	4.70	0.64	1.28	15	1	83	47	36	1	6	1	4	74	2	11
0.66	0.18	0.66	5.80	6.40	0.64	1.29	15	1	83	36	26	2	11	1	7	57	4	18
0.68	0.17	0.73	6.80	7.50	0.64	1.30	15	1	84	33	23	2	12	2	8	53	4	19
0.70	0.17	0.81	7.80	8.50	0.63	1.27	16	1	83	33	21	3	12	2	8	50	4	21
0.72	0.17	0.90	8.60	9.40	0.62	1.23	16	2	82	35	19	3	13	2	8	49	4	21
0.74	0.17	1.00	9.60	10.40	0.61	1.23	16	2	82	36	17	3	13	2	9	47	4	22
0.76	0.18	1.10	10.20	11.10	0.60	1.21	16	2	82	46	17	3	13	2	9	47	5	22
0.78	0.19	1.22	10.80	11.70	0.59	1.20	16	2	82	51	16	3	13	2	9	47	5	22
0.80	0.20	1.34	11.30	12.20	0.59	1.21	16	2	82	56	16	3	13	2	9	48	5	21
0.82	0.21	1.46	11.60	12.70	0.59	1.19	16	3	81	61	16	3	12	2	8	50	5	21
0.84	0.23	1.60	12.00	13.00	0.59	1.18	16	3	81	65	16	3	12	2	8	52	4	19

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁵ (%)					Invertebrate Habitat Types ¹⁶ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.86	0.24	1.75	12.30	13.40	0.59	1.18	16	3	81	67	17	3	11	2	7	54	4	19
0.88	0.26	1.90	12.50	13.60	0.59	1.21	16	3	81	69	18	3	11	2	7	55	4	18
0.90	0.27	2.07	12.70	13.80	0.59	1.22	16	3	81	71	20	3	11	2	7	56	4	18
0.92	0.29	2.24	12.90	14.00	0.60	1.23	15	3	82	73	24	2	11	2	7	57	4	18
0.94	0.31	2.43	13.00	14.20	0.61	1.24	15	3	82	75	28	2	11	2	7	58	4	18
0.96	0.32	2.62	13.20	14.40	0.62	1.26	15	3	82	76	34	2	10	1	7	58	4	17
0.98	0.34	2.83	13.40	14.60	0.63	1.28	15	3	83	77	41	2	10	1	7	59	4	17
1.00	0.35	3.05	13.50	14.70	0.64	1.30	14	3	83	78	49	2	10	1	7	60	3	16
1.02	0.37	3.28	13.60	14.90	0.65	1.32	14	3	83	79	53	2	10	1	6	61	3	16
1.04	0.39	3.53	13.70	15.00	0.66	1.34	13	3	84	81	57	2	9	1	6	62	3	16
1.06	0.41	3.79	13.80	15.10	0.68	1.38	13	3	84	81	62	2	9	1	6	64	3	16
1.08	0.43	4.06	13.80	15.20	0.69	1.42	12	3	85	82	65	2	9	1	6	65	3	15
1.10	0.44	4.34	13.90	15.30	0.70	1.44	11	4	85	83	69	2	9	1	6	66	3	14
1.12	0.46	4.64	14.00	15.40	0.72	1.47	10	4	86	84	72	2	9	1	6	67	3	14
1.14	0.48	4.96	14.10	15.50	0.74	1.49	9	5	86	85	74	1	8	1	6	68	2	14
1.16	0.50	5.29	14.10	15.60	0.75	1.54	8	5	87	85	76	1	8	1	5	69	2	13
1.18	0.51	5.63	14.20	15.70	0.77	1.58	7	6	88	85	77	1	8	1	5	70	2	13
1.20	0.53	5.99	14.30	15.90	0.79	1.61	6	6	88	86	78	1	8	1	5	69	2	14
1.22	0.54	6.37	14.50	16.10	0.81	1.65	5	7	89	86	79	1	8	1	6	68	2	14
1.24	0.54	6.77	15.20	16.80	0.83	1.67	4	7	89	84	77	1	9	1	6	65	2	16
1.26	0.55	7.18	15.50	17.20	0.85	1.69	4	7	89	82	77	1	10	1	6	64	2	16
1.28	0.56	7.61	15.80	17.50	0.87	1.76	3	7	90	80	75	1	10	1	7	63	2	17
1.30	0.57	8.06	16.00	17.80	0.89	1.79	3	7	90	82	76	1	11	1	7	62	2	18
1.32	0.58	8.53	16.30	18.00	0.91	1.85	3	7	90	81	76	1	11	1	7	61	2	18

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁵ (%)					Invertebrate Habitat Types ¹⁶ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
1.34	0.59	9.02	16.40	18.20	0.93	1.88	3	7	90	83	76	1	11	1	7	60	2	18
1.36	0.61	9.53	16.50	18.40	0.95	1.91	2	7	91	85	75	1	11	1	7	60	2	18
1.38	0.62	10.06	16.70	18.50	0.97	1.98	2	7	91	86	75	1	11	1	7	59	2	19
1.40	0.64	10.61	16.80	18.70	0.99	2.01	2	7	91	86	75	1	11	1	8	59	2	19
1.42	0.65	11.18	16.90	18.80	1.01	2.06	2	6	91	88	76	1	11	1	8	58	2	19
1.44	0.67	11.77	17.00	18.90	1.03	2.06	2	7	92	90	77	1	12	1	8	58	2	19
1.46	0.68	12.39	17.30	19.30	1.05	2.14	2	6	92	87	74	1	12	1	8	57	2	20
1.48	0.68	12.92	17.80	19.80	1.07	2.16	2	6	92	86	74	1	12	1	8	56	2	21
1.50	0.69	13.44	18.10	20.10	1.08	2.19	2	6	92	86	73	1	12	1	8	55	2	21

SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1m, F.3=Fast Depth>0.3m; SCS=Slow Coarse Sediment, FCS=Fast Coarse Sediment, SCS=Slow Fine Sediment, FFS=Fast Fine Sediment; VEG = vegetation in water; SBR=Slow Bedrock, FBR=Fast Bedrock, Shaded = measured 21/3/2007(0.21m³/s) & 21/4/2007 (0.052m³/s)

Table 4.17 Tabulated hydraulic data for EWR Site Mal 1 on the Malgas River (boulder/cobble bed)

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁷ (%)					Invertebrate Habitat Types ¹⁸ (%)			
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS
0.02	0.01	0.000	0.30	0.30	0.00	0	100	0	0	0	0	80	0	20	0
0.04	0.02	0.000	0.50	0.60	0.00	0	100	0	0	0	0	80	0	20	0
0.06	0.04	0.000	0.60	0.70	0.00	0	100	0	0	0	0	80	0	20	0
0.08	0.05	0.000	0.70	0.80	0.00	0	100	0	0	0	0	80	0	20	0
0.10	0.06	0.000	0.80	0.90	0.00	0	100	0	0	0	0	80	0	20	0
0.12	0.08	0.000	0.90	1.00	0.00	0	100	0	0	0	0	80	0	20	0
0.14	0.09	0.001	0.90	1.10	0.01	0	100	0	0	0	0	80	0	20	0
0.16	0.11	0.001	1.00	1.20	0.01	0	100	0	0	0	0	80	0	20	0
0.18	0.12	0.002	1.10	1.30	0.02	0	100	0	0	0	0	80	0	20	0
0.20	0.12	0.003	1.30	1.60	0.02	0	100	0	0	0	0	80	0	20	0
0.22	0.13	0.005	1.40	1.80	0.03	0	100	0	0	0	0	80	0	20	0
0.24	0.11	0.008	1.90	2.40	0.04	0	100	0	0	0	0	80	0	20	0
0.26	0.11	0.011	2.30	2.80	0.04	0	100	0	0	0	0	80	0	20	0
0.28	0.10	0.016	3.00	3.60	0.05	0	100	0	0	0	0	80	0	20	0
0.30	0.11	0.022	3.40	4.10	0.06	0	100	0	0	0	0	80	0	20	0
0.32	0.12	0.030	3.90	4.70	0.07	0	100	0	0	0	0	80	0	20	0
0.34	0.13	0.039	4.30	5.10	0.07	0	99	0	1	1	0	79	1	20	0
0.36	0.13	0.051	4.80	5.70	0.08	0	98	0	2	1	0	78	2	20	0
0.38	0.13	0.066	5.40	6.30	0.09	0	96	0	4	2	1	77	3	19	1
0.40	0.15	0.083	5.70	6.70	0.10	0	94	0	6	3	1	75	5	19	1
0.42	0.16	0.11	5.80	6.90	0.11	0	93	0	7	5	1	74	6	19	1
0.44	0.18	0.13	6.00	7.10	0.12	0	91	0	9	6	2	73	7	18	2
0.46	0.19	0.16	6.20	7.30	0.13	0	89	0	11	9	2	71	9	18	2
0.48	0.20	0.19	6.40	7.50	0.15	1	86	0	13	11	2	68	10	18	3
0.50	0.22	0.23	6.70	7.70	0.16	1	84	1	15	13	3	66	12	18	3

¹⁷ SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1 m, F.3=Fast Depth>0.3 m.

¹⁸ SCS=Slow Coarse Sediment, FCS=Fast Coarse Sediment, SFS=Slow Fine Sediment, FFS=Fast Fine Sediment; Shaded = measured 21/3/2007(0.14 m³/s) & 21/4/2007 (0.068 m³/s)

Flow depth (m)	Av. flow depth (m)	Discharge (m³/s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁷ (%)					Invertebrate Habitat Types ¹⁸ (%)			
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS
0.52	0.23	0.28	6.90	8.00	0.18	1	78	4	18	15	4	63	14	18	4
0.54	0.23	0.34	7.40	8.50	0.19	1	73	6	21	17	6	61	16	19	5
0.56	0.24	0.40	7.90	9.00	0.21	1	70	6	25	20	7	57	19	18	6
0.58	0.24	0.47	8.30	9.50	0.23	1	65	6	28	22	10	53	21	18	7
0.60	0.26	0.55	8.70	9.90	0.25	1	61	6	33	25	13	49	24	18	9
0.62	0.27	0.64	8.90	10.10	0.27	1	58	6	36	29	16	47	26	17	10
0.64	0.29	0.74	9.00	10.20	0.29	1	54	6	40	33	19	44	29	16	11
0.66	0.30	0.85	9.10	10.40	0.31	1	50	6	44	38	23	41	32	15	12
0.68	0.32	0.97	9.20	10.50	0.33	1	46	7	47	43	27	38	34	15	13
0.70	0.33	1.11	9.30	10.60	0.36	1	42	7	51	48	30	35	37	13	14
0.72	0.35	1.27	9.40	10.80	0.38	1	37	8	55	52	34	32	40	13	15
0.74	0.37	1.44	9.50	10.90	0.41	1	33	8	59	56	37	30	42	12	17
0.76	0.38	1.63	9.60	11.00	0.44	1	28	10	62	59	40	27	44	11	18
0.78	0.40	1.84	9.70	11.20	0.47	1	25	11	65	62	43	25	46	10	19
0.80	0.41	2.07	9.80	11.30	0.51	2	21	12	67	64	47	23	48	9	19
0.82	0.43	2.32	9.90	11.40	0.54	2	18	11	70	66	50	21	50	9	20
0.84	0.45	2.59	10.00	11.50	0.58	2	16	11	73	69	54	19	51	8	21
0.86	0.46	2.89	10.10	11.70	0.62	2	13	12	75	72	59	18	53	7	22
0.88	0.47	3.21	10.30	11.90	0.66	2	11	12	77	74	63	16	54	7	23
0.90	0.48	3.56	10.50	12.10	0.70	2	10	11	79	75	66	15	55	6	24
0.92	0.49	3.94	10.70	12.40	0.74	2	9	10	81	75	67	13	56	6	25
0.94	0.50	4.36	10.90	12.60	0.79	2	8	10	83	76	69	12	57	5	26
0.96	0.52	4.80	11.10	12.90	0.84	2	7	9	84	77	69	11	57	5	27
0.98	0.53	5.29	11.30	13.10	0.89	2	6	8	86	78	69	10	58	5	28
1.00	0.54	5.80	11.50	13.30	0.94	2	5	7	87	80	71	9	59	4	29
1.02	0.55	6.36	11.70	13.60	0.99	2	5	7	89	81	71	8	59	4	29
1.04	0.56	6.96	11.90	13.80	1.04	2	4	6	90	82	72	7	60	3	30
1.06	0.57	7.60	12.10	14.00	1.10	2	3	6	91	83	72	6	60	3	31
1.08	0.58	8.29	12.30	14.30	1.16	2	3	6	92	84	72	5	60	3	32
1.10	0.59	9.02	12.50	14.50	1.22	3	2	5	93	85	74	5	60	3	32
1.12	0.60	9.81	12.60	14.70	1.28	3	2	4	94	86	74	4	61	2	33
1.14	0.62	10.64	12.80	14.90	1.35	3	2	4	94	90	76	4	61	2	34

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁷ (%)					Invertebrate Habitat Types ¹⁸ (%)			
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS
1.16	0.63	11.54	13.00	15.10	1.41	3	2	4	95	89	75	3	61	2	34
1.18	0.64	12.49	13.10	15.30	1.48	3	2	3	95	89	75	3	60	2	35
1.20	0.65	13.50	13.30	15.50	1.55	3	1	3	95	88	76	3	60	2	35
1.22	0.66	14.57	13.50	15.80	1.63	3	1	3	96	91	77	3	60	2	35
1.24	0.67	15.71	13.70	16.00	1.70	3	1	3	96	90	77	3	60	2	36
1.26	0.68	16.92	14.00	16.40	1.78	4	1	3	96	89	77	2	59	2	37
1.28	0.69	18.20	14.30	16.70	1.86	4	1	3	96	90	76	2	59	1	37
1.30	0.69	19.55	14.60	17.00	1.94	4	1	3	96	90	77	2	58	1	38
1.32	0.70	20.98	14.90	17.40	2.02	4	1	2	96	87	76	2	58	1	39
1.34	0.70	22.49	15.20	17.70	2.11	4	1	2	97	87	76	2	57	1	40
1.36	0.71	24.09	15.50	18.10	2.20	4	1	2	97	87	75	2	56	1	40
1.38	0.71	25.78	15.80	18.40	2.28	5	1	2	97	87	76	2	56	1	41
1.40	0.72	27.55	16.10	18.70	2.37	5	1	2	97	89	75	2	55	1	42
1.42	0.73	29.42	16.40	19.00	2.47	5	1	2	97	89	77	2	55	1	42
1.44	0.74	31.39	16.60	19.30	2.56	5	1	2	97	89	75	2	54	1	43
1.46	0.75	33.46	16.90	19.60	2.66	5	1	2	97	90	75	1	54	1	44
1.48	0.76	35.25	17.10	19.80	2.72	6	1	2	97	91	77	1	53	1	44
1.50	0.76	36.43	17.40	20.10	2.74	6	1	2	97	91	76	1	53	1	45

SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1m, F.3=Fast Depth>0.3m; SCS=Slow Coarse Sediment, FCS=Fast Coarse Sediment, SCS=Slow Fine Sediment, FFS=Fast Fine Sediment; VEG = vegetation in water; SBR=Slow Bedrock, FBR=Fast Bedrock, Shaded = measured 21/3/2007(0.21m³/s) & 21/4/2007 (0.052m³/s)

Table 4.18 Tabulated hydraulic data for EWR Site Gou 1 on the Goukamma River (cobble bed)

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁹ (%)					Invertebrate Habitat Types ²⁰ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.02	0.01	0.000	0.50	0.50	0.01	0.03	100	0	0	0	0	80	0	20	0	0	0	0
0.04	0.02	0.001	1.30	1.30	0.03	0.10	100	0	0	0	0	80	0	20	0	0	0	0
0.06	0.03	0.003	1.80	1.80	0.05	0.23	100	0	0	0	0	80	0	20	0	0	0	0
0.08	0.04	0.007	3.10	3.10	0.07	0.23	100	0	0	0	0	80	0	20	0	0	0	0
0.10	0.05	0.016	3.90	3.90	0.09	0.30	97	0	3	0	0	78	2	19	1	0	0	0
0.12	0.06	0.029	4.20	4.30	0.11	0.38	94	0	6	1	0	74	5	19	1	1	0	0
0.14	0.07	0.049	4.90	5.00	0.14	0.47	90	0	10	3	0	70	7	18	2	3	0	0
0.16	0.08	0.078	5.60	5.70	0.17	0.56	85	0	15	6	0	65	11	16	3	4	0	0
0.18	0.10	0.12	6.00	6.10	0.20	0.66	77	0	23	12	0	58	17	15	4	6	0	0
0.20	0.11	0.17	6.50	6.70	0.24	0.77	69	0	31	18	0	51	23	13	6	7	0	0
0.22	0.12	0.23	7.30	7.40	0.28	0.88	60	0	40	23	0	45	29	11	7	8	0	0
0.24	0.13	0.30	7.70	7.80	0.30	0.95	56	0	44	29	0	41	32	10	8	8	0	0
0.26	0.15	0.37	7.70	7.90	0.32	1.00	53	0	47	34	0	38	34	10	9	10	0	0
0.28	0.17	0.44	7.80	8.00	0.34	1.06	50	0	50	39	0	35	35	9	9	11	0	0
0.30	0.19	0.52	7.90	8.10	0.36	1.13	47	0	53	44	1	33	37	9	9	12	0	0
0.32	0.20	0.61	7.90	8.10	0.38	1.18	45	0	55	51	4	31	38	8	10	13	0	0
0.34	0.22	0.71	8.00	8.20	0.40	1.23	42	0	58	56	9	28	40	7	10	14	0	0
0.36	0.24	0.82	8.00	8.30	0.42	1.27	39	0	61	60	17	26	41	7	11	16	0	0
0.38	0.26	0.94	8.10	8.40	0.45	1.31	36	0	64	62	25	24	42	6	11	17	0	0
0.40	0.28	1.07	8.20	8.40	0.47	1.36	34	0	66	65	31	22	43	6	11	18	0	0
0.42	0.29	1.20	8.20	8.50	0.50	1.39	31	0	69	66	36	20	44	5	12	19	0	0
0.44	0.31	1.35	8.30	8.60	0.52	1.43	29	0	71	69	42	19	45	5	12	20	0	0

¹⁹ SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1 m, F.3=Fast Depth>0.3 m.

²⁰ SCS=Slow Fine Sediment, FFS=Fast Fine Sediment; SBR=Slow Bedrock, FBR=Fast Bedrock, Shaded = measured 22/3/2007(0.29m³/s) & 21/4/2007 (0.21m³/s).

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁹ (%)					Invertebrate Habitat Types ²⁰ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
0.46	0.33	1.51	8.40	8.70	0.55	1.47	27	0	73	70	49	17	45	4	12	21	0	1
0.48	0.34	1.67	8.50	8.90	0.57	1.52	26	0	74	71	53	16	45	4	12	22	0	1
0.50	0.28	1.85	11.00	11.30	0.59	1.56	25	0	75	56	44	16	46	4	13	19	0	1
0.52	0.30	2.04	11.30	11.70	0.61	1.58	23	1	76	56	48	15	46	4	13	21	0	1
0.54	0.31	2.24	11.60	12.00	0.63	1.57	20	3	77	56	51	14	45	4	13	22	0	1
0.56	0.32	2.45	12.00	12.30	0.64	1.60	18	4	78	57	51	13	45	4	14	23	0	1
0.58	0.33	2.67	12.30	12.60	0.66	1.59	16	5	79	62	50	12	45	4	14	25	0	1
0.60	0.34	2.91	12.60	13.00	0.67	1.63	14	6	80	64	50	11	45	3	14	26	0	1
0.62	0.35	3.15	12.90	13.30	0.69	1.61	13	6	80	71	50	11	44	3	14	27	0	1
0.64	0.37	3.41	13.20	13.60	0.71	1.65	12	7	81	72	50	10	44	3	14	28	0	1
0.66	0.38	3.68	13.50	13.90	0.72	1.67	11	7	82	73	49	10	44	3	14	29	0	1
0.68	0.39	3.96	13.80	14.30	0.74	1.67	10	8	83	74	49	9	43	3	14	30	0	1
0.70	0.39	4.25	14.30	14.70	0.75	1.71	9	8	83	74	48	9	43	3	14	30	0	1
0.72	0.40	4.56	14.80	15.20	0.77	1.72	8	8	84	74	47	8	43	3	14	31	0	1
0.74	0.41	4.88	15.20	15.70	0.78	1.72	8	8	84	73	46	8	43	3	14	31	0	1
0.76	0.40	5.21	16.50	17.00	0.80	1.75	8	7	85	70	45	8	43	3	15	30	0	1
0.78	0.40	5.56	17.40	17.90	0.81	1.78	8	7	85	69	45	8	44	3	15	30	0	1
0.80	0.40	5.92	17.90	18.40	0.82	1.81	8	6	86	69	47	7	43	3	15	30	0	1
0.82	0.41	6.29	18.40	18.90	0.83	1.79	8	6	86	70	53	7	43	3	15	31	0	1
0.84	0.42	6.68	18.90	19.40	0.84	1.81	8	6	86	70	53	7	43	2	16	31	0	1
0.86	0.44	7.08	19.10	19.60	0.85	1.82	8	6	87	73	54	7	42	2	16	32	0	1
0.88	0.45	7.50	19.40	19.90	0.86	1.84	8	5	87	76	55	6	42	2	15	33	0	1
0.90	0.47	7.92	19.60	20.20	0.87	1.86	7	5	87	80	56	6	42	2	15	33	0	1
0.92	0.48	8.37	19.90	20.40	0.88	1.84	7	5	87	82	56	6	41	2	15	34	0	1
0.94	0.49	8.83	20.10	20.70	0.89	1.87	7	5	88	82	57	6	41	2	15	35	0	1
0.96	0.51	9.30	20.30	21.00	0.90	1.88	7	5	88	83	58	6	40	2	15	35	0	1
0.98	0.52	9.78	20.50	21.20	0.91	1.93	6	5	89	84	60	5	40	2	15	36	0	1

Flow depth (m)	Av. flow depth (m)	Discharge (m ³ /s)	Width (m)	Perimeter (m)	Av. Velocity (m/s)	Vel. 98% (m/s)	Fish Habitat Types ¹⁹ (%)					Invertebrate Habitat Types ²⁰ (%)						
							SS	SD	F	F.1	F.3	SCS	FCS	SFS	FFS	VEG	SBR	FBR
1.00	0.54	10.29	20.70	21.40	0.92	1.96	6	5	89	84	61	5	40	2	15	37	0	1
1.02	0.55	10.80	20.90	21.60	0.93	1.96	5	6	89	85	64	5	40	2	15	37	0	1
1.04	0.57	11.33	21.10	21.80	0.95	1.97	5	6	89	86	67	5	40	2	15	37	0	1
1.06	0.58	11.88	21.30	22.10	0.96	1.96	5	6	89	85	69	5	39	2	15	37	0	2
1.08	0.60	12.44	21.50	22.30	0.97	1.99	4	6	90	85	72	5	39	2	15	38	0	2
1.10	0.61	13.02	21.70	22.60	0.98	2.03	4	6	90	86	73	4	39	2	16	38	0	2
1.12	0.62	13.62	22.00	22.80	0.99	2.03	4	6	90	87	76	4	39	2	16	37	0	2
1.14	0.64	14.23	22.20	23.10	1.00	2.08	4	6	90	86	76	4	39	2	16	37	0	2
1.16	0.65	14.85	22.40	23.30	1.02	2.10	4	6	91	86	78	4	39	2	16	37	0	2
1.18	0.67	15.49	22.60	23.60	1.03	2.13	3	6	91	86	77	4	40	2	16	36	0	2
1.20	0.68	16.15	22.80	23.80	1.04	2.12	3	6	91	88	79	4	40	2	16	36	0	2
1.22	0.69	16.83	23.00	24.00	1.05	2.18	3	5	90	87	79	4	40	2	17	36	0	2
1.24	0.71	17.52	23.30	24.30	1.07	2.19	3	6	91	87	79	4	40	2	17	35	0	2
1.26	0.72	18.23	23.50	24.50	1.08	2.18	3	6	92	88	79	4	40	2	17	35	0	2
1.28	0.73	18.95	23.70	24.80	1.09	2.23	2	6	92	88	79	4	40	2	17	36	0	2
1.30	0.75	19.69	23.90	25.00	1.10	2.23	2	6	92	89	80	4	40	1	17	36	0	2
1.32	0.76	20.45	24.10	25.30	1.12	2.26	2	6	92	88	81	4	40	1	17	36	0	2
1.34	0.77	21.22	24.40	25.60	1.13	2.28	2	6	92	89	80	3	39	1	17	37	0	2
1.36	0.78	22.02	24.80	26.00	1.14	2.33	2	6	93	88	79	3	39	1	17	37	0	2
1.38	0.79	22.83	25.10	26.30	1.15	2.35	2	6	93	87	80	3	39	1	17	37	0	2
1.40	0.80	23.66	25.40	26.60	1.16	2.39	2	5	93	89	79	3	39	1	17	37	0	2

SS=Slow Shallow, SD=Slow Deep, F=Fast, F.1=Fast Depth>0.1m, F.3=Fast Depth>0.3m; SCS=Slow Coarse Sediment, FCS=Fast Coarse Sediment, SCS=Slow Fine Sediment, FFS=Fast Fine Sediment; VEG = vegetation in water; SBR=Slow Bedrock, FBR=Fast Bedrock, Shaded = measured 21/3/2007(0.21m³/s) & 21/4/2007 (0.052m³/s)

4.3 WATER QUALITY

See Section 13.

4.4 GEOMORPHOLOGY

4.4.1 Introduction

The aim of this Section is to present the results of the field survey to the four EWR sites where Intermediate Reserve Determinations were done, viz. GB 1, Ka 1, Mal 1, Gou 1, and to report on the potential bed material load (PBML) modelling exercise for the present-day flow scenarios. These are presented together with the generic lists for geomorphology, and the results generated for the PBML exercise for different scenarios for input to DRIFT (King *et al.*, 2003).

Note: Geomorphological investigation is not required for Rapid I or II River Quantity Reserve determinations.

4.4.2 Grading data

Table 4.19 and Figure 4.38 display the results of the grading analysis for the sites²¹. The results for the Goukamma River (Gou 1) indicate that the bed is dominated by a coarse armour layer, with over 85% of the bed material coarser than 2 mm. The step section of the Groot Brak (GB 1) shows a similar bed material size distribution, with ~95% of the bed coarser than 2 mm. As would be expected, the pool section of the Groot Brak River (GB 1), although dominated by

Table 4.19 Grading data for the four EWR sites (% retained)

Sieve size (percentage retained)	GB 1 (Step)	GB 1 (Pool)	Ka 1 (Run)	Mal 1 (Run)	Gou 1 (Riffle)
256	0.7	2.7	2.7		2.1
128	3.8	17.8	6.9		13.5
64	7.0	18.7	8.8	3.5	17.8
32	13.8	17.8	17.6	6.8	15.6
16	37.7	7.1	21.1	18.6	21.1
8	0.5	0.2	5.3	17.6	9.4
4	0.2	0.9	1.1	1.9	0.5
2	0.5	17.1	21.3	29.5	7.2
1		12.8	12.1	0.5	8.3
0.5		2.9	2.4	0.1	4.1
0.25		0.6	0.2		0.4
0.125		0.8	0.4		

²¹ At least 500 samples were taken at each cross-section utilising the Wolman (1954) method.

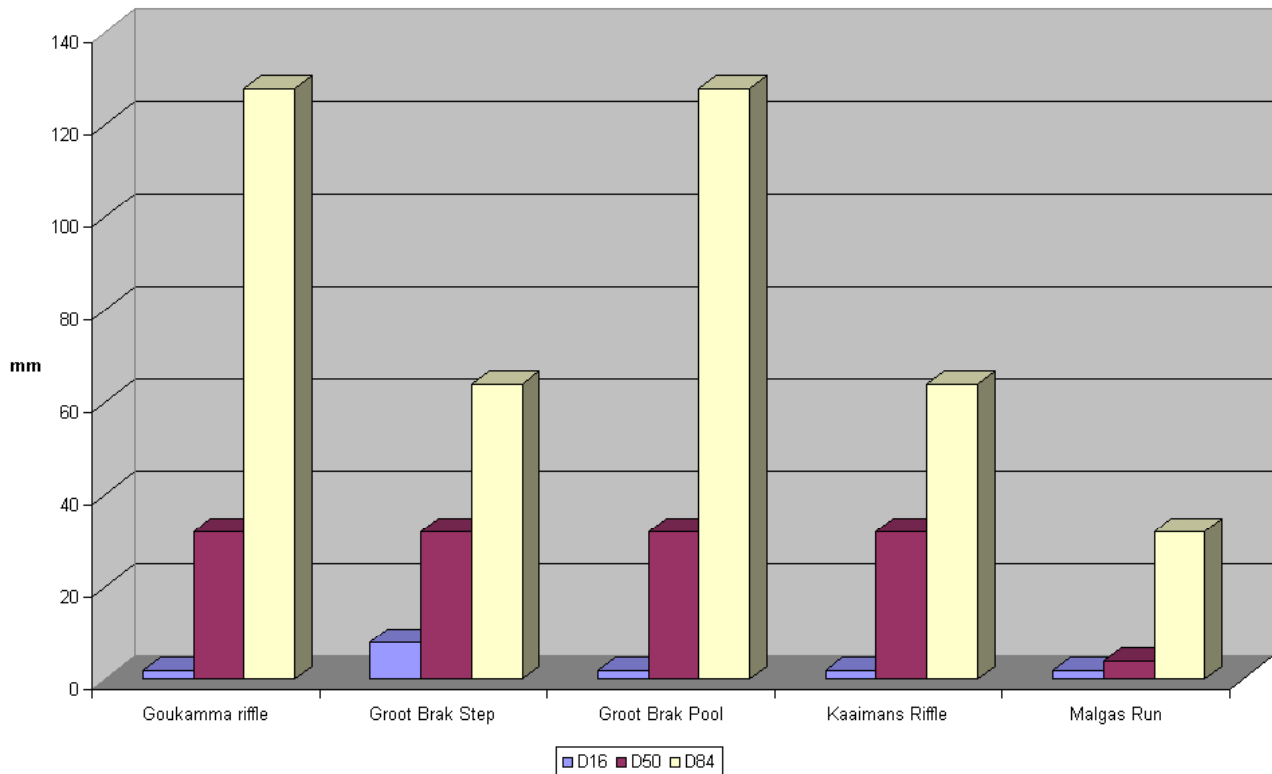


Figure 4.38 d_{16} , d_{50} and d_{84} for the four EWR sites

coarse bed material, has a greater proportion of the bed as fine bed material (>20%). The Kaaimans site (Ka 1) shows a similar distribution of bed material to the Groot Brak River (GB 1) step section. The Malgas River (Mal 1) bed material is well sorted, with a narrower range of bed material sizes. Finer overbank sediments occur on the benches and lateral bars at all sites.

4.4.3 Potential bed material load estimations

METHODS

A technique for determining the range of effective discharges necessary to maintain channel form for EWRs for southern African rivers has been developed by Dollar and Rowntree (2003). The basis of the technique is that for a channel to be stable in the long-term, the amount of bed material entering a reach must equal the amount of bed material leaving the reach. Calculating the PBML and how this changes under different flow conditions (scenarios) is helpful in determining EWRs (especially for DRIFT). Computing PBML requires information on the magnitude, frequency, duration and timing of flows (that determine the hydraulic conditions necessary for PBML), the bed material grain-size distribution, the type and spacing of the bed forms (form resistance), the effect of vegetation, antecedent conditions and catchment sediment

supply. Practically, it is difficult to account for all these factors,²² and hence it is necessary to make a number of assumptions in determining effective discharges, these include:

- the bed material sampling program for each EWR site is representative of the catchment sediment supply of the material to the channel (hence PBML as opposed to bed load)²³;
- the catchment sediment supply of material to each EWR site is based on the existing bed material and its size distribution, and is available for transport at all discharges;
- average conditions can be used; and
- the channel geometry is stable.

A full critique of this technique is available in Dollar and Rowntree (2003). Two are mentioned here. First, the values that are generated are linked to individual cross-sections and represent bed material transport *potential* within the prediction limits of the equations for average conditions, and second, the technique does not account for sediment supply. These need to be considered in interpreting the results. It is argued, however, given that predictions of all transport formulae show large uncertainties (through for example sediment packing, variability of the near-bed turbulent velocity field and modification of the velocity field by upstream protruding grains), this approach provides a useful tool for setting EWRs,²⁴ but needs to be used with circumspection by a scientist/engineer who is aware of the limitations of the approach.

In brief, the approach utilises daily hydrological time series, daily flow duration curves, cross-sectional and hydraulic information, bed material grain-size distributions and bed load transport formulae (Table 4.21) to compute PBML for different (defined) flow classes. The approach also allows for the computation of critical entrainment values and effective discharges for each cross-section for each EWR site.

Coding was developed to account for the scenarios required by DRIFT. These scenarios are generated by removing different flow classes [e.g. Intra-annual floods (classes 1 to 4), and the 1-, 2-, 5-, 10- and 20-year return period floods] from the present-day daily time series (assuming all other conditions remain constant as required by DRIFT) and computing the effect of this on PBML.

²² Benda *et al.* (2002) make the point that sediment transport is difficult to predict accurately even though it may be done with precision. For example, hydrodynamic models that seek to predict changes in the physical dimensions of channels rely on sediment input information from contributing basins, an unresolved problem. In addition, all models are influenced by various degrees of uncertainty, assumptions and choice of model schematisation (van Vuren *et al.*, 2002).

²³ The supply of bed material to a reach is a function of inputs from the catchment (e.g., directly from the slope processes), mass wasting (e.g., of bars and benches) and the energy available for transport (expressed either as sheer stress, stream power, velocity or some other hydraulic descriptor). All of these are variable in space and time. Since, we cannot predict how this bed material will change over time, when we sample the bed material for modelling, we assume that the sample distribution will represent the material at all times over X number of years. This is clearly not the case but the modelling cannot be done without the assumption.

²⁴ Other methods are available (cf. Basson and Beck, 2002).

HYDROLOGY

The hydrology used for the analysis represents 26 years of data (1 October 1978 to 30 September 2004) for the Groot Brak River, 40 years of data (1 October 1961 to 31 March 2001) for the Kaaimans and Malgas Rivers and 40 years of data (1 January 1961 to 31 May 2001) for the Goukamma River (see Section 4.1). The daily time series are available as a natural time series and a present-day time series. The present-day time series were utilised for the DRIFT scenarios.

Examples of the flow classes used are given in Table 4.20.

Table 4.20 Examples of the flow classes used

Percent exceeded	Discharge	Geometric mean Q
0.01	101.57	
0.10	42.53	65.726
1.00	8.59	19.118
5.00	2.03	4.180
10.00	1.15	1.528
20.00	0.65	0.864
30.00	0.48	0.556
40.00	0.38	0.424
50.00	0.30	0.337
60.00	0.24	0.267
70.00	0.19	0.211
80.00	0.14	0.164
90.00	0.09	0.115
95.00	0.06	0.072
99.00	0.00	0.000

The values that are given in the figures are the geometric means of the class. For example, for flow class 0.01-0.10 (101.57 to 42.53 m³/s) the geometric mean is 65.726 m³/s. This value is used to represent the flow classes.

RESULTS

Groot Brak River (GB 1)

The PBML model was run using both the natural and present-day hydrological daily time series; however the results are only displayed for the present-day time series. The 1-day daily flow duration curve generated from the daily time series for the Groot Brak River (GB 1) is presented in Figure 4.39.

Cross-section A (step)

The rated cross-section for the step cross-section was surveyed and is presented in Figure 4.40. Under present-day conditions, the most effective flows (in terms of work – volume of bed material moved) are those in the 5-1% flow classes which account for ~42% of the total PBML (Figure 4.41). Lower discharges and associated hydraulic conditions (low unit stream powers²⁵) (Figure 4.41) although not capable of mobilising large portions of the bed material, transport sediment over a wider range of flow classes than the Goukamma River (Gou 1) (Figure 4.57).

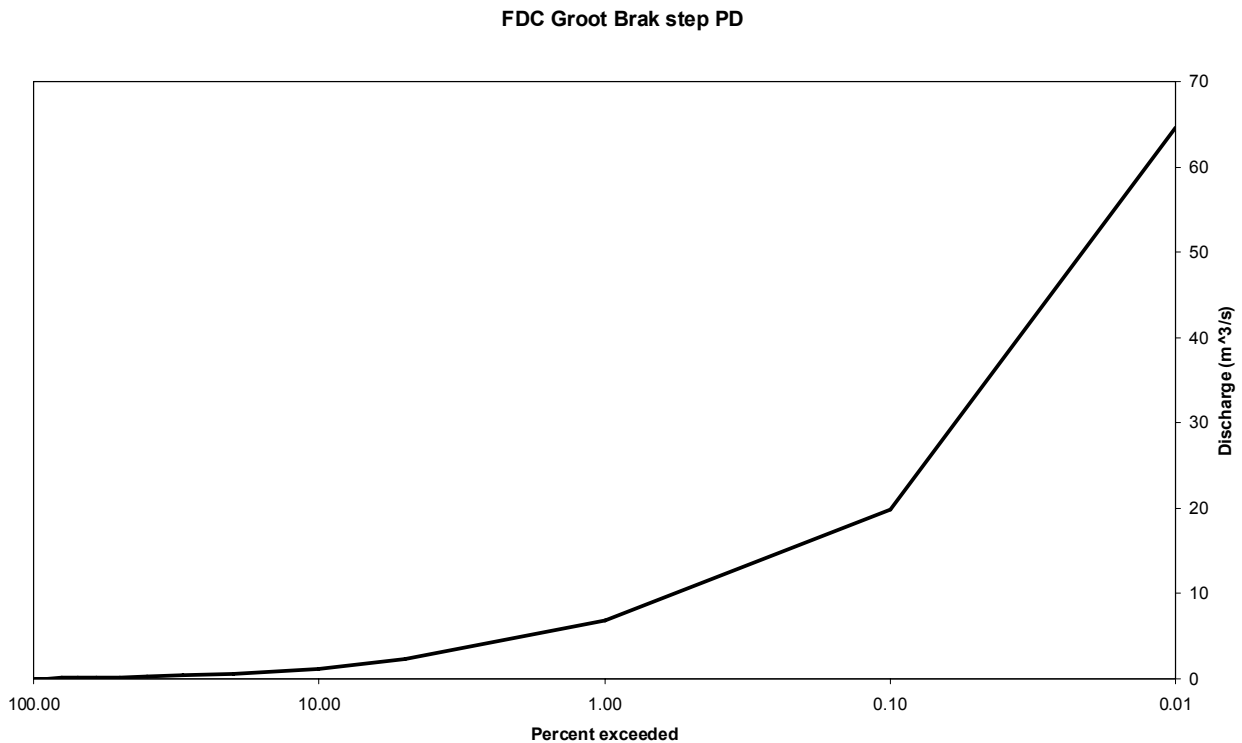


Figure 4.39 1-day daily flow duration for the present-day daily time series for the Groot Brak River (GB 1)

²⁵ Unit Stream Power is a measure of the power of the river and is expressed in watts per unit area (m^2 in this case) and is calculated as the specific weight of the fluid $\times Q \times$ energy slope / channel width. The graphs indicate that even though the highest flow class has the highest unit stream power, because its energy is only directed at the bed for a short time, its overall effectiveness is not as great as the next lowest class.

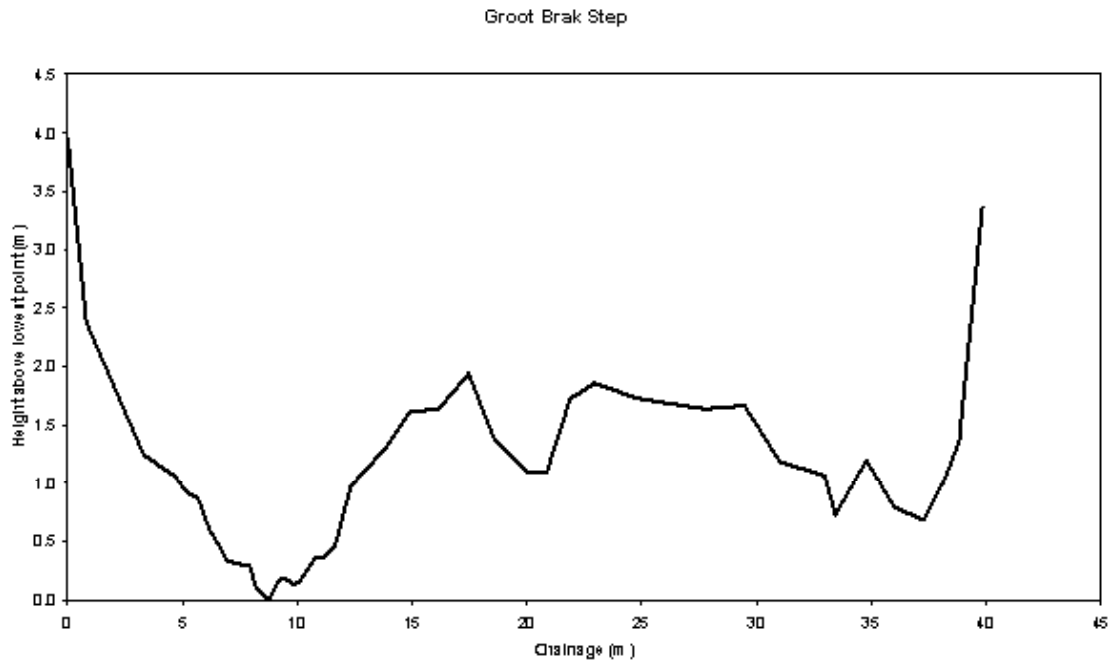


Figure 4.40 Groot Brak River (GB 1) step cross-section

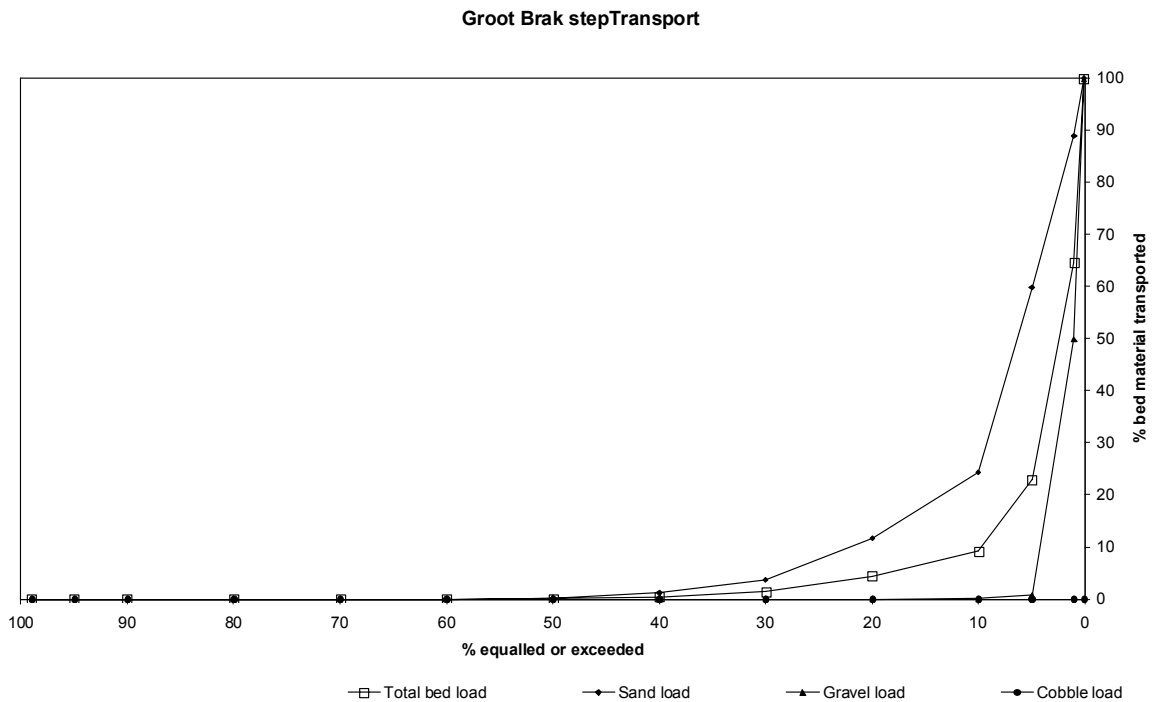


Figure 4.41 Cumulative potential bed material load for the present-day daily time series, Groot Brak River (GB 1) for the step cross-section

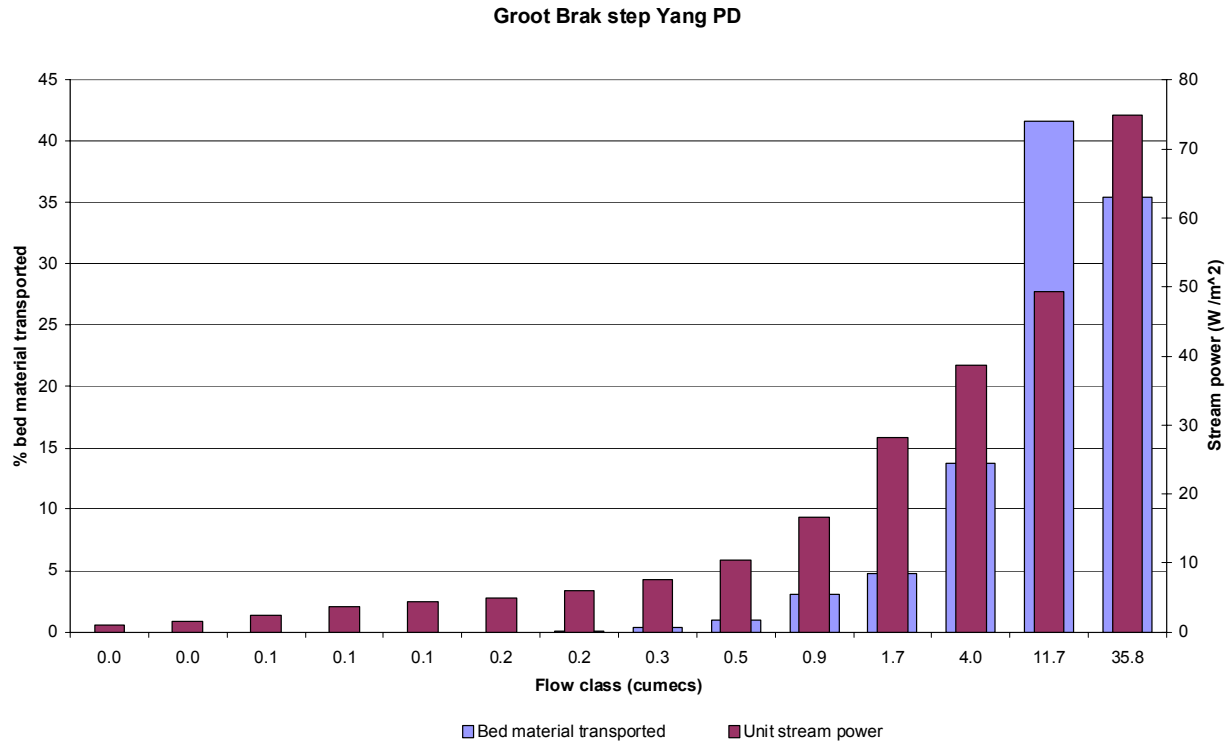


Figure 4.42 Potential bed material load for the present-day daily time series, step cross-section, Groot Brak River (GB 1)

Cross-section B (pool)

The rated cross-section for the pool cross-section is presented in (Figure 4.43). Under present-day conditions, the most effective flows (in terms of work – volume of bed material moved) are those in the 5-1% flow class which accounts for ~42% of the total PBML (Figure 4.44). The distribution of bed material transported under different flow classes is different in the pool (Figure 4.45) and step (Figure 4.42) cross-sections. A greater proportion of the bed material is transported under higher flow conditions in the pool cross-section, as would be expected.

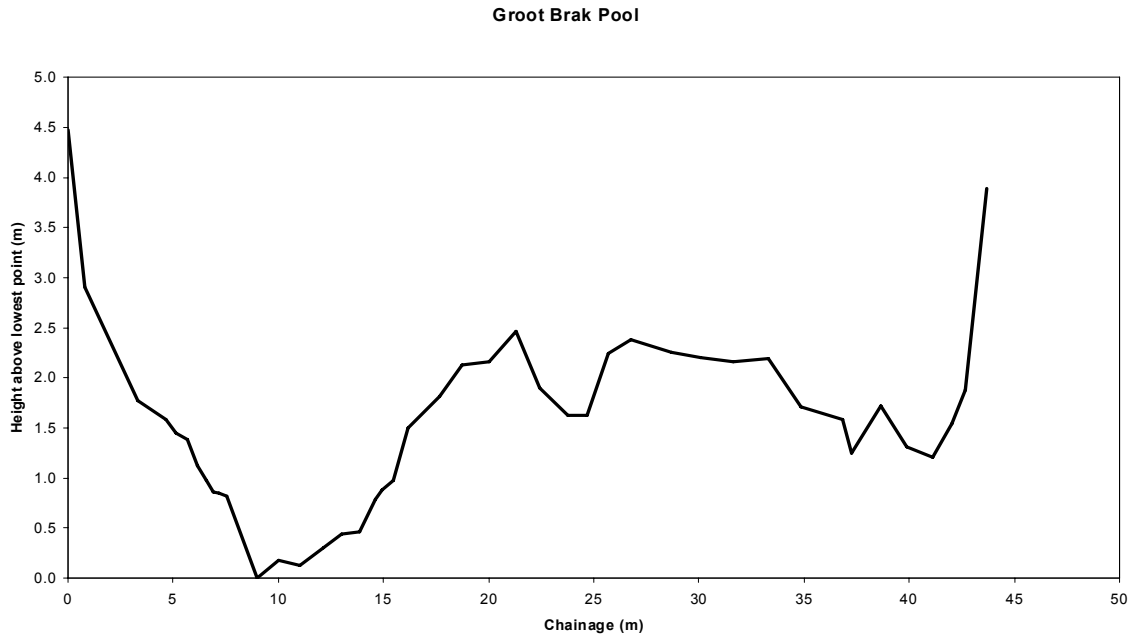


Figure 4.43 Groot Brak River (GB 1) pool cross-section

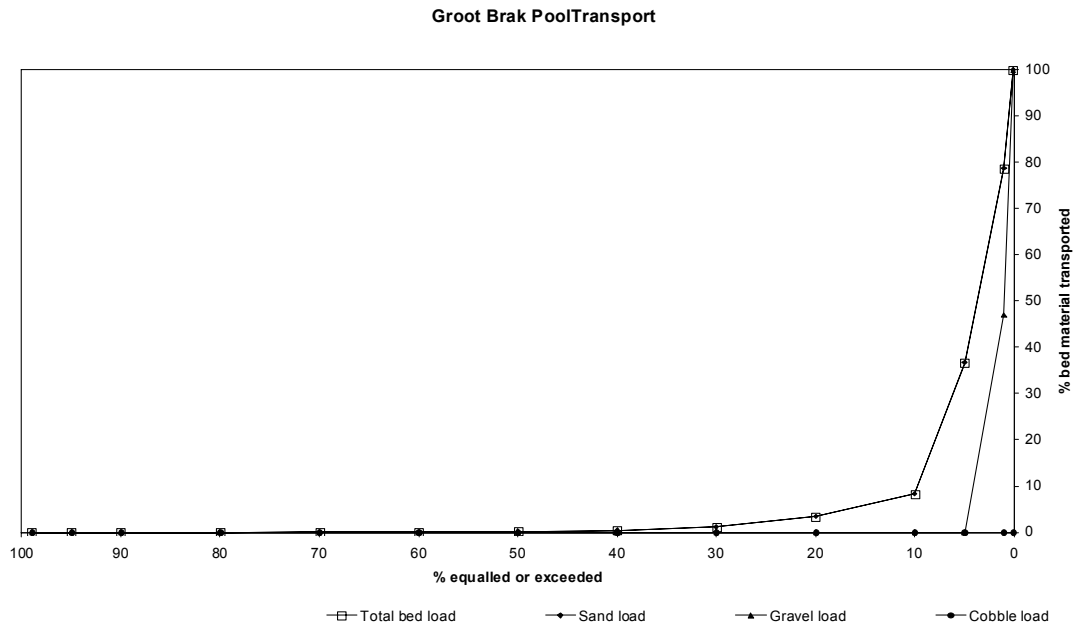


Figure 4.44 Cumulative potential bed material load for the present-day daily time series, pool cross-section, Groot Brak River (GB 1)

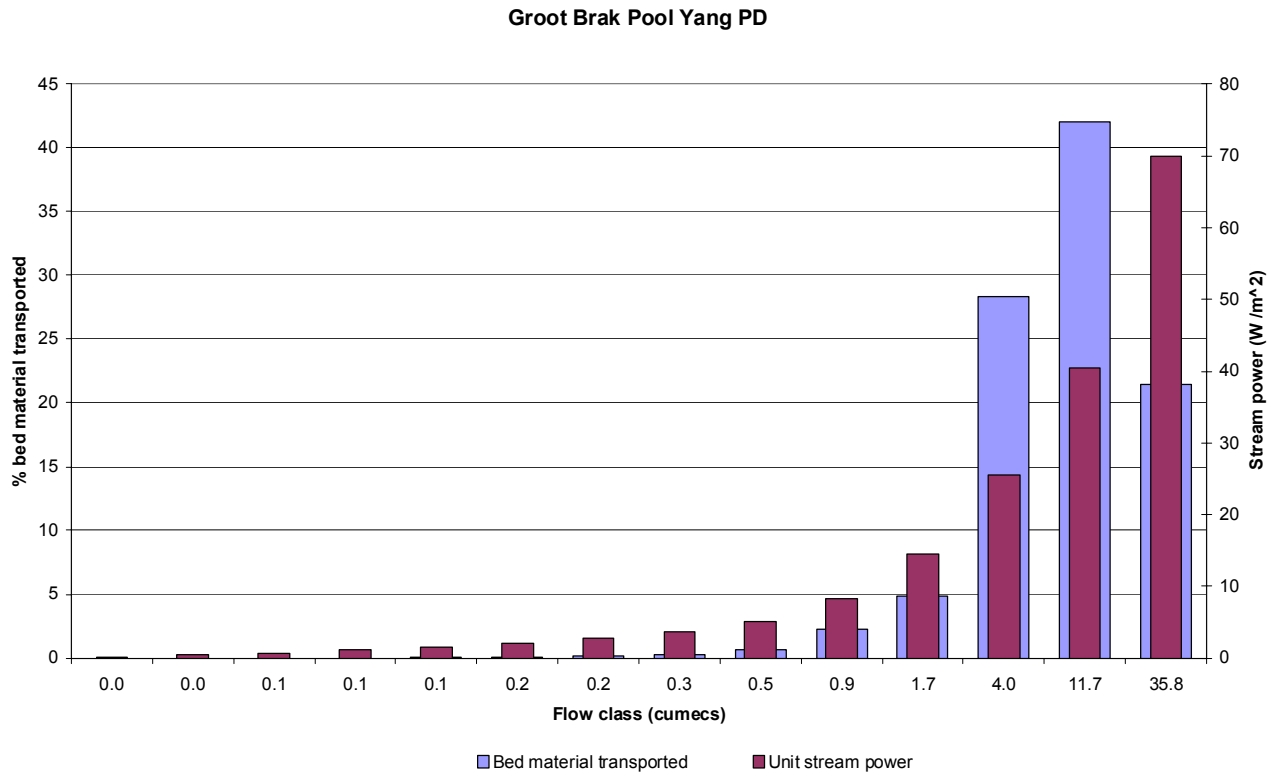


Figure 4.45 Potential bed material load for the present-day daily time series, pool cross-section, Groot Brak River (GB 1)

Kaaimans River (Ka 1)

Although the PBML model was run using both the natural and present-day hydrological daily time series, only the present-day time series data are displayed. The 1-day daily flow duration curve generated from the daily time series is presented in Figure 4.46.

Cross-section

The rated cross-section for the riffle cross-section is presented in Figure 4.46. Under present-day conditions, the most effective flows (in terms of work – volume of bed material moved) are those in the 5-1% flow class which accounts for ~30% of the total PBML (Figure 4.48). The Kaaimans River (Ka 1) shows a different sediment distribution to the two previously mentioned rivers, with a greater proportion of bed material distributed over a variety of discharges (Figure 4.49).

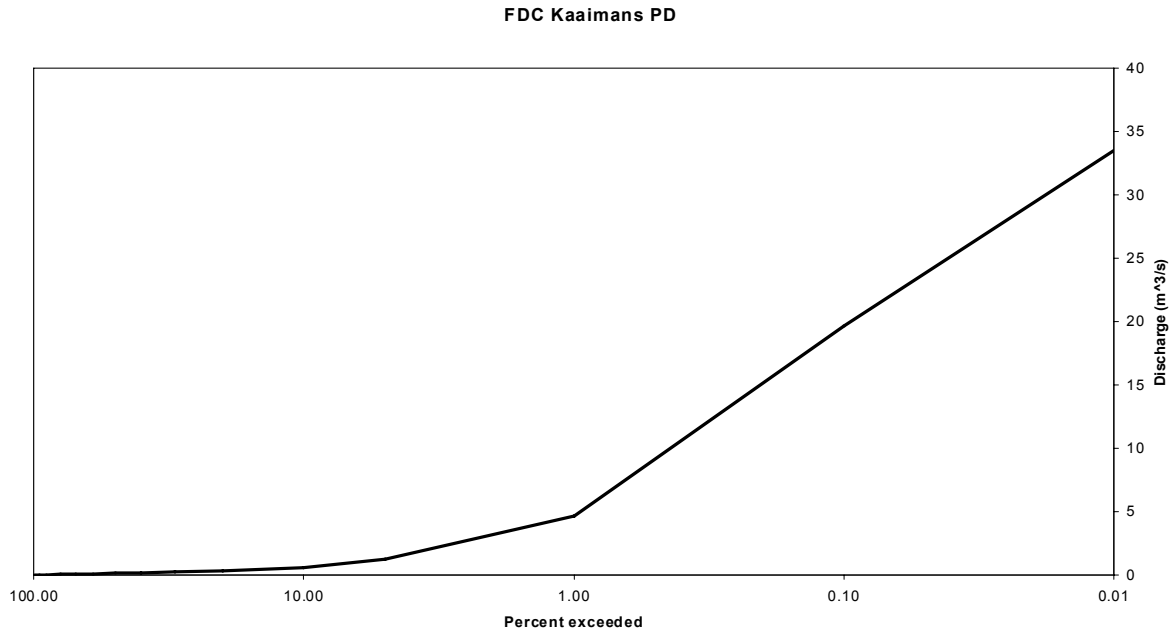


Figure 4.46 1-day daily flow duration for the present-day daily time series for the Kaaimans River (Ka 1)

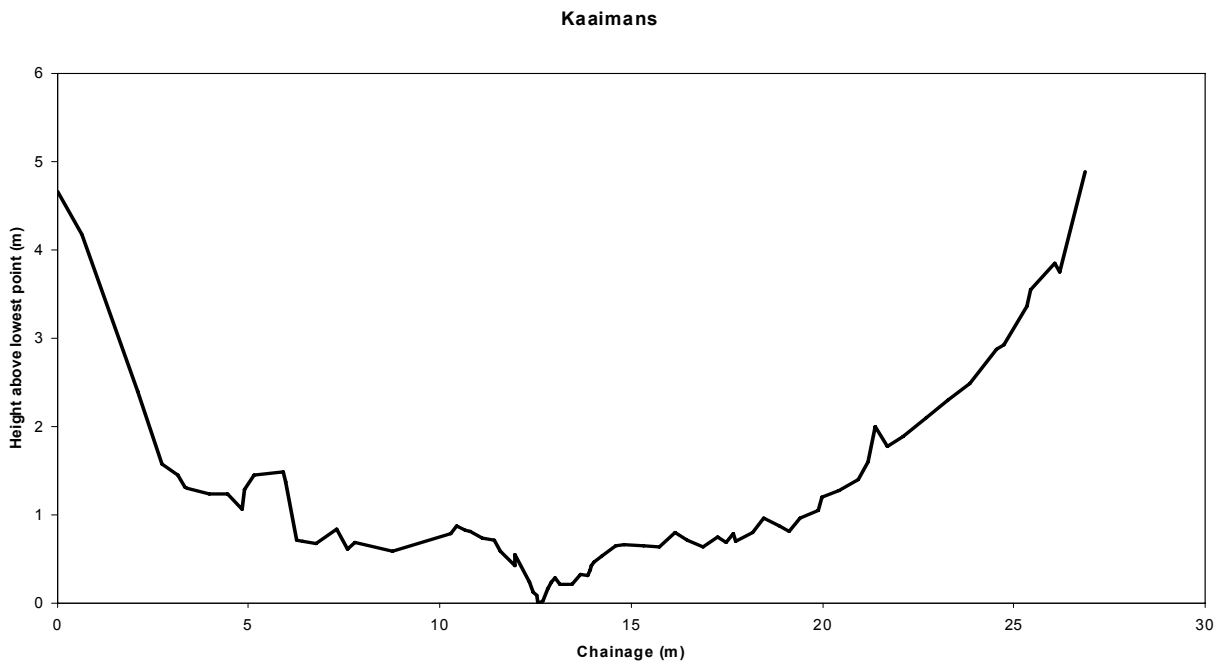


Figure 4.47 Kaaimans River (Ka 1) cross-section

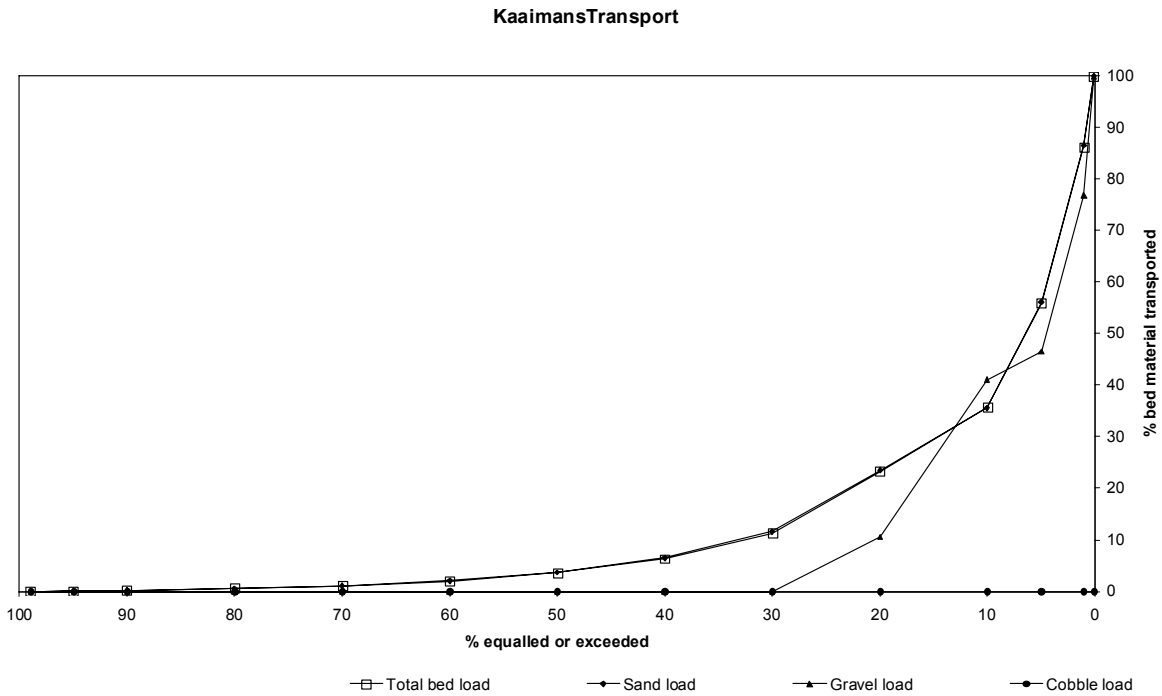


Figure 4.48 Cumulative potential bed material load for the present-day daily time series, Kaaimans River (Ka 1)

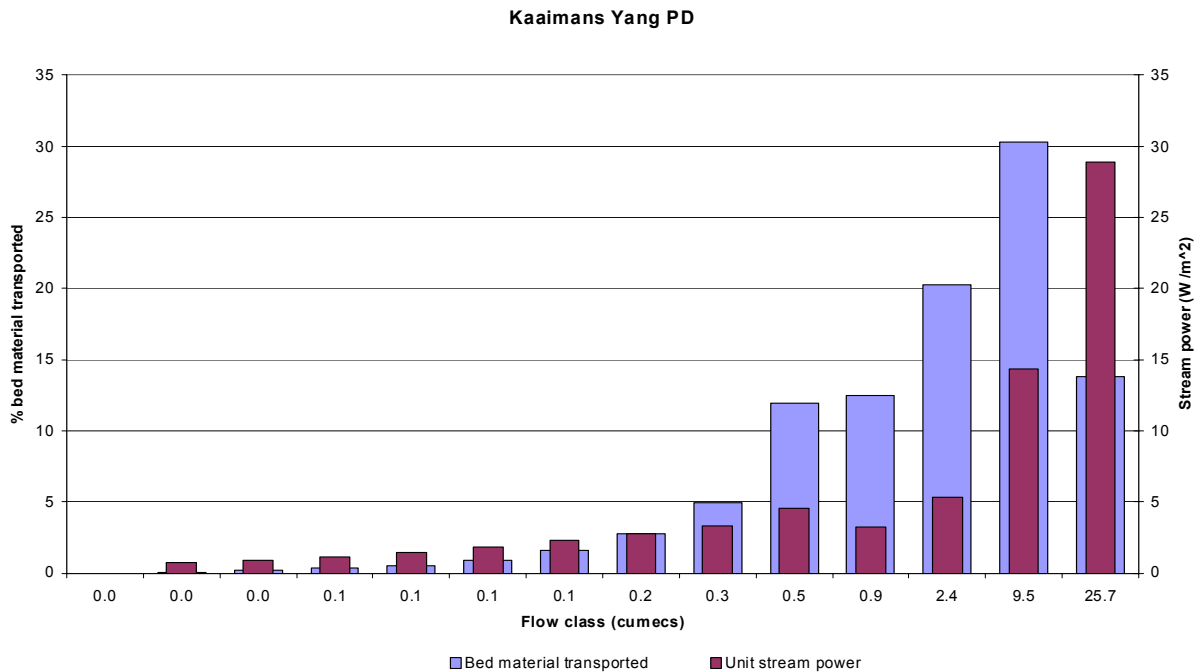


Figure 4.49 Potential bed material load for the present-day daily time series, Kaaimans River (Ka 1)

Malgas River (Mal 1)

Again, the PBML model was run using both the natural and present-day hydrological daily time series. Only the present-day time series data are reported as these were used to interpret the results in the EWR workshop. The 1-day daily flow duration curve generated from the daily time series is presented in Figure 4.50.

Cross-section

The rated cross-section for the riffle cross-section is presented in Figure 4.51. Under present-day conditions, the most effective flows (in terms of work – volume of bed material moved) are those in the 5-1% flow class which accounts for ~51% of the total PBML (Figure 4.52). Lower discharges and associated hydraulic conditions (low unit stream powers) (Figure 4.53) are simply not capable of mobilising large portions of the bed material.

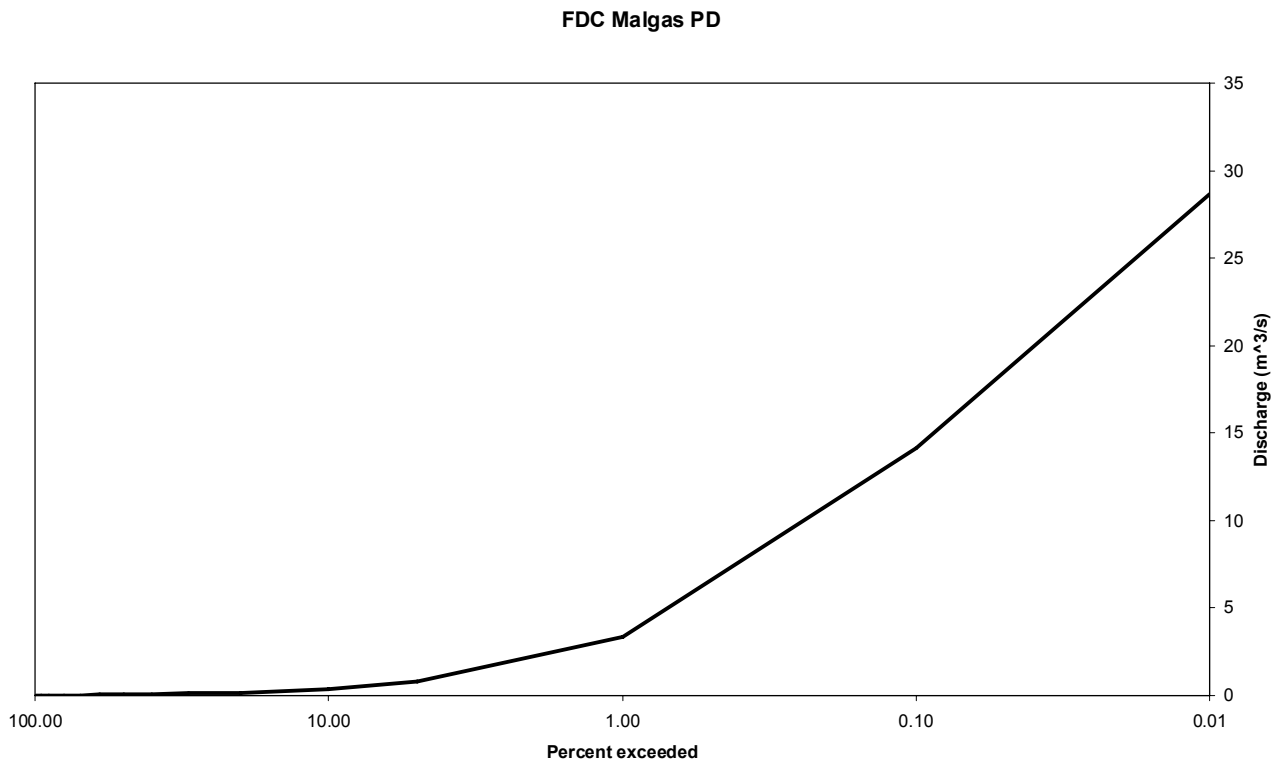


Figure 4.50 1-day daily flow duration for the present-day daily time series for the Malgas River (Mal 1)

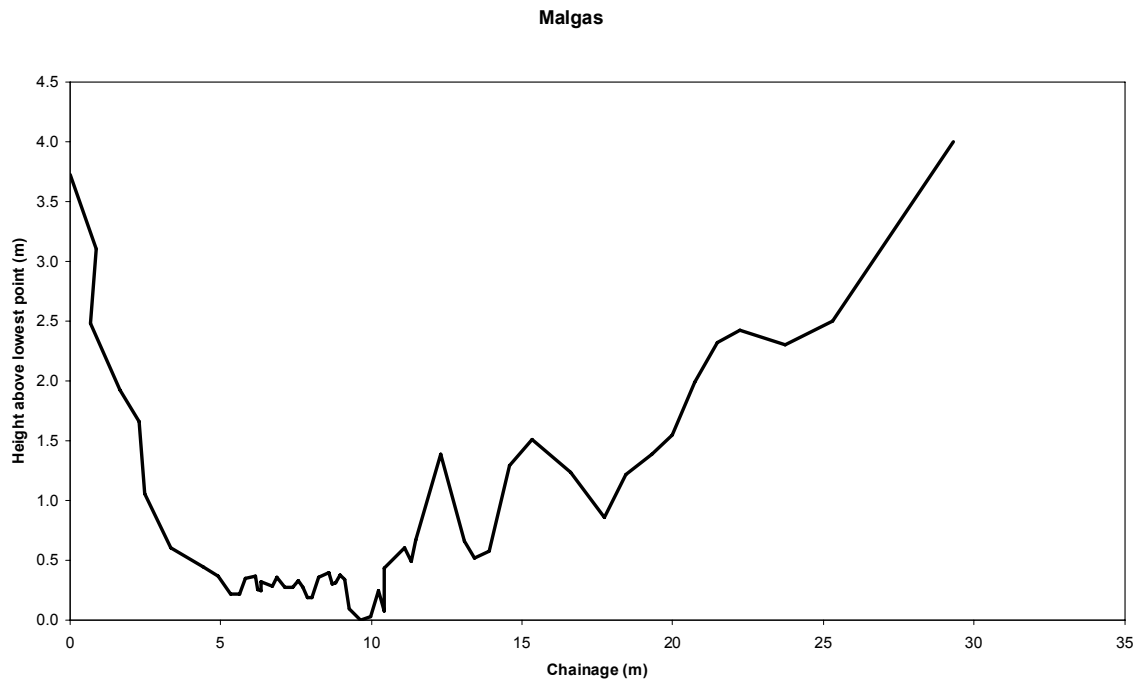


Figure 4.51 Malgas River (Mal 1) cross-section

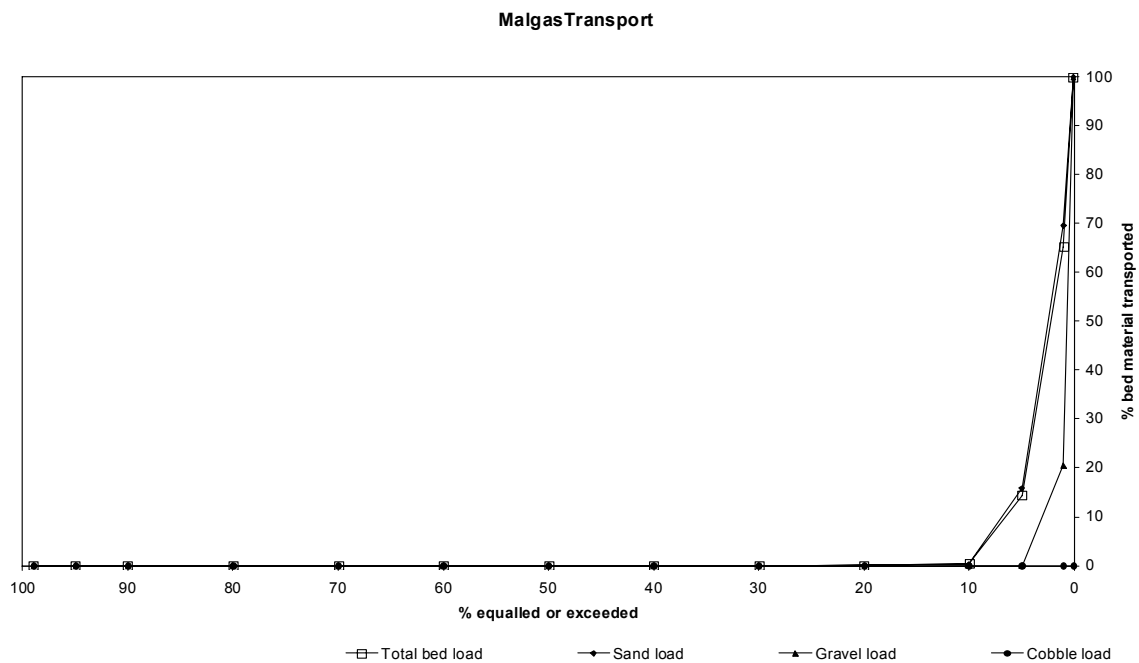


Figure 4.52 Cumulative potential bed material load for the present-day daily time series, Malgas River (Mal 1)

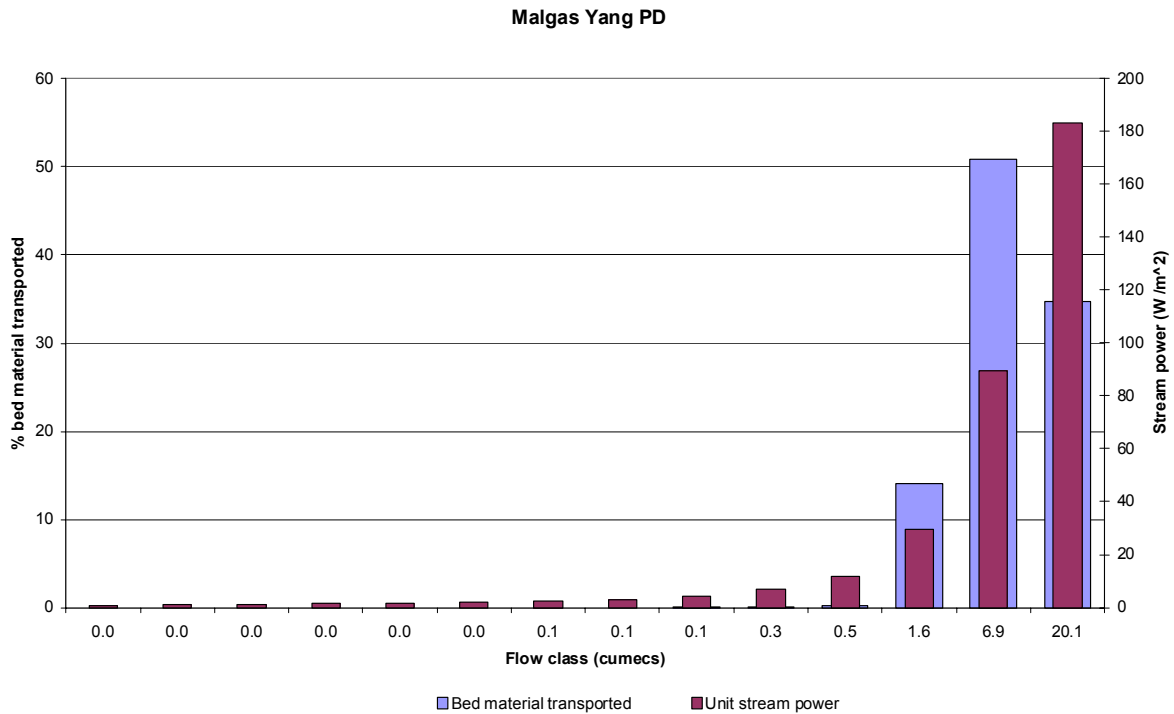


Figure 4.53 Potential bed material load for the present-day daily time series, Malgas River (Mal 1)

Goukamma River (Gou 1)

The PBML model was run using both the natural and present-day hydrological daily time series. The results are only presented for the present-day time series, as these data were used to interpret the results in the EWR workshop. The 1-day daily flow duration curve generated from the daily time series is presented in Figure 4.54.

Cross-section

The rated cross-section for the riffle cross-section is presented in Figure 4.55. Under present-day conditions, the most effective flows (in terms of work – volume of bed material moved) are those in the 1-0.1% flow classes which account for ~53% of the total PBML (Figure 4.56). Lower discharges and associated hydraulic conditions (low unit stream powers) (Figure 4.57) are simply not capable of mobilising large portions of the bed material; as the bed is mainly armoured.

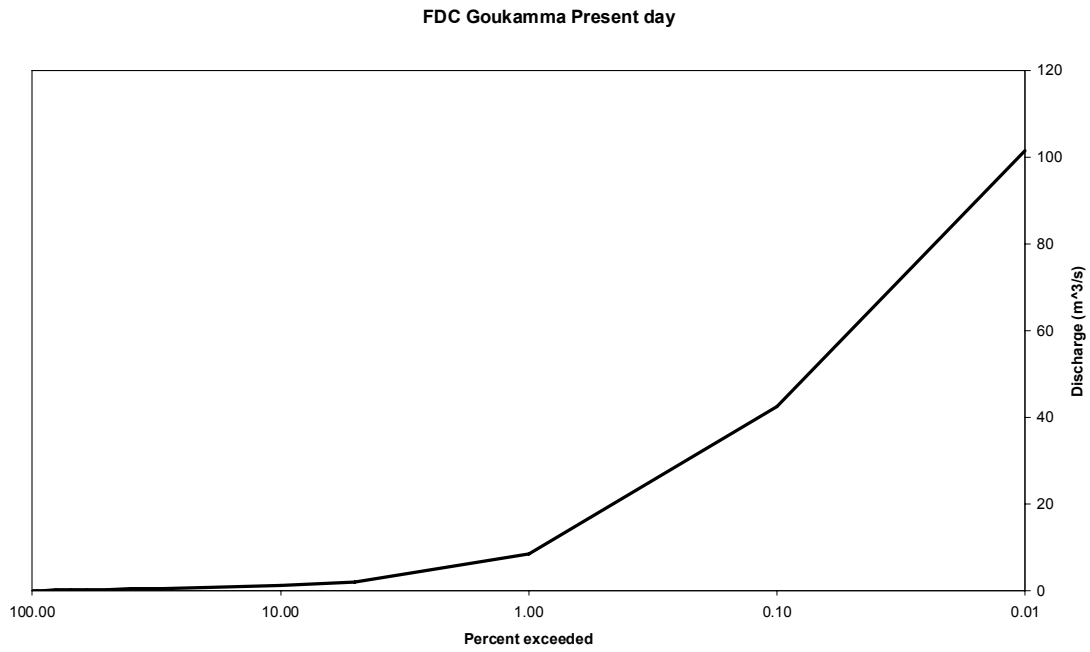


Figure 4.54 1-day daily flow duration for the present-day daily time series for the Goukamma River (Gou 1)

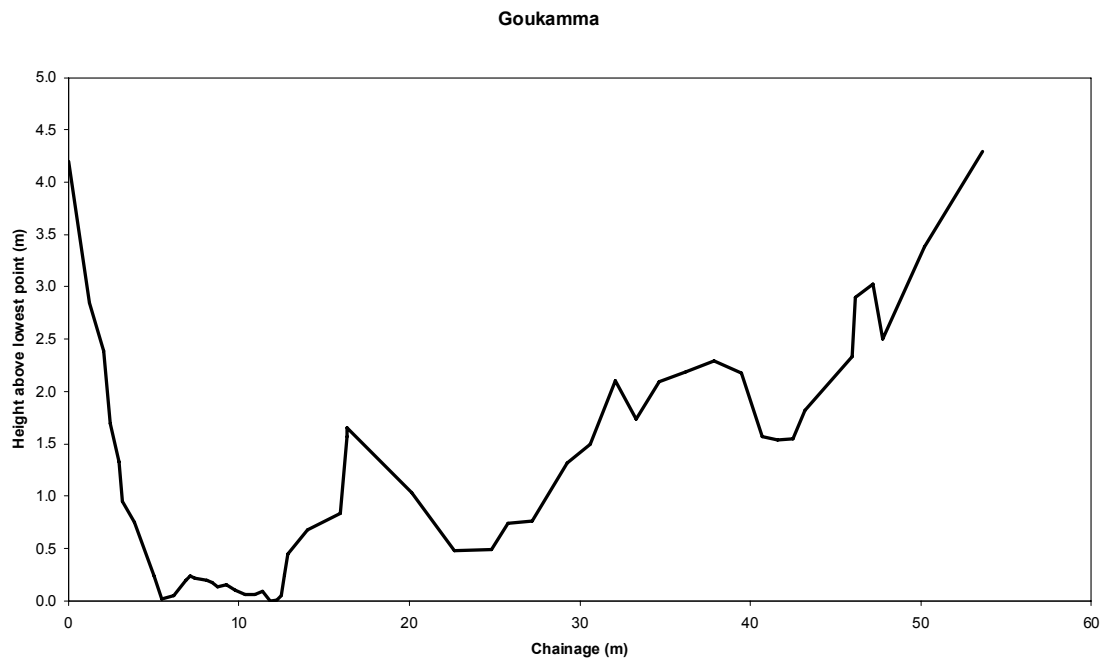


Figure 4.55 Goukamma River (Gou 1) cross-section

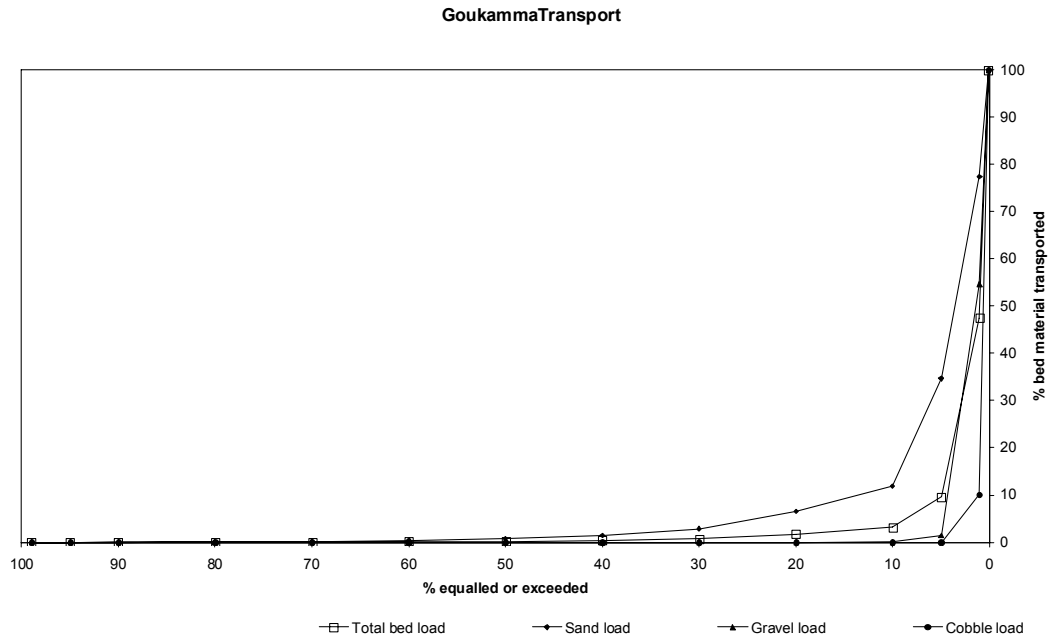


Figure 4.56 Cumulative potential bed material load for the present-day daily time series, Goukamma River (Gou 1)

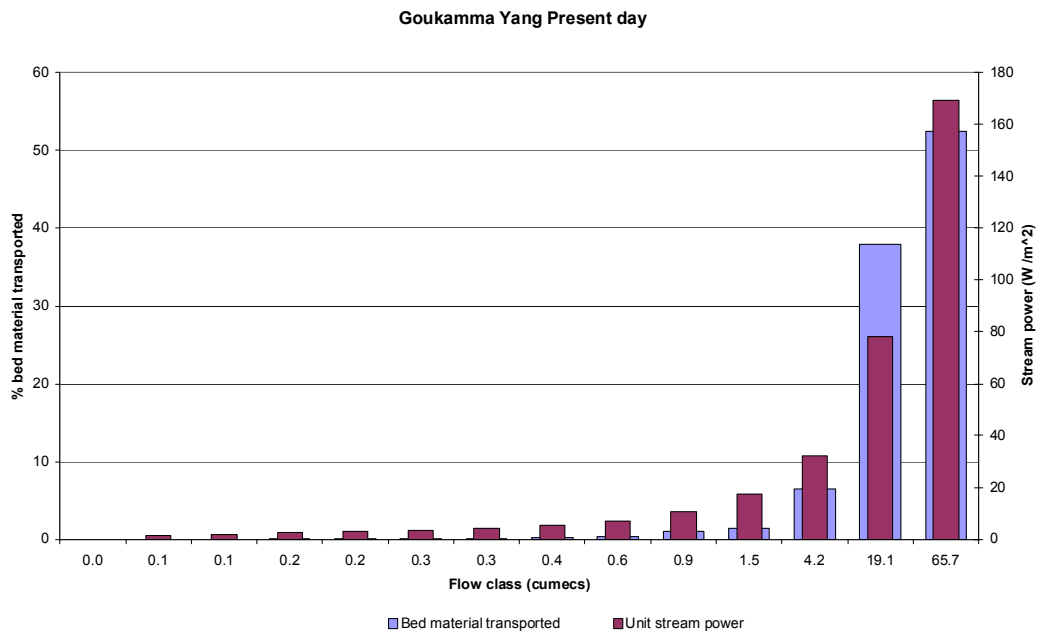


Figure 4.57 Potential bed material load for the present-day daily time series, Goukamma River (Gou 1)

4.4.4 Geomorphology Generic Lists

The results from the computations in Section 4.1 are utilised to help predict the consequences of different flow change scenarios²⁶ (e.g. removing all 1 in 2-year return period events from the present-day record) for input into DRIFT.

The generic lists used in the DRIFT process are lists of components (e.g. geomorphology), sub-components (e.g. bed material transport potential, average depth), and elements (e.g. groupings making up elements, depth distributions making up average depth for example) that are used to describe the consequences of flow changes (King *et al.*, 2003). For geomorphology, the following sub-component list was compiled:

- width;
- slope;
- cross-sectional average depth;
- sediment discharge;
- geodiversity of geomorphic units;
- change in the proportion of fine material on the bed; and
- overbank sedimentation.

RATIONALE FOR THE GENERIC LIST

The generic list was chosen based on the assumption that broad predictions (qualitative and quantitative) can be made about how the aforementioned sub-components (e.g. width, slope, depth) respond to changes in water and sediment discharge (computed earlier for different classes –Section 4.1).

For example, it is common knowledge that spatial width variation generally occurs concurrently with bed scour or fill in response to changing water and/or sediment supply (Chang, 2002). Variation in width represents the river's adjustment towards equal power gradient. Channels undergoing scour have a **slope** (energy gradient) greater than adjacent areas. A change in **depth** and **width** effectively reduces the energy gradient due to decreased boundary²⁷ resistance and lowered bed elevation.

Alternately, rivers undergoing fill have a lower elevation and a flatter slope. Channel widening effectively steepens the energy gradient due to increasing boundary resistance and rising bed elevation. Adjustments of channel width effectively reduce the spatial variation in power expenditure or nonuniformity in the water-surface profile. Because **sediment discharge** is a direct function of stream power (γQS), channel adjustment in the direction of equal power expenditure also favours uniformity in sediment discharge. A reduction in the width, slope, depth and sediment discharge will generally result in reduced heterogeneity (**geodiversity of geomorphic units**), and consequently a reduction in habitat diversity. Furthermore, assuming

²⁶ Provided by the hydrologist.

²⁷ Boundary conditions refer to the spatial arrangement of the small-scale geomorphic features that make up the physical form of the channel.

constant catchment sediment supply, reducing the magnitude, frequency and duration of effective discharges will increase the proportion of **fine material** on the riverbed (*cf.* Milhous, 1973). Similarly, reducing the magnitude, frequency and duration of overbank flows will halt the development of floodplains (where they exist), and will also cut off the supply of sediment (and associated nutrients and seeds) (**overbank sedimentation**) necessary for the healthy functioning of the riparian zone. In reality, all of these elements are interlinked and operate in feedback loops.

APPLICATION OF THE GENERIC LIST

Application of the generic list requires a degree of circumspection, as predicting changes in river channels is never straightforward, and there is seldom a simple linear relationship between cause (hydrological change) and effect (sub-components). The approach adopted for this study therefore utilises the concept of equilibrium²⁸, regime theory²⁹ and qualitative (see Table 4.21) and quantitative information (see Section 4.4.3) to predict the possible changes³⁰ in the generic list sub-components to changes³¹ in flow. Lane (1955) depicted the concept of equilibrium as:

$$Q_s d \propto QS$$

Equation A2

Where Q is the flow discharge, Q_s is the sediment discharge, d is the median grain size and S is the channel slope.

This concept can be utilised to predict changes in generic list sub-components. The approach taken is adapted from a qualitative model of channel change developed by Schumm (1969) (Table 4.21).

These relationships (Table 4.21) suggest that channel slope is controlled by discharge, sediment load and calibre (size). Reduction in slope leads to aggradation, deficit in catchment sediment supply leads to degradation, development of a more sinuous course, and coarsening of the bed material. Aggradation and degradation, or short-term scour and fill of the channel bed are accompanied by significant changes in width. As a rule, aggrading channels tend to widen and degrading channels tend to narrow.

28 An equilibrium river reach is one in which the transport capacities for water and sediment are in balance. Adjustments of equilibrium can be induced by tectonic, climatic and hydrological events, and/or human influence (direct and indirect – e.g. impoundments, mining, land use). Where any of these factors disturb equilibrium, the channel will adjust (change) in order to restore equilibrium.

29 Regime theory holds that discharge is the dominant variable to which dependent variables such as width, depth, velocity and meander wavelength adjust

30 The complexities involved in predicting these changes have hampered the development of analytical tools for prediction (Chang, 2002; Dollar, 2004). These are mainly related to indeterminacy and equifinality (Thornes, 1977), or respectively, the channel has many different ways of responding to changes, and that the same result could be achieved by numerous pathways. An additional problem is one of thresholds.

31 It is important to note that the adjustments in regime relate to adjustments of equilibrium, and not to transient behaviour.

Table 4.21 Qualitative model of channel change (after Schumm, 1969)

Increase in discharge alone $Q^+ \sim B^+ D^+ F^+ \lambda^+ S^-$	Decrease in discharge alone $Q^- \sim B^- D^- F^- \lambda^- S^+$
Increase in bed-material discharge $Q_s^+ \sim B^+ D^+ F^+ \lambda^+ S^+ P^-$	Decrease in bed-material discharge $Q_s^- \sim B^- D^- F^- \lambda^- S^- P^+$
Discharge and bed material discharge increase together; for example, during urban construction, or during early phases of afforestation $Q^+ Q_s^+ \sim B^+ D^+ F^+ \lambda^+ S^+ P^-$	
Discharge and bed material discharge decrease together; for example, downstream of a reservoir $Q^- Q_s^- \sim B^- D^- F^- \lambda^- S^- P^+$	
Discharge increases as bed-material discharge decreases; for example, increasing humidity in an initially sub-humid zone $Q^+ Q_s^- \sim B^+ D^+ F^- \lambda^+ S^+ P^+$	
Discharge decreases as bed-material increases; for example, increased water use combined with land-use pressure $Q^- Q_s^+ \sim B^- D^- F^+ \lambda^- S^- P^-$	

where

Q	discharge
S	slope (water surface)
D	mean depth
B	surface width
F	width/depth ratio
λ	wavelength
P	sinuosity

METHOD

Table 4.21 was used together with the PBML model and Table 4.22 to predict the consequences of changing flow classes as required by DRIFT (see King *et al.*, 2003). This required developing further code to predict the consequences of different levels of change³² (e.g. removing intra-annual floods from the daily time series, or removing the 1:10 year floods), as the procedure is computationally intense.

RESULTS

This Section presents the severity tables for different flow changes for the EWR Sites for each cross-section. The procedure that was followed to populate these tables was to:

- Obtain the flow change classes required by DRIFT.
- Remove the flows that occur within each change class (e.g. for Class 1(iv) remove all the flows within the 16-26m³/s band) from the present-day daily time series.

³² The consequences of each flow change level assume that all other flow components remain unchanged from pre-development conditions.

- Utilise the modified time series to run the PBML model.
- Utilise the results from Equation A2, and the rules developed in Table 4.21 and Table 4.22 to populate the severity table for each scenario for each cross-section.
- Input the results plus comments into DRIFT solver.

Table 4.22 Severity tables for geomorphology subcomponents

Width, depth, slope, sediment discharge and geodiversity subcomponents			
Severity rating	Severity of change	Equivalent loss (-ve)	Equivalent gain (+ve)
0	None	No change	No change
1	Negligible	0-5% change in PBML	0-5% change in PBML
2	Low	5.1-10% change in PBML	5.1-10% change in PBML
3	Moderate	10.1-20% change in PBML	10.1-20% change in PBML
4	Severe	20.1-40% change in PBML	20.1-40% change in PBML
5	Critically severe	>40% change in PBML	>40% change in PBML
Fine material on the bed subcomponent			
0	None	No change	No change
1	Negligible	0-5% change in potential sand-fraction transport	0-5% change in potential sand-fraction transport
2	Low	5.1-20% change in potential sand-fraction transport	5.1-20% change in potential sand-fraction transport
3	Moderate	20.1-40% change in potential sand-fraction transport	20.1-40% change in potential sand-fraction transport
4	Severe	40.1-60% change in potential sand-fraction transport	40.1-60% change in potential sand-fraction transport
5	Critically severe	>60% change potential sand-fraction transport	>60% change potential sand-fraction transport
Overbank sedimentation subcomponent			
0	None	No change	No change
1	Negligible	0-5% change in overbank flows (frequency)	0-5% change in overbank flows (frequency)
2	Low	6-10% change in overbank flows (frequency)	6-10% change in overbank flows (frequency)
3	Moderate	11-20% change in overbank flows (frequency)	11-20% change in overbank flows (frequency)
4	Severe	21-50% change in overbank flows (frequency)	21-50% change in overbank flows (frequency)
5	Critically severe	>50% change in overbank flows (frequency)	>50% change in overbank flows (frequency)

The results of the above process for each site for each cross-section are presented in Table 4.27 to Table 4.26. The severity ratings for the reported change levels were entered directly into the DRIFT database and are not repeated here.

Table 4.23 Groot Brak River (GB 1) Step section

Size Class ³³	Q range (m ³ /s)	Cross-section A Percentage change from present-day time series				
		Stream power (ω)	Sand load	Gravel load	Cobble load	Total load
Width, depth, slope, sediment discharge and geodiversity						
1(1)		-5.4	-17.7	-13.4	-	-15.0
1(2)		-5.4	-17.8	-13.4	-	-15.0
1(3)		-5.5	-17.9	-13.4	-	-15.1
2(1)		-5.9	-18.8	-13.4	-	-15.4
2(2)		-6.2	-19.5	-13.4	-	-15.7
2(3)		-6.8	-20.7	-13.4	-	-16.2
3(1)		-8.0	-25.2	-13.5	-	-17.9
3(2)		-7.9	-36.6	-53.1	-	-46.9
4(1)		-7.5	-46.3	-68.3	-	-60.0
5(1)		-19.8	-53.1	-97.2	-	-80.7
Fine material on the bed (see Table 4.22)						
1(1)			-17.7			
1(2)			-17.8			
1(3)			-17.9			
2(1)			-18.8			
2(2)			-19.5			
2(3)			-20.7			
3(1)			-25.2			
3(2)			-36.6			
4(1)			-46.3			
5(1)			-53.1			
Overbank sedimentation (see Table 4.22)						
1(1)	-					
1(2)	-					
1(3)	-					
2(1)	-					
2(2)	-					
2(3)	-					
3(1)	-					
3(2)	-					
4(1)	-					
5(1)	60%					

³³ Of DRIFT floods.

Table 4.24 Groot Brak River (GB 1) Pool section

Size Class	Q range (m³/s)	Cross-section B Percentage change from present-day time series				
		ω	Sand load	Gravel load	Cobble load	Total load
Width, depth, slope, sediment discharge and geodiversity						
1(1)		-5.7	-19.2	-21.2	-	-19.3
1(2)		-5.8	-19.3	-21.2	-	-19.3
1(3)		-5.8	-19.3	-21.2	-	-19.3
2(1)		-6.1	-19.7	-21.2	-	-19.7
2(2)		-6.4	-19.9	-21.2	-	-19.9
2(3)		-6.8	-20.6	-21.2	-	-20.6
3(1)		-7.7	-24.9	-21.2	-	-24.9
3(2)		-13.5	-45.2	-58.1	-	-45.3
4(1)		-17.2	-57.4	-64.9	-	-57.4
5(1)		-32.1	-74.0	-99.1	-	-74.0
Fine material on the bed (see Table 4.22)						
1(1)			-19.2			
1(2)			-19.3			
1(3)			-19.3			
2(1)			-19.7			
2(2)			-19.9			
2(3)			-20.6			
3(1)			-24.9			
3(2)			-45.2			
4(1)			-57.4			
5(1)			-74.0			
Overbank sedimentation (see Table 4.22)						
1(1)	-					
1(2)	-					
1(3)	-					
2(1)	-					
2(2)	-					
2(3)	-					
3(1)	-					
3(2)	-					
4(1)	-					
5(1)	59%					

Table 4.25 Kaaimans River (Ka 1)

Size Class	Q range (m³/s)	Percentage change from present-day time series				
		ω	Sand load	Gravel load	Cobble load	Total load
Width, depth, slope, sediment discharge and geodiversity						
1(1)		-2.5	-7.6	-2.7	-	-7.5
1(2)		-2.6	-8.0	-3.0	-	-7.9
1(3)		-2.7	-9.1	-3.7	-	-9.0
1(4)		-2.8	-10.3	-5.9	-	-10.2
2(1)		-2.7	-10.4	-7.4	-	-10.3
2(2)		-12.4	-23.2	-38.2	-	-23.6
3(1)		-4.3	-14.2	-7.3	-	-14.0
3(2)		-16.6	-34.4	-44.5	-	-34.7
4(1)		-4.7	-15.0	-8.5	-	-14.9
5(1)		-29.7	-37.9	-42.1	-	-38.0
Fine material on the bed (see Table 4.22)						
1(1)			-7.6			
1(2)			-8.0			
1(3)			-9.1			
1(4)			-10.3			
2(1)			-10.4			
2(2)			-23.2			
3(1)			-14.2			
3(2)			-34.4			
4(1)			-15.0			
5(1)			-37.9			
Overbank sedimentation (see Table 4.22)						
1(1)	-					
1(2)	-					
1(3)	-					
1(4)	-					
2(1)	-					
2(2)	-					
3(1)	-					
3(2)	-					
4(1)	-					
5(1)	52%					

Table 4.26 Malgas River (Mal 1)

Size Class	Q range (m³/s)	Percentage change from present-day time series				
		ω	Sand load	Gravel load	Cobble load	Total load
Width, depth, slope, sediment discharge and geodiversity						
1(1)		-10.9	-20.3	-50.2	-	-22.9
1(2)		-11.4	-21.7	-50.2	-	-24.1
1(3)		-21.1	-23.5	-50.2	-	-25.8
1(4)		-11.1	-21.3	-50.2	-	-23.8
2(1)		-11.4	-22.2	-50.2	-	-24.6
2(2)		-37.1	-70.0	-93.0	-	-72.0
3(1)		-15.5	-39.3	-57.0	-	-40.9
3(2)		-39.3	-75.2	-94.3	-	-77.4
4(1)		-17.4	-46.5	-60.6	-	-47.7
5(1)		-42.5	-75.0	-96.3	-	-76.9
Fine material on the bed (see Table 4.22)						
1(1)			-20.3			
1(2)			-21.7			
1(3)			-23.5			
1(4)			-21.3			
2(1)			-22.2			
2(2)			-70.0			
3(1)			-39.3			
3(2)			-75.2			
4(1)			-46.5			
5(1)			-75.0			
Overbank sedimentation (see Table 4.22)						
1(1)	-					
1(2)	-					
1(3)	-					
1(4)	-					
2(1)	-					
2(2)	-					
3(1)	-					
3(2)	-					
4(1)	-					
5(1)	42%					

Table 4.27 Goukamma River (Gou 1)

Size Class	Q range (m³/s)	Percentage change from present-day time series				
		ω	Sand load	Gravel load	Cobble load	Total load
Width, depth, slope, sediment discharge and geodiversity						
1(1)		-6.1	-20.9	-28.6	-32.7	-27.8
1(2)		-13.1	-26.9	-41.3	-69.5	-45.8
1(3)		-6.5	-21.7	-28.6	-32.7	-28.0
2(1)		-5.9	-21.7	-28.6	-32.7	-28.0
2(2)		-13.4	-28.9	-41.4	-69.5	-46.3
2(3)		-5.9	-22.6	-29.5	-32.9	-28.7
3(1)		-7.6	-32.2	-40.7	-33.2	-36.0
4(1)		-39.1	-62.9	-93.6	-100	-87.7
Fine material on the bed (see Table 4.22)						
1(1)			-20.9			
1(2)			-26.9			
1(3)			-21.7			
2(1)			-21.7			
2(2)			-28.9			
2(3)			-22.6			
3(1)			-32.2			
4(1)			-62.9			
Overbank sedimentation (see Table 4.22)						
1(1)	-					
1(2)	-					
1(3)	-					
2(1)	-					
2(2)	-					
2(3)	-					
3(1)	-					
4(1)	62%					

4.5 VEGETATION

4.5.1 Introduction

Specific detail about longitudinal and lateral riparian zonation patterns is scanty and virtually non-existent for the study rivers, namely the Groot Brak, Maalgas, Silver/Kaaimans, Goukamma, Gwaing, Maalgate and Swart Rivers. Noetsie River was not sampled for vegetation during the study period. However, historical background and aerial photographs were used to determine the PES. Partial studies include the Groot Brak Estuary (Morant, 1983) while the Wilderness/Knysna lakes have been treated more from a management perspective, such as the problem of macrophyte encroachment (Weisser and Howard-Williams, 1982). Morant (1983) and Bornman and Adams (2005) summarize the state of the Noetsie River estuary.

4.5.2 Methods

Sampling sites for the assessment of riparian vegetation should be reasonably natural, but actual site selection rests with the requirements of a number of different disciplines (e.g.

geomorphology, flow, invertebrates, fish, etc.), thus sites are not always optimum in terms of their botanical condition. The following ecological data were recorded to meet botanical requirements for each transect at each site (Kemper and Boucher, 2000):

- locality and applicable site details including photographic records;
- on ground identification of lateral vegetation zones;
- visual estimates of vegetation cover per zone;
- listing the dominant species in each vertical stratum (e.g. tree, shrub, herb) per zone, with a visual estimate of the total cover (Braun-Blanquet cover-abundance scale) of the conspicuous species in each stratum and
- a simple (not to scale) sketch of the transect profile with additional observations/notes.

The riparian vegetation model (Boucher, 2002; Kemper and Boucher, 2000) illustrated below (Table 4.28) was derived from samples of different lateral zones found in riparian vegetation in South Africa and Lesotho. It has not been used in the Southern Cape before so this is an opportunity to test it in the region.

Based on studies of riparian vegetation and different flow classes, Boucher (2002) identified a generalised pattern of plant community changes perpendicular to the river channel from the water's edge. He identified a set of plant community "zones" reflecting primarily differences in the length and regularity of inundation. The nomenclature for and the relationship between these vegetation zones and different flow regimes are provided in Table 4.26 (extracted from Boucher, 2002).

Table 4.28 Riparian vegetation model used to sample riparian vegetation in South Africa and Lesotho (Boucher, 2002; Kemper and Boucher, 2000)

Zone	Subzone	Inundation interval	Abb.	Marker
Dry Bank Zone	Back Dynamic (Transitional)	c. >20 year floods	BD	Debris line
	Tree-Shrub	2-20 year floods	TS	Bottom Dry Bank
	Lower Dynamic	Class 3, 4 Floods	LD	
Wet Bank Zone	Upper – <i>Salix/Prionium</i>	Class 2, 3 Floods	WU	Top Wet Bank
	Lower – Fringing Sedges	Wet Season Lowflows Class 1 Floods	WL	
Aquatic Zone	Rooted Aquatics	Dry Season Lowflow	AM	Perennial free water
	Floating Aquatics	No flow	AA	

4.5.3 Descriptions of riparian vegetation in rivers sampled

Eighty-seven samples were distributed through the study area with a total of 167 species recorded in them of which 39 (24%) of the species were exotic. This information is summarized

in Table 4.29 with sample detail provided in the description of each site (site locations are given in the descriptions of each site (Table 2.1).

The vegetation in most of the rivers sampled during this study have been impacted to some degree, such as through forestry (e.g., Maa 2) encroaching into the Back Dynamic Zone or through nutrient enriched water from farming (e.g., Moe 2), from channel manipulation (e.g., Moo 1) and from recent high floods scouring the channel (e.g., Gou 1). Debris accumulations were prevalent, particularly in alien infested areas (e.g. Moo 1).

The following plant communities, arranged hierarchically, were found in vegetation sampled during the present study based on the analysis of sample data collected and analysed following Zürich-Montpellier phytosociological techniques (Werger, 1974) as adapted and applied in Lesotho by Boucher and Tlale (1999).

VEGETATION CLASSIFICATION

The vegetation classification presented here (Table 4.29) is the result of the analysis of the data collected at each sampling site:

1. *Cyperus textilis*-*Phragmites australis* Riparian Mixed Wetland
2. *Typha capensis* Riparian Herbland
3. *Pennisetum clandestinum*-*Persicaria lapathifolium* Secondary Fringing Wetlands
4. *Prionium serratum* Riparian Fringing Shrublands.
 - 4.1 *Prionium serratum*-*Cliffortia odorata* Riparian Shrubland
 - 4.1.1 *Prionium serratum*-*Cliffortia odorata* Secondary Disturbed Subcommunity
 - 4.2 *Prionium serratum*-*Juncus lomatophyllus* Wetbank
5. *Rapanea melanophloeos*-*Rhus chirindensis* Forest Margin
 - 5.1 *Rapanea melanophloeos*-*Dietes iridioides* Riparian Forest
 - 5.1.1 *Rapanea melanophloeos*-*Halleria lucida* Riparian Woodland Subcommunity
 - 5.1.2 *Rapanea melanophloeos*-*Diospyros whyteana* Riparian Fringing Forest Subcommunity
 - 5.2 *Rapanea melanophloeos*-*Acalypha capensis* Forest Fringe
 - 5.3 *Rapanea melanophloeos*-*Aloe arborescens* Rocky Scrub Forest
6. Poorly defined samples with widespread species.

DESCRIPTIONS OF PLANT COMMUNITIES

Cyperus textilis-*Phragmites australis* Riparian Mixed Wetland

This community was recorded at the following sites: GB1, Maa 1 and Gwa 1. It is mainly found on silty substratums. The distinguishing species in this study are: *Acacia karroo*, *Cyperus textilis* and *Phragmites australis*. The presence of these species in this system implies a higher salinity with fine sediments. *A. karroo* is a typically karroid region riparian fringing tree, as are the herbaceous diagnostic species *C. textilis* and *P. australis*. The implication from this is that higher salinities are expected in these parts of the sampled rivers.

Table 4.29 Summary of the vegetation data collected in March 2007

Community number	1	2	3	4.1.1	4.1	4.2	4	5.1.1	5.1.2	5.1	5.2	5.3	6
Number of samples in each plant community	3	3	5	3	8	20	11	4	4	17	4	4	4
1. <i>Cyperus textilis</i>-<i>Phragmites australis</i> Riparian Mixed Wetland													
<i>Cyperus textilis</i> Thunb.	3												
<i>Phragmites australis</i> (Cav.) Steud.	3							1					
<i>Acacia karroo</i> Hayne	1												
2. <i>Typha capensis</i> Riparian Herbland													
<i>Typha capensis</i> (Rohrb.) N.E.Br.		3		1									
3. <i>Pennisetum clandestinum</i>-<i>Persicaria lapathifolium</i> Secondary Fringing Wetlands													
<i>Pennisetum clandestinum</i> Chiov. *	1	3	3	1									
<i>Persicaria lapathifolia</i> (L.) Gray *	2	1	2	3									
<i>Arundo donax</i> L. *	2		1	1									
<i>Verbena bonariensis</i> L. *		2	1										
<i>Chenopodium ambrosioides</i> L. *		1	2										
<i>Populus x canescens</i> (Aiton) Sm. *		1	1										
<i>Solanum nigrum</i> L. *		1	1										
<i>Tagetes minuta</i> L. *		1	1										
<i>Canna indica</i> L. *		1	1										
4.1 <i>Prionium serratum</i>-<i>Cliffortia odorata</i> Riparian Shrubland													
<i>Cliffortia odorata</i> L.f.				3	8								
<i>Cliffortia heterophylla</i> Weim.				1	1								
4.2 <i>Prionium serratum</i>-<i>Juncus lomatophyllus</i> Wetbank													
<i>Juncus lomatophyllus</i> Spreng.	1					17							
<i>Isolepis prolifer</i> R.Br.	1					13							
<i>Lobelia erinus</i> L.						7	1						
<i>Centella asiatica</i> (L.) Urb.	1					7				1			
<i>Juncus acutus</i> L.					1	5							1
<i>Mariscus thunbergii</i> (Vahl) Schrad.						4				1			
<i>Lauremburgia repens</i> P.J.Bergius					1	3							
<i>Wimmerella arabidea</i> (C.Presl)L.Serra, M.B.Crespo & Lammers						5				1			
<i>Juncus bufonius</i> L. *						4							
<i>Panicum repens</i> L.						2							
<i>Isolepis cernua</i> (Vahl) Roem. & Schult.						2							
4. <i>Prionium serratum</i> Riparian Fringing Shrublands													
<i>Prionium serratum</i> (L.f.) Drège ex E.Mey.	1		1	3	4	14	11						
<i>Panicum schinzii</i> Hack.			1	1	1	2	1						
<i>Phytolacca dioica</i> L. *		2			1	1							
<i>Oplismenus hirtellus</i> (L.) P.Beauv.			1			2							
<i>Paspalum dilatatum</i> Poir. *			1			2							
5.1.1 <i>Rapanea melanophloeos</i>-<i>Halleria lucida</i> Riparian Woodland													
<i>Halleria lucida</i> L.				3	1		4						
5.1.2 <i>Rapanea melanophloeos</i>-<i>Diospyros whyteana</i> Riparian Fringing Forest													
<i>Diospyros whyteana</i> (Hiern) F.White								1	4				
<i>Trichocladus crinitus</i> (Thunb.) Pers.									3				
5.1 <i>Rapanea melanophloeos</i>-<i>Dietes iridioides</i> Riparian Forest													
<i>Dietes iridioides</i> (L.) Sweet ex Klatt					1	3	6	2	3	9			
<i>Paspalum urvillei</i> Steud. *		1		2		9	1			4			
<i>Brachylaena neriifolia</i> (L.) R.Br.					1	2	5		1	7			
<i>Calopsis paniculata</i> (Rottb.) Desv.					1	6	3	1		4			
<i>Nuxia floribunda</i> Benth.				2		1	1	3	6				
<i>Todea barbara</i> (L.) T.Moore				1		5	3			4			
<i>Wachendorfia parviflora</i> W.F.Barker				1	3		1			3			
<i>Bryophyta</i>						4	1			2			
<i>Empodium plicatum</i> (Thunb.) Garside						2	2	1		2			
<i>Cyperus esculentus</i> L. *				1	2	2		1					
<i>Lobelia cf. flaccida</i> (C.Presl) A.DC.						3	1	1		1			
<i>Eucalyptus</i> sp. *					1		1	1		3			
<i>Passerina falcifolia</i> C.H.Wright						1		1		4			
<i>Cortaderia selloana</i> (Schult.) Asch. & Graebn.				1	2			1					
<i>Virgilia oroboides</i> (P.J.Bergius) Salter						1				2			
<i>Juncus effusus</i> L.	1			1	1								
<i>Zantedeschia aethiopica</i> (L.) Spreng.						2	1						
<i>Erica</i> sp.									1	1			
5.2 <i>Rapanea melanophloeos</i>-<i>Acalypha capensis</i> Forest Fringe													
<i>Acalypha capensis</i> (L.f.) Prain & Hutch.		1									4		
<i>Olinia ventosa</i> (L.) Cufod.									1		2		
<i>Conyza scabrida</i> DC.	1	1									1		
5.3 <i>Rapanea melanophloeos</i>-<i>Aloe arborescens</i> Rocky Scrub Forest													

Community number	1	2	3	4.1.1	4.1	4.2	4	5.1.1	5.1.2	5.1	5.2	5.3	6
5. <i>Rapanea melanophloeos</i>-<i>Rhus chirindensis</i> Forest Margin													
<i>Commelina africana</i> L.								2	1	2	2	2	
<i>Rapanea melanophloeos</i> (L.) Mez								2	3	1	2	1	
<i>Rhus chirindensis</i> Baker f.					1			1	1	4	1	1	
<i>Cheilanthes quadripinnata</i> (Forssk.) Kuhn								2	2	3		1	
<i>Podocarpus latifolius</i> (Thunb.) R.Br. ex Mirb.					1			1		3	2		
<i>Chlorophytum comosum</i> (Thunb.) Jacq.						1	1	1	2	1	1		
<i>Epischoenus</i> sp. (Boucher 7R/16)								1		3	2		
<i>Ficinia filiformis</i> (Lam.) Schrad.						2	1	1	1			1	
<i>Persicaria decipiens</i> (R.Br.) K.L.Wilson				1		3	1					1	
<i>Rhamnus prinoides</i> L'Hér.		1						2	1	1	1		
<i>Blechnum attenuatum</i> (Sw.) Mett.						1		1		2	1		
<i>Plectranthus fruticosus</i> L'Hér.								2		1	2		
<i>Pterocelastrus tricuspidatus</i> (Lam.) Sond.					1			1		1	1	1	
<i>Blechnum tabulare</i> (Thunb.) Kuhn					1		2						
<i>Cassine peragua</i> L.										2	1	1	
<i>Diospyros glabra</i> (L.) De Winter										2	2		
<i>Dombeya tiliacea</i> (Endl.) Planch.					1			1	2				
<i>Senecio pterophorus</i> DC.		1			1				2				
<i>Asplenium rutifolium</i> (P.J.Bergius) Kunze										1	1	1	
<i>Erica caffra</i> L.										3			
<i>Grewia flava</i> DC.	1		1							1			
<i>Lantana camara</i> L. *	1									1	1		
<i>Maytenus acuminata</i> (L.f.) Loes.					1				2				
<i>Gnidia</i> sp.					1							1	
<i>Bambusa balcooa</i> Roxb. ex Roxb. *					1					1			
<i>Blechnum australe</i> L.								1	1				
<i>Carpobrotus edulis</i> (L.) L.Bolus		1										1	
<i>Cassine aethiopica</i> Thunb.										2			
<i>Sparrmannia africana</i> L.f.						1				1			
<i>Eragrostis curvula</i> (Schrad.) Nees					1	1							
<i>Maytenus peduncularis</i> (Sond.) Loes.								1				1	
<i>Fuirena hirsuta</i> (P.J.Bergius) P.L.Forbes					1	1							
<i>Gleichenia polypodioides</i> (L.) Sm.						1			1				
<i>Helichrysum crispum</i> (L.) D.Don					1					1			
<i>Hemarthria altissima</i> (Poir.) Stapf & C.E.Hubb.			1			1							
<i>Hypoestes aristata</i> (Vahl) Sol. ex Roem. & Schult.								1	1				
<i>Ipomoea nil</i> (L.) Roth *		1		1									
<i>Maytenus heterophylla</i> (Eckl. & Zeyh.) N.Robson					1					1			
<i>Oxalis incarnata</i> L.								1		1			
<i>Podalyria calyptata</i> (Retz.) Willd.								1		1			
<i>Pseudognaphalium luteo-album</i> (L.) Hilliard & B.L.Burt					1					1			
<i>Ricinus communis</i> L. *			1								1		
<i>Tetraria fimbriolata</i> (Nees) C.B.Clarke			1							1			
<i>Urginea</i> sp.						1	1						
<i>Watsonia meriana</i> (L.) Mill.					1	1							
<i>Ficus</i> sp. *									1			1	
<i>Podocarpus falcatus</i> (Thunb.) R.Br. ex Mirb.									2				
<i>Polygala myrtifolia</i> L.												2	
<i>Rhoicissus tomentosa</i> (Lam.) Wild & R.B.Drumm.									1			1	
6. Poorly defined samples with widespread species													
<i>Acacia mearnsii</i> De Wild. *	2		3			5	4	3	2	3	12	2	3
<i>Acacia melanoxylon</i> R.Br. *					1	4	4	4	2	7	2		1
<i>Clusia pulchella</i> L.	1							5	3		3	1	
<i>Ehrharta erecta</i> Lam.						1	2	1	1	5	2		
<i>Pteridium aquilinum</i> (L.) Kuhn		2	1		1			2	1		2		2
<i>Rubus fruticosus</i> L. *			1		1	1	2	1	1	1	1		
<i>Dittrichia graveolens</i> (L.) Greuter *		1	1			1			1			1	2
<i>Psoralea pinnata</i> L.			1		2	1	1		1	1			
<i>Ehrharta ramosa</i> (Thunb.) Thunb.					1		2			1			1
<i>Ischyrolepis subverticillata</i> Steud.				1	1	1	1						1
<i>Halleria elliptica</i> Thunb.					2					1			1
<i>Setaria megaphylla</i> (Steud.) T.Durand & Schinz			1				2	1					
<i>Ebenaceae</i> (Boucher 1/15)						1				1		1	1
<i>Solanum mauritianum</i> Scop. *										1	1		1
<i>Buddleja saligna</i> Willd.										1			1

Typha capensis Riparian Herbland

This community was only recorded at Site Maa 1. The presence of this species implies wetland soil conditions, in this instance in differing lateral riparian vegetation zones, all on Bokkeveld Group shale substratums. The diagnostic species for the community in this study is the dominant presence of *Typha capensis*. The samples all had a high incidence of exotic weed species, implying that they had a reasonably high degree of disturbance.

Pennisetum clandestinum-*Persicaria lapathifolium* Secondary Fringing Wetlands

This community was recorded at the following sites: Maa 2 (Maalgate lower), Maa 1 (Maalgate upper), Moe 2 (Moeras at Moeras) and Moo 1 (Moordkuil). This community is characterized by the presence of exotic weed species with no other diagnostic species. This implies a very high degree of disturbance where it occurs.

Prionium serratum Riparian Fringing Shrublands

This is a widespread and important group of communities dominated by *Prionium serratum*. It was recorded in the Wetbank and Lower Dynamic Zones at the following sites during this study: 2 (GB 1), 9 (Ka 1), 11 (Si 1) and 12 (Gou 1).

This species is a widespread river edge fringing species in this region. It is important in the protection of river banks from erosion (Boucher and Withers, 2004). It is particularly sensitive to dense shade conditions and in consequence is depressed by dense stands of alien riparian invasives such as *Acacia mearnsii* (black wattle) and *Acacia melanoxylon* (blackwood). During high flow flood conditions the species bends under flow pressure to protect banks from erosion.

Prionium serratum-*Cliffortia odorata* Riparian Shrubland

This community was recorded at the following sites: 2 (GB 1), 5 (Moe 2), 6 (Moe 1) and 10 (Sw 1). The presence of *Cliffortia odorata*, in association with *Prionium serratum*, is diagnostic for this community, which is recognized by a dense tangled mat of *Cliffortia odorata*. It is usually associated with wet conditions on finer-grained substratums, such as are regularly found on Bokkeveld Group shales in the region. This community is susceptible to drying out if base flows are removed. When this occurs, alien species, particularly *Acacia mearnsii* (black wattle), invade the marshes, they basically die and the streams become markedly canalized with water moving straight through instead of percolating through the marshes. The cleaning function is then lost. This can be seen at Moe 1 (Moeras at Molendrif) upstream of the road.

Prionium serratum-*Cliffortia odorata* Secondary Disturbed Subcommunity

This community was recorded at sites 4 (Maa 1), 5 (Moe 2) and 13 (Moo 1). In the case of this community, there has been a history of a fairly high degree of disturbance in the proximity of these wetlands that has resulted in an increase in herbaceous aliens such as *Pennisetum clandestinum* (kikuyu grass), *Persicaria lapathifolia* and *Arundo donax* (Spanish reed).

Prionium serratum-*Juncus lomatophyllus* Wetbank

This community is found along the water's edge and was recorded at the following sites: 12 (Gou 1), 2 (GB 1), 3 (Maa 2), 6 (Moe 1), 9 (Ka 1), and 11 (Si 1). The presence of *Juncus*

Iomatophyllus, *Isolepis prolifer* and *Lobelia erinus*, in association with *Pronium serratum*, are diagnostic for this community. Alien weeds often include *Paspalum urvillei* and dense stands of alien woodies such as *Acacia mearnsii* (black wattle) and *Acacia melanoxylon* (blackwood).

Rapanea melanophloeos-Rhus chirindensis Forest Margin

This group of forest margin communities are typical of these Southern Cape forest edges. The presence of *Commelina africana*, *Rapanea melanophloeos*, *Rhus chirindensis* and *Cheilanthes quadripinnata* are diagnostic for this community. Alien weeds often recorded in the samples include dense stands of alien woodies such as *Acacia mearnsii* (black wattle) and *Acacia melanoxylon* (blackwood).

Rapanea melanophloeos-Dietes iridioides Riparian Forest

This community, found along riparian forest edges was recorded at the following sites: 2 (GB 1), 3 (Maa 2), 7 (Mal 1), 10 (Sw 1) and 12 (Gou 1). The presence of *Brachylaena neriifolia*, *Calopsis paniculata*, *Dietes iridioides*, and *Nuxia floribunda*, are diagnostic for this *Rapanea melanophloeos-Rhus chirindensis* Forest Margin community. Alien weeds often recorded in the samples include *Paspalum urvillei* and dense stands of alien woodies such as *Eucalyptus* sp., *Acacia mearnsii* (black wattle) and *Acacia melanoxylon* (blackwood). Two subcommunities, were recorded, as listed below, which are related to different riparian substratums.

Rapanea melanophloeos-Halleria lucida Riparian Woodland Subcommunity

This community, associated with the deeper finer substratums at the riparian forest edge was recorded at the following sites: 7 (Mal 1), 9 (Ka 1) and 10 (Sw 1). The presence of *Halleria lucida* (ouhout), in association with species characteristic of the *Rapanea melanophloeos-Dietes iridioides* Riparian Forest, are diagnostic for this *Rapanea melanophloeos-Rhus chirindensis* Forest Margin subcommunity.

Rapanea melanophloeos-Diospyros whyteana Riparian Fringing Forest Subcommunity

This community was recorded on shallow soils on shale rock substratums at the following sites: 11 (Si 1) and 12 (Gou 1). The presence of *Diospyros whyteana* and *Trichocladus crinitus* (onderbos), in association with species characteristic of the *Rapanea melanophloeos-Dietes iridioides* Riparian Forest, are diagnostic for this *Rapanea melanophloeos-Rhus chirindensis* Forest Margin subcommunity.

Rapanea melanophloeos-Acalypha capensis Forest Fringe

This community was recorded at the following sites: 7 (Mal 1) and 13 (Moo 1). The presence of *Acalypha capensis* and *Olinia ventosa* are diagnostic for this *Rapanea melanophloeos-Rhus chirindensis* Forest Margin community. Alien woodies such as *Acacia mearnsii* (black wattle) and *Acacia melanoxylon* (blackwood) are important invasive trees in this community.

Rapanea melanophloeos-Aloe arborescens Rocky Scrub Forest

This community is typical of drier, very rocky, lower riparian slopes and was recorded at the following sites: 2 (GB 1) and 3 (Maa 2). The presence of *Aloe arborescens*, *Carissa bispinosa* and *Asparagus volubilis* are diagnostic for this *Rapanea melanophloeos-Rhus chirindensis*

Forest Margin community. Alien woodies such as *Acacia mearnsii* (black wattle) and *Acacia melanoxylon* (blackwood) are important invasive trees in this community.

Poorly defined samples with widespread species

This community was recorded at the following sites: 2 (GB 1), 6 (Moe 1), 10 (Sw 1) and 11 (Si 1). It has few differentiating species except for the presence of widespread species common to many of the samples, such as *Acacia mearnsii*, *Acacia melanoxylon* and *Pteridium aquilinum* (bracken fern). It thus serves as the typical undefined matrix for the riparian zone of the region. This community is usually associated with highly stressed riparian environments here.

RELATIONSHIP TO FLOW

The relationship between discharges and lateral vegetation zones for the Groot Brak (GB1), Malgas (Mal 1), Kaaimans (Ka 1) and Goukamma (Gou 1) Rivers are presented in Table 4.30. The different vegetation zones as indicated were all distinguishable in the field. The discharges volumes were calculated from the surveyed vegetation zone height intervals (Table 4.31).

The comparison of different inundation frequency levels did not reveal a similar relationship to vegetation patterns found in the Western Cape or Lesotho rivers (Table 4.32). The reasons for this dissimilarity is not clear at present, but could be related to season of fieldwork (during a wetter period) or to scouring action of recent floods having either removed some vegetation markers or having changed stream bottom levels or both.

Table 4.30 The relationship between discharges and lateral vegetation zones for the Groot Brak (GB1), Goukamma (Gou 1), Kaaimans (Ka 1) and Malgas (Mal 1) Rivers

EWR site	River name	Top Aquatic	Lower Wetbank	Upper Wetbank	Lower Dynamic	Tree-shrub	Back Dynamic
GB 1	Groot Brak River	0.031 m³s	0.031 to 0.2 m³s	0.2 to 1.439 m³s	1.439 to 4.913 m³s	4.913 to 23.376 m³s	23.376 to 44.480 m³s
Mal 1	Malgas River	No data	0.117 m³s	0.117 to 1.730 m³s	1.730 to 49.192 m³s	49.192 to 97.776 m³s	97.776 + m³s
Ka 1	Kaaimans River	0.018 m³s	0.018 to 0.46 m³s	0.46 to 1.671 m³s	1.671 to 3.654 m³s	3.654 to 13.444 m³s	13.444 to 50 m³s
Gou 1	Goukamma River	0.029 m³s	0.029 to 2.671 m³s	2.671 to 10.802 m³s	10.802 to 23.655 m³s	23.655 to 39.374 m³s	Out of range

Table 4.31 Discharges for different flow types related to lateral vegetation zones at four EWR sites

	Groot Brak River (B)		Malgas River (D)		Kaaimans River (A)		Goukamma River (B)	
Flow type	Calculated Discharge (PD) m ³ s	Veg Zone Discharge m ³ s	Calculated Discharge m ³ s	Veg Zone Discharge m ³ s	Calculated Discharge m ³ s	Veg Zone Discharge m ³ s	Calculated Discharge m ³ s	Veg Zone Discharge m ³ s
Summer Flow Ave (Nov-Apr)	0.926	UWB	0.599	UWB	0.98	UWB	1.766	LWB
Winter Lowflow Ave (May-Oct)	0.767	UWB	0.585	UWB	0.96	UWB	2.093	LWB
Class 1 flood	1.25	UWB	1.25	UWB	1.6	UWB	2.59	LWB
Class 2 flood	2.5	LD	2.5	LD	3.2	LD	5.18	UWB
Class 3 flood	5	TS	5	LD	6.3	TS	10.35	UWB
Class 4 flood	10	TS	10	LD	12.6	TS	20.7	LD
1:2 yr flood	11	TS	11	LD	14	BD	23	LD
1:5 yr flood	23	TS	23	LD	28	BD	50	BD
1:10 yr flood	40	BD	26	LD	34	BD	67	BD
1:20 yr flood	64	BD+	34	LD	37	BD	100	BD

Table 4.32 The relationship between discharges and lateral vegetation zones found in Western Cape and Lesotho

	Function	Element	Reaction to reduction	Function	Element	Reaction to reduction	Function	Element	Reaction to reduction	Function	Element	Reaction to reduction
Winter Low Flow	Maintain	Herb Indig	+	Maintain	Herb Indig	+	Maintain	Herb Indig	0	X		
		Herb Exotic	+		Herb Exotic	+		Herb Exotic	0			
		Woody Indig	0		Woody Indig	0		Woody Indig	0			
		Woody Exot	0		Woody Exot	+		Woody Exot	+			
Summer Low Flow	Maintain	Herb Indig	+	Maintain	Herb Indig	-	Maintain	Herb Indig	-	X		
		Herb Exotic	+		Herb Exotic	+		Herb Exotic	+			
		Woody Indig	0		Woody Indig	-		Woody Indig	-			
		Woody Exot	0		Woody Exot	+		Woody Exot	+			
I	Maintain	Herb Indig	0	Maintain	Herb Indig	-	X			X		
		Herb Exotic	0		Herb Exotic	+						
		Woody Indig	0		Woody Indig	-						
		Woody Exot	0		Woody Exot	+						
II	Reduce	Herb Indig	-	Maintain	Herb Indig	-	Partial Maintain	Herb Indig	-	X		
		Herb Exotic	+		Herb Exotic	+		Herb Exotic	+			
		Woody Indig	-		Woody Indig	-		Woody Indig	-			
		Woody Exot	+		Woody Exot	+		Woody Exot	+			
III	Reduce	Herb Indig	-	Maintain	Herb Indig	-	Partial Maintain	Herb Indig	-	Partial Maintain	Herb Indig	0
		Herb Exotic	+		Herb Exotic	+		Herb Exotic	+		Herb Exotic	0
		Woody Indig	-		Woody Indig	-		Woody Indig	-		Woody Indig	-
		Woody Exot	+		Woody Exot	+		Woody Exot	+		Woody Exot	+
IV	Reduce	Herb Indig	-	Reduce	Herb Indig	+	Maintain	Herb Indig	-	Maintains	Herb Indig	+
		Herb Exotic	+		Herb Exotic	+		Herb Exotic	+		Herb Exotic	+
		Woody Indig	-		Woody Indig	+		Woody Indig	-		Woody Indig	-
		Woody Exot	+		Woody Exot	+		Woody Exot	+		Woody Exot	+
1:2 to 1:20	Reduce	Herb Indig	+	Reduce	Herb Indig	+	Reduces	Herb Indig	+	Maintains	Herb Indig	+
		Herb Exotic	0		Herb Exotic	+		Herb Exotic	+		Herb Exotic	+
		Woody Indig	+		Woody Indig	+		Woody Indig	+		Woody Indig	-
		Woody Exot	0		Woody Exot	+		Woody Exot	+		Woody Exot	+

4.6 MACROINVERTEBRATES

4.6.1 Introduction

Macroinvertebrates referred to here include aquatic insects, fresh water crustaceans (e.g. amphipods, crayfish), aquatic annelids (e.g. worms) and zooplanktons. Aquatic macroinvertebrates consist mostly of immature or adult stages of insects. Their communities offer a reflection of the prevailing flow regime and water quality in a river and they are an essential component of the riverine ecosystem (O’Keeffe and Dickens, 2000). They live under or on the surface of stones, in sediments or in streams, aquatic and marginal vegetation, and are sensitive to changes in water conditions from various anthropogenic impacts (Rosenberg and Resh, 1993; Hawkins and Norris, 2000). Most aquatic macroinvertebrate reach their high population levels during summer months (Dickens and Graham, 2002). The macroinvertebrate fauna of the study rivers was surveyed as part of the regional River Health Programme (RHP) and the historical data are available on the South African Rivers database. There are, however, no species-level data describing the seasonal variation in invertebrate assemblages of the selected rivers. The RHP data (RHP, 2006), together with the collected data during the study, provided guidance for identifying information requirements for this study.

4.6.2 Methods

The macroinvertebrate fauna were sampled at each selected EWR site (refer to Table 2.1) using South African Scoring System version 5 (SASS5) in March 2007, which represents the summer period. The samples were identified to the family level in the field. Where appropriate, data from South African Rivers database were incorporated into the assessments. The interpretation of the invertebrate data is therefore based in the distribution of taxa amongst different biotopes (habitats) defined on the basis of specialist knowledge and following Dickens and Graham (2002).

Most habitats available in the study rivers were sampled, i.e., pool and riffle or a combination thereof. This provides an indication of available macroinvertebrate diversity at the sites. Biotopes (microhabitat for macroinvertebrates) have been grouped into two types, namely SASS biotopes (Dickens and Graham, 2002) and specific biotopes (Dallas, 2005). These are important habitats available for habitation by aquatic organisms. Specific biotopes provide further details of the types of biotope within each SASS biotope. Biotopes were essentially defined on the basis of substratum type (i.e. stones; vegetation; gravel, sand and mud) and flow type (i.e. in-current or out-of-current; Dickens and Graham, 2002; Samways *et al.*, 1996; DWAF, 2005). Description of biotopes sampled during March 2007 survey is given in Table 4.33.

Table 4.33 Description of biotopes sampled during this study

SASS biotopes		Specific biotopes	Description
Stones In Current		SIC	Stones in flowing water, may include bedrock
Stones Out Of Current		SOOC	Stones out of any perceptible current (with visible silt seen accumulating on stone surfaces), may include bedrock
Marginal Vegetation In Current		MV-IC	Emerged and submerged vegetation in fast current; at the river's edge or on the edge of in-channel islands
Marginal	Vegetation Out Of Current	MV-OC	Emerged and submerged vegetation out of any perceptible current; at the river's edge or on the edge of in-channel islands
Floating/Aquatic Vegetation		AQV	Submerged or partially submerged vegetation within the channel, normally in flowing water
Gravel		G	Stones < 20 mm in diameter
Sand		S	Sand grains < 2 mm in diameter
Silt/mud/clay		M	Particles < 0.06 mm in diameter

SAMPLING METHOD: SOUTH AFRICAN SCORING SYSTEM VERSION 5 (SASS5)

South African Scoring System Version 5 (SASS5) (Dickens and Graham, 2002) is a rapid bioassessment technique developed for running water and it is a recognised measure of water quality and general river health. SASS5 makes use of the natural sensitivity or tolerance to adverse water quality of the wide variety of benthic macroinvertebrates in a river. SASS5 thus provides an ideal system to measure the response of aquatic fauna to general water quality conditions in a river. The particular advantage of a biotic index is that the presence of chemical variables, not monitored by chemical analysis, which may have an impact on the river environment, can be detected.

SASS5 produces three different and complementary scores, SASS5 score (i.e. sum of the scores), Number of Taxa and Average Score per Taxon (ASPT). Of these, ASPT is generally the most reliable, as this is the least variable of the scores (Dallas, 2000; Dickens and Graham, 2002) and provides the most reliable measure of a “close to natural” river system. The other two scores are used to aid interpretation.

A soft 950µm mesh net on a 45 cm square frame on a stout handle was used to collect the macroinvertebrates (Figure 4.58). The three most common biotopes present at a site were sampled separately for Intermediate Reserve Determination study sites (GB 1, Mal 1, Ka 1 and Gou 1). At Rapid I/II study sites, biotopes were combined in a single sample. Kick sampling was done for five minutes in stone biotopes while holding the net below the water level moving it backward and inward. About 1 m² of the streambed was sampled. Vegetation was swept with the net for a 1 m stretch. Where there was no instream vegetation, only marginal vegetation was sampled. All the collected material was poured into the white flat-bottomed sorting tray. Twigs, leaves and trash were removed from the tray to find the macroinvertebrates easier within 15

minutes restricted time per sample. With the aid of soft forceps and hand magnifying lens, benthic macroinvertebrates were identified to the lowest practicable level (generally family for insects and order or class for other macroinvertebrates). The specific number of species present for Baetidae and Hydropsychidae families was recorded. Gerber and Gabriel (2002) field guide, was used to verify identification of benthic macroinvertebrates while in the field. RHP – SASS Score sheets were used to record the data.

MACRO INVERTEBRATE RESPONSE ASSESSMENT INDEX (MIRAI)

MIRAI is the macroinvertebrate module for the Ecostatus model (see Kleynhans *et al.*, 2006 for details). MIRAI (Kleynhans *et al.*, 2006) was used to determine macroinvertebrate Ecostatus for each of the Groot Brak, Kaaimans, Goukamma and Malgas sites during the workshop in June 2007 (see Section 5).



Figure 4.58 Macroinvertebrate sampling in the Goukamma River

4.6.3 Results

GROOT BRAK RIVER AT KLEINPLAAS (GB 1)

The habitat preferences for all taxa sampled from Groot Brak River (GB 1) range from cobbles; marginal and aquatic vegetation; gravel and sand; and water surface (Table 4.34). GB 1 supported a high number of taxa ranging from the less sensitive to very sensitive taxa (Table 4.35). The most sensitive taxa sampled were Helodidae, Notonemouridae, Telagonodidae and Barbarochthonidae. High abundances were also recorded for Barbarochthonidae and Simuliidae (Table 4.35). Taxa with moderately fast to very fast flow velocity preferences included Gyrinidae, Simuliidae, Coenagrionidae, and Notonemouridae. GB 1 resulted in a relatively higher SASS scores (

Table 4.36) as more and sensitive taxa were recorded. Such SASS results are an indication of very good ecological condition of a river system in terms of macroinvertebrates.

Table 4.34 Habitat diversity assessment for the Intermediate Reserve Determination study sites

Site	Advantages	Disadvantages	General Comments
Groot Brak (GB 1)	• Good range of biotopes, with some that are sensitive to flow changes • Extensive cobble substrata at depth that allow for invertebrates sampling • Some floating Macrophytes and gravel • Supported high macroinvertebrate diversity with more that are highly sensitive to flow modification	Negligible	Excellent. Riffles, runs, and pool habitat present an optimal condition, diverse velocity and depth of flow present (i.e. slow, fast, shallow and deep water) Comparable with good habitat conditions for the ecoregion
Malgas (Mal 1)	• Good range of biotopes, with some that are sensitive to flow changes • Extensive cobble substrata interspersed with gravel and sand at depth that allow for invertebrates sampling • Supported relatively high macroinvertebrate diversity with more that are highly sensitive to flow modification	Very little marginal vegetation (mostly Restioids on the small island) with lack of floating vegetation Site located just below the bridge	Good mix between riffles, runs, and pools, relatively diverse velocity and depth of flow conditions
Kaaimans (Ka 1)	• Good range of biotopes, with some that are sensitive to flow changes • Extensive cobble substrata at depth that allow for invertebrates sampling • Emergent vegetation on both river banks dominated by Palmiet species • Supported relatively high macroinvertebrate diversity with more that are highly sensitive to flow modification	Limited floating vegetation and gravel	Good mix between riffles, runs, and pools, relatively diverse velocity and depth of flow conditions Some gravel mixed with sands
Goukamma (Gou 1)	• Good range of biotopes, with some that are sensitive to flow changes • Extensive boulder/cobble substrata at depth that allow for invertebrates sampling • Floating and marginal vegetation were present • Supported relatively high macroinvertebrate diversity with more that are highly sensitive to flow modification	No gravel, sand and mud biotopes Lots of spiders observed on marginal vegetation, may impact on invertebrate species abundance	Good mix between riffles, runs, and pools, relatively diverse velocity and depth of flow conditions

Table 4.35 The relative abundance of key macroinvertebrate taxa from GB 1

Description			Biotope			
Group	Taxon/Family	Sensitivity score	S	VG	GSM	ALL
Annelida	Oligochaeta	1	1			1
Plecoptera	Notonemouridae	14	1	A	A	A
Ephemeroptera	Baetidae > 2 sp	12	B	A	A	B
Ephemeroptera	Heptageniidae	13	1	1	A	A
Ephemeroptera	Leptophlebiidae	9	A	1	A	A
Ephemeroptera	Telagonodidae	12	A			A
Odonata	Coenagrionidae	4		A	1	A
Odonata	Aeshnidae	8			1	1
Odonata	Libellulidae	4		1	A	A
Hemiptera	Naucoridae	7		1		1
Hemiptera	Veliidae	5		1		1
Megaloptera	Corydalidae	8	B			B
Trichoptera	Dipseudopsidae	10			A	A
Trichoptera	Philopotamidae	10	A			A
Trichoptera	Barbarochthonidae	13	B	B	B	B
Trichoptera	Lepidostomatidae	10			A	A
Coleoptera	Elmidae	8	B	A	A	B
Coleoptera	Gyrinidae	5		A	A	A
Coleoptera	Helodidae	12	A	1	1	A
Diptera	Athericidae	10	A	A	A	B
Diptera	Ceratopogonidae	5			1	1
Diptera	Chironomidae	2	A			A
Diptera	Simuliidae	5	B	B		B
Diptera	Tipulidae	5		1		1

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.36 SASS scores calculated for GB 1

SASS5 score	192
No. of taxa	24
Average Score Per Taxon (ASPT)	8.0

KAAIMANS RIVER AT OLD KNYSNA-GEORGE ROAD (Ka 1)

Ka 1 supported a fairly high number of taxa ranging from the less sensitive to sensitive taxa (Table 4.37). The most sensitive taxa were Notonemouridae, Telagonodidae and Barbrarochthonidae, although the former was sampled in very low abundance (Table 4.37). Most of the recorded taxa were in very low abundance. An ASPT value for this site (Table 4.38) gives an indication of unmodified river conditions.

Table 4.37 The relative abundance of key macroinvertebrate taxa from Ka 1

Description			Biotope				
Group	Taxon/Family	Sensitivity score	SIC	SOOC	VG	GSM	ALL
Annelida	Oligochaeta	1	A				A
Plecoptera	Notonemouridae	14		1			1
Ephemeroptera	Baetidae > 2 sp	12	B	A			B
Ephemeroptera	Heptageniidae	13	A	1		1	A
Ephemeroptera	Leptophlebiidae	9	A	A		1	A
Ephemeroptera	Telagonodidae	12	A	A			A
Odonata	Coenagrionidae	4		1	A		A
Odonata	Lestidae	8	1				1
Odonata	Platycnemidae	10		1			1
Odonata	Protoneuridae	8			A		A
Odonata	Libellulidae	4	A	1	A		A
Hemiptera	Corixidae	3	A	A			B
Hemiptera	Gerridae	5		A			A
Hemiptera	Naucoridae	7	A	1	A	A	A
Hemiptera	Veliidae/Mesoveliidae	5			A		A
Megaloptera	Corydalidae	8	A	A			A
Trichoptera	Philopotamidae	10	B				B
Trichoptera	Barbarochthonidae	13	B	B	B	B	B
Trichoptera	Leptoceridae	6		A	A		A
Coleoptera	Elmidae/Dryopidae	8	A	1		A	A
Diptera	Athericidae	10	A	A		1	A
Diptera	Simuliidae	5	B				B

Biotope: SIC = Stones In-Current; SOOC = Stone Out Of Current; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.38 SASS scores calculated for Ka 1

SASS5 score	175
No. of taxa	22
Average Score Per Taxon (ASPT)	8.0

MALGAS RIVER AT OU BRUG (MAL 1)

The Malgas River (Mal 1) at Ou Brug supported fairly high number of taxa ranging from the less sensitive to the sensitive taxa (Table 4.39). Highly sensitive taxa in Mal 1 include, Helodidae, Telagonodidae, Perlidae, Notonemouridae and Barbarochthonidae. High abundances were recorded for Corydalidae and Barbarochthonidae (Table 4.39). Taxa with moderately fast to very fast flow velocity preference include, Elmidae, Gyrinidae, Naucoridae, Corydalidae, Notonemouridae, and Leptoceridae. The habitat preferences for all taxa sampled from Mal 1 ranges from cobbles; marginal and aquatic vegetation; gravel, and sand; and water surface (Table 4.34). An ASPT and SASS score for Mal 1 (Table 4.40) gives an indication of good water conditions.

Table 4.39 The relative abundance of key macroinvertebrate taxa from Mal 1

Description			Biotope			
Group	Taxon/Family	Sensitivity score	S	VG	GSM	ALL
Annelida	Oligochaeta	1	1		1	A
Plecoptera	Notonemouridae	14	A	A	A	A
Plecoptera	Perlidae	12	A			A
Ephemeroptera	Baetidae > 2 sp	12		A		A
Ephemeroptera	Leptophlebiidae	9			1	1
Ephemeroptera	Telagonodidae	12		1		1
Hemiptera	Gerridae	5			1	1
Hemiptera	Naucoridae	7	A	1	1	A
Hemiptera	Veliidae	5		1		1
Megaloptera	Corydalidae	8	B	A	1	B
Trichoptera	Barbarochthonidae	13	B	B	B	B
Trichoptera	Leptoceridae	6	A		A	A
Trichoptera	Pisuliidae	10		1	1	A
Coleoptera	Dytiscidae	5	A		A	A
Coleoptera	Elmidae	8	A	A	A	B
Coleoptera	Gyrinidae	5		1	A	A
Coleoptera	Helodidae	12			1	1
Diptera	Athericidae	10	A	A	A	B
Diptera	Ceratopogonidae	5			A	A
Diptera	Tipulidae	5		1		1

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.40 SASS scores calculated for Mal 1

SASS5 score	164
No. of taxa	20
Average Score Per Taxon (ASPT)	8.2

GOUKAMMA/HOMTINI RIVER AT OLD KNYSNA-GEORGE ROAD (GOU 1)

The Goukamma/ Homtini River at the old Knysna-George Road (Gou 1) supported a relatively high number of taxa ranging from less sensitive to very sensitive taxa (Table 4.41). The most sensitive taxa were Notonemouridae, Telagonodidae and Helodidae (Table 4.41). Nearly all the recorded taxa were in very low abundance. The SASS scores for this site (

Table 4.42) indicates reasonably good river conditions in terms of macroinvertebrates.

Table 4.41 The relative abundance of key macroinvertebrate taxa from riffle biotope at Gou 1

Description			Biotope (In riffle)			
Group	Taxon	Sensitivity score	S	VG	GSM	ALL
Annelida	Oligochaeta	1			1	1
Plecoptera	Notonemouridae	14	A	A		A
Ephemeroptera	Baetidae > 2 sp	12	B	B	A	B
Ephemeroptera	Leptophlebiidae	9	1		A	A
Ephemeroptera	Telagonodidae	12	A	A	A	A
Odonata	Coenagrionidae	4		A		A
Odonata	Aeshnidae	8	1			1
Odonata	Libellulidae	4	A	A	1	A
Hemiptera	Naucoridae	7		A	1	A
Hemiptera	Veliidae	5		A		A
Megaloptera	Corydalidae	8	A	A		B
Trichoptera	Philopotamidae	10	A	1		A
Trichoptera	Leptoceridae	6	A	A		A
Coleoptera	Elmidae	8	B	A		B
Coleoptera	Gyrinidae	5			1	1
Coleoptera	Helodidae	12	A	A	A	A
Diptera	Athericidae	10	A		1	4
Diptera	Chironomidae	2	1	A	1	A
Diptera	Simuliidae	5	A	B	A	B
Diptera	Syrphidae	1			A	A

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.42 SASS scores calculated from riffle at Gou 1

SASS5 score	143
No. of taxa	20
Average Score Per Taxon (ASPT)	7.2

Table 4.43 The relative abundance of key macroinvertebrate taxa for pool at Gou 1

Description			Biotope (In pool)		
Group	Taxon/Family	Sensitivity score	S	VG	ALL
Plecoptera	Notonemouridae	14	A	A	A
Ephemeroptera	Heptageniidae	13	A		A
Ephemeroptera	Oligoneuridae	15	A		A
Ephemeroptera	Telagonodidae	12	A		A
Odonata	Coenagrionidae	4		A	A
Odonata	Libellulidae	4		A	A
Hemiptera	Gerridae	5		1	1
Hemiptera	Naucoridae	7	1		1
Hemiptera	Veliidae	5		A	A
Megaloptera	Corydalidae	8		1	1
Trichoptera	Barbarochthonidae	13	B	B	B
Trichoptera	Leptoceridae	6	A	A	B
Coleoptera	Elmidae/Dryopidae	8	1		1
Coleoptera	Gyrinidae	5	A	A	A
Coleoptera	Helodidae	12	A		A
Diptera	Athericidae	10	A		A
Diptera	Simuliidae	5		1	1

Biotope: S = Stones; VG = Vegetation; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.44 SASS scores calculated for pool at Gou 1

SASS5 score	146
No. of taxa	17
Average Score Per Taxon (ASPT)	8.6

MAALGATE RIVER AT SIEBEN SCHWABEN (MAA 1)

The results for the Maalgate River at Sieben Schwaben (Maa 1) are provided in Table 4.45 to Table 4.47:

Table 4.45 The relative abundance of key macroinvertebrate taxa from Maa 1

Description			Biotope		
Group	Taxon/Family	Sensitivity score	SIC	VG	ALL
Ephemeroptera	Baetidae 1sp	4	A	A	A
Odonata	Coenagrionidae	4		1	1
Hemiptera	Veliidae/Mesoveliidae	5	1		1
Coleoptera	Elmidae/Dryopidae	8	A	A	A
Coleoptera	Helodidae	12	A		A
Diptera	Chironomidae	2	A	A	A
Diptera	Simuliidae	5	B	1	B

Biotope: S = Stones; VG = Vegetation; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.46 SASS scores calculated for Maa 1

SASS5 score	40
No. of taxa	7
Average Score Per Taxon (ASPT)	5.7

Table 4.47 Habitat diversity assessment at Maa 1 site during March 2007

Advantages	Disadvantages	General Comments
- Extensive boulder/cobble substrata at depth that allow for invertebrates sampling - Floating and marginal vegetation were present - Supported relatively lower macroinvertebrate diversity with more that are more tolerant to flow modification	Poor range of biotopes, with some that are not represented at the site No gravel, sand and mud biotopes Located just below the bridge	Very poor Dominated by one habitat type (usually runs) and by one velocity/depth condition (slow-shallow) Highly modified river bed and banks Severe loss of habitat and impairment of stream function

MOERAS RIVER AT MOLENDRIF (MOE 1)

The results for the Moeras River at Molendrif (Moe 1) are provided in Table 4.48 to Table 4.50.

Table 4.48 The relative abundance of key macroinvertebrate taxa from Moe 1

Description			Sampled Biotopes		
Group	Taxon/Family	Sensitivity score	S	VG	ALL
Annelida	Oligochaeta	1			A
Odonata	Coenagrionidae	4			A
Odonata	Libellulidae	4			A
Hemiptera	Veliidae/Mesoveliidae	5			1
Megaloptera	Corydalidae	8			A
Trichoptera	Hydropsychidae 1 sp	4			1
Trichoptera	Barbarochthonidae	13			1
Trichoptera	Leptoceridae	6			1
Coleoptera	Dytiscidae	5			1
Coleoptera	Elmidae/Dryopidae	8			A
Coleoptera	Gyrinidae	5			1
Diptera	Chironomidae	2			A
Diptera	Simuliidae	5			B

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances (ALL): 1 = 1, A = 2-10, B = 10-100

Table 4.49 SASS scores calculated for Moe 1

SASS5 score	70
No. of taxa	13
Average Score Per Taxon (ASPT)	5.4

Table 4.50 Habitat diversity assessment at Moe 1

Advantages	Disadvantages	General Comments
- Extensive boulder/cobble substrata at depth that allow for invertebrates sampling - Little floating and marginal vegetation were present - Supported relatively lower macroinvertebrate diversity with more that are more tolerant to flow modification	Poor range of biotopes, with some that are not represented at the site No gravel, sand and mud biotopes Highly modified river bed and banks	Poor Very narrowly main-channel with banks partially covered with vegetation Significant loss of macroinvertebrate habitat

SWART RIVER AT OLD KNYSNA-GEORGE ROAD (SW 1)

The results for the Swart River at the Old Knysna-George Road (Sw 1) are provided in Table 4.51 to Table 4.53.

Table 4.51 The relative abundance of key macroinvertebrate taxa from Sw 1

Description			Sampled Biotopes		
Group	Taxon/Family	Sensitivity score	S	VG	ALL
Crustacea	Potamonautidae	3			A
Hydracarina		8			1
Ephemeroptera	Baetidae > 2 sp	12			B
Ephemeroptera	Caenidae	6			1
Odonata	Libellulidae	4			1
Hemiptera	Belostomatidae	3			A
Hemiptera	Naucoridae	7			A
Hemiptera	Nepidae	3			1
Hemiptera	Veliidae	5			A
Trichoptera	Ecnomidae	8			1
Trichoptera	Barbarochthonidae	13			B
Trichoptera	Leptoceridae	6			A
Trichoptera	Pisuliidae	10			A
Coleoptera	Elmidae	8			1
Coleoptera	Gyrinidae	5			1
Diptera	Ceratopogonidae	5			1
Diptera	Chironomidae	2			A
Diptera	Culicidae	1			1
Diptera	Simuliidae	5			B
Gastropoda	Ancylidae	6			A

Biotope: S = Stones; VG = Vegetation; ALL = Combined sampled biotopes. Estimate abundances (ALL): 1 = 1, A = 2-10, B = 10-100

Table 4.52 SASS scores calculated from Swart River at Old Knysna-George Road (Sw 1) site during March 2007 sampling period

SASS5 score	120
No. of taxa	20
Average Score Per Taxon (ASPT)	6.0

Table 4.53 Habitat diversity assessment for Sw 1

Advantages	Disadvantages	General Comments
- Extensive boulder/cobble substrata at depth that allow for invertebrates sampling - Supported relatively higher macroinvertebrate diversity with more that are more tolerant to flow modification (especially those that prefer low flows and silts)	Poor range of biotopes, with some that are not represented at the site No floating and marginal vegetation available to inverts No gravel, sand and mud biotopes High turbidity, possibly due to the dam above the site	Poor Silt deposited at the site with lots of dead leaf materials Few riffles present, runs dominant Significant loss of habitat; however, the present habitats were successful in supporting higher macroinvertebrate diversity

SILVER RIVER AT OLD KNYSNA-GEORGE ROAD (Si 1)

The results for Silver River (Si 1) are provided in Table 4.54 to Table 4.56:

Table 4.54 The relative abundance of key macroinvertebrate taxa at Silver River (Si 1)

Description			Sampled Biotope			
Group	Taxon/Family	Sensitivity score	S	VG	GSM	ALL
Ephemeroptera	Baetidae > 2 sp	12				B
Ephemeroptera	Heptageniidae	13				1
Odonata	Coenagrionidae	4				1
Odonata	Aeshnidae	8				1
Hemiptera	Naucoridae	7				A
Hemiptera	Veliidae/Mesoveliidae	5				1
Megaloptera	Corydalidae	8				B
Trichoptera	Barbarochthonidae	13				A
Trichoptera	Lepidostomatidae	10				A
Trichoptera	Pisuliidae	10				A
Diptera	Athericidae	10				1
Diptera	Ceratopogonidae	5				1
Diptera	Chironomidae	2				A
Diptera	Simuliidae	5				A

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances (TOT): 1 = 1, A = 2-10, B = 10-100

Table 4.55 SASS scores calculated for Si 1

SASS5 score	112
No. of taxa	14
Average Score Per Taxon (ASPT)	8

Table 4.56 Habitat diversity assessment at Silver River Si 1 site during March 2007 using macroinvertebrates

Advantages	Disadvantages	General Comments
- Good range of biotopes with both floating and marginal vegetation represented - Extensive boulder/cobble substrata at depth that allow for invertebrates sampling - Supported moderate macroinvertebrate diversity with more that prefer fast flowing systems.	None	Good. Good mix between riffles, runs, and pools, relatively diverse velocity and depth of flow conditions Habitat structure slightly impaired, mostly by floods

MOORDKUIL RIVER (Moo 1)

The results for the Moordkuil River (Moo 1) are provided in Table 4.57 and Table 4.59.:

Table 4.57 The relative abundance of key macroinvertebrate taxa at Moo 1

Description			Biotope			
Group	Taxon/Family	Sensitivity score	S	VG	GSM	ALL
Annelida	Oligochaeta	1		1		1
Crustacea	Potamonautidae	3	A			A
Plecoptera	Notonemouridae	14		1		1
Ephemeroptera	Baetidae 1sp	4			A	A
Ephemeroptera	Caenidae	6	B	B		B
Ephemeroptera	Heptageniidae	13	1	A	1	A
Ephemeroptera	Leptophlebiidae	9	A			A
Odonata	Coenagrionidae	4		A	1	A
Odonata	Aeshnidae	8	A	A	B	B
Odonata	Corduliidae	8			1	1
Odonata	Libellulidae	4	A	A	1	B
Hemiptera	Corixidae	3		A		A
Megaloptera	Corydalidae	8	A			A
Trichoptera	Hydropsychidae 2 sp	6	B			B
Trichoptera	Philopotamidae	10	A	1		A
Trichoptera	Barbarochthonidae	13		A		A
Trichoptera	Leptoceridae	6	A			A
Trichoptera	Pisuliidae	10		1		1
Coleoptera	Dytiscidae	5		A		A
Coleoptera	Elmidae	8	A		1	A
Coleoptera	Helodidae	12		1		1
Diptera	Athericidae	10		A	1	A
Diptera	Ceratopogonidae	5		1		1
Diptera	Simuliidae	5	B	B	A	B

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100

Table 4.58 SASS scores calculated for Moo 1

SASS5 score	175
No. of taxa	24
Average Score Per Taxon (ASPT)	7.3

Table 4.59 Habitat diversity assessment at Moo 1

Advantages	Disadvantages	General Comments
• Good range of biotopes with both floating and marginal vegetation represented • Extensive cobble interspersed with gravel substrata at depth that allow for invertebrates sampling • Supported fairly high macroinvertebrate diversity with more that are sensitive to flow modification • Several patches of sand for burrowing invertebrates • Gravel/sand deposited on both river banks.	None	Excellent Riffles, runs, and pool habitat present an optimal condition for macroinvertebrates, diverse velocity and depth of flow present (i.e. slow, fast, shallow) Comparable with good habitat conditions for the ecoregion

NOETSIE RIVER ON N2 (NOE 1)

The Noetsie River at the National Road N2 (Noe 1) had fewer macroinvertebrate taxa than many of the other sites (Table 4.60), and most of these were tolerant, i.e., sensitivity score ranging from 4 – 6 (Kleyhans et al, 2006). All the sampled taxa were in very low (<10) abundance. Only one species of Baetidae was present. Barbarochthonidae was the only sampled taxon with a higher sensitivity score (Table 4.60). The ASPT for this river indicates poor river conditions (Table 4.61). There was a lack of taxa with a very fast (>0.6 m/s) water flow preference but a large abundance of Simuliidae with a very fast water preference. Low SASS scores at Noe 1 may be attributed to low flows, a bridge above the site and the pine plantation on either side of the river, however, most likely the poor scores were a result of the fact that the site was just a few meters away from the source and heavily infested with pine trees.

Table 4.60 The relative abundance of key macroinvertebrate taxa at Noe 1

Description			Biotope			
Group	Taxon/Family	Sensitivity score	S	VG	GSM	ALL
Ephemeroptera	Baetidae 1sp	4				B
Ephemeroptera	Caenidae	6				A
Hemiptera	Corixidae	3				A
Trichoptera	Barbarochthonidae	13				B
Diptera	Muscidae	1				A
Diptera	Simuliidae	5				B

Biotope: S = Stones; VG = Vegetation; GSM = Gravel, Sand and Mud; ALL = Combined sampled biotopes. Estimate abundances: 1 = 1, A = 2-10, B = 10-100.

Table 4.61 SASS scores calculated at Noetsie River (Noe 1) site during June 2007 sampling period

SASS5 score	32
No. of taxa	6
Average Score Per Taxon (ASPT)	5.3

Table 4.62 Habitat diversity assessment in Noe 1 site during June 2007 using macroinvertebrates

Advantages	Disadvantages	General Comments
- Extensive sand substrata at depth that allow for invertebrates sampling - Floating and marginal vegetation were present - Range of biotopes are represented at the site	Supported relatively less macroinvertebrate diversity with more that are more tolerant to high sediment load River flows through plantation of pine trees Site located just below a bridge	Poor in macroinvertebrate diversity About 1.5 m width The stream is covered almost completely with vegetation in most part High sediment load in the stream

4.6.4 Characterisation of rivers using macroinvertebrate communities

Cluster analysis of rivers was done to relate the different river reaches in terms of macroinvertebrate assemblages. Rivers that are more similar in terms of macroinvertebrate assemblages were clustered together and the resultant five river groups were apparent (Figure 4.59). Rivers with the most similar macroinvertebrate communities clustered together (Si 1 and Sw 1; Gou 1, Ka1 and Moo 1; Moe 1 and Maa 1; Mal 1 and GB 1) (Figure 4.59 and Figure 4.60). Group 4 (Noe 1 only) was less similar to any of the sites. This is the only site situated very close

to the source and in the middle of pine tree plantation. GB 1 and Mal 1 are more similar in terms of the macroinvertebrates although situated in different quaternary catchments.

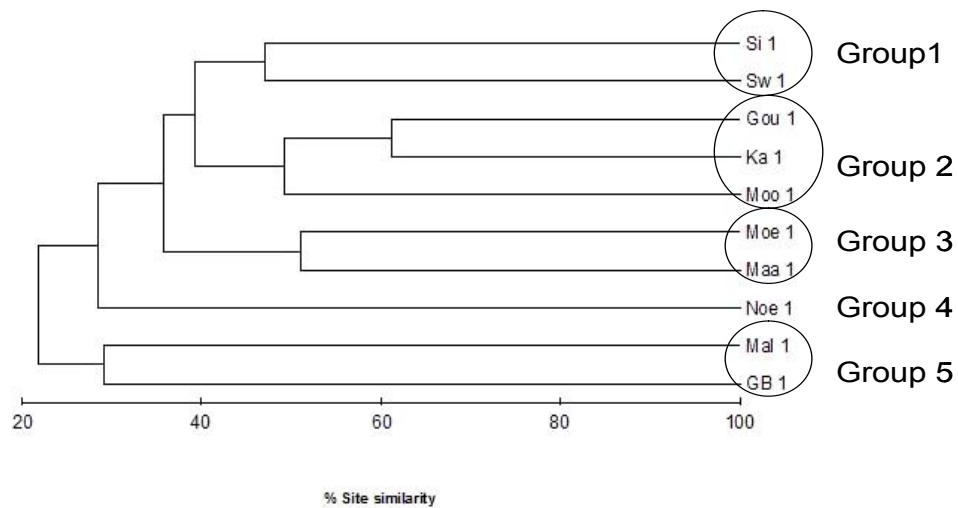


Figure 4.59 Dendrogram showing classification of sites in terms of their macroinvertebrate assemblages. Si 1 = Silver, Sw 1 = Swart, Gou 1 = Goukamma, Ka 1 = Kaaimans, Moo 1 = Moordkuil, Moe 1 = Moeras at Moelendrict, Maa 1 = Maalgate, Noe 1 = Noetsie, Mal 1 = Malgas, GB1 = Groot Brak

MACROINVERTEBRATES										
Similarity										
	GB 1	Ka 1	Gou 1	Mal 1	Maa 1	Moe 1	Moo 1	Sw 1	Si 1	Noe 1
GB 1										
Ka 1	26.156									
Gou 1	34.036	61.27								
Mal 1	29.066	31.116	25.1							
Maa 1	16.938	21.347	47.248	3.1585						
Moe 1	30.355	39.624	50.507	14.336	51.119					
Moo 1	32.508	50.943	47.636	21.79	28.136	44.949				
Sw 1	24.579	41.801	40.443	16.478	27.674	40.163	33.784			
Si 1	32.408	45.256	42.736	23.112	23.176	35.144	31.23	47.002		
Noe 1	16.378	28.246	15.954	0	44.684	24.385	35.112	32.191	18.259	

Figure 4.60 Similarity matrix for all the sampled rivers during March 2007, created using Primer Version 5

4.6.5 Conceptual consequences of flow changes for macroinvertebrates

The generic list used to predict changes in macroinvertebrates following flow manipulation in DRIFT is given in Table 4.63. A refined Generic list with example species is given in Table 4.64. Conceptual relationship graphs (Figure 4.61 to Figure 4.64) between macroinvertebrate species considered for DRIFT and reduction (relative to natural) in flows were constructed to show how different macroinvertebrate will be affected following to flow modifications. Macro-Invertebrate Response Assessment Index (MIRAI) manual was used to verify macroinvertebrates flow and habitat preferences (Kleynhans *et al.* 2006). Different groups of macroinvertebrates respond differently to flow modifications. Historical data collected elsewhere in the country were used to construct the graphs. The resultant conceptual relationship graphs were used as guide to generate a generic list used to predict changes in macroinvertebrates following flow changes. DRIFT requires that specialists' made prediction of component (i.e. macroinvertebrates) change in different flow levels. A maximum of ten elements (i.e macroinvertebrate species) are required into the DRIFT entry sheet. More than ten macroinvertebrate species were sampled, resulting in the grouping of macroinvertebrates in the generic list (Table 4.63). It was assumed that species that fall in the same group would respond similarly to the changes in flow modification. Since macroinvertebrate biotopes are usually associated with geomorphology and vegetation; the geomorphologist, botanist and water quality specialist predictions were considered when predicting the changes in macroinvertebrates.

Table 4.63 Generic list and information used to predict changes in macroinvertebrates with changes in flow using DRIFT

Generic list (Element)	Comments on ratings for flood responses
Detritivorous Mayflies (Riffle/run species)	Geodiversity (riffle/run) was used as surrogate for these species that are usually associated with flow variability.
Detritivorous Mayflies (Stones out of current/sand)	Potential bed material transport was used as surrogate for these species that prefer stones to attach or live under.
Mobile Grazers (Riffle/Run)	Geodiversity (riffle/run) was used as surrogate for this species that are usually associated with flow variability.
Mobile Grazers (Marginal vegetation)	Overbank sedimentation and vegetation were used as surrogates for these species that are usually associated with the river banks.
Less Mobile Grazers: predator resistant (Riffle/Run)	Geodiversity (riffle/run) was used as surrogate for these species that are usually associated with flow variability.
Less Mobile Grazers: predator resistant (Marginal vegetation)	Overbank sedimentation and vegetation were used as surrogates for these species that are usually associated with the river banks.
Sensitive (flow and WQ) predators (Pool)	Water quality, water depth and geodiversity of geomorphic units were used as surrogates.
Sensitive (flow and WQ) predators (Riffle/Run)	Potential bed material transport was used as surrogate for these species with pool preference.
Tough predators (Marginal vegetation)	Overbank sedimentation and vegetation were used as surrogates for these species that are usually associated with the river banks.
Tough predators (Riffle/Run)	Geodiversity of geomorphic units was used as surrogate for these species that are usually associated with flow variability.

Table 4.64 Refined Generic list with example taxa

Generic List				
Detritivorous Mayflies	Mobile Grazers	Less Mobile Grazers (predator resistant)	Sensitive (flow and WQ) predators	Tough predators
Caenidae; Trichorythidae; Economidae, and Leptophlebiidae	Heptageniidae; Telamonidae; and Baetid Demoreptus	Dryopidae; Elmidae; Leptoceridae and Blephariceridae	Corydalidae; Athericidae; Elmidae; Perlidae; Trichorythidae and Caenidae	Libellulidae; Cordulidae; and Gomphidae

INFORMATION USED TO CONSTRUCT RELATIONSHIPS FOR WET AND DRY SEASON LOWFLOWS

Data from this and previous studies, specifically Brown *et al.* (2006), Metsi (2000) and DWAF (2005), were used to construct conceptual relationships between the key macroinvertebrate species and the reduction in flow regime. The latter two references comprise predictions for the changes in abundances of key species as a result of flow manipulations made by macroinvertebrate specialists during those studies, while Brown *et al.* (2006) monitored changes downstream of the LHP structures once the flow changes had taken place (10 years on; Table 4.65). In Table 4.65, the original predicted trends (Metsi, 2000) are also provided. Figure 4.61 indicates the general response pattern of key macroinvertebrates to different natural flow level changes. These depicted relationships are important in environmental flow assessments, because they give an indication of direction of change in macroinvertebrates following flow manipulations.

The intra-annual floods affect macroinvertebrate communities predominately through their influence on water quality and habitat quality. The predicted changes in these aspects (water and habitat quality) were provided by the relevant specialists, e.g., changes in habitat quality were predicted by the geomorphologist (embeddeness) and by botanist (vegetation changes). At the workshop, these predicted changes were used to assess the likely effects on the macroinvertebrate communities on a case-by-case basis.

Table 4.65 Summary of the actual and predicted changes in key macroinvertebrate species recorded from riffles downstream of LHP structures between October 1998 and 2005 (Brown *et al.*, 2006b; Metsi, 2000)

Key Taxa	IFR Site 1	IFR Site 2	IFR Site 7	Predicted trend
	Actual percentage change in macroinvertebrate abundance			
Hydropsychidae: <i>Cheumatopsyche thomasseti</i>	27% increase	81% decrease	100% decrease	Decrease
Baetidae: <i>Baetis harrisoni</i>	100% increase	100% increase	100% increase	Increase
Oligochaeta: Oligochaeta worms	No change	No change	No change	Increase
Caenidae	37% increase	83% increase	93% increase	Increase
Leptophlebiidae: <i>Adenophlebia</i> sp.	100% decrease	No change	100% increase	Increase
Simuliidae: <i>Simulium</i> sp.	98% increase	31% decrease	57% decrease	Increase

Note: No relationships were developed for the inter-annual floods as these are predominately associated with channel forming actions.

RELATIONSHIPS FOR WET SEASON LOWFLOW (WSLF) CHANGES

The resultant conceptual relationships between the key species identified for the Intermediate Reserve Determination study sites and changes in the WSLF were constructed using the data in Table 4.66 and Table 4.67. The relationships themselves are depicted in Figure 4.61 and Figure 4.62 respectively. These depicted relationships are important in environmental flow assessments, because they give an indication of the recorded direction of change in macroinvertebrates following flow manipulations. The relationships were used to guide the DRIFT response predictions. Where there was no significant correlation, it was assumed that species was not responsive to changes in that flow type.

Table 4.66 Theoretical, predicted abundance change of key macroinvertebrate species following WSLF manipulation at LHDA IFR Sites 1, 2 and 7 (Brown *et al.*, 2006b)

Number	Percentage reduction in WSLF, relative to natural	<i>Cheumatopsyche</i> sp.	<i>Baetis</i> sp.	Oligochaeta	Caenidae	<i>Adenophlebia</i> sp.	<i>Simulium</i> sp. (increase with flow manipulation)	<i>Simulium</i> sp. (decrease with flow manipulation), e.g. <i>S. denotum</i> and <i>S. vorax</i> .
1	100	0	0	0	0	0	0	0
2	60.42	2	3	0	2	-5		
3	10	-4	3	0	3	0		
4	29.13	-5	3	0	3	3		
5	80	0		0		No significant relationship	0	
6	60	-1		0			2.5	
7	30	-3		0			3.5	
8	4	-5		0			4	
9	82	-0.5					0.5	-1.5
10	14	-3					3.5	-3.5
11	4	-4.5					3.5	-3.5
12	80	-0.5					0.5	-0.5
13	70	-1.5					1.5	-1
14	33	-3					3	-4
15	17	-4.5					4.5	-4.5

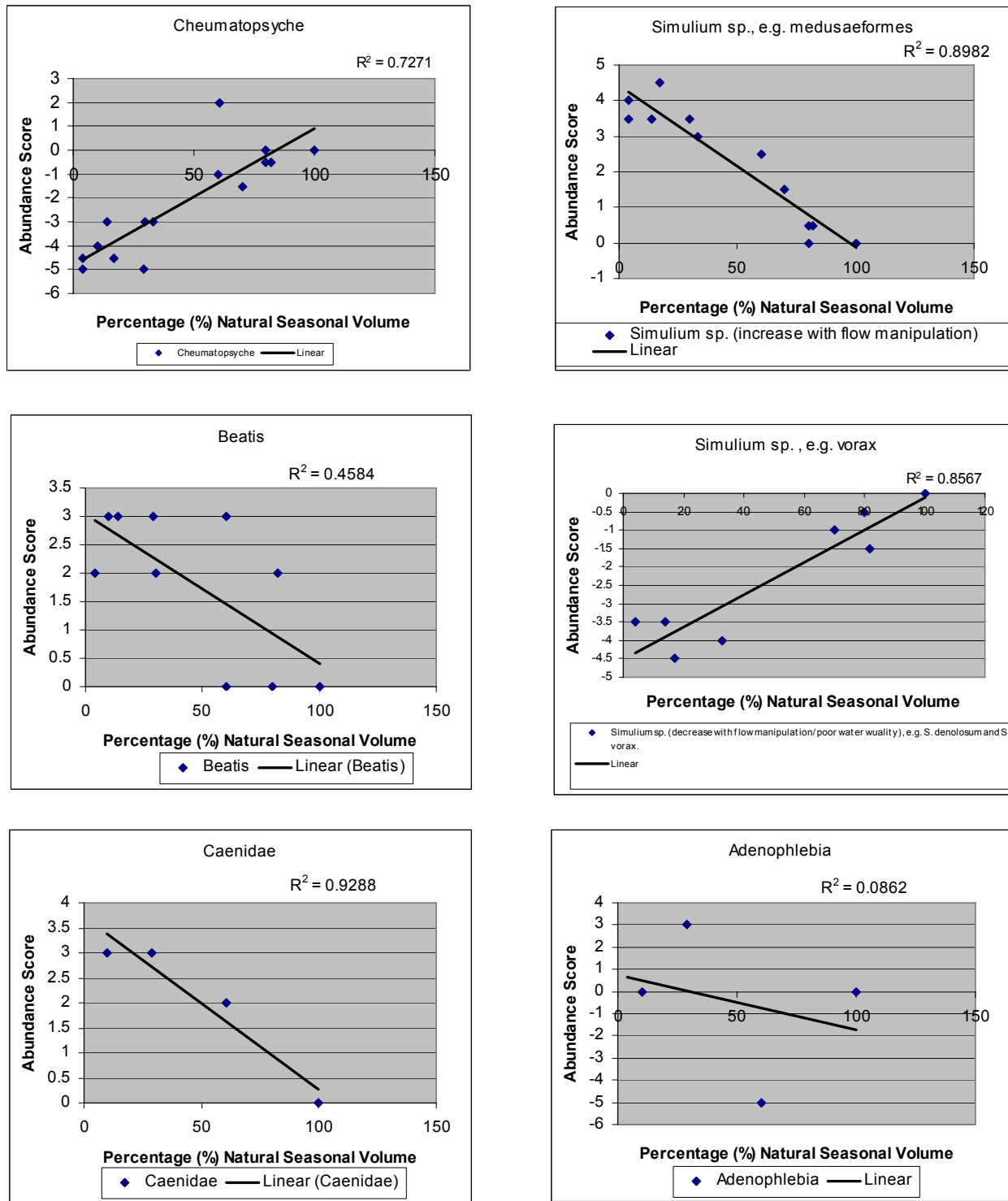


Figure 4.61 Conceptual relationships between key macroinvertebrate species and reductions (relative to natural) in Winter lowflows as represented in Table 4.66

Table 4.67 Predicted Integrity change of key macroinvertebrate species following WSLF manipulation at Olifant/Doring Sites 1, 3 and 6 (DWAf, 2005); and Breede sites 2 and 4 (Brown and King, 2002)

WET SEASON LOWFLOWS					Generic List														
Study	Site	PES	MAR Change level	%nMAR	Detritivorous Mayflies (e.g. Caenidae; Trichorythidae; some Baetids; Ecnomidae, and Leptophlebiidae)			Mobile Grazers (Heptageniidae; Telagonodidae; Demoreptus (Beatid indicator))			Less Mobile Grazers (predator resistant) (e.g. Dryopidae; Elmidae; Leptoceridae (Athrripsodes), Blephariceridae;			Sensitive (flow and WQ) predators (e.g. Corydalidae; Athericidae; Elmidae; Perlidae; Trichorythidae and Caenidae)			Tough predators (e.g. Libellulidae; Cordulidae; Gomphidae)		
						Raw	Adjusted Integrity score		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score
Olifants Doring	1 D		94	28%	PD	0	-2	PD	0	-2	PD	0	-2	PD	0	-2	PD	0	-2
Olifants Doring	1 D		87.332	26%	Upper	0	-2	Upper	0	-2	Upper	0	-2	Upper	0	-2	Upper	0	-2
Olifants Doring	1 D		72.5	22%		0	-2		-1	-3		-0.75	-2.75		-1	-3		0	-2
Olifants Doring	1 D		52.22	16%		-0.75	-2.75		-1.66667	-3.66667		-0.75	-2.75		-2	-4		-0.66667	-2.66667
Olifants Doring	1 D		30.83	9%		-1	-3		-2.33333	-4.33333		-2	-4		-2	-4		-1	-3
Olifants Doring	1 D		87.332	26%	Lower	-1	-3	Lower	-1	-3	Lower	-1	-3	Lower	-1	-3	Lower	-0.66667	-2.66667
Olifants Doring	1 D		72.5	22%		-1.75	-3.75		-2	-4		-1.75	-3.75		-2	-4		-0.66667	-2.66667
Olifants Doring	1 D		52.22	16%		-2.5	-4.5		-3	-5		-1.75	-3.75		-4	-6		-2.33333	-4.33333
Olifants Doring	1 D		30.83	9%		-2.5	-4.5		-3.66667	-5.66667		-3.25	-5.25		-4	-6		-2.33333	-4.33333
Olifants Doring	3 B		3.09	40%	PD	0	0	PD	0	0	PD	0	0	PD	0	0	PD	0	0
Olifants Doring	3 B		2.78	36%	Upper	0	0	Upper	0	0	Upper	0	0	Upper	0	0	Upper	0	0
Olifants Doring	3 B		1.79	23%		0	0		0	0		0	0		0	0		0	0
Olifants Doring	3 B		1.07	14%		-0.66667	-0.66667		-2	-2		-1.33333	-1.33333		-1	-1		-1	-1
Olifants Doring	3 B		0.79	10%		-0.66667	-0.66667		-2	-2		-1.33333	-1.33333		0	0		-0.66667	-0.66667
Olifants Doring	3 B		2.78	36%	Lower	0	0	Lower	0	0	Lower	0	0	Lower	0	0	Lower	0	0
Olifants Doring	3 B		1.79	23%		-0.66667	-0.66667		-1	-1		-2	-2		-1	-1		-1	-1
Olifants Doring	3 B		1.07	14%		-2	-2		-3	-3		-3	-3		-2	-2		-2	-2
Olifants Doring	3 B		0.79	10%		-2	-2		-3.33333	-3.33333		-3	-3		-1	-1		-1.66667	-1.66667
Olifants Doring	6 B/C		42.19	31%	PD	0	-0.5	PD	0	-0.5	PD	0	-0.5	PD	0	-0.5	PD	0	-0.5
Olifants Doring	6 B/C		35.56	26%	Upper	0	-0.5	Upper	0	-0.5	Upper	0	-0.5	Upper	0	-0.5	Upper	0	-0.5
Olifants Doring	6 B/C		28.38	21%		0	-0.5		-0.5	-1		-0.5	-1		0	-0.5		0	-0.5
Olifants Doring	6 B/C		20.12	15%		0	-0.5		-0.5	-1		-1	-1.5		-1	-1.5		0	-0.5
Olifants Doring	6 B/C		6.4	5%		-1	-1.5		-2	-2.5		-2	-2.5		-3	-3.5		-1	-1.5
Olifants Doring	6 B/C		35.56	26%	Lower	0	-0.5	Lower	-0.5	-1	Lower	-0.5	-1	Lower	-1	-1.5	Lower	0	-0.5
Olifants Doring	6 B/C		28.38	21%		-1	-1.5		-1	-1.5		-1.5	-2		-2	-2.5		-0.33333	-0.83333
Olifants Doring	6 B/C		20.12	15%		-2	-2.5		-3.5	-4		-2.5	-3		-2	-2.5		-1.33333	-1.83333
Olifants Doring	6 B/C		6.4	5%		-2.5	-3		-3.5	-4		-3.5	-4		-4	-4.5		-2.66667	-3.16667
Breede	2 B		131	83%				PD	0	0									
Breede	2 B		31.8	20%				Upper	0	0									
Breede	2 B		24.6	16%					0	0									
Breede	2 B		12.8	8%					-1	-1									
Breede	2 B		5.28	3%					-2	-2									
Breede	2 B		31.8	20%				Lower	0	0									
Breede	2 B		24.6	16%					0	0									
Breede	2 B		12.8	8%					-2	-2									
Breede	2 B		5.28	3%					-3	-3									
Breede	4 B/C		1059.31	62%	PD	0	-0.5	PD	0	-0.5									
Breede	4 B/C		220.6	13%	Upper	0	-0.5	Upper	0	-0.5									
Breede	4 B/C		160.9	9%		0	-0.5		0	-0.5									
Breede	4 B/C		100.4	6%		-1	-1.5		-1	-1.5									
Breede	4 B/C		30.8	2%		-1	-1.5		-1	-1.5									
Breede	4 B/C		220.6	13%	Lower	0	-0.5	Lower	0	-0.5									
Breede	4 B/C		160.9	9%		0	-0.5		0	-0.5									
Breede	4 B/C		100.4	6%		-1	-1.5		-1	-1.5									
Breede	4 B/C		30.8	2%		-3	-3.5		-3	-3.5									

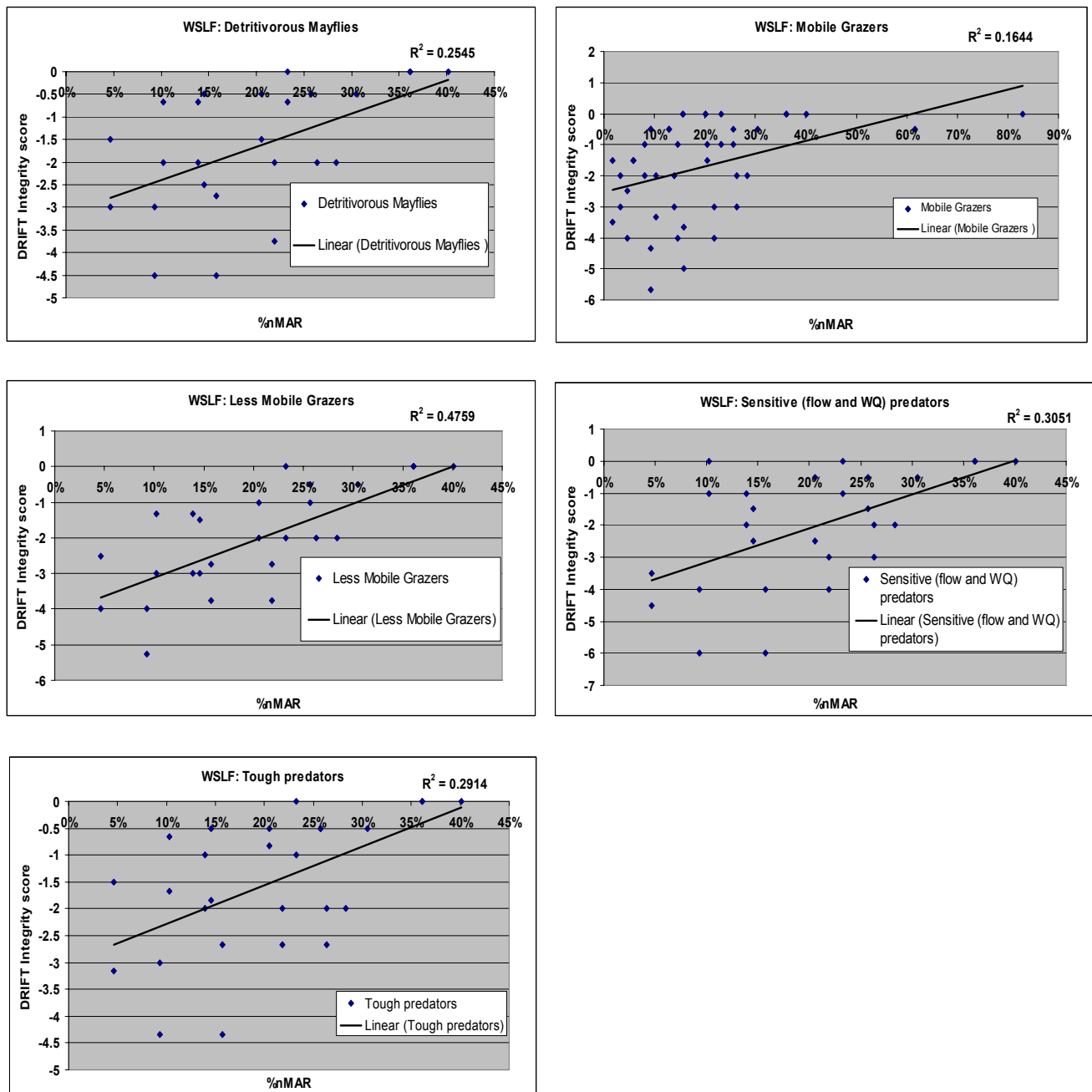


Figure 4.62 Conceptual relationships between key macroinvertebrate species considered for DRIFT and reductions (relative to natural) in WSLF as

RELATIONSHIPS FOR DRY SEASON LOWFLOWS (DSLFL) CHANGES

The resultant conceptual relationships between the key species identified for the Intermediate Reserve Determination study sites and changes in the DSLFL were constructed using the data in Table 4.68 and Table 4.69. The relationships themselves are depicted in Figure 4.63 and Figure 4.64, respectively, and were used for making predictions of the changes in macroinvertebrates following flow manipulations for Intermediate Reserve Determination study sites.

Table 4.68 Theoretical, predicted abundance change of key macroinvertebrate species following DSLF manipulation at LHDA IFR Sites 1, 2 and 7 (Brown *et al.*, 2006)

Number	Percentage reduction in WSLF, relative to natural	<i>Cheumatopsyche</i> sp.	<i>Baetis</i> sp.	Oligochaeta	Caenidae	<i>Adenophlebia</i> sp.	<i>Simulium</i> sp. (increase with flow manipulation)	<i>Simulium</i> sp. (decrease with flow manipulation), e.g. <i>S. denotolum</i> and <i>S. vorax</i> .
1	100	0	0	0	0	0	0	0
2	53	2	3	0	2	-5		
3	41	-3	3	0	3	0		
4	32	-5	3	0	3	3		
5	83	0				No significant relationship	0	0
6	50	-3					2	-3
7	18	-5					5	-5
8	8	-5					5	-5
9	72	0					1.5	0
10	24	-3					3.5	-4
11	12	-4.5					3.5	-4.5
12	79	-0.5					0.5	-0.5
13	55	-1.5					1	-3.5
14	29	-3					4	-4.5
15	17	-4.5					4.5	-4.5

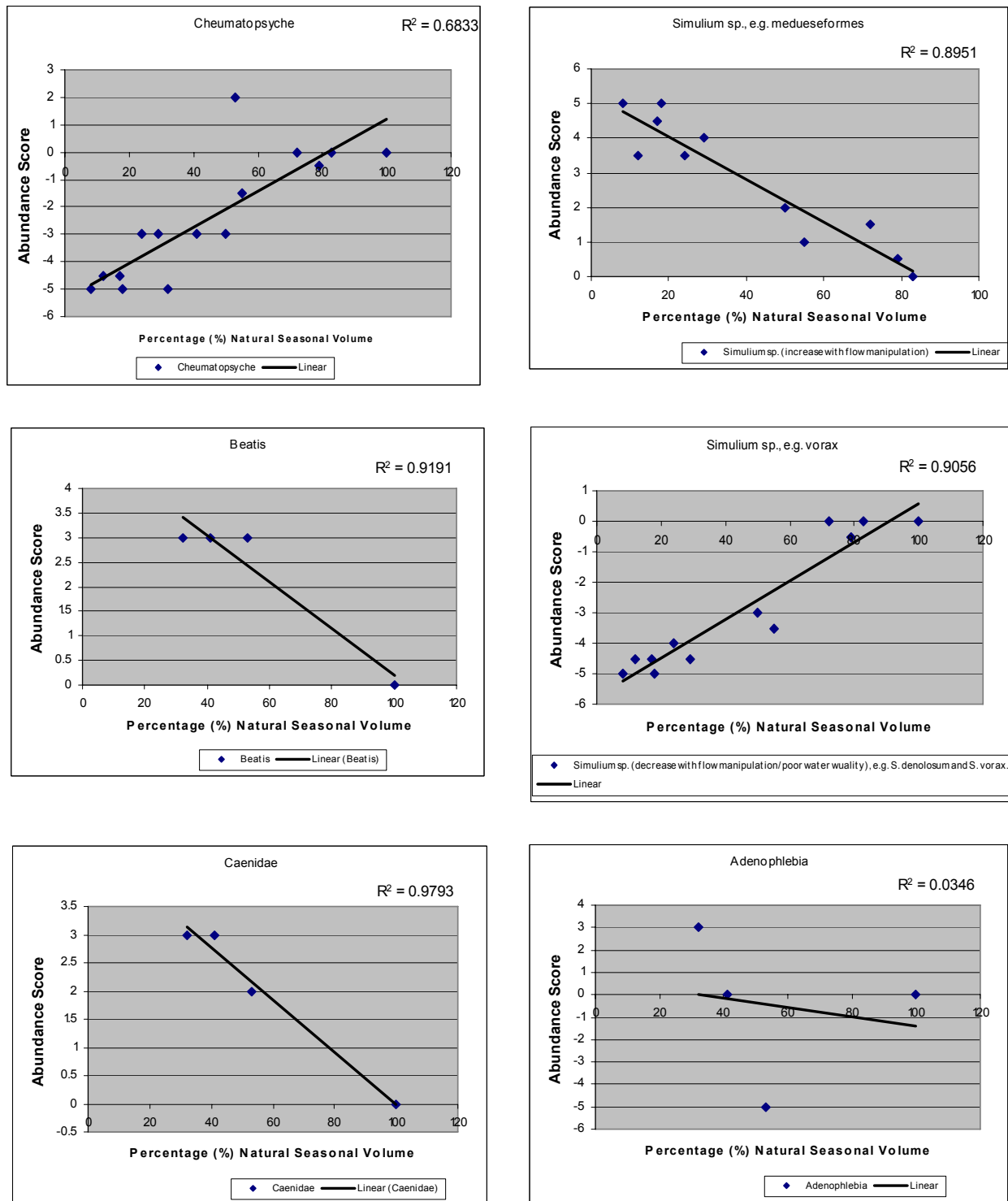


Figure 4.63 Conceptual relationships between key macroinvertebrate species and reductions (relative to natural) in dry season lowflows as represented in Table 4.68

Table 4.69 Predicted abundance change of key macroinvertebrate species following DSLF manipulation at Olifant/Doring Sites 1, 3 and 6 (DWAf, 2005); and Breede sites1, 2 and 4 (Brown and King, 2002)

DRY SEASON LOWFLOWS					Generic List														
Study	Site	PES	MAR Change level	%nMAR	Detritivorous Mayflies (e.g. Caenidae; Trichorythidae; some Baetids; Ecnomidae, and Leptophlebiidae)			Mobile Grazers (Heptageniidae; Telagonodidae; Demoreptus (Beatid indicator))			Less Mobile Grazers (predator resistant) (e.g. Dryopidae; Elmidae; Leptoceridae (Athrissodes), Blephariceridae;			Sensitive (flow and WQ) predators (e.g. Corydalidae; Athericidae; Elmidae; Perlidae; Trichorythidae and Caenidae)			Tough predators (e.g. Libellulidae; Cordulidae; Gomphidae)		
				%nMAR		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score		Raw	Adjusted Integrity score
				%nMAR			us			Grazers			Mobile			(flow and			predators
Olifants Doring	1 D		18.4	6%	PD	0	-2	PD	0	-2	PD	0	-2	PD	0	-2	PD	0	-2
Olifants Doring	1 D		14.3	4%	Upper	0	-2	Upper	-0.33333	-2.33333	Upper	0	-2	Upper	0	-2	Upper	-0.66667	-2.66667
Olifants Doring	1 D		18.41	6%		0	-2		0	-2		0	-2		0	-2		0	-2
Olifants Doring	1 D		25.23	8%		0.5	-1.5		0.333333	-1.66667		0	-2		0	-2		1	-1
Olifants Doring	1 D					0	-2		0	-2		0	-2		0	-2		0	-2
Olifants Doring	1 D		14.3	4%	Lower	-1	-3	Lower	-1.33333	-3.33333	Lower	-1.5	-3.5	Lower	0	-2	Lower	-1.33333	-3.33333
Olifants Doring	1 D		18.41	6%		0.5	-1.5		0	-2		1	-1		0	-2		0.333333	-1.66667
Olifants Doring	1 D		25.23	8%		1.5	-0.5		1.666667	-0.33333		1.25	-0.75		1	-1		3	1
Olifants Doring	1 D					0	-2		0	-2		0	-2		0	-2		0	-2
Olifants Doring	3 B		0.92	12%	PD	0	0	PD	0	0	PD	0	0	PD	0	0	PD	0	0
Olifants Doring	3 B		0.72	9%	Upper	0	0	Upper	0	0	Upper	0	0	Upper	0	0	Upper	0	0
Olifants Doring	3 B		0.57	7%		0	0		0	0		0	0		0	0		0	0
Olifants Doring	3 B		0.37	5%		-0.66667	-0.66667		-2.66667	-2.66667		-1.66667	-1.66667		-3	-3		-1.33333	-1.33333
Olifants Doring	3 B		0.15	2%		-0.66667	-0.66667		-3.33333	-3.33333		-2	-2		-4	-4		-1.33333	-1.33333
Olifants Doring	3 B		0.72	9%	Lower	0	0	Lower	0	0	Lower	0	0	Lower	0	0	Lower	0	0
Olifants Doring	3 B		0.57	7%		0	0		0	0		-0.66667	-0.66667		0	0		0	0
Olifants Doring	3 B		0.37	5%		-2	-2		-3.66667	-3.66667		-2.66667	-2.66667		-4	-4		-2.33333	-2.33333
Olifants Doring	3 B		0.15	2%		-2	-2		-4.33333	-4.33333		-3.66667	-3.66667		-5	-5		-3.33333	-3.33333
Olifants Doring	6 B/C		2.95	2%	PD	0	-0.5	PD	0	-0.5	PD	0	-0.5	PD	0	-0.5	PD	0	-0.5
Olifants Doring	6 B/C		1.62	1%	Upper	-0.5	-1	Upper	-0.5	-1	Upper	-0.5	-1	Upper	-1	-1.5	Upper	0	-0.5
Olifants Doring	6 B/C		0.9	1%		-0.5	-1		-0.5	-1		-0.5	-1		-2	-2.5		0	-0.5
Olifants Doring	6 B/C		0.18	0%		-1.5	-2		-2	-2.5		-0.5	-1		-3	-3.5		-0.66667	-1.16667
Olifants Doring	6 B/C					0	-0.5		0	-0.5		0	-0.5		0	-0.5		0	-0.5
Olifants Doring	6 B/C		1.62	1%	Lower	-1.5	-2	Lower	-2.5	-3	Lower	-1.5	-2	Lower	-4	-4.5	Lower	-0.66667	-1.16667
Olifants Doring	6 B/C		0.9	1%		-2	-2.5		-3	-3.5		-2	-2.5		-4	-4.5		-1.33333	-1.83333
Olifants Doring	6 B/C		0.18	0%		-3	-3.5		-3.5	-4		-3	-3.5		-5	-5.5		-2.33333	-2.83333
Olifants Doring	6 B/C		0.18	0%		0	-0.5		0	-0.5		0	-0.5		0	-0.5		0	-0.5
Breede	1 D/E		287.43	86%										PD	0	-2.5			
Breede	1 D/E		30.89	9%										Upper	1	-1.5			
Breede	1 D/E		32.48	10%											2	-0.5			
Breede	1 D/E		30.89	9%										Lower	1	-1.5			
Breede	1 D/E		32.48	10%											1	-1.5			
Breede	2 B		131	83%				PD	0	0									
Breede	2 B		8.9	6%				Upper	0	0									
Breede	2 B		6.8	4%					0	0									
Breede	2 B		4.5	3%					-1	-1									
Breede	2 B		2.7	2%					-2	-2									
Breede	2 B		8.9	6%				Lower	0	0									
Breede	2 B		6.8	4%					0	0									
Breede	2 B		4.5	3%					-2	-2									
Breede	2 B		2.7	2%					-3	-3									
Breede	4 B/C		1059.31	62%	PD	0	-0.5	PD	0	-0.5									
Breede	4 B/C		220.6	13%	Upper	0	-0.5	Upper	0	-0.5									
Breede	4 B/C		160.9	9%		0	-0.5		0	-0.5									
Breede	4 B/C		100.4	6%		-1	-1.5		-1	-1.5									
Breede	4 B/C		30.8	2%		-1	-1.5		-1	-1.5									
Breede	4 B/C		220.6	13%	Lower	0	-0.5	Lower	0	-0.5									
Breede	4 B/C		160.9	9%		-1	-1.5		-1	-1.5									
Breede	4 B/C		100.4	6%		-2	-2.5		-2	-2.5									
Breede	4 B/C		30.8	2%		-3	-3.5		-3	-3.5									

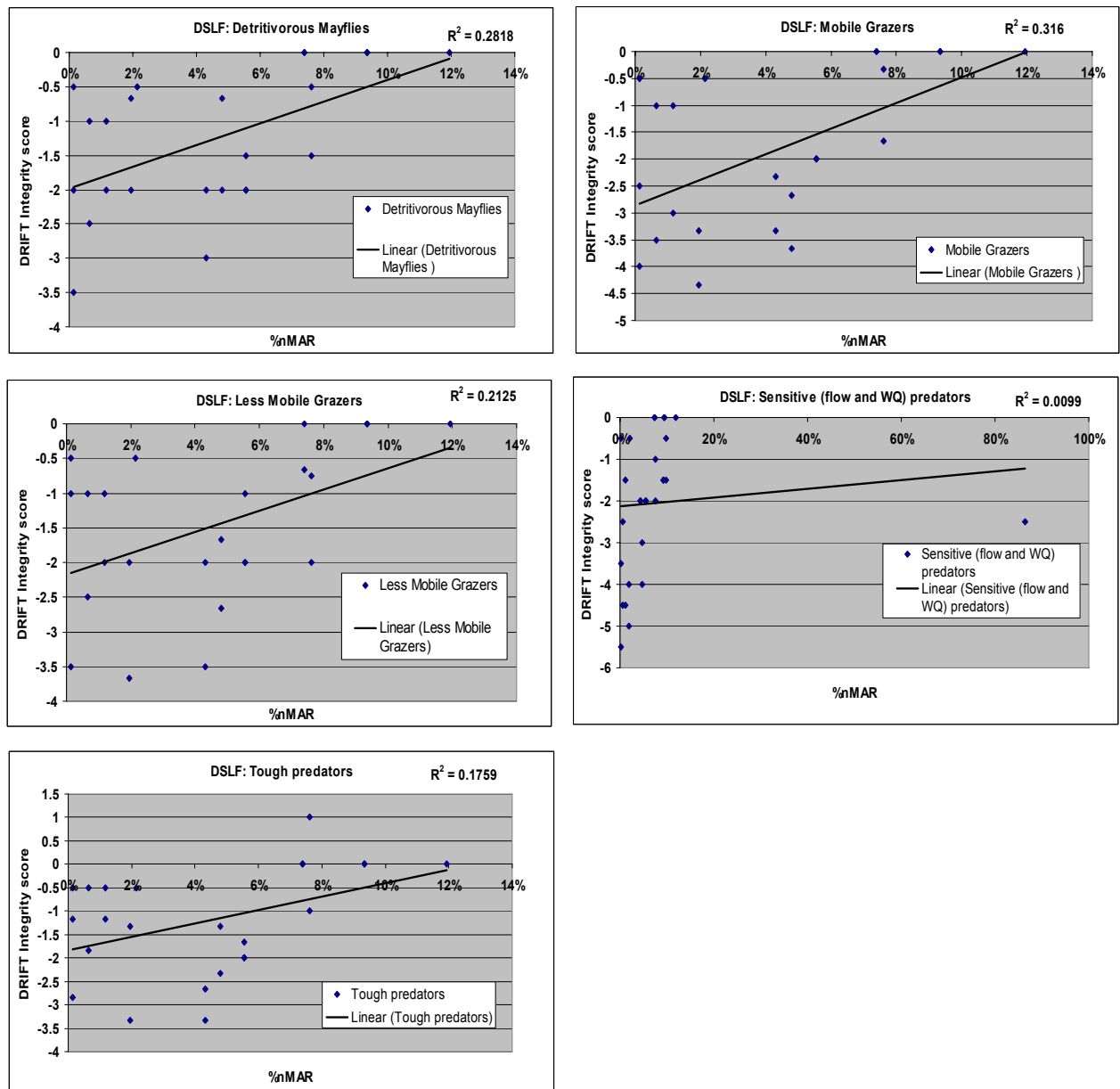


Figure 4.64 Conceptual relationships between key macroinvertebrate species considered for DRIFT and reductions (relative to natural) in DSLF as represented in Table 4.69

4.7 FISH

4.7.1 Introduction

The catchments considered in this study, viz. Klein Brak to Noetsie Rivers are home to nine indigenous and nine introduced or translocated fish species (Table 4.70). Not all of these species occur in each catchment nor do they necessarily occur throughout those in which they do occur. Most of the study sites in the systems surveyed were in the middle to upper reaches with relatively cool temperatures and fairly steep gradients. Consequently, the

indigenous fish assemblage was expected to comprise the small-bodied *Pseudobarbus afer*, *Sandelia capensis* and *Galaxias zebratus* and the catadromous eel *Anguilla mossambica*. The pools and temperature in the reaches were all expected to be conducive to the alien largemouth bass (*Micropterus salmoides*) with smallmouth bass (*Micropterus dolomieu*) either seasonally sympatric during the summer or confined to the lower reaches. All the other species were expected to be mostly confined to the middle, lower and/or degraded reaches of these systems.

Table 4.70 Fish species known to occur in catchments from the Klein Brak to Noetsie Rivers

Indigenous species		Introduced species	
<i>Pseudobarbus afer</i>	Eastern Cape Redfin	<i>Micropterus dolomieu</i>	Smallmouth bass
<i>Galaxias zebratus</i>	Cape galaxias	<i>Micropterus salmoides</i>	Largemouth bass
<i>Sandelia capensis</i>	Cape kurper	<i>Micropterus punctatus</i>	Spotted bass
<i>Anguilla mossambica</i>	Longfin eel	<i>Lepomis macrochirus</i>	Bluegill sunfish
<i>Anguilla marmorata</i>	Madagascan mottled eel	<i>Cyprinus carpio</i>	Carp
<i>Anguilla bengalensis labiata</i>	African mottled eel	<i>Gambusia affinis</i>	Mosquito fish
<i>Myxus capensis</i>	Freshwater mullet	<i>Clarias gariepinus</i>	Sharptooth catfish
<i>Mugil cephalus</i>	Flathead mullet	<i>Oreochromis mossambicus</i>	Mozambique tilapia
<i>Liza richardsonii</i>	Southern mullet	<i>Tilapia sparrmanii</i>	Banded tilapia

4.7.2 Expected conceptual consequences of flow changes on fish

The generic responses list for fish is provided in Table 4.71 and the responses of key taxa to changes in flow are given in Table 4.72.

Table 4.71 Fish generic response list

Flow change	Effect on fish community	Broader implications of changes to the fish community.
Effect of declining winter low-flows.	- Dispersal, especially of young of the year, into available habitat will be compromised - Facultative catadromous species recruit in winter	Older cohorts could out-compete young for available food resulting in slow growth. Fast growing species (usually exotics) will dominate

Flow change	Effect on fish community	Broader implications of changes to the fish community.
Effect of declining summer low-flows.	• Emigration and recruitment of catadromous species delayed or diminished due to a decline in the intensity of cues. • Reduced oxygen concentrations may inhibit egg and larval survival. Eggs and larvae require well-aerated water usually at the head of pools. • Sub-lethal levels of stress such as those from increased temperatures, lower oxygen concentrations, increased toxin concentrations etc. could result in lower reproductive output and slower growth • A cocktail of different sources of stress could lead to mass mortalities	• Longer residence periods for catadromous species or other species confined to a particular stretch of stream. If young are recruiting to parent streams, the failure of the adults' emigration to spawning grounds will also result in reduced recruitment • Introduced species are relatively long-lived and successful in that they can tolerate a wider range of habitat changes. Longevity provides a much greater chance of outliving poor conditions and of spawning success. The fish fauna will be dominated by these species. • Mass mortalities are likely to be of indigenous fish species
Effect of declining flow variability in low-flows.	• Steady low flows will lead to dominance of the macroinvertebrate population by a few taxa. • Research to date has indicated that these species will tend to be sedentary filter feeders. • Spawning cues and conditions (especially serial spawners) may respond to flow variability or there may be very short windows that are conducive to spawning	• Sedentary filter feeders are less available as food to many indigenous and exotic fish. Thus, there would be a concomitant reduction in these fish populations. • Decline in spawning frequency for serial spawners

Flow change	Effect on fish community	Broader implications of changes to the fish community.
General effect of flood and high-flow reduction.	- Floods are more disruptive to alien than indigenous species, the latter having adapted to these events within their particular habitat - Indigenous species use floods and high flows for dispersal and may recolonise areas left vacant by alien species some of which are washed downstream - Catadromous species use floods and high flows for spawning migrations to, and recruitment from the sea	Same as above. Responses vary according to the magnitude of the reductions in flow. Longer residence periods for catadromous species or other species confined to a particular stretch of stream. If young are recruiting to parent streams, the failure of the adults' emigration to spawning grounds will also result in reduced recruitment
Effects of loss of Class 1 and 2 floods	- As above, reduced, migration, dispersal and recruitment of adults and juveniles - Loss of events in the summer would result in a reduction in water quality. Indigenous species are generally tolerant of changes in water quality, but if severe, will either curtail or reduce reproductive output. - Eggs and larvae are susceptible to poor water quality and usually die. - Juvenile fish are more tolerant than adults purely because all their resources are put into growth. Once they have to apportion some of their resources into reproduction, or maintain a larger body size, they succumb and die. - Parasite loads increase with poor water quality, contributing to a decline in individual and population health - Some introduced species continue to reproduce, overpopulating waters with stunted individuals. These species are usually flushed downstream or out of the system with floods	- Isolated populations of unhealthy fish - Isolated communities dominated by alien species - Reduced recruitment, migration and dispersal - Reproductive failure

Flow change	Effect on fish community	Broader implications of changes to the fish community.
Effects of reduction of Class 3 and 4 Floods	Facultative catadromous species and estuarine associated species migrate out of the system during the first spates.	
Effects of $\geq 1:2$ year floods	- These floods flush out the interstitial spaces between cobbles, thereby keeping them clean of sediments. Loss of these floods will lead to changes in geomorphological features resulting in subtle and gradually more pronounced changes in the invertebrate species composition - Loss of interstitial spaces results in loss of habitat and refuge for small and juvenile fish - Changes in invertebrate species composition may result in a change in fish species composition depending on their preferred prey - Accumulation of sediments will favour introduced species that forage amongst the sediments	- These floods maintain habitat for juvenile and small species of fish - Loss of these floods creates habitat favourable to introduced species
Effects of loss of floods 1:5 and greater floods	- Reduction in species diversity as a result of a reduction in habitat diversity (see geomorphology). - Physical disturbance results in periodic displacement of individuals from a population, providing an opportunity for colonisation by new individuals and reducing competition and thus competitive exclusion - The above are applicable to the relationships between indigenous and alien species, the latter tending to be flushed out of their habitat or even the system	Greater rates of increase in the distribution and abundance of most introduced species

Flow change	Effect on fish community	Broader implications of changes to the fish community.
Effect of increased salinity	• Osmotic stress will have an effect on the behaviour of non-tolerant species. Changes in behaviour are often accompanied by increased mortalities through predation • Most of the introduced species are tolerant of high salinities. Cold temperature tolerance of Cichlids e.g. <i>T. sparrmanii</i> & <i>O.mossambicus</i> increases with higher salinities. Species such as these will broaden their distribution into the cooler reaches. • Whereas some indigenous species are tolerant of high salinities it is not known whether this holds true for their eggs and larvae	• A wider distribution for introduced species, perhaps into the last refugia of the native fauna
Effect of increased nutrient loads through increased irrigation runoff	Mainly secondary effects: • Increased growth of algae and floating macrophytes. Nocturnal respiration by plants may reduce oxygen levels to lethal levels • Extensive growth of floating macrophyte reduces the air water interface also resulting in depleted oxygen levels • Phytoplankton blooms reduce visibility for visual predators	• Low oxygen levels will only benefit the more tolerant introduced species
Effect of loss of perenniality	• Catadromous species wont recruit or migrate to spawn	• Eventual loss of catadromous species from the system
Effect of seasonal reversal of low-flows	• Cues for spawning, migration and other behaviour may occur at the wrong time. The effects of stop start physiological responses on fish are unknown, but are likely to be energetically expensive and cause a deterioration in the health of the individual and population	• Indigenous species are adapted to the seasonal changes within a system as well as to extremes such as drought. However, all of these have a certain periodicity that fish have evolved to “anticipate” and respond to. There is no inbuilt response to seasonal reversal of flows

Table 4.72 Key taxa and responses to changes in flow

Key taxa	Ecological significance	Direction of change	Most important aspects of the flow regime
<i>S. capensis</i>	Vulnerable southwestern Cape endemic confined to the upper reaches and small tributaries of most systems by alien fish, which predate on its young. A significant predator of the Baetidae, Chironomidae and Elmidae, etc., such that it may maintain or alter invertebrate community structure by reducing the dominance of some species. Being a small species it forms a large component of the diet of piscivorous birds and eels in the systems in which it occurs.	↓	Is tolerant of poor water quality but inundated marginal vegetation, submerged vegetation or emergent vegetation is essential for survival. Needs vegetation through which it can manoeuvre and may prefer some vegetation types above others. Tolerance of poor water quality does not necessarily extend to eggs and larvae A large proportion of its feeding behaviour entails ambushing prey drifting down from upstream. Low flows may cause a switch to more energetically expensive foraging behaviour. Territorial behaviour during breeding makes space a limiting factor. Shallow marginal areas would have been required for breeding in the mainstream during summer. Juveniles need the marginal refuge.
<i>G. zebratus</i>	Vulnerable southwestern Cape endemic confined to small tributaries, shallow isolated areas and upper reaches of most systems by alien fish, which predate on its young. Actively select preferred prey and therefore one of the deciding factors in invertebrate community structure. Preyed on by the Gomphidae, <i>Sandelia capensis</i> and by small piscivorous birds such as the Malachite kingfisher.	↓	Adapted to cope with medium to short term perturbations that include periods of poor water quality and low flows. Prolonged periods of low flow and poor water quality are likely to see it disappear from a system. Devotes all its energy into producing a few eggs, which are likely to require well aerated flowing or well-mixed water for survival. Low flow can result in the loss of much of the fast flow, macrophyte habitat that it utilises.
<i>P. afer</i>	Rare southern Cape endemic confined to south coast river systems. Excluded from the lower reaches, mainstream and larger tributaries of many systems by alien predators. An omnivore actively selecting different prey types	↓	May breed twice during summer relying on steady periods of summer rain and freshettes as a spawning cue. Water abstraction is greatest during summer and likely to be having an impact by removing spawning cues and thereby reducing spawning frequency.

Key taxa	Ecological significance	Direction of change	Most important aspects of the flow regime
	depending on season and locality thereby having a role in structuring invertebrate communities.		This is a short-lived species (3 years) so one missed opportunity could result in total reproductive failure.
Anguillidae, 3 species but mostly <i>Anguilla mossambica</i> in the upper reaches of southern Cape rivers. <i>A. marmorata</i> and <i>A. bengalensis labiata</i> usually in the middle and lower reaches.	Two southern African endemics and one Indo-Pacific in origin all catadromous with similar life-history characteristics. The largest piscivorous predators in southern Cape rivers and probably the most dominant before the advent of the aliens. Also a major predator on crabs and frogs.	↓	Summer floods for the spawning migration of adults to the sea and for recruitment of juveniles. The juveniles rely on flood borne cues to locate and enter the estuary and are facilitated in their upstream migration by water inundated marginal areas and vegetation. Moist surfaces of instream obstacles are required for the elvers to overcome them. Depending on the length of the river, upstream migration may take up to a year, requiring sufficient flow throughout.
<i>M. dolomieu</i> and <i>M. salmoides</i> .	Introduced species that have colonised the mainstreams and larger tributaries of most southern and southwestern Cape systems. <i>M. salmoides</i> tends to occur higher upstream than <i>M. dolomieu</i> and has a greater preference for deep pool areas. Have excluded the smaller endemic species from the mainstreams and/or lower reaches of most systems	↑	Low flows have enabled both these species to colonise most stream habitats. Being early maturing long-lived species they have ample time to outlive even the most extreme low flow conditions and breed successfully once conditions improve. Low flows and associated increases in winter temperatures probably allow them to breed earlier and more frequently every season. Spring and summer floods may have a role in flushing eggs and larvae from nesting sites thereby controlling their numbers

4.7.3 Site specific methods and results

This Section makes reference to change levels, which are defined in Section 4.1.

GROOT BRAK RIVER (GB 1)

Indigenous fish expected to be at the study site were *S. capensis*, *G. zebratus*, *P. afer* and *A. mossambica*. Introduced species in this reach are likely to be confined to *M. salmoides* with *M. dolomieu* further downstream. However, *M. dolomieu* may be found in this reach during the warmer summer months.

Two seine hauls were made in a 25 m long 0.4-1.8 m deep pool at the site whereas 300 m of riffle, shallow pool and *Palmiet* beds were sampled visually and with hand-nets. Only seven *S. capensis*, 50-87 mm in length were caught. The largest individual was found in the deep

pool whereas the remaining six were evenly spread amongst *Palmiet* roots in shallow backwaters and amongst limited *Juncus* and *Isolepis* in the riffles.

The current low numbers of fish in the reach may partly be due to the presence of the alien *M. salmoides* and/or the two large floods in the catchment over the 18 months prior to sampling. Many fish would have been washed downstream, as would have their favoured high flow habitat of *Juncus* and *Isolepis*. In turn, the life histories and behaviour of most of the indigenous species are likely to make them resilient to one but not two >20 year floods within such a short time period. This said, recovery may be slower due to predation by alien species which are likely to be the first to recolonise the reach from downstream.

The Groot Brak River (GB 1) response to reduced flow is similar to that for the Goukamma River and other systems and the same rationales apply. However, it appears to be more impacted and less resilient than the Goukamma River. In winter and summer there is a loss in flow, vegetation and therefore habitat variability as the stream progresses from change levels (CLs) 1-4.

In winter CL 1 and CL 2 see slight losses (<10%) in riffle water level and wetted perimeter with no discernible impact on fish. CL 3 may see a slight increase in *Palmiet* and *Isolepis* growth and therefore fish habitat. By CL 4 there is an overall increase in *Palmiet* and decrease in indigenous fringing vegetation the latter being replaced by aliens. There is an overall increase in marginal and overhanging cover and no significant change in pool size. However, food washed down from the riffles into the pools may decrease resulting in a slight change in foraging behaviour as most of the small species have a preference for that food source. Eels are unlikely to be impacted as there is no change in pool size but loss of variability may provide a slightly more benign environment favouring the alien *M. salmoides*.

In summer, CL 1 and CL 2 are similar to that of winter whereas CL 3 sees a slight decrease in *Isolepis* and therefore a slight drop in the available refuge for small species. The eels experience no change as there is little change in pool size but the loss of variability and more benign environment may favour *M. salmoides*. An abrupt change occurs at CL 4, which is distinct from all the other CLs in winter and summer. The riffles are much reduced at <10cm water depth and the pools become isolated. Riffle food no longer washed down into the pool forcing a change in foraging behaviour of *P. afer*, *G. zebratus* and *S. capensis*. Riffle habitat no longer available causing pool fish densities to rise and a slight change in mean fish size if growth is density dependent. Pool isolation makes the populations of small species more vulnerable to alien predation.

Class I-IV flood requirements are fairly standard across all the rivers in this study. One Class I freshette is needed in spring or early summer as a spawning cue for *P. afer* and to a lesser extent *G. zebratus* and *S. capensis*. Another Class I is needed in late summer to cue the first spawning of *P. afer* young-of-the-year. The second spawning event is fairly significant in this short-lived species. All floods (Class I-IV) in spring and early summer will facilitate the recruitment of glass eels into the system. The first floods in winter will initiate the migration of adult eels out of the river to spawn. Consequently, at least one of the Class II-IV floods is needed in autumn/early winter. The larger Class II-IV spates are also necessary for alien control. *Micropterus* spp. tend to spawn at lower temperatures than the indigenous species

and therefore commence breeding earlier in late winter/ early spring. Floods/freshettes at this time of year are extremely useful in flushing the nests, eggs and larvae of these species.

CL 1 leaves the optimum 2 Class I freshettes for *P. afer* spawning cues, CL 2 severely comprises this species by removing the advantages of a second spawning whereas complete loss of Class I under CL 3 will likely see either a drastic drop in population size or the disappearance of this species from the system. CLs 1 & 2 sees a gradual negative change with the loss of Class II floods but it's only at CL 3 and total loss that pool size and depth are greatly reduced which translates into loss of eel habitat. The loss of Class III & IV floods has a similar but more intensive impact as the loss of Class II with a decrease in pool size, reduced habitat and cues for eels and an increase in the invasive potential of the alien *M. salmoides*.

KAAIMANS RIVER (Ka 1)

Indigenous fish expected to be at the study site were *S. capensis*, *G. zebratus*, *P. afer* and *A. mossambica*. Introduced species in this reach are likely to be confined to *M. salmoides*. The site was sampled visually and with hand-nets over 200 m. In excess of 1 000 *P. afer* were seen, one *S. capensis* and no *G. zebratus*. Shoals of 80-100 *P. afer* were found at the head of two large (30X6 m) pools of 0.2-1.2 m depth. These fish were all maintaining position at the base of the riffles entering the pools and feeding on food drifting from upstream. Fish in these pools ranged from 30-110 mm in length. Smaller shoals of 30-50 fish were found amongst the Palmiet and in the riffles, eddies and backwaters. These fish ranged from 22-74 mm in length. Shallow backwaters and riffle areas of 10-20 cm depth, in most cases, had fewer than 10 fish. The one *S. capensis* seen was approximately 50 mm long and found amongst cobble and gravel in an eddy adjacent to a run.

The Kaaимans River site appeared close to pristine and the high numbers of *P. afer* compared to *S. capensis* and *G. zebratus* is probably typical of that reach. In turn, the latter two species are likely to be dominant in assemblages elsewhere upstream and downstream in the system. With regards to the recent floods, the fish habitat and fish assemblage of the Kaaимans River appears to have been the most resilient compared to the other systems. The Kaaимans River response to reduced flow is similar to that for the Goukamma River and other systems and the same rationales apply.

As with the other rivers, in winter and summer there is a loss in flow, vegetation and therefore habitat variability as the stream progresses from change levels (CLs) 1-4. With summer low-flow CL 1 sees a slight reduction in variability but riffle and pool habitat remain unchanged with sufficient food reaching the pool from upstream. This situation continues through CL 2 whereas in CL 3 fast deep areas are almost halved, deep pools are likely to develop a thermocline and shallow pools warm up. Some of the smaller fish species are likely to move into the cooler areas. However, the riffle area has remained relatively unchanged, continues to function as a habitat and export food downstream into the pool. As with the other systems, eels experience no change as there is little change in pool size but the loss of variability and more benign environment may favour *M. salmoides*. As with the Groot Brak River (GB 1) and other systems, an abrupt change occurs at CL 4. Riffles are almost completely lost and <10cm water depth and the pools become isolated. Riffle food no longer washed down into the pool forcing a change in foraging behaviour of *P. afer*, *G.*

zebratus and *S. capensis*. Riffle habitat no longer available causing pool fish densities to rise and a slight change in mean fish size if growth is density dependent. Pool isolation makes the populations of small species more vulnerable to alien predation.

In winter CL 1 and CL 2 see no significant change in water level and wetted perimeter and no discernible impact on fish. CL 3 sees little change in water depth but a 50% decrease in water velocity over the riffles. There is a slight 10-20% reduction in riffle habitat but <20% of the fish assemblage are in this habitat. There is a slight reduction in food reaching the riffles. These changes will apply to the three small-bodied indigenous species. Eels will not be affected as the pool habitat fairly stable but also suitable for *M. salmoides*. There is also a slight reduction in vegetation cover and refugia. CL 4 sees a complete loss of variability, which would benefit *M. salmoides*. There is a decline in the resuspension of detritus and the amount of food reaching the pool from upstream. Overall, 50% of the riffle habitat is lost for 50% of the time but <20% of the fish assemblage found in riffles resulting in an overall loss of 10-20% of the riffle fauna.

The flood requirements are the same as for the fish assemblage in the Groot Brak River and other systems. However, the loss in variability from present may have a more drastic impact due to previously bass-free reaches becoming invaded by *M. salmoides*.

MALGAS RIVER (Mal 1)

The Malgas River differed from the other systems in that it had a relatively poor fish assemblage even though at least half the site appeared to have ideal habitat. This may be a result of the last two floods and/or the impact of bulldozing above the crossing and/or the lack of instream vegetation such as *Isolepis* in the stream and or the seasonal migration of *Micropterus* spp. from the Gwaing River. The lack of instream vegetation may be partly a result of the shadowing canopy of riparian vegetation and therefore may be a natural phenomenon. The site was sampled visually and using hand-nets but only one *G. zebratus* and one *S. capensis* were caught.

The winter and summer low-flows and the fish response at every CL are similar to the Groot Brak River and other rivers. The current low abundance of fish (and vegetation refuge) is what would be expected at CL 4 for winter and summer in the other rivers.

Fish response to flood removal is similar to the other systems with a few subtle differences. The severity of 'losing' Class I summer floods one at a time with each CL is not as great as for the Kaaimans River as there are more to start with. At CL 3 however, there are no cuing freshettes remaining and *P. afer* and perhaps *S. capensis* and *G. zebratus* populations may crash or completely disappear from the river. The fish response to the loss of Class II-IV floods is the same as for the other systems.

GOUKAMMA RIVER (Gou 1)

The Goukamma River was distinct from the other rivers sampled in that it was the only system sampled that had the full compliment of small bodied indigenous species, i.e., *P. afer*, *S. capensis* and *G. zebratus*. The river was sampled with two seine hauls through deep and shallow pools, with hand-nets and visually over 300 m. The slow shallow pool yielded no fish

whereas five *P. afer* (30-100 mm) and six *S. capensis* (30-45 mm) were caught in the deep pool. A further 14 *S. capensis* (32-80 mm), 34 *P. afer* (30-40 mm) and one *G. zebratus* (60 mm) were seen and/or caught with the hand-nets. Seventy percent of the *S. capensis* were amongst cobble and gravel and 40% in a 0.7 m deep backwater amongst root wads. Ninety percent of the *P. afer* were in an eddy/backwater in the shadow of a large boulder and *Palmiet*, the remainder in the water column above cobble. The one *G. zebratus* caught was amongst cobble at a depth of c. 0.6 m.

Winter and summer low-flows and the fish response at every CL are similar to the Groot Brak River and other systems. Although the fish requirements are the same, the differences lie in the existence of a side channel and the impacts of flood loss. Class III and the top of Class II floods inundate the side channel greatly increasing fish habitat and their lateral refuge from these floods. Loss of these floods and side channel habitat will see an overall drop in fish abundance. Class I floods are completely lost at CL 3, which are likely to see complete loss of *P. afer* from the system firstly by loss of spawning cues and secondly through predation by *M. salmoides* which will increase dramatically in this more benign environment.

5 ECOCLASSIFICATION, ECOLOGICAL SENSITIVITY AND IMPORTANCE AND THE RECOMMENDED AND ALTERNATIVE ECOLOGICAL CATEGORIES

5.1 ECOCLASSIFICATION

For the four main EWR sites, viz. Groot Brak (GB 1), Kaaimans (Ka 1), Malgas (Mal 1) and Goukamma River (Gou 1), the PES was determined using the Ecostatus Models provided by DWAF: Resource Quality Services (RQS; for detailed methodology please see Kleynhans *et al.*, 2006). In some instances, the PES provided by these models did not agree with the specialists' assessment of the PES. In cases such as this, the specialists' assessments were used in preference to those of the models, with motivation (see Delineation Report, Report no. RDM/ K10-K30, K40E/00/ CON/0207). For the remaining sites (see Table 2.1), the PES was determined using independent assessments by the specialists during visits to each of the sites, and then combined using ECOQUATMOD.xls. The overall PES scores for each of the sites are given in Table 5.1 and Table 5.2. Additional supporting information is provided in the Delineation Report (Report No RDM/ K10-K30, K40E/00/ CON/0207).

Table 5.1 Summary PES for the river sites considered in the study

EWR Sites	PES
GB 1 (Groot Brak)	B/C
Moo 1 (Moordkuil)	D
Maa 1 (Maalgate)	D
Maa 2 (Maalgate)	D
Moe 1 (Moeras)	D
Moe 2 (Moeras)	C
Mal 1 (Malgas)	C
Gwa 1 (Gwaing)	E
Sw 1 (Swart)	D
Ka 1 (Kaaimans)	B
Si 1 (Silver)	B
Gou 1 (Goukamma)	B/C
Noe 1 (Noetsie)	B

Table 5.2 ECOQUADMOD scores for the river reaches considered in the study

QUATERNARY CATCHMENT	RIVER	Bed modification (0-5)	Flow modification (0-5)	Introduced instream biota (0-5)	Inundation (0-5)	Riparian/Bank condition (0-5)	Water quality modification (0-5)	DESKTOP HABITAT INTEGRITY	Invertebrate Rating (0-5)	Fish rating (0-5)	INSTREAM EC%	INSTREAM EC	Vegetation Rating (0-5)	ECOSTATUS %	ECOSTATUS EC
K20	Groot Brak (GB1)	1	2	0	0	1	1	85.0	0	2	77.5	B/C	1	80.0	B/C
K10	Moordkuils (Moo1)	5	4	2	0	5	2	70.0	3	2	70.0	C	5	50.0	D
K30A	Maalgate (Maa1)	2	3	1	0	3	2	70.0	3	3	60.0	C/D	3	56.7	D
K30A	Maalgate (Maa2)	1	3	1	0	3		73.0	3.5	3	61.5	C/D	4	54.3	D
K30A	Moerass (Moe 1)	4	3	1	0	3		62.0	3	3	56.0	D	3	54.0	D
K30A	Moerass (Moe 2)	3	3	1	0	2		70.0	2	3	60.0	C/D	2	63.3	C
K30B	Malgas (Ma1)	2	2	1	0	3		74.0	0	2.5	67.0	C	3	64.7	C
K30B	Gwaing (Gw1)	5	3	1	0	5		50.0	3	3	50.0	D	5	36.7	E
K30C	Swart (Sw1)	3	5	1	0	3		58.0	2	2.5	59.0	C/D	3	56.0	D
K30C	Kaaimans (Ka 1)	2	1	0	0	1		86.0	0	1	85.5	B	1	87.0	B
K30C	Silver (Si 1)	1	1	0	0	1		89.0	2	1	87.0	B	1	86.3	B
K40E	Goukamma (Gou 1)	1	1	0	0	1		89.0	0	2	79.5	B/C	1	81.3	B/C
K60G	Noetsie (Noe 1)	2	2		0	2		76.3	3	1.5	78.1	B/C	1	82.1	B
K60G	Noetsie (Noe 2)	0	1		0	1		90.0	0	1	87.5	A/B	1	88.3	A/B

The rivers selected for Intermediate Reserve Determinations are highlighted in yellow in Table 5.2. Unhighlighted rivers were selected for Rapid Reserve Determinations. Noe 2 was only assessed based on specialists' opinion and was therefore not considered for further analysis.

5.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

In general, the study rivers have been accorded a high or very high Ecological Importance and Sensitivity (EIS; Table 5.3). This is based on several aspects, *viz.*:

- their location in relatively undisturbed parts of the Outeniqua catchments (very high EIS sites);
- the diversity and uniqueness of their biota, in particular, vegetation;
- their importance and migratory corridors;
- the fact that the rivers are strongly perennial and are thus likely to be sensitive to flow changes;
- the refuge provided by the rivers and their riparian zones from the agricultural and urban activities in the surrounding catchments.

Table 5.3 EIS for the study sites

River	EWR Site	Quaternary Catchment	PES	EIS
Groot Brak	GB 1	K20A	B/C	HIGH
Kaaimans	Ka 1	K30C	B	VERY HIGH
Malgas	Mal 1	K30B	C	HIGH
Goukamma	Gou 1	K40E	B/C	VERY HIGH
Maalgate	Maa 1 and Maa 2	K30A	D	HIGH
Moeras	Moe 1	K30A	D	HIGH
	Moe 2		C	HIGH
Gwaing	Gwa 1	K30B	E	HIGH
Swart	Sw 1	K30C	D	HIGH
Silver	Si 1	K30C	B	VERY HIGH
Noetsie	Noe 1	K60G	B	VERY HIGH
Moordkuil	Moo 1	K10F	D	HIGH

5.3 RECOMMENDED AND ALTERNATIVE ECOLOGICAL STATUS

The Recommended Ecological Categories (REC) and Alternative Ecological Categories (AEC) for each of the study sites are provided in Table 5.4.

Table 5.4 Recommended Ecological Categories (REC) and Alternative Ecological Categories (AEC) for each of the study sites

EWR Site	REC	AEC 1	AEC 2	Level of determination
GB 1	B/C	C	B	Intermediate
Ka 1	B	C	A/B	Intermediate
Mal 1	C	D	B	Intermediate
Gou 1	B/C	C	None	Intermediate
Maa 1 and Maa 2	D	C	None	Rapid II
Moe 1	D	C	None	
Moe 2	C	D	None	
Gwa 1	D	None	None	Rapid II
Sw 1	D	None	None	Rapid II
Si 1	B	C	None	Rapid II
Noe 1	A/B	B	C	Rapid I
Moo 1	Not applicable – review only.			

No EWRs are given for conditions below a D-Category, as per RDM recommendations. Also, EWR were not provided for higher categories where non-flow related aspects make it impossible to achieve a higher ecological status. For instance, where housing has encroached on the river and the river is channelised and/or canalised, additional flow is unlikely to provide for a better ecological condition.

6 RESULTS FOR EWR SITE GB 1 (GROOT BRAK AT KLEINPLAAS ROAD)

6.1 RIVER REACH REPRESENTED BY GB 1

EWR Site GB 1 (Figure 6.1) is representative of the Groot Brak River between Ernest Robertson Dam and Wolwedans Dam.



Figure 6.1 Groot Brak River at Kleinplaas Road (GB 1)

6.2 PRESENT ECOLOGICAL STATUS

The PES for EWR GB 1 is Category B/C (Table 6.1). Details of the PES assessments comprising this are provided in the Delineation Report (DWAf, 2007b).

Table 6.1 PES, EIS and REC for Groot Brak River (GB 1)

Component of the riverine ecosystem	PES		EIS	Recommended Ecological Category*
	Category	Trajectory		
Hydrology	C	Stable	<i>High EIS</i> , because of the presence of rare and endangered species (fish) and a diversity of habitat types. Plus the support it provides to the Groot Brak Estuary and the fact that it is an important corridor through farmland for wildlife.	B/C
Water quality	B	Stable		
Geomorphology	B	Stable		
Riparian vegetation	B	Stable		
Macroinvertebrates	A/B	Stable		
Fish	D	Stable		
PES	B/C	Stable		

6.2.1 Major contributing factors to the PES

The major factors contributing to the PES for EWR GB 1 were:

- localised manipulation of the river channel (non-flow related);
- constant lowflows – as evidenced by reduction of the riparian vegetation band and some bank slumping;
- a poor fish fauna, possibly related to the flushing effect of a large (c. 1:50 year flood that came through the system c. 1 year before the assessments where undertaken).

6.3 PRESENT DAY FLOWS

In order to provide specialists with some kind of reference point at which to begin their deliberations, the CLs on the naturalised low flow duration curves that most closely approximated the present day condition were identified. It is difficult to judge where the present day flows sit on the scale of the naturalised flows, particularly without the relevant daily data. Evaluation of the monthly present-day data provided by DWAF (to the extent possible), however, indicated that the present day flows most closely approximated the following CLs on the naturalised flow duration curves:

- Winter lowflows – c. Level 3 change
- Summer lowflows – c. Level 3 change.

6.4 CHANGE LEVELS CONSIDERED BY SPECIALISTS

6.4.1 Change levels for Groot Brak River (GB 1) lowflows

The following lowflow CLs were considered at the Rivers workshop:

Summer:

1. Decrease: Cut off at 30th percentile.
2. Decrease: Cut off at 50th percentile.
3. Decrease: Cut off at 70th percentile.
4. Decrease: Cut off at 90th percentile.

Winter:

1. Decrease: Cut off at 30th percentile.
2. Decrease: Cut off at 50th percentile.
3. Decrease: Cut off at 70th percentile.
4. Decrease: Cut off at 90th percentile.

6.4.2 Change levels for Groot Brak River (GB 1) floods

Floods will retain their (naturalised) magnitudes and durations, and the reduction levels comprised changes in annual frequency of occurrence as indicated in Table 6.2.

Table 6.2 Change levels for Groot Brak River (GB 1) floods (see Section 4.1 for details)

Flood Class	Present day	Change level 1	Change level 2	Change level 3	Change level 4
1	3-4	2	1	0	
2	3-4	2	1	0	
3	2-3	1	0		
4	1-2	0			
>= 1:2	Present	Absent	-	-	-

6.5 DRIFT CATEGORY OUTPUT FOR GB 1

The DRIFT CATEGORY output for GB 1 is given in Figure 6.2.

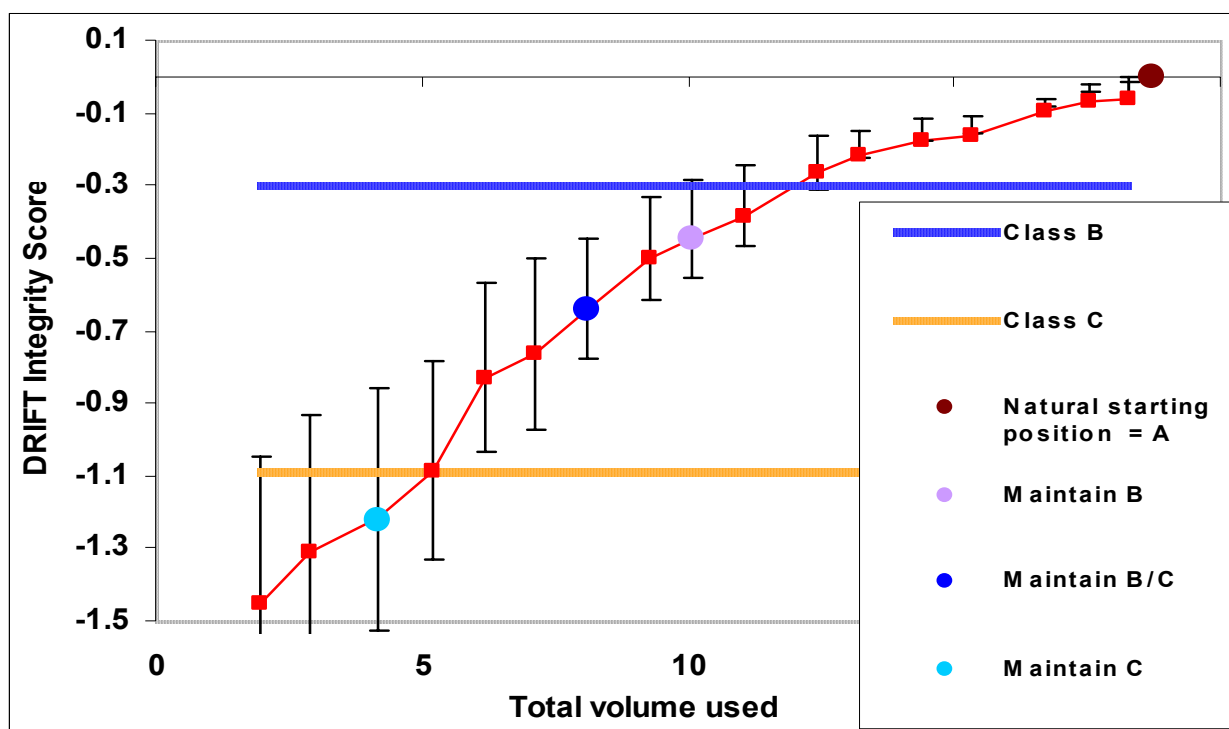


Figure 6.2 The DRIFT CATEGORY output for GB 1³⁴ (volume in MCM/a)

Three category options are presented for the Groot Brak River (GB 1). These are:

- Option 1: REC – Maintain PES – Category B/C.
- Option 2: AEC – Retain option of restoring non-flow related aspects and improve overall ecological condition to Category B.
- Option 3: Allow a reduction in PES to Category C.

³⁴ NB: The Groot Brak site used NATURAL as reference condition because there were no present day daily hydrological data available for the site. All of the other sites used PRESENT DAY as their reference point, as per standard DRIFT practice.

Each of these is addressed sequentially in the following sections.

6.6 DETAILED EWR OPTION 1: MAINTAIN RECOMMENDED ECOLOGICAL CATEGORY (REC_B/C)

6.6.1 Overview of EWR Option 1

This section provides a brief summary of EWR Option 1 (REC_B/C) for GB 1.

TARGET ECOLOGICAL CATEGORY

Maintain Recommended Ecological Category (REC_B/C) = B/C.

ECOLOGICAL WATER REQUIREMENTS

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e. $\geq 1:2$ year return period³⁵). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using other methods, the DRIFT volumes are reported both including and excluding the volumes of the $\geq 1:2$ year return period flood.

Mean annual volume required for the river for Option 1 (REC_B/C)– GB 1:

Including the volume for the $\geq 1:2$ year floods: 10.09 MCM a⁻¹
= c. 53.9% nMAR and 98.9% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods³⁶: 6.3 MCM a⁻¹
= c. 33.6% nMAR and 61.8% present day MAR.

Note: The long-term average is 29.5 % of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 1 (REC_B/C) at GB 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter lowflows	Level 4, i.e., Capped at the 90% percentile of the naturalised lowflow duration curve.
2	Summer lowflows:	Level 3, i.e., Capped at the 70% percentile of the naturalised lowflow duration curve.
3	Class 1 Intra-annual floods:	present day.
4	Class 2 Intra-annual floods:	present day.

³⁵ Previously all inter-annual floods were excluded in the reported volume, but recent studies have started to include floods with a 1:2 year return period, i.e. Komati Basin EWR Study.

³⁶ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet the Ecostatus target for this scenario.

5	Class 3 Intra-annual floods:	Level 2, i.e., no Class 3 floods.
6	Class 4 Intra-annual floods:	present day.
7	Inter-annual floods (1:2 year):	Present Day, i.e., no dam.
8	Inter-annual floods (1:5 year):	Present Day, i.e., no dam.
9	Inter-annual floods (1:10 year):	Present Day, i.e., no dam.
10	Inter-annual floods (1:20 year):	Present Day, i.e., no dam.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 1 (REC) was specifically designed to maintain present ecological status, viz. Category B/C. This will, however, only be possible if no further non-flow related impacts occur on the river.

OVERALL INTEGRITY SCORE: EWR OPTION 1 (REC_B/C)

EWR Option 1 (REC_B/C) was assigned an **Overall Integrity Score of -0.64**, i.e., a slight REDUCTION in PES but maintaining a B/C-Category.

EXPECTED EC

EWR Option 1 (REC_B/C) is expected to maintain a Category-B/C condition.

6.6.2 EWR Option 1 (REC) Hydrology

A portion of the modified flow regime for EWR Option 1 (REC_B/C) is shown in Figure 6.3 and Table 6.3 provides a breakdown of the flow regime required to meet EWR Option 1 (REC_B/C) - to be met at the inflow to Wolwedans Dam. Note that the values given are an ESTIMATE of the flows required. Actual volumes depend on climate. The flood requirements are detailed in Table 6.4 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 6.5 and Table 6.6, respectively.

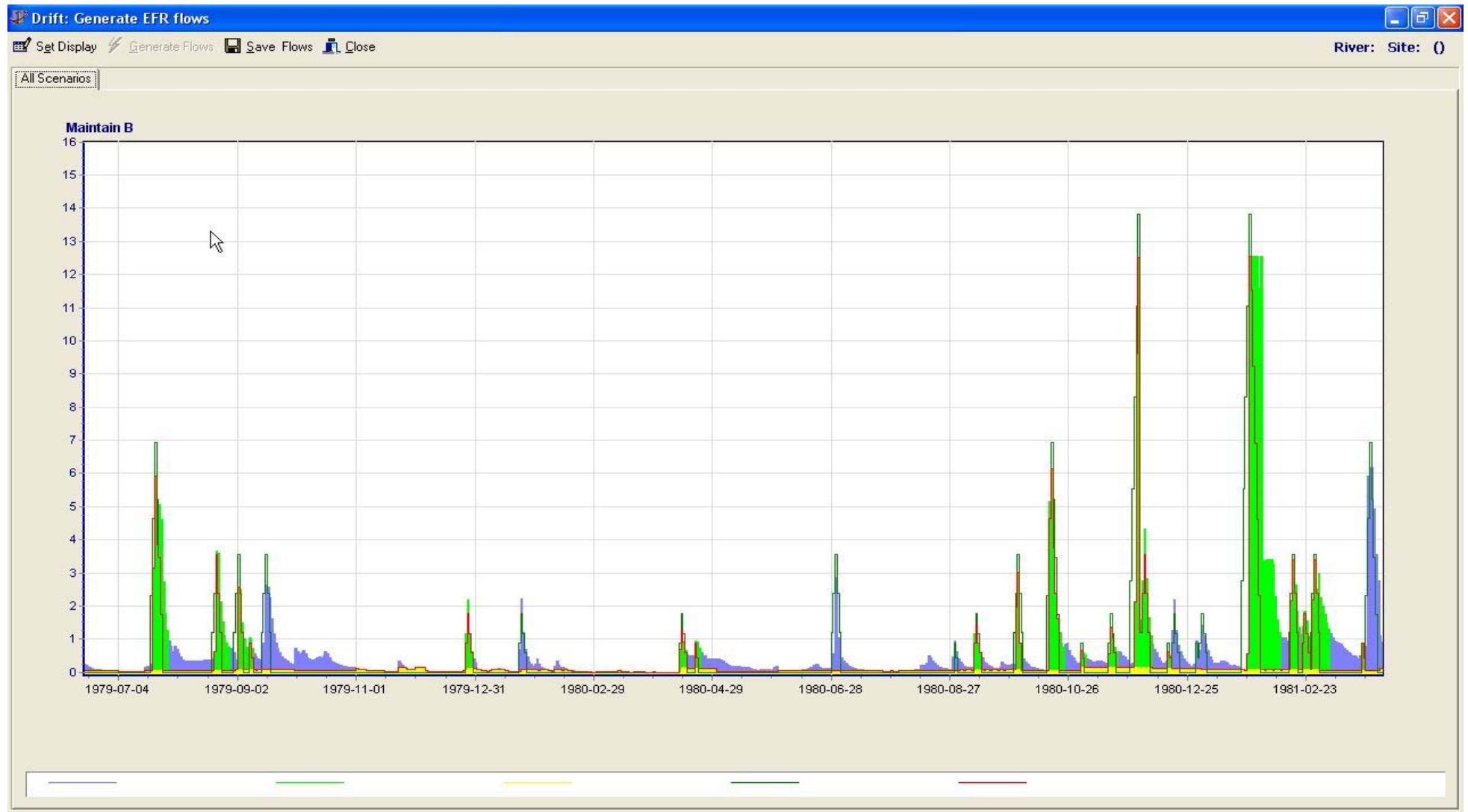


Figure 6.3 A portion of the modified flow regime for EWR Option 1 (REC_B/C) at GB 1. The blue line (original flow) is Present Day flow in the river, green line = high flow, yellow line = low flow, red = EFR flow

Table 6.3 Water quantity for EWR Option 1 (REC_B/C) at GB 1 (Groot Brak River at Kleinplaas Road). To be met at inflow to Wolwedans Dam

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 18.7 MCM (estimated). PD MAR = 10.2														
EWR Ecostatus Category = B/C.														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.051	0.141	0.131	0.091	0.071	0.061	0.121	0.031	0.041	0.051	0.061	0.071	2.15	11.5%
FLOOD Class 1: 1: m ³ s ⁻¹	2					1				0.5		With Oct	0.64	3.4%
FLOOD Class 2: 2.12: m ³ s ⁻¹	1					2				0.5		With Oct	1.64	8.7%
FLOOD Class 3: 3.56: m ³ s ⁻¹	-												0	0%
FLOOD Class 4: 6.95: m ³ s ⁻¹	1												1.88	10.1%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												3.78	20.2%
MAINTENANCE TOTAL (Volume)	Annual ³⁷												10.09	54%
	Long-term average ³⁸												5.52	30%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.05	0.05	0.04	0.03	0.03	0.02	0.04	0.03	0.04	0.05	0.06	0.07	1.33	7%
FLOOD Peak m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

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.

Table 6.4 Summary of the flood requirements for GB 1 – EWR Option 1 (REC_B/C)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood requested has a return period of 1:1)					
Class 1	1	2	0.183	3.5	August - April
Class 2	2.12	4	0.469	3.5	October - May
Class 3	3.56	5	0.944	0	Not applicable
Class 4	6.95	6	1.878	1	Any time
Inter-annual Class (return period given below)					
1:2	11	6	3.76	Present	Not stipulated
1:5	22	8	5	Present	Not stipulated
1:10	40	8	6	Present	Not stipulated
1:20	64	8	6	Present	Not stipulated

Table 6.5 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 1 (REC – B/C) for GB 1. MCM = million cubic metres

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	1.776	0.145	0.137	0.12	0.073	0.07	0.061	0.051	0.05	0.04	0.031	0.025	0.004	5.519
Jan	2.892	0.097	0.093	0.092	0.092	0.091	0.091	0.091	0.09	0.06	0.03	0.02	0.01	0.517
Feb	0.888	0.073	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.04	0.03	0.02	0	0.22
Mar	1.601	0.096	0.065	0.063	0.062	0.061	0.061	0.061	0.06	0.03	0.021	0.02	0.01	0.311
Apr	2.328	0.872	0.137	0.125	0.122	0.122	0.121	0.12	0.12	0.061	0.041	0.02	0	0.738
May	1.102	0.034	0.033	0.032	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.01	0.167
Jun	0.436	0.043	0.042	0.041	0.041	0.041	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.123
Jul	1.057	0.051	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0.219
Aug	1.776	0.063	0.063	0.061	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.01	0.388
Sep	0.872	0.075	0.073	0.071	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.02	0.236
Oct	8.968	0.993	0.055	0.053	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.04	0	0.831
Nov	8.787	0.872	0.145	0.143	0.142	0.142	0.141	0.141	0.14	0.08	0.05	0.04	0	1.077
Dec	1.776	0.656	0.134	0.133	0.132	0.132	0.131	0.131	0.13	0.07	0.04	0.02	0.01	0.692
Summer	1.543	0.072	0.071	0.062	0.06	0.051	0.051	0.05	0.041	0.038	0.031	0.03	0.01	1.964
Winter	2.085	0.478	0.142	0.133	0.124	0.097	0.091	0.071	0.063	0.057	0.03	0.02	0	3.555

Table 6.6 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 1 (REC_B/C) for GB 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.099	0.093	0.093	0.092	0.092	0.091	0.091	0.091	0.09	0.06	0.03	0.02	0.01	0.209
Feb	0.073	0.073	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.04	0.03	0.02	0	0.148
Mar	0.066	0.065	0.064	0.062	0.062	0.061	0.061	0.06	0.06	0.03	0.021	0.02	0.01	0.138
Apr	0.137	0.132	0.126	0.122	0.122	0.121	0.121	0.12	0.12	0.06	0.04	0.02	0	0.263
May	0.034	0.033	0.032	0.031	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.01	0.081
Jun	0.055	0.042	0.042	0.041	0.041	0.041	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.103
Jul	0.053	0.051	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0.133
Aug	0.064	0.063	0.062	0.061	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.01	0.159
Sep	0.081	0.073	0.072	0.071	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.02	0.179
Oct	0.055	0.054	0.053	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.04	0	0.132
Nov	0.149	0.145	0.144	0.143	0.142	0.142	0.141	0.141	0.14	0.08	0.05	0.04	0	0.312
Dec	0.135	0.134	0.133	0.133	0.132	0.132	0.131	0.131	0.13	0.07	0.04	0.02	0.01	0.294
Winter	0.073	0.071	0.071	0.061	0.06	0.051	0.051	0.05	0.041	0.035	0.03	0.03	0.01	0.787
Summer	0.145	0.142	0.141	0.131	0.122	0.092	0.09	0.071	0.062	0.057	0.03	0.02	0	1.364

6.7 DETAILED EWR OPTION 2: MAINTAIN ALTERNATIVE ECOLOGICAL CATEGORY = B (AEC-Restore B)

6.7.1 Overview of EWR Option 2 (AEC-Restore B)

This section provides a brief summary of EWR Option 2 (AEC-Restore B) for GB 1.

TARGET ECOLOGICAL CATEGORY

Maintain Alternative Ecological Category (AEC-Restore B) = B.

ECOLOGICAL WATER REQUIREMENTS

Mean annual volume required for the river for Option 2 (AEC-Restore B)– GB 1:

Including the volume for the $\geq 1:2$ year floods: 8.92 MCM a⁻¹
= c. 47.7% nMAR and 87.5% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods³⁹: 5.14 MCM a⁻¹
= c. 27.5% nMAR and 50.4% present day MAR.

Note: The long-term average is 43% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

³⁹ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet the Ecostatus target for this scenario.

FLOW REDUCTION LEVELS USED

For EWR Option 2 (AEC-Restore B) at GB 1, the following mix of change levels for the 10 components was selected:

1	Winter lowflows	Level 4, i.e., Capped at the 90% percentile of the naturalised lowflow duration curve.
2	Summer lowflows:	Level 3, i.e., Capped at the 70% percentile of the naturalised lowflow duration curve.
3	Class 1 Intra-annual floods:	present day.
4	Class 2 Intra-annual floods:	present day.
5	Class 3 Intra-annual floods:	Level 2, i.e., no Class 3 floods.
6	Class 4 Intra-annual floods:	present day.
7	Inter-annual floods (1:2 year):	Present Day, i.e., no dam.
8	Inter-annual floods (1:5 year):	Present Day, i.e., no dam.
9	Inter-annual floods (1:10 year):	Present Day, i.e., no dam.
10	Inter-annual floods (1:20 year):	Present Day, i.e., no dam.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 2 (AEC-Restore B) was designed to maintain a B Category. However, this will only be achieved if some restoration of the river system is undertaken, as currently it is a combination of flow and non-flow related impacts that have resulted in a B/C Category.

OVERALL INTEGRITY SCORE: EWR OPTION 2 (AEC-RESTORE B)

EWR Option 2 (AEC-Restore B) was assigned an **Overall Integrity Score of -0.45**, i.e., a reduction in condition from a natural/unimpacted A Category⁴⁰ to a B Category.

EXPECTED EC

EWR Option 2 (AEC-Restore B) is expected to maintain a Category-B condition, if there is some river restoration aimed at reversing some of the non-flow related impacts.

6.7.2 EWR Option 2 (AEC-Restore B) Hydrology

A portion of the modified flow regime for EWR Option 2 (AEC-Restore B) is shown in Figure 6.4 and Table 6.7 provides a breakdown of the flow regime required to meet EWR Option 2 (AEC-Restore B) - to be met at the inflow to Wolwedans Dam. Note that the values given

⁴⁰ NB: The Groot Brak site used NATURAL as reference condition because there were no present day daily hydrological data available for the site. All of the other sites used PRESENT DAY as their reference point, as per standard DRIFT practice.

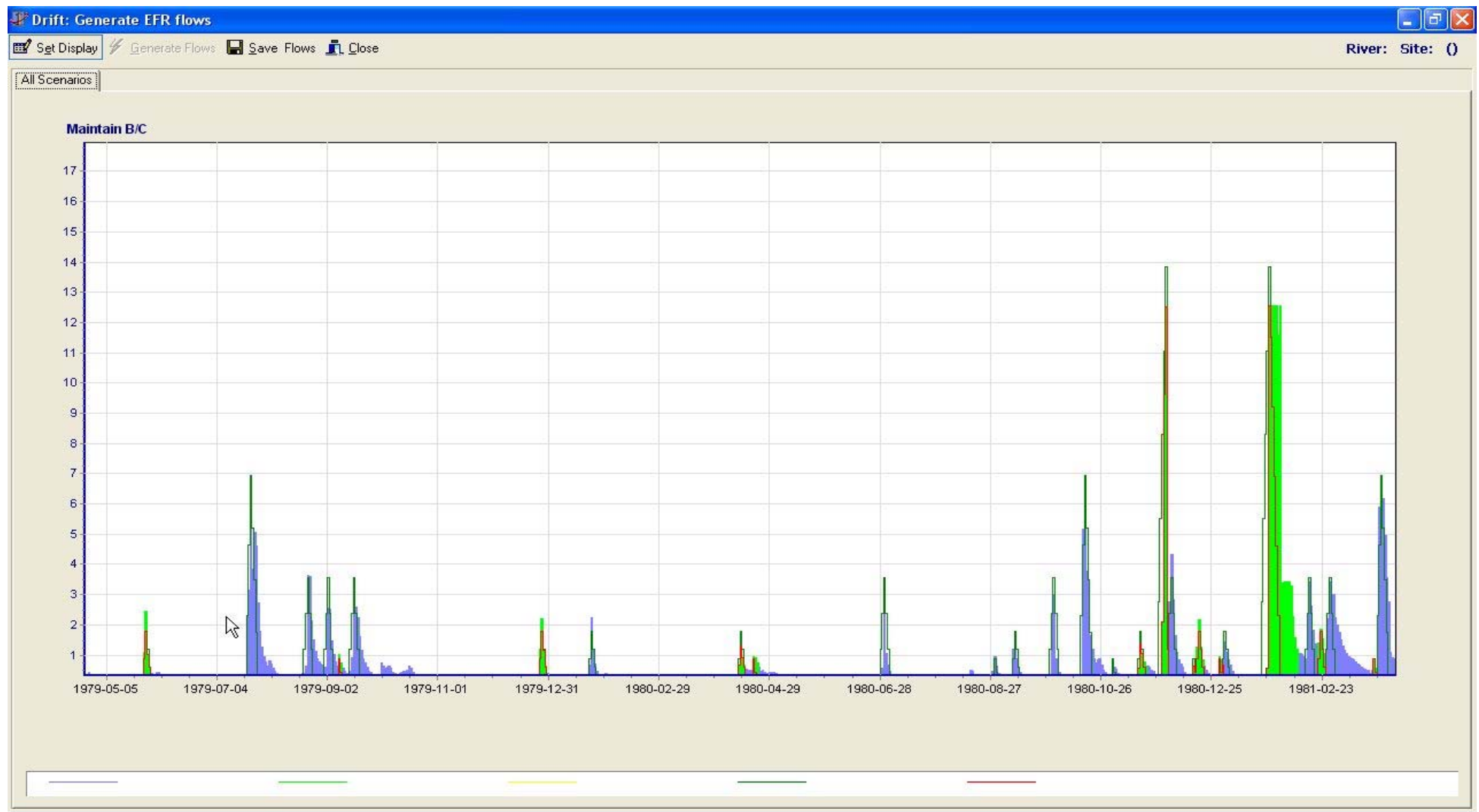


Figure 6.4 A portion of the modified flow regime for EWR Option 2 (AEC-Restore B) at GB 1. The blue line (original flow) is Present Day flow in the river

Table 6.7 Water quantity for EWR Option 2 (AEC-Restore B) at GB 1 (Groot Brak River at Kleinplaas Road). To be met at inflow to Wolwedans Dam. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 18.7 MCM (estimated). PD MAR = 10.2														
EWR Ecstatus Category = B.														
MAINTENANCE														
LOW FLOWS Q m³s ⁻¹	0.051	0.141	0.131	0.091	0.071	0.061	0.121	0.031	0.041	0.051	0.061	0.071	2.15	11.5%
FLOOD Class 1: 1: m³s ⁻¹	2					1				0.5		With Oct	0.64	3.4%
FLOOD Class 2: 2.12: m³s ⁻¹	1											With Oct	0.47	2.5%
FLOOD Class 3: 3.56: m³s ⁻¹	-												0	0%
FLOOD Class 4: 6.95: m³s ⁻¹	1												1.88	10.1%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												3.78	20.2%
MAINTENANCE TOTAL (Volume)	Annual												8.92	48%
	Long-term average												8.06	43%
DROUGHT														
LOW FLOWS m³s ⁻¹	0.05	0.05	0.04	0.03	0.03	0.02	0.04	0.03	0.04	0.05	0.06	0.07	1.33	7%
FLOOD Peak m³s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

are an ESTIMATE of the flows required. Actual volumes depend on climate. The flood requirements are detailed in Table 6.8 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 6.9 and Table 6.10, respectively.

Table 6.8 Summary of the flood requirements for GB 1 – EWR Option 2 (AEC-Restore B)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood requested has a return period of 1:1)					
Class 1	1	2	0.183	3.5	August - April
Class 2	2.12	4	0.469	1	October - May
Class 3	3.56	5	0.944	0	Not applicable
Class 4	6.95	6	1.878	1	Any time
Inter-annual Class (return period given below)					
1:2	11	6	3.76	Present	Not stipulated
1:5	22	8	5	Present	Not stipulated
1:10	40	8	6	Present	Not stipulated
1:20	64	8	6	Present	Not stipulated

Table 6.9 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 2 (AEC-Restore B) for GB 1. MCM = million cubic metres

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	1.776	0.145	0.137	0.12	0.073	0.07	0.061	0.051	0.05	0.04	0.031	0.025	0.004	5.519
Jan	2.892	0.097	0.093	0.092	0.092	0.091	0.091	0.091	0.09	0.06	0.020	0.019	0.01	0.517
Feb	0.888	0.073	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.04	0.03	0.02	0	0.22
Mar	1.601	0.096	0.065	0.063	0.062	0.061	0.061	0.061	0.06	0.03	0.021	0.02	0.01	0.311
Apr	2.328	0.872	0.137	0.125	0.122	0.122	0.121	0.12	0.12	0.061	0.041	0.02	0	0.738
May	1.102	0.034	0.033	0.032	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.01	0.167
Jun	0.436	0.043	0.042	0.041	0.041	0.041	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.123
Jul	1.057	0.051	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0.219
Aug	1.776	0.063	0.063	0.061	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.01	0.388
Sep	0.872	0.075	0.073	0.071	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.02	0.236
Oct	2.300	0.993	0.055	0.053	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.04	0	0.831
Nov	4.600	0.872	0.145	0.143	0.142	0.142	0.141	0.141	0.14	0.08	0.05	0.04	0	1.077
Dec	1.776	0.656	0.134	0.133	0.132	0.132	0.131	0.131	0.13	0.07	0.038	0.02	0.01	0.692
Winter	2.085	0.478	0.142	0.133	0.124	0.097	0.091	0.071	0.063	0.057	0.03	0.02	0	3.555
Summer	1.543	0.072	0.071	0.062	0.06	0.051	0.051	0.05	0.041	0.038	0.031	0.03	0.01	1.964

Table 6.10 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 2 (AEC-Restore B) for GB 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.099	0.093	0.093	0.092	0.092	0.091	0.091	0.091	0.09	0.06	0.03	0.02	0.01	0.209
Feb	0.073	0.073	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.04	0.03	0.02	0	0.148
Mar	0.066	0.065	0.064	0.062	0.062	0.061	0.061	0.06	0.06	0.03	0.021	0.02	0.01	0.138
Apr	0.137	0.132	0.126	0.122	0.122	0.121	0.121	0.12	0.12	0.06	0.04	0.02	0	0.263
May	0.034	0.033	0.032	0.031	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.01	0.081
Jun	0.055	0.042	0.042	0.041	0.041	0.041	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.103
Jul	0.053	0.051	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0.133
Aug	0.064	0.063	0.062	0.061	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.01	0.159
Sep	0.081	0.073	0.072	0.071	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.02	0.179
Oct	0.055	0.054	0.053	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.04	0	0.132
Nov	0.149	0.145	0.144	0.143	0.142	0.142	0.141	0.141	0.14	0.08	0.05	0.04	0	0.312
Dec	0.135	0.134	0.133	0.133	0.132	0.132	0.131	0.131	0.13	0.07	0.04	0.02	0.01	0.294
Winter	0.145	0.142	0.141	0.131	0.122	0.092	0.09	0.071	0.062	0.057	0.03	0.02	0	1.364
Summer	0.073	0.071	0.071	0.061	0.06	0.051	0.051	0.05	0.041	0.035	0.03	0.03	0.01	0.787

6.8 DETAILED EWR OPTION 3: MAINTAIN ALTERNATIVE ECOLOGICAL CATEGORY = C (AEC_C)

6.8.1 Overview of EWR Option 3

This section provides a brief summary of EWR Option 3 (AEC_C) for GB 1.

TARGET ECOLOGICAL CATEGORY

Maintain Alternative Ecological Category (AEC_C) = C.

ECOLOGICAL WATER REQUIREMENTS

Mean annual volume required for the river for Option 3 – GB 1:

Including the volume for the $\geq 1:2$ year floods: 2.99 MCM a⁻¹
= c. 15.9% nMAR and 29.3% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods⁴¹: 2.99 MCM a⁻¹
= c. 15.9% nMAR and 29.3% present day MAR.

Note: The long-term average is 18% of nMAR. This is the ACTUAL impact on MAR.

⁴¹ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet the Ecostatus target for this scenario.

FLOW REDUCTION LEVELS USED

For EWR Option 3 (AEC_C) at GB 1, the following mix of change levels for the 10 components was selected:

1	Winter lowflows	Level 4, i.e., Capped at the 90% percentile of the naturalised lowflow duration curve.
2	Summer lowflows:	Level 3, i.e., Capped at the 70% percentile of the naturalised lowflow duration curve.
3	Class 1 Intra-annual floods:	Level 1, i.e., 2 Class 1 floods.
4	Class 2 Intra-annual floods:	present day.
5	Class 3 Intra-annual floods:	Level 2, i.e., no Class 3 floods.
6	Class 4 Intra-annual floods:	Level 1, i.e., no Class 4 floods.
7	Inter-annual floods (1:2 year):	Not requested.
8	Inter-annual floods (1:5 year):	Not requested.
9	Inter-annual floods (1:10 year):	Not requested.
10	Inter-annual floods (1:20 year):	Not requested.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 3 (AEC-C) was designed to maintain a C Category. This is a reduction in condition relative to present day (2007) conditions.

OVERALL INTEGRITY SCORE: EWR OPTION 1 (REC)

EWR Option 3 (AEC_C) was assigned an **Overall Integrity Score of -1.22**, i.e., a reduction in condition from a natural/unimpacted A Category⁴² to a C Category.

EXPECTED EC

EWR Option 3 (AEC-C) is expected to maintain a Category-C condition.

6.8.2 EWR Option 3 (REC) Hydrology

A portion of the modified flow regime for EWR Option 3 (AEC) is shown in Figure 6.5 and Table 6.11 provides a breakdown of the flow regime required to meet EWR Option 3 (AEC_C) - to be met at the inflow to Wolwedans Dam. Note that the values given are an ESTIMATE of the flows required. Actual volumes depend on climate. The flood requirements are detailed in Table 6.12 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 6.13 and Table 6.14 respectively.

⁴² NB: The Groot Brak site used NATURAL as reference condition because there were no present day daily hydrological data available for the site. All of the other sites used PRESENT DAY as their reference point, as per standard DRIFT practice.

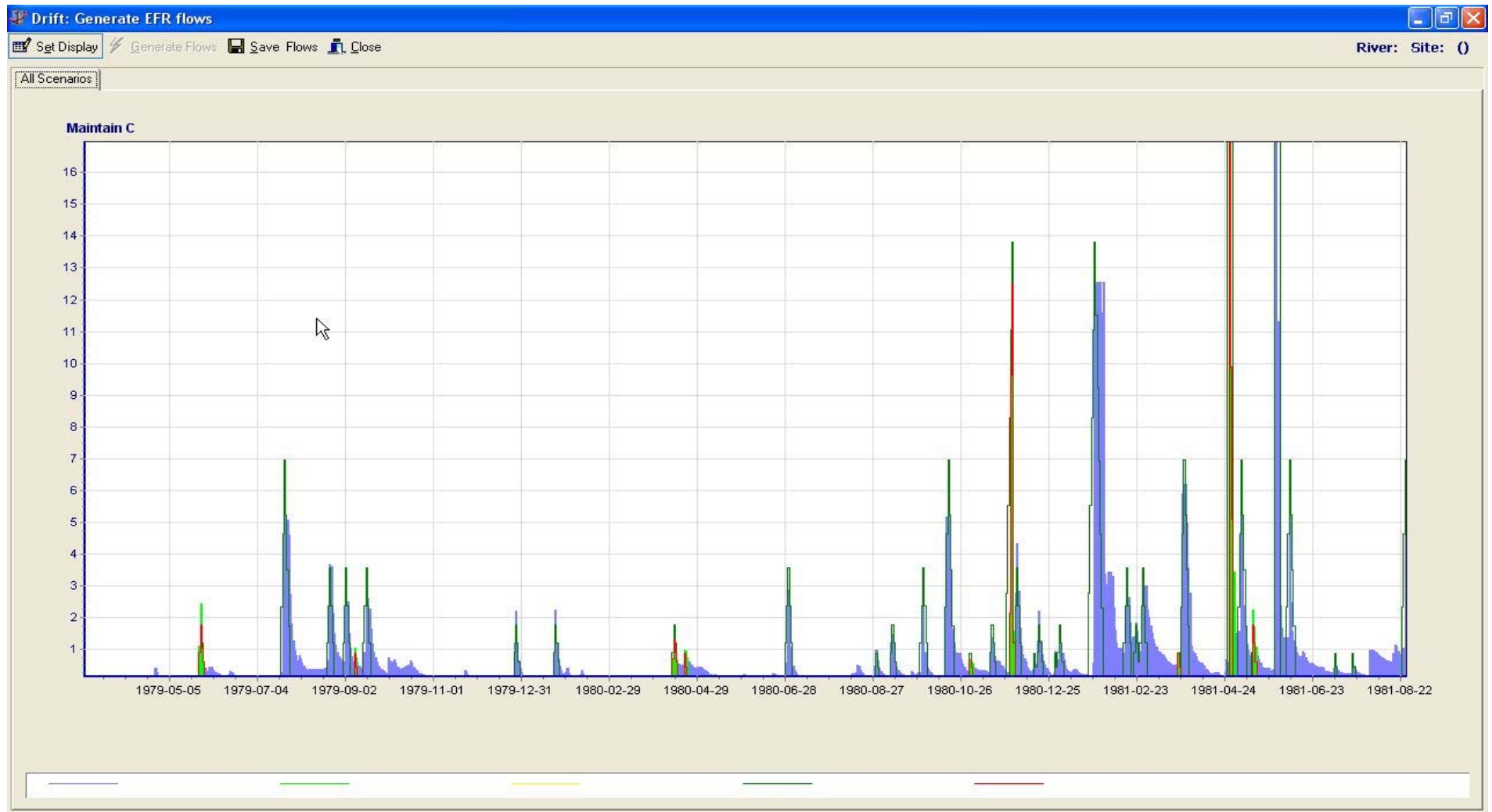


Figure 6.5 A portion of the modified flow regime for EWR Option 3 (AEC_C) at GB 1. The blue line (original flow) is Present Day flow in the river

Table 6.11 Water quantity for EWR Option 3 (AEC_C) at GB 1 (Groot Brak River at Kleinplaas Road). To be met at inflow to Wolwedans Dam. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 18.7 MCM (estimated). PD MAR = 10.2														
EWR Ecostatus Category = C.														
MAINTENANCE														
LOW FLOWS Q m³s⁻¹	0.051	0.141	0.131	0.091	0.071	0.061	0.121	0.031	0.041	0.051	0.061	0.071	2.15	11.5%
FLOOD Class 1: 1: m³s⁻¹						1						With Oct	0.37	2.0%
FLOOD Class 2: 2.12: m³s⁻¹						1						With Oct	0.47	2.5%
FLOOD Class 3: 3.56: m³s⁻¹	-												0	0%
FLOOD Class 4: 6.95: m³s⁻¹	-												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												0	0%
MAINTENANCE TOTAL (Volume)	Annual ⁴³												2.99	16%
	Long-term average ⁴⁴												3.49	19%
DROUGHT														
LOW FLOWS m³s⁻¹	0.05	0.05	0.04	0.03	0.03	0.02	0.04	0.03	0.04	0.05	0.06	0.07	1.33	7%
FLOOD Peak m³s⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁴³ Calculated as the volume of water required to meet the full requirements.

⁴⁴ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

**Table 6.12 Summary of the flood requirements for GB 1 – EWR Option 3 (AEC_C):
Maintain a C-Category river**

Flood type	Daily average peak ($\text{m}^3 \text{s}^{-1}$)	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood requested has a return period of 1:1)					
Class 1	1	2	0.183	2	August - April
Class 2	2.12	4	0.469	1	October - May
Class 3	3.56	5	0.944	0	Not applicable
Class 4	6.95	6	1.878	0	Any time
Inter-annual Class (return period given below)					
1:2	11	6	3.76	Present	Not stipulated
1:5	22	8	5	Present	Not stipulated
1:10	40	8	6	Present	Not stipulated
1:20	64	8	6	Present	Not stipulated

Table 6.13 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 3 (AEC_C) for GB 1. MCM = million cubic metres

Month	Percentiles (data are in $\text{m}^3 \text{s}^{-1}$)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	1.184	0.071	0.064	0.052	0.051	0.05	0.041	0.040	0.031	0.030	0.021	0.02	0.004	3.492
Jan	0.035	0.034	0.032	0.031	0.031	0.031	0.031	0.030	0.030	0.030	0.030	0.02	0.010	0.088
Feb	0.436	0.031	0.031	0.031	0.031	0.031	0.031	0.030	0.030	0.030	0.030	0.02	0.000	0.090
Mar	0.642	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.020	0.020	0.02	0.010	0.093
Apr	2.328	0.535	0.045	0.043	0.042	0.041	0.041	0.040	0.040	0.040	0.040	0.02	0.000	0.524
May	1.102	0.034	0.033	0.032	0.031	0.031	0.031	0.030	0.030	0.030	0.030	0.03	0.010	0.167
Jun	0.056	0.042	0.042	0.041	0.041	0.041	0.040	0.040	0.040	0.040	0.040	0.03	0.020	0.107
Jul	0.053	0.051	0.051	0.051	0.051	0.051	0.051	0.050	0.050	0.050	0.050	0.04	0.030	0.133
Aug	5.531	0.063	0.063	0.061	0.061	0.061	0.061	0.061	0.060	0.060	0.060	0.04	0.010	0.487
Sep	4.428	0.075	0.073	0.071	0.071	0.071	0.071	0.071	0.070	0.070	0.070	0.05	0.020	0.450
Oct	1.501	0.055	0.054	0.052	0.051	0.051	0.051	0.051	0.050	0.050	0.050	0.04	0.000	0.402
Nov	8.297	0.435	0.054	0.052	0.051	0.051	0.051	0.051	0.050	0.050	0.050	0.04	0.000	0.771
Dec	0.872	0.045	0.043	0.042	0.041	0.041	0.041	0.040	0.040	0.040	0.040	0.02	0.010	0.181
Summer	1.286	0.052	0.051	0.044	0.041	0.04	0.031	0.031	0.030	0.022	0.020	0.02	0.000	1.746
Winter	1.184	0.071	0.071	0.061	0.06	0.051	0.051	0.050	0.041	0.038	0.031	0.03	0.010	1.746

Table 6.14 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 3 (AEC_C) for GB 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.099	0.093	0.093	0.092	0.092	0.091	0.091	0.091	0.09	0.06	0.03	0.02	0.01	0.209
Feb	0.073	0.073	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.04	0.03	0.02	0	0.148
Mar	0.066	0.065	0.064	0.062	0.062	0.061	0.061	0.06	0.06	0.03	0.021	0.02	0.01	0.138
Apr	0.137	0.132	0.126	0.122	0.122	0.121	0.121	0.12	0.12	0.06	0.04	0.02	0	0.263
May	0.034	0.033	0.032	0.031	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.01	0.081
Jun	0.055	0.042	0.042	0.041	0.041	0.041	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.103
Jul	0.053	0.051	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0.133
Aug	0.064	0.063	0.062	0.061	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.01	0.159
Sep	0.081	0.073	0.072	0.071	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.02	0.179
Oct	0.055	0.054	0.053	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.04	0	0.132
Nov	0.149	0.145	0.144	0.143	0.142	0.142	0.141	0.141	0.14	0.08	0.05	0.04	0	0.312
Dec	0.135	0.134	0.133	0.133	0.132	0.132	0.131	0.131	0.13	0.07	0.04	0.02	0.01	0.294
Winter	0.145	0.142	0.141	0.131	0.122	0.092	0.09	0.071	0.062	0.057	0.03	0.02	0	1.364
Summer	0.073	0.071	0.071	0.061	0.06	0.051	0.051	0.05	0.041	0.035	0.03	0.03	0.01	0.787

7 RESULTS FOR EWR SITE MAL 1 (MALGAS RIVER AT OU BRUG)

7.1 RIVER REACH REPRESENTED BY Mal 1

The EWR site on the Malgas River at Ou Brug (Mal 1) (Figure 7.1) is representative of the Malgas River from the quarry to the confluence with the Gwaing River. The river reach upstream of this, i.e., from the Keur River Bridge to the quarry flows through relatively undisturbed wilderness area, and as such forms a separate reach. The same EWR data will be used for that reach, but the REC would be higher, i.e., A/B (assessed by Dr Brown during the site selection visit), and thus the Reserve requirements would be higher.



Figure 7.1 Malgas River at Ou Brug (Mal 1)



Figure 7.2 Keur River at the bridge

7.2 PRESENT ECOSTATUS

The PES for EWR Mal 1 is Category C.

Table 7.1 PES, EIS and REC for Malgas River (Mal 1)

Component of the riverine ecosystem	PES		EIS	Recommended Ecological Category*
	Category	Trajectory		
Hydrology	C	Stable	<i>High EIS, because of the presence of relatively high diversity of habitats and invertebrates, and that it is an important refuge from the urban area. The whole system is also an important corridor between a nature reserve and the coast.</i>	C
Water quality	B	Stable		
Geomorphology	B/C	Stable		
Riparian vegetation	D	Stable		
Macroinvertebrates	A	Stable		
Fish	C/D	Stable		
PES	C	Stable		

7.2.1 Major contributing factors to the PES

The major factors contributing to the PES for EWR Mal 1 were:

- localised manipulation of the river channel (non-flow related);
- the effects of the upstream quarry, cement factory and road (which carries heavy transport to and from the factory and quarry);
- heavy invasion by *Acacia mearnsii* and *A. melanoxylon*, amongst others.

7.3 CHANGE LEVELS CONSIDERED BY THE SPECIALISTS

7.3.1 Lowflow change levels

The following change levels were be considered at the workshop:

Summer:

1. Decrease: *Cut off at 20th percentile.*
2. Decrease: *Cut off at 40th percentile.*
3. Decrease: *Cut off at 60th percentile.*
4. Decrease: *Cut off at 80th percentile.*

Winter:

1. Decrease: *Cut off at 20th percentile.*
2. Decrease: *Cut off at 40th percentile.*
3. Decrease: *Cut off at 60th percentile.*
4. Decrease: *Cut off at 80th percentile.*

7.3.2 Flood change levels

Floods will retain their (naturalised) magnitudes and durations, and the reduction levels comprise changes in annual frequency of occurrence. Changes in frequency considered are given in Table 7.2.

Table 7.2 Change levels for Malgas River (Mal 1) floods

Flood Class	Present day	Change level 1	Change level 2	Change level 3	Change level 4
1	6	4	2	0	-
2	3	2	1	0	-
3	2	1	0	-	-
4	1	0	-	-	-
≥1:2	Present	Absent	-	-	-

7.4 DRIFT CATEGORY OUTPUT FOR Mal 1

The DRIFT CATEGORY output for Mal 1 is provided in Figure 7.3.

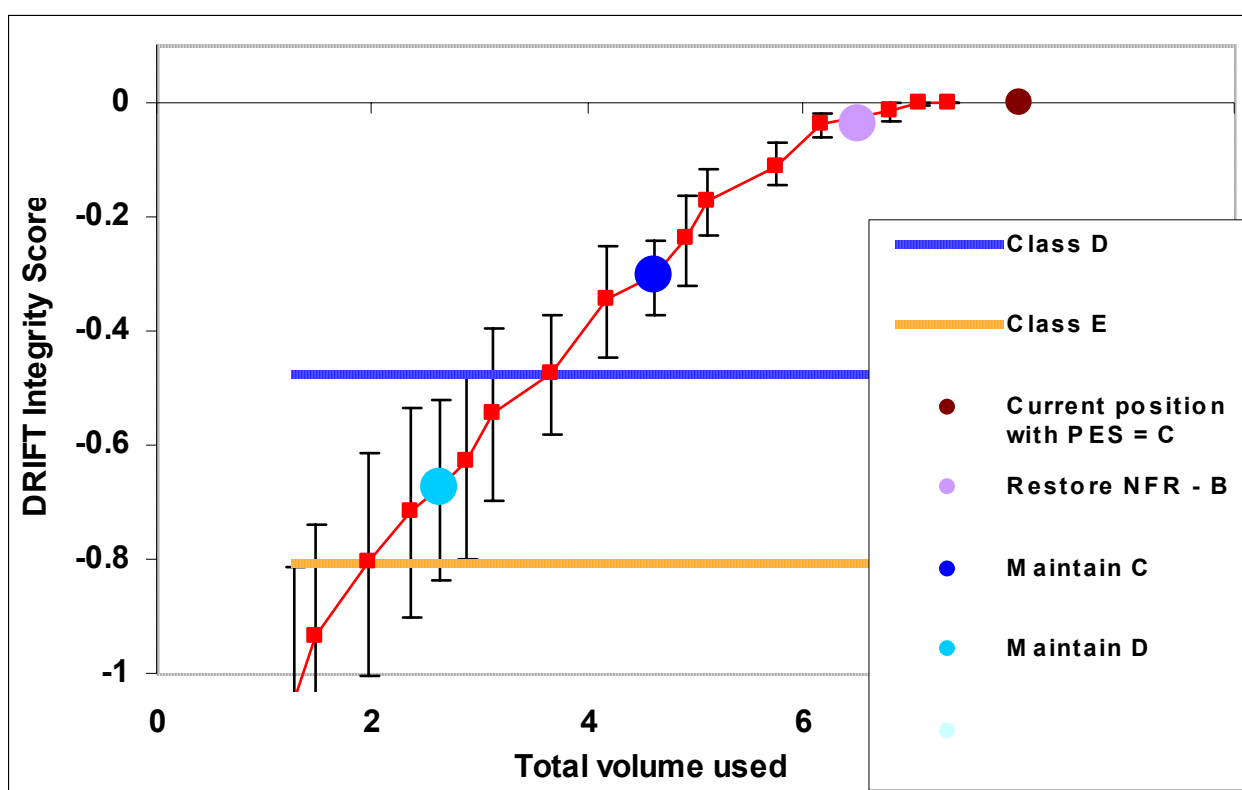


Figure 7.3 The DRIFT CATEGORY output for Mal 1 (volume in MCM/a)

Three options are presented for the Malgas River (Mal 1). These are:

1. Option 1: Recommended Ecological Category – Maintain PES – Category C.
2. Option 2: Alternative Ecological Category – Retain option of restoring non-flow related aspects and improve overall ecological condition to Category B.
3. Option 3: Allow a reduction in PES to Category D.

Each of these is addressed sequentially in the following sections.

7.5 DETAILED EWR OPTION 1: MAINTAIN RECOMMENDED ECOLOGICAL CATEGORY (REC_C)

7.5.1 Overview of EWR Option 1

This section provides a brief summary of EWR Option 1 (REC_C) for Mal 1.

TARGET ECOLOGICAL CATEGORY

Maintain Recommended Ecological Category (REC_C) = C.

ECOLOGICAL WATER REQUIREMENTS

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e., $\geq 1:2$ year return period⁴⁵). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using other methods, the DRIFT volumes are reported both including and excluding the volumes of the $\geq 1:2$ year return period flood.

Mean annual volume required for the river for Option 1 (REC_C) – Mal 1:

Including the volume for the $\geq 1:2$ year floods:	5.43 MCM a ⁻¹
	= c. 49% nMAR and 68% present day MAR.
Excluding the volume for the $\geq 1:2$ year floods ⁴⁶ :	3.81 MCM a ⁻¹
	= c. 35% nMAR and 48% present day MAR.

Note: The long-term average is 32% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

⁴⁵ Previously all inter-annual floods were excluded in the reported volume, but recent studies have started to include floods with a 1:2 year return period i.e. Komati Basin EWR Study.

⁴⁶ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet the Ecostatus target for this scenario.

FLOW REDUCTION LEVELS USED

For EWR Option 1 (REC_C) at Mal 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter lowflows	Level 2, i.e., Capped at the 40% percentile of the PD lowflow duration curve.
2	Summer lowflows:	Level 4, i.e., Capped at the 80% percentile of the PD lowflow duration curve.
3	Class 1 Intra-annual floods:	present day.
4	Class 2 Intra-annual floods:	Level 3, i.e., no Class 2 floods.
5	Class 3 Intra-annual floods:	present day.
6	Class 4 Intra-annual floods:	present day.
7	Inter-annual floods (1:2 year):	Present Day, i.e., no dam.
8	Inter-annual floods (1:5 year):	Present Day, i.e., no dam.
9	Inter-annual floods (1:10 year):	Present Day, i.e., no dam.
10	Inter-annual floods (1:20 year):	Present Day, i.e., no dam.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 1 (REC_C) was specifically designed to limit possible impacts as a result of changes in the flow components that are deemed to threaten the overall Ecostatus. This Ecostatus would, however, be threatened should the non-flow related factors contributing to the reduced condition of the river continue unabated.

OVERALL INTEGRITY SCORE: EWR OPTION 1 (REC)

EWR Option 1 (REC_C) was assigned an **Overall Integrity Score of -0.31**, i.e., a slight REDUCTION in PES but maintaining a C-Category.

EXPECTED EC

EWR Option 1 (REC_C) is expected to maintain C-Category.

7.5.2 EWR Option 1 (REC_C) Hydrology

A portion of the modified flow regime for EWR Option 1 (REC-C) is shown in Figure 7.4 and Table 7.3 provides a breakdown of the flow regime required to meet EWR Option 1 (REC-C). The flood requirements are detailed in Table 7.4 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 7.5 and Table 7.6, respectively.

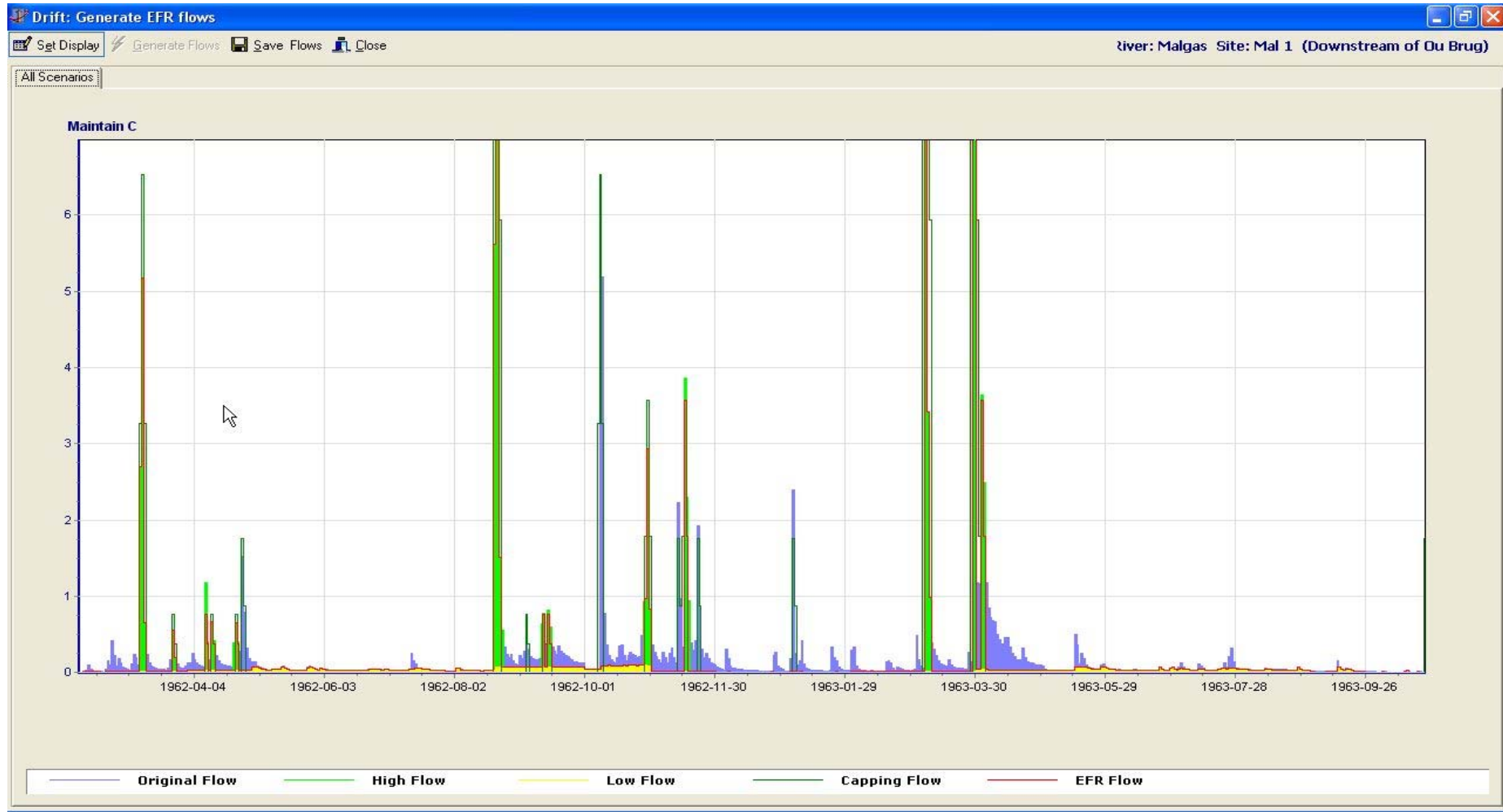


Figure 7.4 A portion of the modified flow regime for EWR Option 1 (REC_C) at Mal 1. The blue line (original flow) is Present Day flow in the river

Table 7.3 Water quantity for EWR Option 1 (REC_C) at Mal 1 (Malgas River at Ou Brug). To be met at Gauge K3H004. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 11 MCM (estimated). PD MAR = 8														
EWR Ecstatus Category = C														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.07	0.02	0.01	0.01	0.02	0.02	0.03	0.05	0.05	0.04	0.05	0.05	1.05	9.5%
FLOOD Class 1: 0.95 m ³ s ⁻¹	5.5											With Oct	0.76	6.9%
FLOOD Class 2: 1.76 m ³ s ⁻¹	-												0	0%
FLOOD Class 3: 3.57 m ³ s ⁻¹	2											With Oct	1.05	9.5%
FLOOD Class 4: 6.53 m ³ s ⁻¹	1												0.94	8.6%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												1.62	14.7%
MAINTENANCE TOTAL (Volume)	Annual ⁴⁷												5.43	49%
	Long-term average ⁴⁸												3.5	32%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.421	4%
FLOOD Peak ⁴⁹ m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁴⁷ Calculated as the volume of water required to meet the full requirements.

⁴⁸ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

⁴⁹ Daily average peak.

Table 7.4 Summary of the flood requirements for Mal 1 – EWR Option 1 (REC_C)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	0.95	2	0.139	5.5	September - April
Class 2	1.76	2	0.249	0	November - March
Class 3	3.57	3	0.523	2	September - March
Class 4	6.53	3	0.943	1	Anytime
Inter-annual Class (return period given below)					
1:2 year	11	4	1.6	Present	Not stipulated
1:5 year	23	4	2	Present	Not stipulated
1:10 year	26	4	2.8	Present	Not stipulated
1:20 year	34	4	2.8	Present	Not stipulated

Table 7.5 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 1 (REC_C) for Mal 1. MCM = million cubic metres

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	2.21	0.093	0.074	0.07	0.045	0.031	0.025	0.021	0.02	0.011	0.01	0.01	0.006	3.544
Jan	1.497	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.177
Feb	1.305	0.202	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.178
Mar	3.267	0.381	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.011	0.01	0	0.372
Apr	1.787	0.381	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.02	0.013	0.01	0.282
May	1.487	0.075	0.073	0.072	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.355
Jun	0.576	0.078	0.073	0.071	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.166
Jul	0.85	0.053	0.052	0.051	0.051	0.05	0.04	0.031	0.03	0.02	0.02	0.01	0.01	0.194
Aug	3.104	0.075	0.074	0.071	0.071	0.07	0.051	0.04	0.031	0.03	0.02	0.011	0.01	0.414
Sep	3.306	0.08	0.073	0.072	0.071	0.07	0.05	0.041	0.03	0.02	0.011	0.01	0.01	0.374
Oct	3.559	0.454	0.095	0.092	0.091	0.09	0.072	0.051	0.041	0.03	0.021	0.011	0.01	0.532
Nov	3.047	0.34	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.011	0.01	0.01	0.313
Dec	1.63	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.188
Summer	1.787	0.202	0.031	0.021	0.021	0.02	0.02	0.012	0.01	0.01	0.01	0.01	0.002	1.51
Winter	2.423	0.093	0.085	0.072	0.071	0.058	0.05	0.04	0.031	0.027	0.02	0.011	0.01	2.035

Table 7.6 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 1 (REC_C) for Mal 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.011	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.027
Feb	0.022	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.047
Mar	0.021	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0	0.05
Apr	0.034	0.031	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.02	0.013	0.01	0.073
May	0.075	0.074	0.073	0.072	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.131
Jun	0.079	0.077	0.073	0.071	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.128
Jul	0.054	0.053	0.052	0.051	0.051	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.099
Aug	0.075	0.074	0.072	0.071	0.071	0.07	0.05	0.04	0.031	0.03	0.02	0.011	0.01	0.132
Sep	0.081	0.074	0.073	0.072	0.071	0.07	0.05	0.04	0.03	0.02	0.011	0.01	0.01	0.122
Oct	0.095	0.094	0.093	0.092	0.091	0.09	0.07	0.05	0.04	0.03	0.02	0.011	0.01	0.17
Nov	0.021	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.011	0.01	0.01	0.05
Dec	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.027
Summer	0.031	0.031	0.03	0.021	0.021	0.02	0.02	0.011	0.01	0.01	0.01	0.01	0.002	0.272
Winter	0.094	0.091	0.075	0.072	0.071	0.057	0.05	0.04	0.031	0.026	0.02	0.011	0.01	0.782

7.6 DETAILED EWR OPTION 2: RETAIN OPTION FOR RESTORATION TO B-CATEGORY (AEC-Restore B)

7.6.1 Overview of EWR Option 2

This Section provides a brief summary of EWR Option 2 (AEC-Restore B) for Mal 1.

TARGET ECOLOGICAL CATEGORY

Maintain Alternative Ecological Category (AEC-Restore B) = B.

ECOLOGICAL WATER REQUIREMENTS

Mean annual volume required for the river for Option 2 (AEC-Restore B) – Mal 1:

Including the volume for the $\geq 1:2$ year floods: 6.6 MCM a⁻¹
= c. 60% nMAR and 83% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods⁵⁰: 5.0 MCM a⁻¹
= c. 45% nMAR and 62% present day MAR.

⁵⁰ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet the Ecostatus target for this scenario.

Note: The long-term average is 40% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 2 (AEC-Restore B) at Mal 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter lowflows	Level 3, i.e., Capped at the 60% percentile of the PD lowflow duration curve.
2	Summer lowflows:	Level 2, i.e., Capped at the 40% percentile of the PD lowflow duration curve.
3	Class 1 Intra-annual floods:	present day.
4	Class 2 Intra-annual floods:	present day.
5	Class 3 Intra-annual floods:	present day.
6	Class 4 Intra-annual floods:	present day.
7	Inter-annual floods (1:2 year):	Present Day, i.e., no dam.
8	Inter-annual floods (1:5 year):	Present Day, i.e., no dam.
9	Inter-annual floods (1:10 year):	Present Day, i.e., no dam.
10	Inter-annual floods (1:20 year):	Present Day, i.e., no dam.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 2 (AEC-Restore B) was designed to support the ecosystem in a B-Category, provided the non-flow related impacts affecting the river are addressed.

OVERALL INTEGRITY SCORE: EWR OPTION 2 (AEC-RESTORE B)

EWR Option 2 (AEC-Restore B) was assigned an **Overall Integrity Score of –0.04**, i.e., a slight REDUCTION in PES if no restoration is undertaken. However, this will support a B-Category river, which can be achieved with restoration of non-flow related aspects.

EXPECTED EC

EWR Option 2 (AEC-Restore B) is expected to maintain a Category-B condition – provided it is accompanied by some restoration. Otherwise it will support a C- or B/C-Category.

7.6.2 EWR Option 2 (AEC-Restore B) Hydrology

A portion of the modified flow regime for EWR Option 2 (AEC-Restore B) is shown in Figure 7.5 and Table 7.7 provides a breakdown of the flow regime required to meet EWR Option 2 (AEC-Restore B). The flood requirements are detailed in Table 7.8 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 7.9 and Table 7.10 respectively.

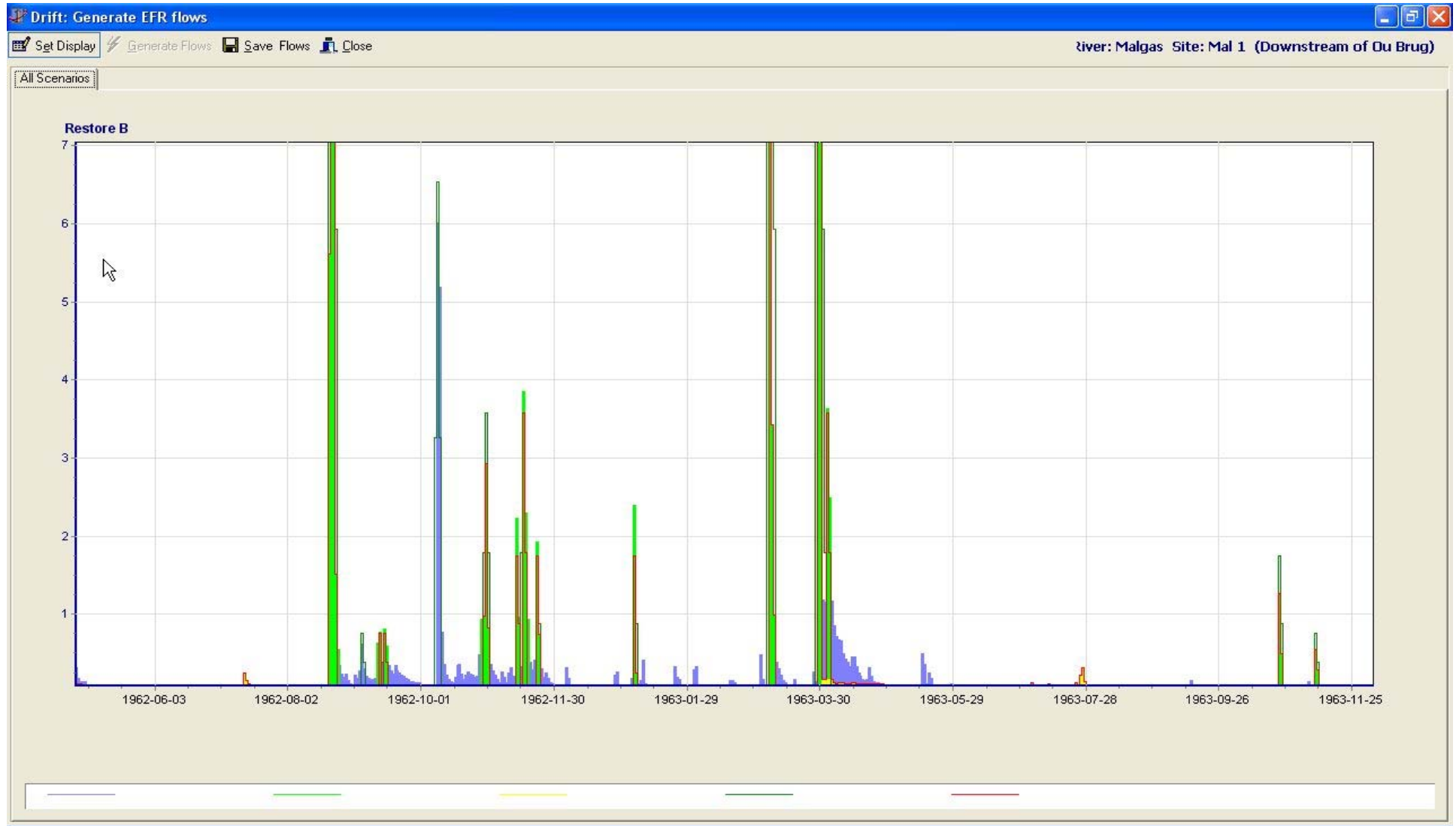


Figure 7.5 A portion of the modified flow regime for EWR Option 2 (AEC-Restore B) at Mal 1. The blue line (original flow) is Present Day flow in the river

Table 7.7 Water quantity for EWR Option 2 (AEC-Restore B) at Mal 1 (Malgas River at Ou Brug). To be met at Gauge K3H004. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 11 MCM (estimated). PD MAR = 8														
EWR Ecostatus Category = B														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.07	0.06	0.04	0.04	0.04	0.06	0.08	0.05	0.05	0.04	0.05	0.05	1.45	13.2%
FLOOD Class 1: 0.95 m ³ s ⁻¹	5.5								Only if not met			With Oct	0.76	6.9%
FLOOD Class 2: 1.76 m ³ s ⁻¹		3					Only if not met					0.75	6.8%	
FLOOD Class 3: 3.57 m ³ s ⁻¹	2						Only if not met					With Oct	1.05	9.5%
FLOOD Class 4: 6.53 m ³ s ⁻¹	1												0.94	8.5%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												1.62	11.7%
MAINTENANCE TOTAL (Volume)	Annual ⁵¹												6.8	60%
	Long-term average ⁵²												4.5	40%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.421	4%
FLOOD Peak ⁵³ m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁵¹ Calculated as the volume of water required to meet the full requirements.

⁵² Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

⁵³ Daily average peak.

Table 7.8 Summary of the flood requirements for Mal 1 – EWR Option 2 (AEC-Restore B)

Flood type	Daily average peak ($\text{m}^3 \text{s}^{-1}$)	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	0.95	2	0.139	5.5	September - April
Class 2	1.76	2	0.249	3	November - March
Class 3	3.57	3	0.523	2	September - March
Class 4	6.53	3	0.943	1	Anytime
Inter-annual Class (return period given below)					
1:2 year	11	4	1.6	Present	Not stipulated
1:5 year	23	4	2	Present	Not stipulated
1:10 year	26	4	2.8	Present	Not stipulated
1:20 year	34	4	2.8	Present	Not stipulated

Table 7.9 Exceedence curves for the complete flow regime (floods and droughts included) required to meet EWR Option 2 (AEC-Restore B) for Mal 1. MCM = million cubic metres

Month	Percentiles (data are in $\text{m}^3 \text{s}^{-1}$)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	2.656	0.381	0.11	0.064	0.051	0.043	0.041	0.038	0.03	0.022	0.012	0.01	0.006	4.496
Jan	1.756	0.222	0.054	0.052	0.051	0.05	0.04	0.03	0.02	0.011	0.01	0.01	0	0.287
Feb	1.756	0.381	0.065	0.062	0.061	0.06	0.042	0.031	0.02	0.02	0.01	0.01	0.01	0.27
Mar	3.267	0.687	0.084	0.082	0.082	0.08	0.062	0.041	0.03	0.02	0.011	0.01	0	0.508
Apr	2.286	0.381	0.115	0.112	0.111	0.11	0.085	0.062	0.04	0.03	0.02	0.013	0.01	0.425
May	1.756	0.043	0.042	0.041	0.041	0.041	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.35
Jun	1.296	0.045	0.042	0.041	0.041	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.169
Jul	0.971	0.342	0.171	0.104	0.074	0.05	0.038	0.032	0.027	0.023	0.018	0.014	0.01	0.288
Aug	3.104	0.043	0.042	0.041	0.041	0.04	0.04	0.04	0.031	0.03	0.02	0.011	0.01	0.395
Sep	3.49	0.381	0.042	0.041	0.041	0.041	0.04	0.04	0.03	0.02	0.011	0.01	0.01	0.369
Oct	3.566	0.762	0.053	0.051	0.051	0.051	0.05	0.05	0.041	0.03	0.021	0.011	0.01	0.551
Nov	3.312	0.762	0.086	0.083	0.082	0.08	0.061	0.04	0.03	0.02	0.011	0.01	0.01	0.547
Dec	1.787	0.359	0.063	0.062	0.062	0.06	0.041	0.031	0.02	0.011	0.01	0.01	0	0.338
Summer	2.694	0.505	0.112	0.082	0.064	0.061	0.05	0.037	0.027	0.018	0.01	0.01	0.002	2.375
Winter	2.521	0.297	0.063	0.05	0.041	0.041	0.04	0.04	0.031	0.026	0.018	0.011	0.01	2.121

Table 7.10 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 2 (AEC-Restore B) for Mal 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.056	0.055	0.053	0.051	0.051	0.05	0.04	0.03	0.02	0.011	0.01	0.01	0	0.094
Feb	0.066	0.064	0.063	0.062	0.061	0.06	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.1
Mar	0.084	0.083	0.083	0.082	0.081	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0	0.144
Apr	0.124	0.114	0.113	0.112	0.111	0.11	0.08	0.06	0.04	0.03	0.02	0.013	0.01	0.19
May	0.043	0.042	0.042	0.041	0.041	0.041	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.092
Jun	0.045	0.044	0.042	0.041	0.041	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.091
Jul	0.47	0.26	0.161	0.103	0.073	0.05	0.038	0.031	0.027	0.023	0.018	0.014	0.01	0.197
Aug	0.043	0.042	0.041	0.041	0.041	0.04	0.04	0.04	0.031	0.03	0.02	0.011	0.01	0.093
Sep	0.046	0.042	0.042	0.041	0.041	0.041	0.04	0.04	0.03	0.02	0.011	0.01	0.01	0.085
Oct	0.053	0.052	0.052	0.051	0.051	0.051	0.05	0.05	0.04	0.03	0.02	0.011	0.01	0.115
Nov	0.086	0.085	0.083	0.082	0.081	0.08	0.06	0.04	0.03	0.02	0.011	0.01	0.01	0.14
Dec	0.064	0.063	0.063	0.062	0.061	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0	0.105
Summer	0.114	0.111	0.084	0.081	0.063	0.06	0.05	0.036	0.027	0.018	0.01	0.01	0.002	0.773
Winter	0.221	0.075	0.051	0.044	0.041	0.041	0.04	0.04	0.031	0.026	0.018	0.011	0.01	0.673

7.7 DETAILED EWR OPTION 3: REDUCTION TO A D-CATEGORY (AEC-D)

7.7.1 Overview of EWR Option 3

This Section provides a brief summary of EWR Option 3 (AEC-D) for Mal 1.

TARGET ECOLOGICAL CATEGORY

Maintain Alternative Ecological Category (AEC-D) = D.

ECOLOGICAL WATER REQUIREMENTS

Mean annual volume required for the river for Option 3 (AEC-D) – Mal 1:

Including the volume for the $\geq 1:2$ year floods: 3.4 MCM a⁻¹
= c. 31.0% nMAR and 42.5% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods⁵⁴: 1.78 MCM a⁻¹
= c. 16% nMAR and 22% present day MAR.

⁵⁴ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet the Ecostatus target for this scenario.

Note: The long-term average is 21.6% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 3 (AEC-D) at Mal 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter lowflows	Level 2, i.e., Capped at the 40% percentile of the PD lowflow duration curve.
2	Summer lowflows:	Level 4, i.e., Capped at the 80% percentile of the PD lowflow duration curve.
3	Class 1 Intra-annual floods:	present day, i.e., 6 flood events.
4	Class 2 Intra-annual floods:	Change Level 3, i.e., no Class 2 floods.
5	Class 3 Intra-annual floods:	Change Level 2, i.e., no Class 3 floods.
6	Class 4 Intra-annual floods:	Change Level 1, i.e., no Class 4 floods.
7	Inter-annual floods (1:2 year):	Present Day, i.e., no dam.
8	Inter-annual floods (1:5 year):	Present Day, i.e., no dam.
9	Inter-annual floods (1:10 year):	Present Day, i.e., no dam.
10	Inter-annual floods (1:20 year):	Present Day, i.e., no dam.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 3 (AEC-D) was designed to support the ecosystem in a D-Category.

OVERALL INTEGRITY SCORE: EWR OPTION 3 (AEC-D)

EWR Option 3 (AEC-D) was assigned an **Overall Integrity Score of –0.68**, i.e., a REDUCTION in PES by one whole category.

EXPECTED EC

EWR Option 3 (AEC-D) is expected to maintain a Category-D condition.

7.7.2 EWR Option 3 (AEC-D) Hydrology

A portion of the modified flow regime for EWR Option 3 (AEC-D) is shown in Figure 7.6 and Table 7.11 provides a breakdown of the flow regime required to meet EWR Option 3 (AEC-D). The flood requirements are detailed in Table 7.12 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 7.13 and Table 7.14 respectively.

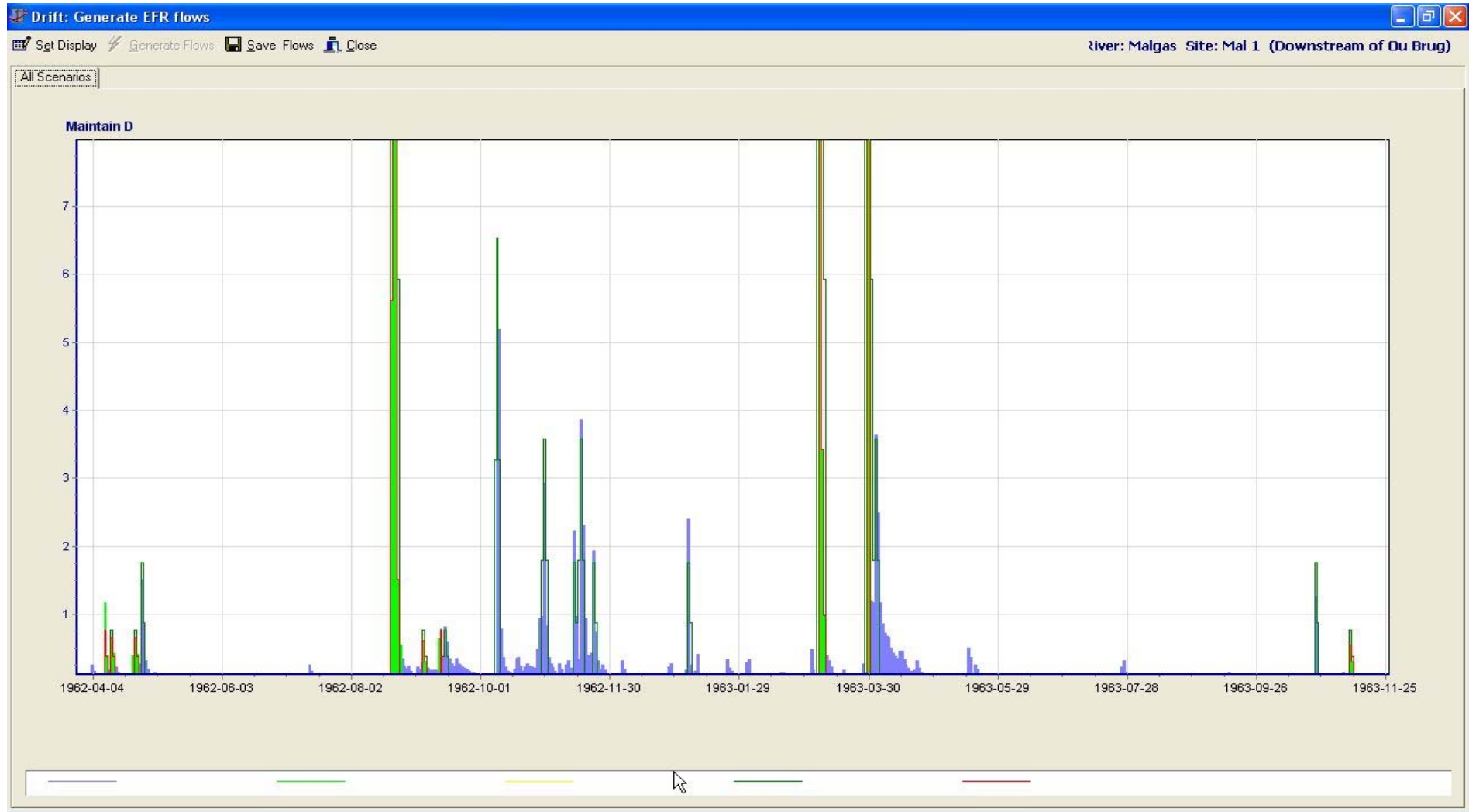


Figure 7.6 A portion of the modified flow regime for EWR Option 3 (AEC-D) at Mal 1. The blue line (original flow) is Present Day flow in the river

Table 7.11 Water quantity for EWR Option 3 (AEC-D) at Mal 1 (Malgas River at Ou Brug). To be met at Gauge K3H004. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 11 MCM (estimated). PD MAR = 8														
EWR Ecostatus Category = D														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.07	0.02	0.01	0.01	0.02	0.02	0.03	0.05	0.05	0.04	0.05	0.05	1.05	9.5%
FLOOD Class 1: 0.95 m ³ s ⁻¹	5.5								Only if not met			With Oct	0.76	6.9%
FLOOD Class 2: 1.76 m ³ s ⁻¹	None												0	0%
FLOOD Class 3: 3.57 m ³ s ⁻¹	None												0	0%
FLOOD Class 4: 6.53 m ³ s ⁻¹	None												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												1.62	14.7%
MAINTENANCE TOTAL (Volume)	Annual ⁵⁵												3.4	31%
	Long-term average ⁵⁶												2.38	22%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.421	4%
FLOOD Peak ⁵⁷ m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁵⁵ Calculated as the volume of water required to meet the full requirements.

⁵⁶ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

⁵⁷ Daily average peak.

Table 7.12 Summary of the flood requirements for Mal 1 – EWR Option 3 (AEC-D)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	0.95	2	0.139	5.5	September - April
Class 2	1.76	2	0.249	0	November - March
Class 3	3.57	3	0.523	0	September - March
Class 4	6.53	3	0.943	0	Anytime
Inter-annual Class (return period given below)					
1:2 year	11	4	1.6	Present	Not stipulated
1:5 year	23	4	2	Present	Not stipulated
1:10 year	26	4	2.8	Present	Not stipulated
1:20 year	34	4	2.8	Present	Not stipulated

Table 7.13 Exceedence curves for the complete flow regime (floods and droughts included) required to meet EWR Option 3 (AEC-D) for Mal 1. MCM = million cubic metres

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	0.762	0.091	0.072	0.067	0.043	0.03	0.025	0.02	0.02	0.011	0.01	0.01	0.006	2.38
Jan	0.762	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.123
Feb	0.596	0.022	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.085
Mar	0.762	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.011	0.01	0	0.192
Apr	0.762	0.034	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.02	0.013	0.01	0.175
May	0.762	0.075	0.073	0.072	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.321
Jun	0.381	0.078	0.073	0.071	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.14
Jul	0.06	0.053	0.052	0.051	0.051	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.105
Aug	0.762	0.074	0.073	0.071	0.071	0.07	0.05	0.04	0.031	0.03	0.02	0.011	0.01	0.331
Sep	0.711	0.075	0.073	0.072	0.071	0.07	0.05	0.041	0.03	0.02	0.011	0.01	0.01	0.267
Oct	2.423	0.301	0.094	0.092	0.091	0.09	0.072	0.05	0.041	0.03	0.021	0.011	0.01	0.421
Nov	0.683	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.011	0.01	0.01	0.157
Dec	0.643	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.061
Summer	0.762	0.031	0.03	0.021	0.021	0.02	0.02	0.012	0.01	0.01	0.01	0.01	0.002	0.794
Winter	0.762	0.092	0.079	0.072	0.071	0.058	0.05	0.04	0.031	0.027	0.02	0.011	0.01	1.586

Table 7.14 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 3 (AEC-D) for Mal 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.011	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.027
Feb	0.022	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.047
Mar	0.021	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0	0.05
Apr	0.034	0.031	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.03	0.02	0.013	0.01	0.073
May	0.075	0.074	0.073	0.072	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.131
Jun	0.079	0.077	0.073	0.071	0.071	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.128
Jul	0.054	0.053	0.052	0.051	0.051	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.099
Aug	0.075	0.074	0.072	0.071	0.071	0.07	0.05	0.04	0.031	0.03	0.02	0.011	0.01	0.132
Sep	0.081	0.074	0.073	0.072	0.071	0.07	0.05	0.04	0.03	0.02	0.011	0.01	0.01	0.122
Oct	0.095	0.094	0.093	0.092	0.091	0.09	0.07	0.05	0.04	0.03	0.02	0.011	0.01	0.17
Nov	0.021	0.021	0.021	0.021	0.021	0.02	0.02	0.02	0.02	0.02	0.011	0.01	0.01	0.05
Dec	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.027
Summer	0.031	0.031	0.03	0.021	0.021	0.02	0.02	0.011	0.01	0.01	0.01	0.01	0.002	0.272
Winter	0.094	0.091	0.075	0.072	0.071	0.057	0.05	0.04	0.031	0.026	0.02	0.011	0.01	0.782

8 RESULTS FOR EWR SITE KA 1 (KAAIMANS RIVER AT OLD ROAD)

8.1 RIVER REACH REPRESENTED BY Ka 1

The EWR site on the Kaaimans River at the Old George-Knysna Road (Ka 1) (Figure 8.1) is representative of the Kaaimans River from where it exits the forest to the estuary.



Figure 8.1 Kaaimans River (Ka 1) at Old George-Knysna Road (Ka 1)

8.2 PES, EIS AND REC

PES, EIS and REC for Kaaimans River (Ka 1) are given in Table 8.1.

Table 8.1 PES, EIS and REC for Kaaimans River (Ka 1)

Component of the riverine ecosystem	PES		EIS	Recommended Ecological Category*
	Category	Trajectory		
Hydrology	B	Stable	<i>Very high EIS</i> , because of the presence of rare and endangered species (fish). High diversity of habitat good invertebrates and excellent vegetation condition and its location in relatively undisturbed natural forest.	B
Water quality	A	Stable		
Geomorphology	B/C	Stable		
Riparian vegetation	A	Stable		
Macroinvertebrates	A	Stable		
Fish	B	Stable		
PES	B	Stable		

* In terms of the RDM policy the Ecstatus Category should not be less than D (DWAF 1999).

8.2.1 Major contributing factors to the PES

The major factors contributing to the PES for EWR Ka 1 were:

- road reserve impinging on left-bank riparian vegetation;
- an otherwise relatively-undisturbed channel;
- excellent right-bank vegetation, macroinvertebrates and water quality conditions.

8.3 CHANGE LEVELS CONSIDERED BY THE SPECIALISTS

8.3.1 Lowflows

The following change levels will be considered at the workshop:

Summer:

1. Decrease: *Cut off at 20th percentile.*
2. Decrease: *Cut off at 40th percentile.*
3. Decrease: *Cut off at 60th percentile.*
4. Decrease: *Cut off at 80th percentile.*

Winter:

1. Decrease: *Cut off at 20th percentile.*
2. Decrease: *Cut off at 40th percentile.*
3. Decrease: *Cut off at 60th percentile.*
4. Decrease: *Cut off at 80th percentile.*

8.3.2 Floods

Floods will retain their (naturalised) magnitudes and durations, and the reduction levels comprise changes in annual frequency of occurrence. The change levels are provided in Table 8.2.

Table 8.2 Change levels for Kaaimans River (Ka 1) floods

Flood Class	Present day	Change level 1	Change level 2	Change level 3	Change level 4
1	4	3	2	1	0
2	2	1	0		
3	2	1	0		
4	1	0			
≥1:2	Present	Absent			

8.4 DRIFT CATEGORY OUTPUT FOR KA 1

The DRIFT CATEGORY output for Ka 1 is provided in Figure 8.2.

Two options are presented for the Kaaimans River (Ka 1). These are:

1. Option 1: Recommended Ecological Category – Maintain PES – Category B.
2. Option 2: Allow a reduction in PES to Category C.

Each of these is addressed sequentially in the following sections:

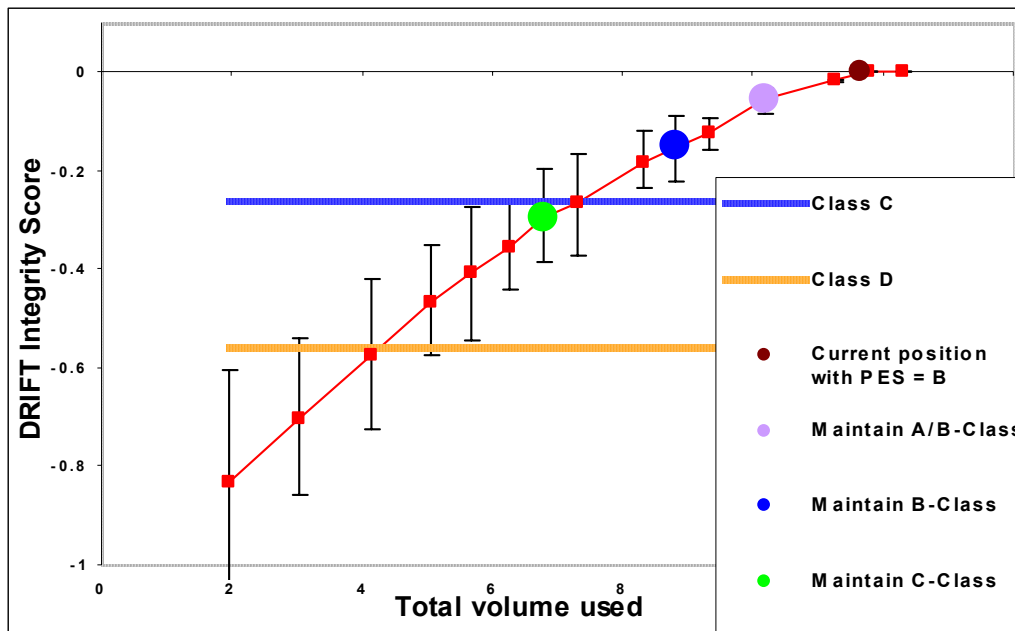


Figure 8.2 The DRIFT CATEGORY output for Ka 1 (volume in MCM/a)

8.5 DETAILED EWR OPTION 1: MAINTAIN RECOMMENDED ECOLOGICAL CATEGORY (REC) – B CATEGORY

8.5.1 Overview of EWR Option 1

This section provides a brief summary of EWR Option 1 (REC-B) for Ka 1.

TARGET ECOLOGICAL CATEGORY

Maintain Recommended Ecological Category (REC-B) = B.

ECOLOGICAL WATER REQUIREMENTS

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e., $\geq 1:2$ year return period). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using other methods, the DRIFT volumes are reported both including and excluding the volumes of the $\geq 1:2$ year return period flood.

Mean annual volume **requested** for the river for Scenario 1 (REC-B) – Ka 1:

Including the volume for the $\geq 1:2$ year floods: 8.5 MCM a^{-1}
= c. 63.2% nMAR and 73.0% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods: 6.5 MCM a^{-1}
= c. 48.0% nMAR and 56.0% present day MAR.

Note: The long-term average is 50% of nMAR, incl. 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 1 (REC-B) at Ka 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter season lowflows:	Level 2, i.e., Capped at the 40% percentile of the PD lowflow duration curve.
2	Summer season lowflows:	Level 2, i.e., Capped at the 40% percentile of the PD lowflow duration curve.
3	Class 1 Intra-annual floods:	Present day.
4	Class 2 Intra-annual floods:	Present day.
5	Class 3 Intra-annual floods:	Present day.
6	Class 4 Intra-annual floods:	Level 1, i.e., no Class IV floods.
7	Inter-annual floods (1:2 year):	Present Day.
8	Inter-annual floods (1:5 year):	Present Day.
9	Inter-annual floods (1:10 year):	Present Day.
10	Inter-annual floods (1:20 year):	Present Day.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 1 (REC-B) was specifically designed to limit possible impacts as a result of changes in the flow components that are deemed to support the B-Category ecostatus. This would, however, be threatened should the non-flow related factors impact on the river, or if the recommended distribution of flows is not adhered to.

OVERALL INTEGRITY SCORE: EWR OPTION 1 (REC-B)

EWR Option 1 (REC-B) was assigned an **Overall Integrity Score of -0.15**, i.e., a very slight REDUCTION in PES but maintaining a B-Category.

EXPECTED EC

EWR Option 1 (REC-B) is expected to maintain a B-Category.

8.5.2 EWR Option 1 (REC) Hydrology

A portion of the modified flow regime for EWR Option 1 (REC-B) is shown in Figure 8.3 and Table 8.3 provides a breakdown of the flow regime required to meet EWR Option 1 (REC). The flood requirements are detailed in Table 8.4 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 8.5 and Table 8.6, respectively.

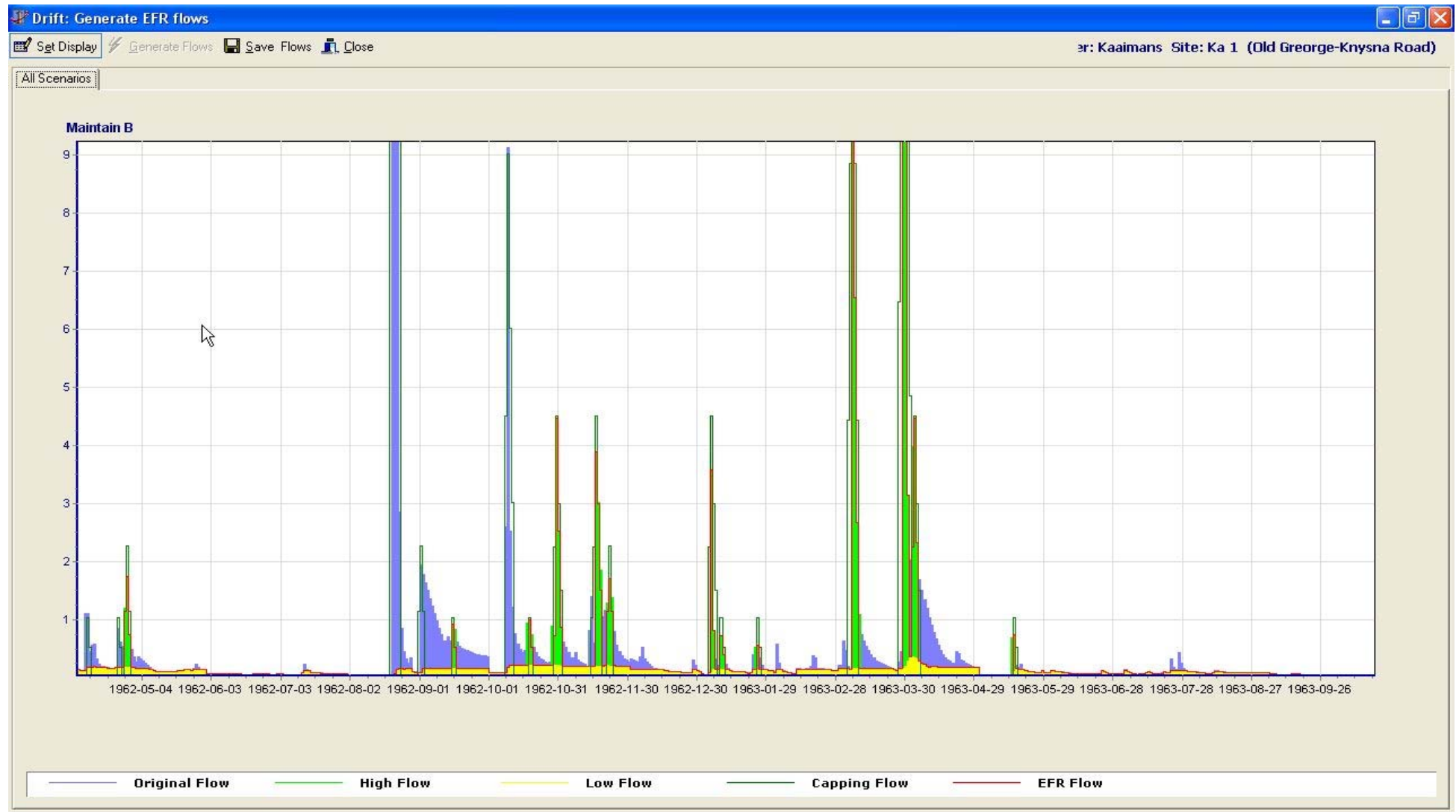


Figure 8.3 The modified flow regime for EWR Option 1 (REC-B) at Ka 1 – as shown by the red line. The blue line (original flow) is Present Day flow in the river

Table 8.3 Water quantity for EWR Option 1 (REC-B) at Ka 1 (Kaaimans River at Old Road). To be met at Gauge K3H001. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 13.46 MCM (estimated). PD MAR = 11.65														
EWR Ecotatus Category = B.														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.16	0.15	0.12	0.10	0.10	0.12	0.15	0.13	0.10	0.10	0.10	0.10	3.46	25.7%
FLOOD Class 1: 1.15 ⁵⁸ : m ³ s ⁻¹	2					2					With Oct		0.72	5.3%
FLOOD Class 2: 2.25 m ³ s ⁻¹	1					1					With Oct		0.76	5.6%
FLOOD Class 3: 4.49 m ³ s ⁻¹	1					1					With Oct		1.52	11.3%
FLOOD Class 4: 9.03 m ³ s ⁻¹													0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												2	14.9%
MAINTENANCE TOTAL (Volume)	Annual ⁵⁹												8.5	63.2%
	Long-term average ⁶⁰												6.7	49.7%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.05	0.05	0.05	0.03	0.05	0.10	0.07	0.06	0.05	0.05	0.05	0.05	1.736	13%
FLOOD Peak m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁵⁸ Daily average peak.

⁵⁹ Calculated as the volume of water required to meet the full requirements.

⁶⁰ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

**Table 8.4 Summary of the flood requirements for Ka 1 – EWR Option 1 (REC-B):
Maintain a B-Category river**

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.15	2	0.18	4	March-May September - November
Class 2	2.25	3	0.38	2	March-May September - November
Class 3	4.49	4	0.76	2	March-May September - November
Inter-annual Class (return period given below)					
1:2 year	-	-	2.7 ⁶¹	Present	Not stipulated

**Table 8.5 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 1 (REC-B) for Kaaimans River (Ka 1).
MCM = million cubic metres**

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	2.445	0.215	0.192	0.162	0.146	0.141	0.121	0.093	0.07	0.053	0.033	0.022	0	6.735
Jan	1.982	0.379	0.144	0.143	0.142	0.14	0.104	0.071	0.051	0.03	0.02	0.011	0.01	0.395
Feb	2.273	0.521	0.145	0.142	0.142	0.14	0.103	0.071	0.06	0.05	0.03	0.02	0	0.436
Mar	3.258	0.785	0.164	0.163	0.162	0.16	0.123	0.091	0.07	0.041	0.03	0.02	0	0.643
Apr	2.087	0.499	0.185	0.182	0.181	0.18	0.151	0.12	0.091	0.07	0.04	0.03	0	0.581
May	4.208	0.158	0.155	0.151	0.151	0.15	0.13	0.1	0.07	0.06	0.04	0.03	0	0.658
Jun	1.043	0.146	0.145	0.143	0.141	0.14	0.101	0.07	0.061	0.05	0.031	0.03	0	0.321
Jul	1.092	0.125	0.123	0.122	0.121	0.12	0.1	0.07	0.06	0.051	0.04	0.03	0	0.353
Aug	3.785	0.159	0.153	0.152	0.151	0.15	0.111	0.091	0.08	0.071	0.03	0.02	0	0.588
Sep	2.273	0.168	0.166	0.164	0.162	0.16	0.124	0.093	0.07	0.061	0.041	0.03	0.01	0.536
Oct	4.507	1.022	0.215	0.213	0.212	0.21	0.165	0.133	0.101	0.071	0.051	0.03	0	0.943
Nov	4.127	0.974	0.195	0.193	0.192	0.19	0.152	0.11	0.09	0.06	0.03	0.02	0	0.809
Dec	2.051	0.145	0.144	0.143	0.142	0.14	0.123	0.092	0.061	0.05	0.03	0.02	0	0.472
Summer	2.273	0.521	0.192	0.164	0.144	0.142	0.126	0.095	0.068	0.049	0.029	0.017	0	3.336
Winter	2.872	0.214	0.205	0.154	0.15	0.136	0.12	0.093	0.07	0.057	0.038	0.029	0	3.399

⁶¹ Combined annual volume.

Table 8.6 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 1 (REC-B) for Kaaimans River (Ka 1). MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.146	0.144	0.143	0.143	0.141	0.14	0.1	0.07	0.05	0.03	0.02	0.011	0.01	0.247
Feb	0.146	0.145	0.143	0.142	0.141	0.14	0.1	0.07	0.06	0.05	0.03	0.02	0	0.235
Mar	0.165	0.164	0.164	0.163	0.162	0.16	0.12	0.09	0.07	0.04	0.03	0.02	0	0.294
Apr	0.201	0.185	0.183	0.182	0.181	0.18	0.15	0.12	0.09	0.07	0.04	0.03	0	0.334
May	0.064	0.062	0.062	0.061	0.061	0.061	0.06	0.06	0.06	0.06	0.04	0.03	0	0.148
Jun	0.053	0.052	0.052	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.03	0.03	0	0.121
Jul	0.052	0.052	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0	0.126
Aug	0.074	0.072	0.072	0.071	0.071	0.071	0.07	0.07	0.07	0.07	0.03	0.02	0	0.167
Sep	0.063	0.063	0.062	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.03	0.01	0.146
Oct	0.072	0.072	0.072	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.03	0	0.178
Nov	0.207	0.195	0.194	0.192	0.191	0.19	0.15	0.11	0.09	0.06	0.03	0.02	0	0.343
Dec	0.145	0.144	0.144	0.142	0.142	0.14	0.12	0.09	0.06	0.05	0.03	0.02	0	0.27
Summer	0.197	0.192	0.182	0.162	0.143	0.141	0.123	0.092	0.067	0.049	0.028	0.017	0	1.724
Winter	0.072	0.071	0.071	0.07	0.062	0.061	0.06	0.052	0.051	0.05	0.038	0.028	0	0.886

8.6 DETAILED EWR OPTION 2: MAINTAIN Alternative ECOLOGICAL CATEGORY (AEC_C) – C CATEGORY

8.6.1 Overview of EWR Option 2

This section provides a brief summary of EWR Option 2 (AEC_C) for Ka 1.

TARGET ECOLOGICAL CATEGORY

Maintain Alternative Ecological Category (AEC_C) = C.

ECOLOGICAL WATER REQUIREMENTS

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e., $\geq 1:2$ year return period⁶²). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using other methods, the DRIFT volumes are reported both including and excluding the volumes of the $\geq 1:2$ year return period flood.

⁶² Previously all inter-annual floods were excluded in the reported volume, but recent studies have started to include floods with a 1:2 year return period i.e. Komati Basin EWR Study.

Mean annual volume **requested** for the river for Option 2 (AEC – C Category) – Ka 1:

Including the volume for the $\geq 1:2$ year floods: 6.44 MCM a⁻¹
= c. 47.8% nMAR and 55.3% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods⁶³: 4.44 MCM a⁻¹
= c. 33.0% nMAR and 38.1% present day MAR.

Note: The long-term average is 35% of nMAR, incl. 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 2 (AEC_C) at Ka 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

4	Winter season lowflows PD lowflow duration curve.	Level 3, i.e., Capped at the 60% percentile of the
5	Summer season lowflows:	Level 2, i.e., Capped at the 80% percentile of the PD lowflow duration curve.
6	Class 1 Intra-annual floods:	present day.
7	Class 2 Intra-annual floods:	present day.
8	Class 3 Intra-annual floods:	Level 2, i.e., no Class III floods.
9	Class 4 Intra-annual floods:	Level 1, i.e., no Class IV floods.
10	Inter-annual floods (1:2 year):	Present Day.
11	Inter-annual floods (1:5 year):	Present Day.
12	Inter-annual floods (1:10 year):	Present Day.
13	Inter-annual floods (1:20 year):	Present Day.

OVERALL INTEGRITY SCORE: EWR OPTION 2 (AEC_C)

EWR Option 2 (AEC_C) was assigned an **Overall Integrity Score of -0.294**, i.e., a REDUCTION in PES by one full category to a C-Category.

EXPECTED EC

EWR Option 2 (AEC_C) is expected to maintain a Category-C condition.

8.6.2 EWR Option 2 (AEC) Hydrology

A portion of the modified flow regime for EWR Option 2 (AEC – C Category) is shown in Figure 8.4 and Table 8.7 provides a breakdown of the flow regime required to meet EWR Option 2 (AEC_C). The flood requirements are detailed in Table 8.8 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 8.9 and Table 8.10, respectively.

⁶³ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet a C category.

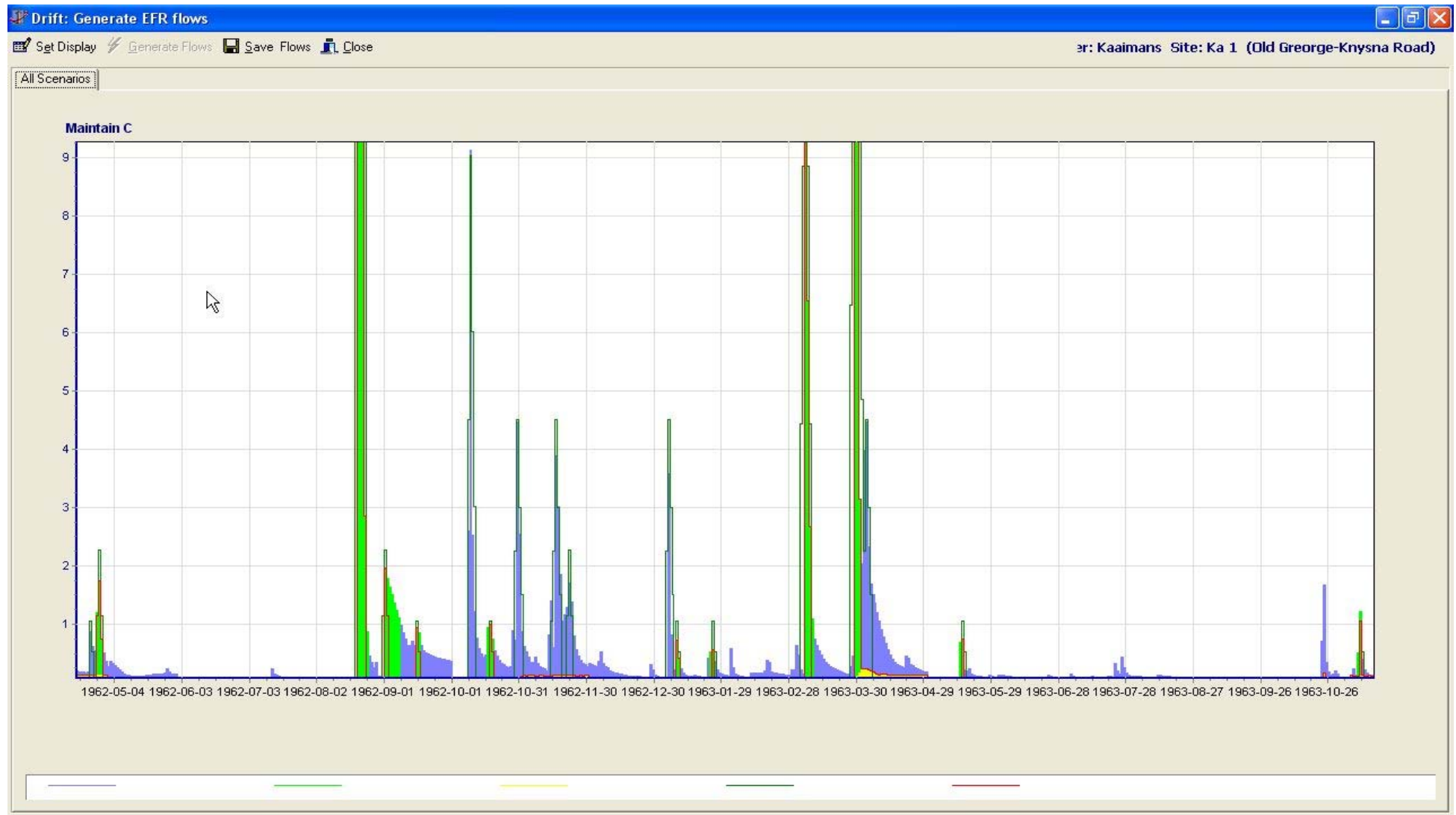


Figure 8.4 The modified flow regime for EWR Option 2 (AEC_C) at Ka 1 – as shown by the red line. The blue line (original flow) is Present Day flow in the river

Table 8.7 Water quantity for EWR Option 2 (AEC_C) at Ka 1 (Kaaimans River at Old Road). To be met at Gauge K3H001. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 13.46 MCM (estimated). PD MAR = 11.65														
EWR Ecostatus Category = C.														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.13	0.06	0.05	0.03	0.05	0.04	0.07	0.1	0.07	0.07	0.09	0.09	2.96	18%
FLOOD Class 1: 1.15 ⁶⁴ ; m ³ s ⁻¹	2					2					With Oct		0.72	5.3%
FLOOD Class 2: 2.25 m ³ s ⁻¹	1					1					With Oct		0.76	5.7%
FLOOD Class 3: 4.49 m ³ s ⁻¹													0	-
FLOOD Class 4: 9.03 m ³ s ⁻¹													0	-
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												2	14.9%
MAINTENANCE TOTAL (Volume)	Annual ⁶⁵												6.44	51%
	Long-term average ⁶⁶												4.64	35%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.05	0.05	0.05	0.03	0.05	0.10	0.07	0.06	0.05	0.05	0.05	0.05	1.736	13%
FLOOD Peak m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁶⁴ Daily average peak.

⁶⁵ Calculated as the volume of water required to meet the full requirements.

⁶⁶ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

Table 8.8 Summary of the flood requirements for Ka 1 – EWR Option 2 (AEC_C)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.15	2	0.18	4	March-May September - November
Class 2	2.25	3	0.38	2	March-May September - November
Inter-annual Class (return period given below)					
1:2 year	-	-	2.7^{67}	Present	Not stipulated

**Table 8.9 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 2 (AEC_C) for Kaaimans River (Ka 1).
MCM = million cubic metres**

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	1.679	0.121	0.112	0.091	0.072	0.071	0.067	0.06	0.051	0.05	0.033	0.022	0	4.642
Jan	1.043	0.072	0.072	0.072	0.071	0.071	0.071	0.07	0.05	0.03	0.02	0.011	0.01	0.212
Feb	0.856	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.06	0.05	0.03	0.02	0	0.196
Mar	2.273	0.521	0.092	0.092	0.092	0.091	0.091	0.09	0.07	0.04	0.03	0.02	0	0.49
Apr	1.957	0.499	0.123	0.122	0.121	0.121	0.121	0.12	0.091	0.07	0.04	0.03	0	0.494
May	2.145	0.063	0.062	0.061	0.061	0.061	0.06	0.06	0.06	0.06	0.04	0.03	0	0.502
Jun	0.07	0.052	0.052	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.031	0.03	0	0.141
Jul	0.061	0.052	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.05	0.04	0.03	0	0.196
Aug	1.862	0.074	0.072	0.071	0.071	0.071	0.07	0.07	0.07	0.07	0.03	0.02	0	0.47
Sep	2.273	0.07	0.062	0.062	0.061	0.061	0.061	0.06	0.06	0.06	0.042	0.03	0.01	0.481
Oct	3.253	0.499	0.072	0.071	0.071	0.071	0.071	0.071	0.07	0.07	0.05	0.03	0	0.544
Nov	2.205	0.119	0.113	0.112	0.111	0.111	0.111	0.11	0.092	0.06	0.031	0.02	0	0.554
Dec	1.719	0.093	0.093	0.092	0.091	0.091	0.091	0.09	0.061	0.05	0.03	0.02	0	0.364
Summer	1.362	0.123	0.121	0.111	0.092	0.091	0.073	0.071	0.067	0.049	0.028	0.017	0	2.309
Winter	1.804	0.072	0.071	0.071	0.064	0.061	0.06	0.052	0.051	0.05	0.038	0.029	0	2.333

⁶⁷ Combined annual volume.

Table 8.10 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 2 (AEC_C) for Kaaimans River (Ka 1). MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.032	0.031	0.031	0.031	0.031	0.031	0.03	0.03	0.03	0.03	0.02	0.011	0.01	0.076
Feb	0.052	0.052	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.03	0.02	0	0.114
Mar	0.042	0.041	0.041	0.041	0.041	0.041	0.041	0.04	0.04	0.04	0.03	0.02	0	0.103
Apr	0.078	0.072	0.072	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.04	0.03	0	0.166
May	0.106	0.104	0.102	0.101	0.101	0.101	0.1	0.1	0.07	0.06	0.04	0.03	0	0.22
Jun	0.074	0.073	0.072	0.072	0.071	0.071	0.07	0.07	0.06	0.05	0.03	0.03	0	0.157
Jul	0.073	0.073	0.072	0.071	0.071	0.071	0.07	0.07	0.06	0.05	0.04	0.03	0	0.163
Aug	0.096	0.092	0.092	0.091	0.091	0.091	0.09	0.09	0.08	0.07	0.03	0.02	0	0.205
Sep	0.094	0.094	0.093	0.092	0.092	0.091	0.091	0.09	0.07	0.06	0.04	0.03	0.01	0.199
Oct	0.133	0.133	0.132	0.132	0.131	0.131	0.131	0.13	0.1	0.07	0.05	0.03	0	0.293
Nov	0.065	0.062	0.062	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.03	0.02	0	0.144
Dec	0.052	0.052	0.051	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.03	0.02	0	0.126
Summer	0.072	0.071	0.07	0.061	0.051	0.051	0.05	0.041	0.04	0.031	0.028	0.017	0	0.729
Winter	0.133	0.132	0.13	0.1	0.092	0.09	0.073	0.071	0.07	0.057	0.038	0.028	0	1.238

8.7 DETAILED EWR OPTION 3: BUILD IN OPPORTUNITIES FOR IMPROVEMENT TO AN A/B CATEGORY (AEC_A/B)

8.7.1 Overview of EWR Option 3 (AEC_A/B)

This section provides a brief summary of EWR Option 3 (AEC_A/B) for Ka 1.

TARGET ECOLOGICAL CATEGORY

Build in opportunities for improvement to an A/B Category = A/B.

ECOLOGICAL WATER REQUIREMENTS

Mean annual volume **requested** for the river for Option 3 (AEC_A/B) – Ka 1:

Including the volume for the $\geq 1:2$ year floods: 10.19 MCM a⁻¹
= c. 75.7% nMAR and 87.5% pd MAR.

Excluding the volume for the $\geq 1:2$ year floods⁶⁸: 8.19 MCM a⁻¹
= c. 60.8% nMAR and 70.3% pd MAR.

Note: The long-term average is 54% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

⁶⁸ It is however **vital** for the $\geq 1:2$ year return period floods to come through to meet a C category.

FLOW REDUCTION LEVELS USED

For EWR Option 3 (AEC_A/B) at Ka 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1. Winter season lowflows PD lowflow duration curve.	Level 2, i.e., Capped at the 60% percentile of the
2. Summer season lowflows: PD lowflow duration curve.	Level 2, i.e., Capped at the 80% percentile of the
3. Class 1 Intra-annual floods:	Present day.
4. Class 2 Intra-annual floods:	Present day.
5. Class 3 Intra-annual floods:	Present day.
6. Class 4 Intra-annual floods:	Present day.
7. Inter-annual floods (1:2 year):	Present Day.
8. Inter-annual floods (1:5 year):	Present Day.
9. Inter-annual floods (1:10 year):	Present Day.
10. Inter-annual floods (1:20 year):	Present Day.

OVERALL INTEGRITY SCORE: EWR OPTION 3 (AEC_A/B)

Option 3 (AEC_A/B) was assigned an **Overall Integrity Score of -0.056**, i.e., a slight REDUCTION in PES (see comments below).

EXPECTED EC

Without improvement of non-flow related aspects affecting PES, e.g., road and upstream forestry activities, Option 3 (AEC_A/B) is expected to maintain a Category-B condition. However, if these are reduced, then the condition will be an A/B-Category.

8.7.2 EWR Option 3 (AEC_A/B)

A portion of the modified flow regime for EWR Option 3 (AEC_A/B) is shown in Figure 8.5 and Table 8.11 provides a breakdown of the flow regime required to meet Option 3 (AEC_A/B). The flood requirements are detailed in Table 8.12 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 8.13 and Table 8.14, respectively.

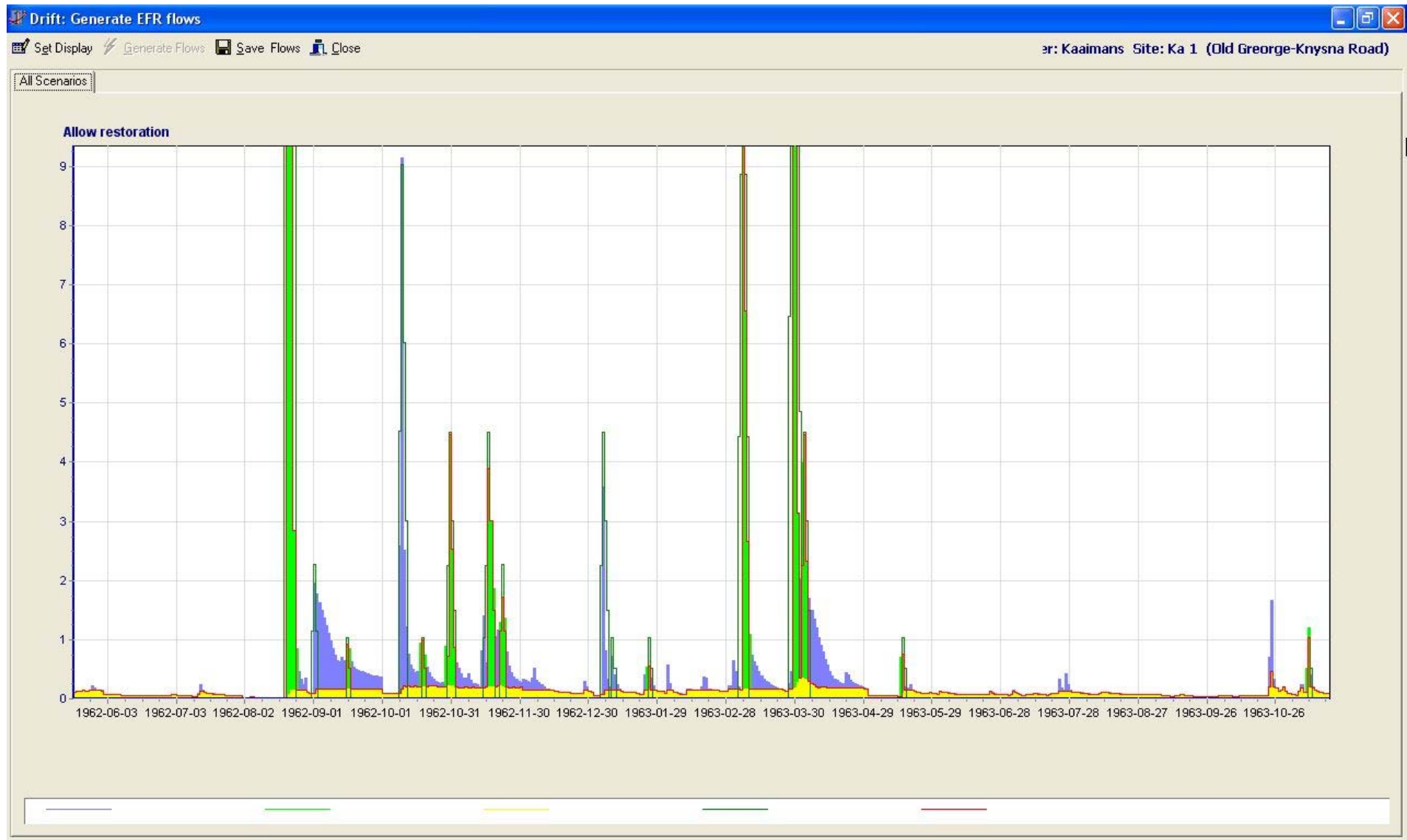


Figure 8.5 The modified flow regime for Option 3 (AEC_A/B) at Ka 1 – as shown by the red line. The blue line (original flow) is Present Day flow in the river

Table 8.11 Water quantity for EWR Option 3 (AEC_A/B) at Ka 1 (Kaaimans River at Old Road). To be met at Gauge K3H001. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 13.46 MCM (estimated). PD MAR = 11.65														
EWR Ecstatus Category = A/B (provided non-flow related impacts are addressed successfully)														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.16	0.15	0.12	0.10	0.10	0.12	0.15	0.13	0.10	0.10	0.10	0.10	3.46	25.7%
FLOOD Class 1: 1.15 ⁶⁹ : m ³ s ⁻¹	3					3					With Oct		1.08	8.3%
FLOOD Class 2: 2.25 m ³ s ⁻¹	1					1					With Oct		0.76	5.7%
FLOOD Class 3: 4.49 m ³ s ⁻¹	1					1					With Oct		1.52	11.4%
FLOOD Class 4: 9.03 m ³ s ⁻¹	1												1.37	10.2%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												2	14.9%
MAINTENANCE TOTAL (Volume)	Annual ⁷⁰												10.19	76%
	Long-term average ⁷¹												7.23	54%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.05	0.05	0.05	0.03	0.05	0.10	0.07	0.06	0.05	0.05	0.05	0.05	1.56	12%
FLOOD Peak m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁶⁹ Daily average peak.

⁷⁰ Calculated as the volume of water required to meet the full requirements.

⁷¹ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

Table 8.12 Summary of the flood requirements for Ka 1 – Option 3 (AEC_A/B)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.15	2	0.18	6	March-May September - November
Class 2	2.25	3	0.38	2	March-May September - November
Class 3	4.49	4	0.76	2	March-May September - November
Class 4	9.03	4	1.37	1	Not stipulated - anytime
Inter-annual Class (return period given below)					
1:2	-	-	2.7^{72}	Present	Not stipulated - anytime

**Table 8.13 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 3 (AEC_A/B) for Kaaimans River (Ka 1).
MCM = million cubic metres**

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	3.261	0.47	0.192	0.162	0.146	0.141	0.121	0.093	0.07	0.053	0.033	0.022	0	7.231
Jan	2.273	0.146	0.144	0.143	0.142	0.14	0.103	0.071	0.051	0.03	0.02	0.011	0.01	0.436
Feb	2.273	0.185	0.144	0.142	0.142	0.14	0.102	0.07	0.06	0.05	0.03	0.02	0	0.422
Mar	4.188	1.032	0.165	0.164	0.162	0.16	0.123	0.091	0.07	0.041	0.03	0.02	0	0.772
Apr	3.761	0.938	0.191	0.183	0.182	0.18	0.155	0.122	0.092	0.07	0.04	0.031	0	0.711
May	4.5	0.16	0.155	0.151	0.151	0.15	0.13	0.1	0.07	0.06	0.04	0.03	0	0.713
Jun	1.043	0.146	0.145	0.143	0.141	0.14	0.101	0.07	0.061	0.05	0.031	0.03	0	0.325
Jul	1.332	0.125	0.123	0.122	0.121	0.12	0.1	0.07	0.06	0.051	0.04	0.03	0	0.372
Aug	4.507	0.16	0.154	0.152	0.151	0.15	0.111	0.091	0.08	0.071	0.03	0.021	0	0.675
Sep	2.496	0.281	0.167	0.164	0.162	0.16	0.124	0.093	0.071	0.061	0.042	0.03	0.01	0.508
Oct	4.507	1.137	0.215	0.213	0.212	0.21	0.166	0.133	0.102	0.071	0.051	0.03	0	1.018
Nov	3.895	0.855	0.195	0.193	0.192	0.19	0.153	0.111	0.092	0.06	0.031	0.02	0	0.734
Dec	2.822	0.519	0.144	0.143	0.142	0.14	0.123	0.092	0.062	0.05	0.03	0.02	0	0.546
Summer	3.261	0.557	0.192	0.164	0.144	0.142	0.126	0.095	0.068	0.049	0.029	0.018	0	3.62
Winter	3.253	0.215	0.21	0.154	0.15	0.136	0.12	0.093	0.07	0.058	0.039	0.029	0	3.611

⁷² Combined annual volume.

**Table 8.14 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 2 (AEC_A/B) for Kaaimans River (Ka 1).
MCM = million cubic metres**

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.146	0.144	0.143	0.143	0.141	0.14	0.100	0.07	0.05	0.03	0.02	0.011	0.01	0.247
Feb	0.146	0.145	0.143	0.142	0.141	0.14	0.100	0.07	0.06	0.05	0.03	0.02	0	0.235
Mar	0.165	0.164	0.164	0.163	0.162	0.16	0.120	0.09	0.07	0.04	0.03	0.02	0	0.294
Apr	0.201	0.185	0.183	0.182	0.181	0.18	0.150	0.12	0.09	0.07	0.04	0.03	0	0.334
May	0.064	0.062	0.062	0.061	0.061	0.061	0.060	0.06	0.06	0.06	0.04	0.03	0	0.148
Jun	0.053	0.052	0.052	0.051	0.051	0.051	0.051	0.05	0.05	0.05	0.03	0.03	0	0.121
Jul	0.052	0.052	0.051	0.051	0.051	0.051	0.050	0.05	0.05	0.05	0.04	0.03	0	0.126
Aug	0.074	0.072	0.072	0.071	0.071	0.071	0.070	0.07	0.07	0.07	0.03	0.02	0	0.167
Sep	0.063	0.063	0.062	0.061	0.061	0.061	0.061	0.06	0.06	0.06	0.04	0.03	0.01	0.146
Oct	0.072	0.072	0.072	0.071	0.071	0.071	0.071	0.07	0.07	0.07	0.05	0.03	0	0.178
Nov	0.207	0.195	0.194	0.192	0.191	0.19	0.150	0.11	0.09	0.06	0.03	0.02	0	0.343
Dec	0.145	0.144	0.144	0.142	0.142	0.14	0.120	0.09	0.06	0.05	0.03	0.02	0	0.27
Summer	0.197	0.192	0.182	0.162	0.143	0.141	0.123	0.092	0.067	0.049	0.028	0.017	0	1.724
Winter	0.072	0.071	0.071	0.07	0.062	0.061	0.060	0.052	0.051	0.05	0.038	0.028	0	0.886

9 RESULTS FOR EWR SITE GOU 1 (GOUKAMMA ON OLD ROAD)

9.1 RIVER REACH REPRESENTED BY Gou 1

The EWR Site on the Goukamma River at the Old George-Knysna Road (Gou 1) is representative of the Goukamma River from where it exits the forest to the tidal influence, just upstream of the National Road N2.



Figure 9.1 Goukamma River at Old George-Knysna Road (Gou 1)

9.2 PRESENT ECOSTATUS

The PES for EWR Gou 1 is Category B/C. PES, EIS and REC for Goukamma River (Gou 1) are given in Table 9.1.

Table 9.1 PES, EIS and REC for Goukamma River (Gou 1)

Component of the riverine ecosystem	PES		EIS	Recommended Ecological Category*
	Category	Trajectory		
Hydrology	B	Stable	Very High EIS, because of location, diverse vegetation, a high diversity of habitat types, and excellent macroinvertebrate condition(s)	B/C
Water quality	B	Stable		
Geomorphology	B	Stable		
Riparian vegetation	B	Stable		
Macroinvertebrates	A	Stable		
Fish	C	Stable		
PES	B/C	Stable		

* In terms of the RDM policy the Ecstatus should not be less than D (DWAF 1999).

9.2.1 Major contributing factors to the PES

The major factors contributing to the PES for EWR Gou 1 were:

- channel modification (mainly non-flow related), probably resulting in fish populations being less resilient due to floods;
- presence of some alien plants, such as bramble.

9.3 CHANGE LEVELS CONSIDERED BY THE SPECIALISTS

9.3.1 Goukamma River (Gou 1) Lowflow Change levels

The following change levels will be considered at the workshop:

Summer:

1. Decrease: *Cut off at 20th percentile.*
2. Decrease: *Cut off at 40th percentile.*
3. Decrease: *Cut off at 60th percentile.*
4. Decrease: *Cut off at 80th percentile.*

Winter:

1. Decrease: *Cut off at 20th percentile.*
2. Decrease: *Cut off at 40th percentile.*
3. Decrease: *Cut off at 60th percentile.*
4. Decrease: *Cut off at 80th percentile.*

9.3.2 Goukamma River (Gou 1) Flood Change levels

Floods will retain their (naturalised) magnitudes and durations, and the reduction levels comprise changes in annual frequency of occurrence (Table 9.2).

Table 9.2 Change levels for Goukamma River (Gou 1) floods

Flood Class	Present day	Change level 1	Change level 2	Change level 3	Change level 4
1	6	4	2	0	-
2	2	1	0	-	-
3	1	0	-	-	-
4	1	0	-	-	-
≥1:2	Present	Absent	-	-	-

9.4 DRIFT CATEGORY OUTPUT FOR GOU 1

The DRIFT Category output for Gou 1 is provided in Figure 9.2.

Two options are presented for the Goukamma River (Gou 1). These are:

- Option 1: Recommended Ecological Category – Maintain PES – Category B/C.
- Option 2: Allow a reduction in PES to Category C.

Each of these is addressed sequentially in the following sections.

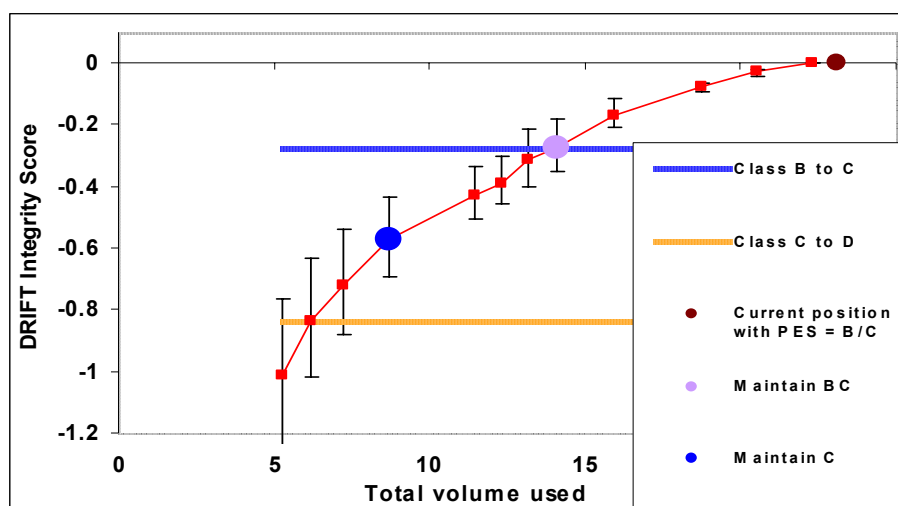


Figure 9.2 The DRIFT CATEGORY output for Gou 1 (volume in MCM/a)

9.5 DETAILED EWR OPTION 1: MAINTAIN RECOMMENDED ECOLOGICAL CATEGORY (REC_B/C)

9.5.1 Overview of EWR Option 1

This section provides a brief summary of EWR Option 1 (REC_B/C) for Gou 1.

TARGET ECOLOGICAL CATEGORY

Recommended Ecological Category (REC_B/C) = B/C.

ECOLOGICAL WATER REQUIREMENTS

In South Africa EWR results are traditionally reported without including the volume of water required to meet the inter-annual floods (i.e., $\geq 1:2$ year return period⁷³). Thus, to facilitate the comparison between the results obtained using DRIFT and those obtained using other methods, the DRIFT volumes are reported both including and excluding the volumes of the $\geq 1:2$ year return period flood.

Mean annual volume required for the river for Option 1 (REC_B/C) – Gou 1:

Including the volume for the $\geq 1:2$ year floods:	14.1 MCM a ⁻¹ = c. 53.0% nMAR and 61.0% present day MAR.
Excluding the volume for the $\geq 1:2$ year floods	9.6 MCM a ⁻¹ = c. 36.1% nMAR and 41.6% present day MAR.

⁷³ Previously all inter-annual floods were excluded in the reported volume, but recent studies have started to include floods with a 1:2 year return period i.e. Komati Basin EWR Study.

Note: The long-term average is 47% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 1 (REC_B/C) at Gou 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter lowflows	Level 4, i.e., Capped at the 80% percentile of the PD lowflow duration curve.
2	Summer lowflows:	Level 2, i.e., Capped at the 40% percentile of the PD lowflow duration curve.
3	Class 1 Intra-annual floods:	present day.
4	Class 2 Intra-annual floods:	present day.
5	Class 3 Intra-annual floods:	Level 2, i.e., no Class III floods.
6	Class 4 Intra-annual floods:	Level 1, i.e., no Class IV floods.
7	Inter-annual floods (1:2 year):	Present Day, i.e., no dam.
8	Inter-annual floods (1:5 year):	Present Day, i.e., no dam.
9	Inter-annual floods (1:10 year):	Present Day, i.e., no dam.
10	Inter-annual floods (1:20 year):	Present Day, i.e., no dam.

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 1 (REC_B/C) was specifically designed to limit possible impacts as a result of changes in the flow components that are deemed to threaten the PES.

OVERALL INTEGRITY SCORE: EWR OPTION 1 (REC)

EWR Option 1 (REC_B/C) was assigned an **Overall Integrity Score of -0.27**, i.e., a slight REDUCTION in PES but maintaining a B/C-Category.

EXPECTED EC

EWR Option 1 (REC_B/C) is expected to maintain a Category-B/C condition.

9.5.2 EWR Option 1 (REC) Hydrology

A portion of the modified flow regime for EWR Option 1 (REC_B/C) is shown in Figure 9.3 and Table 9.3 provides a breakdown of the flow regime required to meet EWR Option 1 (REC_B/C). The flood requirements are detailed in Table 9.4 and the rule curves for the complete flow and lowflow component of the flow regimes are given in Table 9.5 and Table 9.6 respectively.

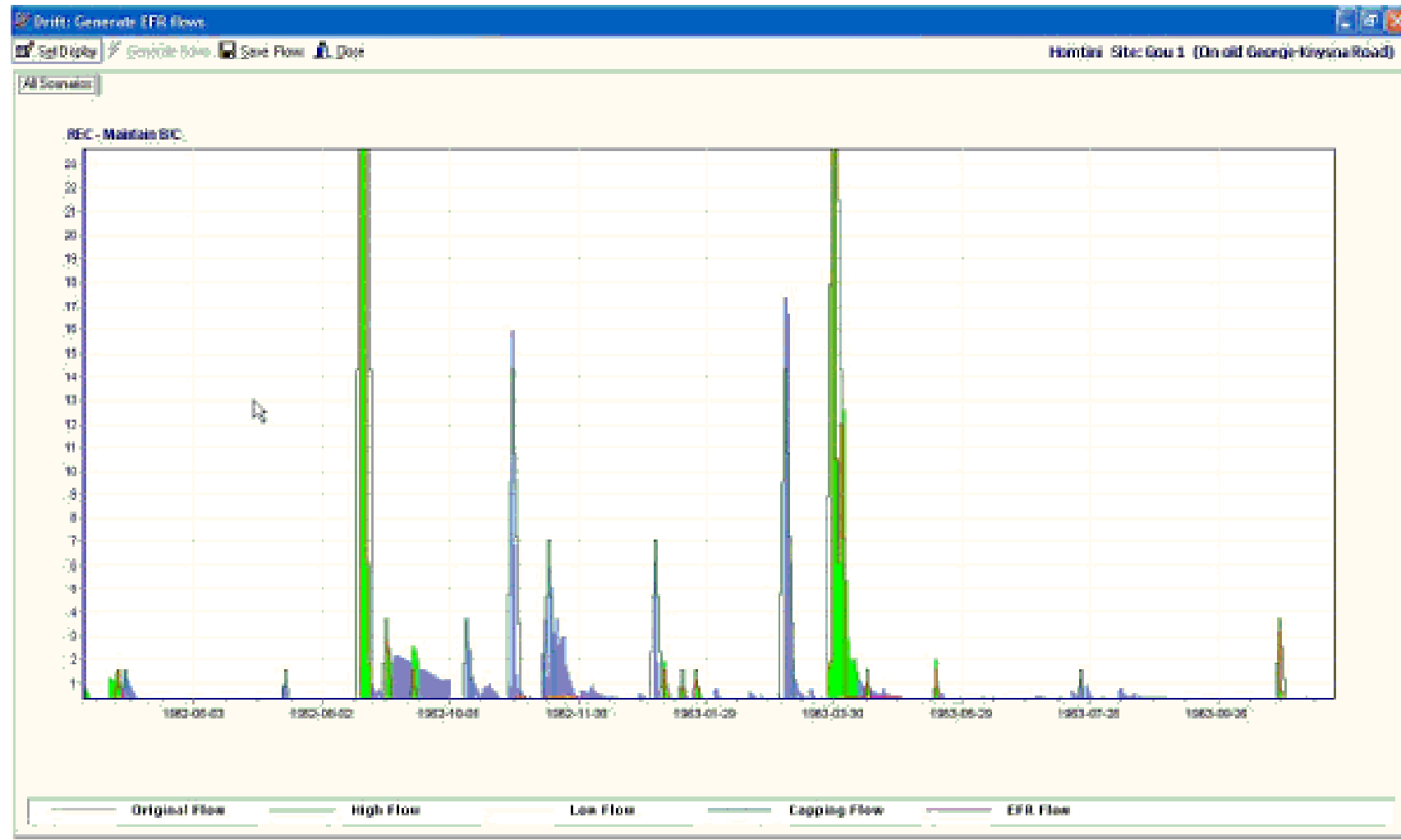


Figure 9.3 A portion of the modified flow regime for EWR Option 1 (REC_B/C) at Gou 1. The blue line (original flow) is Present Day flow in the river

Table 9.3 Water quantity for EWR Option 1 (REC_B/C) at Gou 1 (Goukamma River at Old Road). To be met at the bridge over the Old Road. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 26.6MCM (estimated). PD MAR = 23.1														
EWR Ecstatus Category = B/C														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.211	0.38	0.27	0.21	0.2	0.25	0.32	0.131	0.131	0.141	0.181	0.181	6.17	19.9%
FLOOD Class 1: .95: m ³ s ⁻¹	3					2						With Oct	1.95	7.3%
FLOOD Class 2: 1.76 m ³ s ⁻¹	2												1.44	5.4%
FLOOD Class 3: 3.57: m ³ s ⁻¹	None requested												0	0%
FLOOD Class 4: 6.53 m ³ s ⁻¹	None requested												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												4.5	16.9%
MAINTENANCE TOTAL (Volume)	Annual ⁷⁴												14.1	53%
	Long-term average ⁷⁵												12.4	47%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.14	0.12	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.1	2.236	8%
FLOOD Peak ⁷⁶ m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁷⁴ Calculated as the volume of water required to meet the full requirements.

⁷⁵ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

⁷⁶ Daily average peak.

Table 9.4 Summary of the flood requirements for Gou 1 – EWR Option 1 (REC_B/C)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM) ⁷⁷	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	2.08	3	0.39	5	Sept-May
Class 2	3.73	3	0.72	2	Anytime
Class 3	7.04	4	1.41	0	Not applicable
Class 4	14.06	4	2.74	0	Not applicable
Inter-annual Class (return period given below)					
1:2	23	4	3.4	Present	Not stipulated
1:5	50	7	7	Present	Not stipulated
1:10	67	7	8	Present	Not stipulated
1:20	100	7	12	Present	Not stipulated

Table 9.5 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 1 (REC_B/C) for Gou 1. MCM = million cubic metres

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	3.726	0.793	0.32	0.222	0.202	0.181	0.163	0.151	0.134	0.131	0.095	0.056	0	12.441
Jan	2.214	0.739	0.163	0.163	0.162	0.162	0.161	0.16	0.121	0.092	0.061	0	0	0.698
Feb	2.301	0.793	0.168	0.162	0.162	0.161	0.161	0.16	0.132	0.102	0.061	0.04	0	0.586
Mar	3.424	0.793	0.208	0.203	0.202	0.202	0.201	0.2	0.161	0.121	0.072	0.044	0	0.99
Apr	6.809	0.793	0.276	0.272	0.272	0.271	0.271	0.27	0.202	0.141	0.101	0.071	0	1.279
May	4.333	0.134	0.133	0.132	0.131	0.131	0.131	0.131	0.13	0.13	0.09	0.05	0	1.185
Jun	2.803	0.209	0.135	0.133	0.132	0.132	0.131	0.131	0.13	0.13	0.07	0.05	0	0.592
Jul	1.586	0.143	0.143	0.142	0.142	0.141	0.141	0.14	0.14	0.14	0.1	0.05	0	0.676
Aug	6.055	0.209	0.183	0.182	0.182	0.181	0.181	0.181	0.18	0.18	0.141	0.08	0.01	1.215
Sep	7.163	1.235	0.19	0.182	0.182	0.181	0.181	0.181	0.181	0.18	0.14	0.1	0	1.424
Oct	7.043	1.243	0.228	0.212	0.212	0.212	0.211	0.211	0.211	0.21	0.17	0.14	0.09	1.446
Nov	7.043	1.242	0.341	0.323	0.322	0.321	0.321	0.32	0.253	0.191	0.14	0.121	0.05	1.514
Dec	3.099	0.678	0.23	0.223	0.222	0.222	0.221	0.22	0.17	0.13	0.09	0.06	0	0.836
Summer	3.726	0.793	0.322	0.272	0.223	0.204	0.185	0.162	0.16	0.125	0.079	0.05	0	5.903
Winter	4.695	0.713	0.212	0.185	0.181	0.18	0.142	0.14	0.132	0.131	0.111	0.063	0	6.538

⁷⁷ per event.

Table 9.6 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 1 (REC_B/C) for Gou 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.281	0.276	0.275	0.274	0.272	0.27	0.21	0.16	0.12	0.09	0.06	0	0	0.502
Feb	0.271	0.254	0.254	0.253	0.252	0.25	0.2	0.16	0.13	0.1	0.06	0.04	0	0.442
Mar	0.327	0.318	0.315	0.314	0.312	0.31	0.25	0.2	0.16	0.12	0.07	0.04	0	0.603
Apr	0.394	0.389	0.386	0.383	0.382	0.38	0.32	0.27	0.2	0.14	0.1	0.07	0	0.727
May	0.134	0.133	0.133	0.132	0.131	0.131	0.131	0.131	0.13	0.13	0.09	0.05	0	0.328
Jun	0.137	0.136	0.134	0.133	0.132	0.132	0.131	0.131	0.13	0.13	0.07	0.05	0	0.31
Jul	0.143	0.143	0.143	0.142	0.142	0.141	0.141	0.14	0.14	0.14	0.1	0.05	0	0.343
Aug	0.185	0.183	0.183	0.182	0.181	0.181	0.181	0.18	0.18	0.18	0.14	0.08	0.01	0.448
Sep	0.19	0.188	0.185	0.182	0.182	0.181	0.181	0.181	0.18	0.18	0.14	0.1	0	0.435
Oct	0.229	0.213	0.213	0.212	0.212	0.211	0.211	0.211	0.21	0.21	0.17	0.14	0.09	0.537
Nov	0.474	0.454	0.435	0.433	0.431	0.43	0.38	0.32	0.25	0.19	0.14	0.12	0.05	0.844
Dec	0.363	0.356	0.346	0.344	0.342	0.34	0.27	0.22	0.17	0.13	0.09	0.06	0	0.645
Summer	0.449	0.431	0.384	0.345	0.313	0.274	0.253	0.212	0.163	0.124	0.078	0.05	0	3.764
Winter	0.213	0.212	0.211	0.182	0.181	0.18	0.142	0.137	0.132	0.131	0.111	0.062	0	2.401

9.6 DETAILED EWR OPTION 2: ALTERNATIVE ECOLOGICAL CATEGORY (AEC_C)

9.6.1 Overview of EWR Option 1

This section provides a brief summary of EWR Option 2 (AEC_C) for Gou 1.

TARGET ECOLOGICAL CATEGORY

Maintain Alternative Ecological Category (AEC_C) = C.

ECOLOGICAL WATER REQUIREMENTS

Mean annual volume required for the river for Option 2 (AEC_C) at Gou 1:

Including the volume for the $\geq 1:2$ year floods: 8.7 MCM a⁻¹
= c. 32.7% nMAR and 37.7% present day MAR.

Excluding the volume for the $\geq 1:2$ year floods: 8.7 MCM a⁻¹
= c. 32.7% nMAR and 37.7% present day MAR.

No $\geq 1:2$ year floods stipulated.

Note: The long-term average is 28% of nMAR, including 1:2 year floods. This is the ACTUAL impact on MAR.

FLOW REDUCTION LEVELS USED

For EWR Option 2 (AEC) at Gou 1, the following mix of change levels for the 10 components was selected for the Minimum Degradation Scenario – relative to Present Day:

1	Winter lowflows	Level 4, i.e., Capped at the 80% percentile of the PD lowflow duration curve.
2	Summer lowflows:	Level 3, i.e., Capped at the 60% percentile of the PD lowflow duration curve.
3	Class 1 Intra-annual floods:	present day.
4	Class 2 Intra-annual floods:	present day.
5	Class 3 Intra-annual floods:	Level 2, i.e., no Class III floods.
6	Class 4 Intra-annual floods:	Level 1, i.e., no Class IV floods.
7	Inter-annual floods (1:2 year):	Level 1, i.e., no 1:2 floods.
8	Inter-annual floods (1:5 year):	Level 1, i.e., no 1:5 floods.
9	Inter-annual floods (1:10 year):	Level 1, i.e., no 1:10 floods
10	Inter-annual floods (1:20 year):	Level 1, i.e., no 1:20 floods

GENERAL OVERVIEW OF THE EXPECTED CONDITION OF THE RIVER

The flow regime presented in EWR Option 2 (AEC_C) was designed to allow degradation of the system by almost a full category.

OVERALL INTEGRITY SCORE: EWR OPTION 2 (AEC_C)

EWR Option 2 (AEC_C) was assigned an **Overall Integrity Score of -0.57**, i.e., a REDUCTION in PES to a C-Category.

EXPECTED EC

EWR Option 2 (AEC) is expected to maintain a Category-C condition.

9.6.2 EWR Option 1 (REC) Hydrology

A portion of the modified flow regime for EWR Option 2 (AEC_C) is shown in Figure 9.4, and Table 9.7 provides a breakdown of the flow regime required to meet EWR Option 2 (AEC_C). The flood requirements are detailed in Table 9.8 and the rule curves are given in Table 9.9 and Table 9.10.

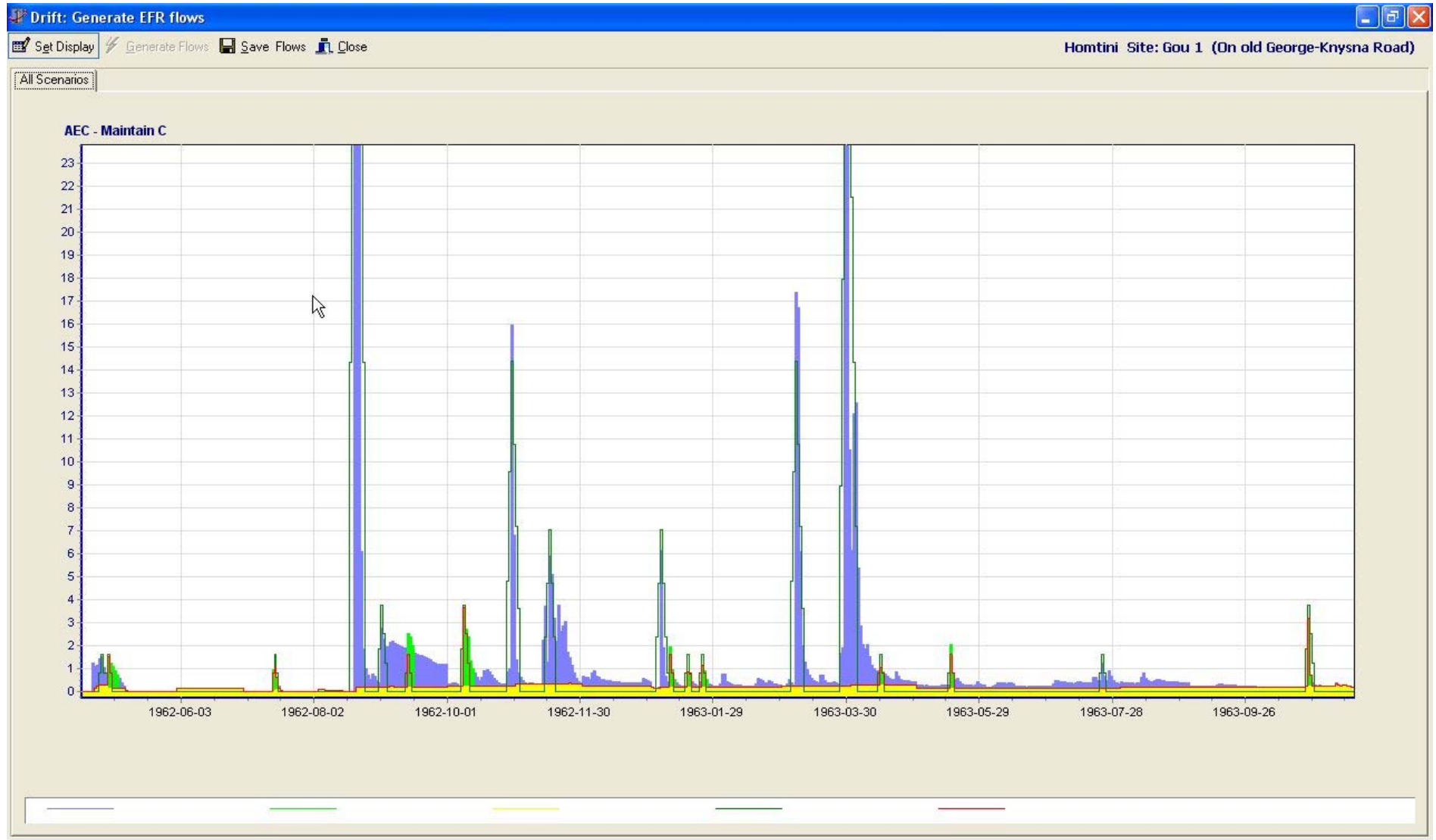


Figure 9.4 A portion of the modified flow regime for EWR Option 2 (AEC_C) at Gou 1. The blue line (original flow) is Present Day flow in the river

Table 9.7 Water quantity for EWR Option 2 (AEC_C) at Gou 1 (Goukamma River at Old Road). To be met at the bridge over the Old Road. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 26.6MCM (estimated). PD MAR = 23.1														
EWR Ecstatus Category = C														
MAINTENANCE														
LOW FLOWS Q m ³ s ⁻¹	0.211	0.321	0.221	0.161	0.161	0.201	0.271	0.131	0.131	0.141	0.181	0.181	5.31	19.9%
FLOOD Class 1: .95: m ³ s ⁻¹	3					2						With Oct	1.95	7.3%
FLOOD Class 2: 1.76 m ³ s ⁻¹	2												1.44	5.4%
FLOOD Class 3: 3.57: m ³ s ⁻¹	None requested												0	0%
FLOOD Class 4: 6.53 m ³ s ⁻¹	None requested												0	0%
Inter-annual floods	Estimated annual volume (1:2; 1:5; 1:10 and 1:20 year floods)												0	0%
MAINTENANCE TOTAL (Volume)	Annual ⁷⁸												8.7	33%
	Long-term average ⁷⁹												7.5	28%
DROUGHT														
LOW FLOWS m ³ s ⁻¹	0.14	0.12	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.1	2.236	8%
FLOOD Peak ⁸⁰ m ³ s ⁻¹	-	-	-	-	-	-	-	-	-	-	-	-	0	0%

⁷⁸ Calculated as the volume of water required to meet the full requirements.

⁷⁹ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

⁸⁰ Daily average peak.

Table 9.8 Summary of the flood requirements for Gou 1 – EWR Option 2 (AEC_C)

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM) ⁸¹	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	2.08	3	0.39	5	Sept-May
Class 2	3.73	3	0.72	2	Anytime
Class 3	7.04	4	1.41	0	Not applicable
Class 4	14.06	4	2.74	0	Not applicable
Inter-annual Class (return period given below)					
1:2	23	4	3.4	0	Not applicable
1:5	50	7	7	0	Not applicable
1:10	67	7	8	0	Not applicable
1:20	100	7	12	0	Not applicable

Table 9.9 Exceedence curves for the complete flow regime (floods and droughts included) required to meet Option 2 (AEC_C) for Gou 1. MCM = million cubic metres

Month	Percentiles (data are in m^3s^{-1})													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
All	2.009	0.352	0.28	0.221	0.202	0.181	0.163	0.149	0.134	0.131	0.095	0.056	0	7.528
Jan	1.586	0.552	0.163	0.163	0.162	0.162	0.161	0.16	0.121	0.091	0.061	0	0	0.521
Feb	2.348	0.793	0.168	0.162	0.162	0.161	0.161	0.16	0.132	0.101	0.06	0.04	0	0.598
Mar	2.484	0.793	0.205	0.203	0.202	0.202	0.201	0.2	0.161	0.121	0.071	0.043	0	0.689
Apr	2.875	0.287	0.276	0.272	0.272	0.271	0.271	0.27	0.201	0.141	0.101	0.071	0	0.792
May	1.334	0.133	0.133	0.132	0.131	0.131	0.131	0.131	0.13	0.13	0.09	0.05	0	0.411
Jun	1.63	0.137	0.135	0.133	0.132	0.132	0.131	0.131	0.13	0.13	0.07	0.05	0	0.431
Jul	1.014	0.143	0.143	0.142	0.142	0.141	0.141	0.14	0.14	0.14	0.101	0.05	0	0.413
Aug	1.418	0.185	0.183	0.182	0.182	0.181	0.181	0.181	0.18	0.18	0.14	0.08	0.01	0.565
Sep	2.201	0.198	0.188	0.182	0.182	0.181	0.181	0.181	0.181	0.18	0.14	0.1	0	0.632
Oct	3.232	1.087	0.227	0.212	0.212	0.212	0.211	0.211	0.211	0.21	0.17	0.14	0.09	0.869
Nov	3.129	0.793	0.34	0.322	0.322	0.321	0.321	0.32	0.253	0.191	0.14	0.121	0.05	0.942
Dec	2.484	0.254	0.229	0.223	0.222	0.222	0.221	0.22	0.17	0.13	0.09	0.06	0	0.666
Summer	2.408	0.793	0.322	0.272	0.223	0.203	0.184	0.162	0.16	0.125	0.078	0.05	0	4.209
Winter	1.829	0.213	0.211	0.183	0.181	0.18	0.142	0.14	0.132	0.131	0.111	0.063	0	3.32

⁸¹ per event.

Table 9.10 Exceedence curves for the lowflow component of the flow regime (droughts included) required to meet Option 2 (AEC_C) for Gou 1. MCM = million cubic metres

Month	Percentiles (data are in m ³ s ⁻¹)													MAR [MCM]
	1	5	10	20	30	40	50	60	70	80	90	95	99	
Jan	0.166	0.163	0.163	0.163	0.162	0.162	0.161	0.16	0.12	0.09	0.06	0	0	0.354
Feb	0.173	0.163	0.162	0.162	0.162	0.161	0.161	0.16	0.13	0.1	0.06	0.04	0	0.332
Mar	0.211	0.205	0.204	0.203	0.202	0.202	0.201	0.2	0.16	0.12	0.07	0.04	0	0.453
Apr	0.28	0.277	0.274	0.272	0.272	0.271	0.271	0.27	0.2	0.14	0.1	0.07	0	0.584
May	0.134	0.133	0.133	0.132	0.131	0.131	0.131	0.131	0.13	0.13	0.09	0.05	0	0.328
Jun	0.137	0.136	0.134	0.133	0.132	0.132	0.131	0.131	0.13	0.13	0.07	0.05	0	0.31
Jul	0.143	0.143	0.143	0.142	0.142	0.141	0.141	0.14	0.14	0.14	0.1	0.05	0	0.343
Aug	0.185	0.183	0.183	0.182	0.181	0.181	0.181	0.18	0.18	0.18	0.14	0.08	0.01	0.448
Sep	0.19	0.188	0.185	0.182	0.182	0.181	0.181	0.181	0.18	0.18	0.14	0.1	0	0.435
Oct	0.229	0.213	0.213	0.212	0.212	0.211	0.211	0.211	0.21	0.21	0.17	0.14	0.09	0.537
Nov	0.353	0.338	0.324	0.322	0.322	0.321	0.321	0.32	0.25	0.19	0.14	0.12	0.05	0.699
Dec	0.235	0.23	0.224	0.223	0.222	0.222	0.221	0.22	0.17	0.13	0.09	0.06	0	0.487
Summer	0.334	0.322	0.312	0.271	0.222	0.202	0.169	0.162	0.16	0.124	0.078	0.05	0	2.909
Winter	0.213	0.212	0.211	0.182	0.181	0.18	0.142	0.137	0.132	0.131	0.111	0.062	0	2.401

10 SUMMARY RESULTS FOR INTERMEDIATE RESERVE DETERMINATIONS

The summary results of REC for the Intermediate Reserve Determination EWR sites are provided in Table 10.1.

Table 10.1 The annual estimates of the Reserves for the REC for each Intermediate Reserve Determination EWR site

Method	River	Site	Quaternary Catchment	Portion of the EWR	PES	EIS	REC	Method/ Calculation Notation	MCMa ⁻¹	%nMAR	MCMa ⁻¹	%nMAR
									(incl. ≥1:2 year floods)		(excluding ≥1:2 year floods ⁸²)	
Intermediate (DRIFT)	Groot Brak	GB 1	K20A	MAINTENANCE TOTAL (Volume)	B/C	H	B/C	DRIFT Annual ⁸³	10.1	47%	6.3	34%
								Long-term average ⁸⁴	5.5	30%		
	Malgas	Mal 1	K30A	MAINTENANCE TOTAL (Volume)	C	H	C	DRIFT Annual	5.4	50%	3.8	35%
								Long-term average	3.5	32%		
	Kaaimans	Ka 1	K30C	MAINTENANCE TOTAL (Volume)	B	VH	B	DRIFT Annual	8.5	63%	6.5	48%
								Long-term average	6.7	50%		
	Goukamma	Gou 1	K40E	MAINTENANCE TOTAL (Volume)	B/C	VH	B/C	DRIFT Annual	14.1	53%	9.6	36%
								Long-term average	12.4	47%		

⁸² For comparison with Desktop results.

⁸³ Calculated as the volume of water required to meet the full requirements.

⁸⁴ Calculated using the historical flow sequence, and only 'releasing' requirements in response to 'natural' cues.

11 RESULTS FOR THE RAPID RESERVE DETERMINATIONS

11.1 INTRODUCTION

Rapid determinations were undertaken at the sites listed in Table 11.1, where they occurred in the same quaternary, information from sites was combined to determine the PES. Additionally, sites were combined if it was not possible to measure river flow separately for each site. Information on the activities making up the Rapid determinations is provided in Section 3.2. In summary:

- Rapid II's: Full team consideration for the delineation, Ecostatus assessments and Desktop adjustments. Plus, calibration of the Desktop using Intermediate data generated for similar sites in the catchment.
- Rapid I's: Vegetation and macroinvertebrate assessments for Ecostatus. Plus, full team calibration of the Desktop using Intermediate data generated for similar sites in adjacent catchments.

Table 11.1 Study sites at which Rapid determinations were done

River	Site Name	Description	PES	EIS	Determination level
Maalgate	Maa 1	@ Sieben Schwaben	Category D	High	Rapid II
	Maa 2	@ R102/DWAF gauging weir	Category D	High	Rapid II
Moeras	Moe 1	@ Molendrif	Category D	High	Rapid II
	Moe 2	@ R102	Category C	High	Rapid II
Gwaing	Gwa 1	@ R102	Category E	High	Rapid II
Swart	Sw 1	@ Old George-Knysna Road	Category D	High	Rapid II
Silver	Si 1	@ Old George-Knysna Road	Category B	Very High	Rapid II
Noetsie	Noe 1	@ N2	Category B	Very High	Rapid I
Moordkuil	Moo 1	@ Road parallel to flood plain	Category D	High	Reviewed existing Rapid III

In this Section the .tab and .rul tables are provided for the maintenance of PES, and for alternative conditions for maintenance, where appropriate. No EWRs are given for conditions below a D-Category, as per RDM recommendations. Also, EWRs were not provided for higher categories where non-flow related aspects make it impossible to achieve a higher ecological status. For instance, where housing has encroached on the river and the river is channelised and/or canalised, additional flow is unlikely to provide for a better ecological condition.

All tables were produced using the Desktop Version 2⁸⁵ and IFR (instream flow requirement) Edit. The Desktop Model is a rule-based model calibrated using trends emerging from the existing Comprehensive Reserve determinations (Hughes and Hannart, 2003). The existing

⁸⁵ Refer to Hughes and Hannart (2003) for the details of the model and its use.

Desktop Model does not incorporate any data from the study area in the calibration as these were not available until now. Thus, for this study, the model was calibrated using the results from the Reserve determinations presented in Sections 6 to 9 and IFR Edit. No seasonal distributions were changed. In general, this resulted in a slight increase in recommended flows relative to what would have been recommended by the uncalibrated Desktop. These increases were mainly because lowflows were deemed to be especially important in these strongly perennial systems. Each calibration was checked with the specialist. The hydrological data used were produced by DWAF: Hydrological Services for the Outeniqua Coast Assessment study (DWAF, 2007a), i.e., not WR90 data.

The delineation exercises guided which sites were used for calibration (e.g., Dollar's grouping of rivers in Figure 11.1, DWAF, 2007b). These were discussed with the specialists and the sites agreed on for use in calibration at each of the Rapid II/I sites are given in Table 11.2.

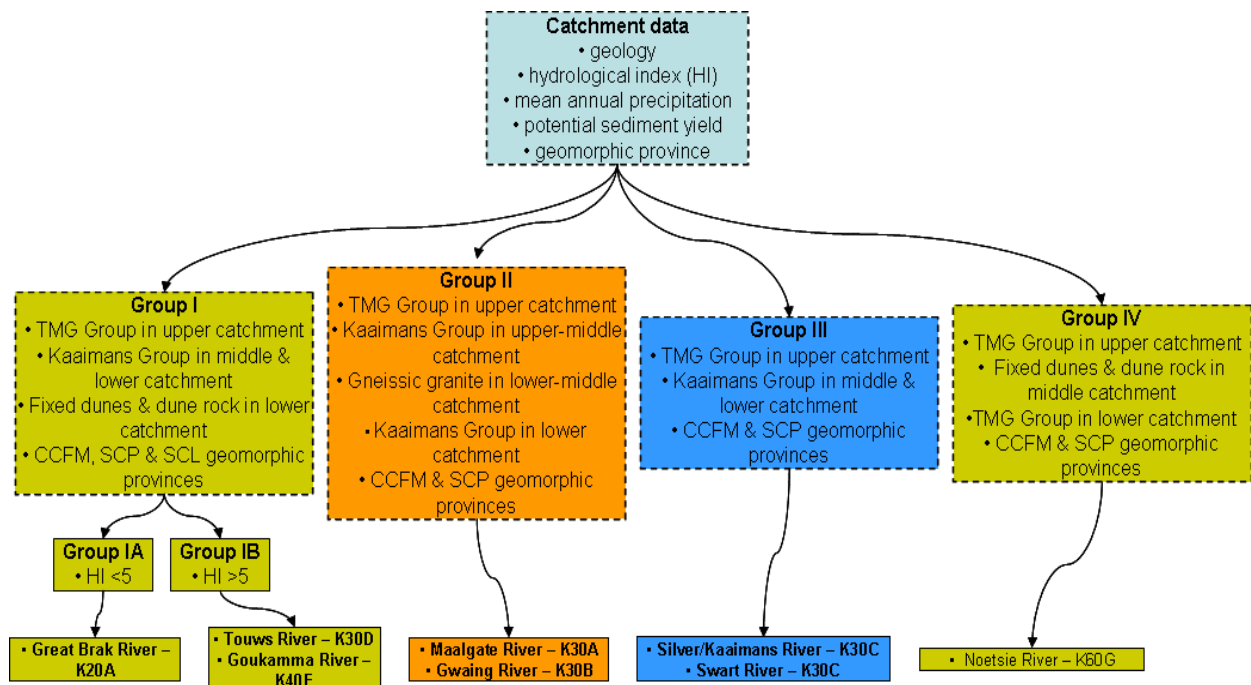


Figure 11.1 Simple 'expert-based' approach for grouping the rivers of the study area

Table 11.2 Intermediate Reserve Determination sites used to ‘calibrate’ the desktop

River	Site Name	IFR Edit populated using results from Intermediate sites
Maalgate	Maa 1	Malgas (Mal 1)
	Maa 2	
Moeras	Moe 1	Malgas (Mal 1)
	Moe 2	
Gwaing	Gwa 1	Malgas (Mal 1)
Swart	Sw 1	Kaaimans (Ka 1)
Silver	Si 1	Kaaimans (Ka 1)
Noetsie	Noe 1	Goukamma (Gou 1)

The resultant outputs for the Desktop were also discussed in workshop sessions and adjusted where necessary.

It is important to note that the Desktop requires specification of flood flows for a particular month. If the flood does not occur in the specified month, then the long-term average will exclude that flood, even if it occurs early in the following month. In reality, floods for EWRs are recommended for a suite of months. This makes the chances of the flood actually occurring higher, which makes the long-term average higher. This should be taken into consideration when modelling EWR requirements for water resource developments and/or management, and when reviewing these results. Also, the Desktop Model does not include floods with a return period of two years or greater, and these are required if these rivers are to be maintained in their target conditions.

11.2 MAALGATE RIVER (Maa 1 and Maa 2)

There is no means of measuring flow at Maa 1, so the determination were for a reserve to be monitored at Maa 2, at the DWAF gauging weir no. K3H003. Data for both sites was, however, used for the determination of PES and EIS.

PES = D-Category.



Figure 11.2 Maalgate River at Sieben Schwaben (Maa 1)



Figure 11.3 Maalgate River at R102 (Maa 2)

REC: D-CATEGORY

Table 11.3 Summary table for D-Category EWRs at Maa 2

Desktop Version 2, Generated on 6/11/2007

Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :

Total Runoff : Runoff : Maalg

Annual Flows (Mill. cu. m or index values):

MAR = 35.256

S.Dev. = 17.090

CV = 0.485

Q75 = 0.800

Q75/MMF = 0.272

BFI Index = 0.380

CV(JJA+JFM) Index = 2.277

Ecological Category = D

Total IFR = 5.594 (15.87 %MAR)

Maint. Lowflow = 3.385 (9.60 %MAR)

Drought Lowflow = 1.391 (3.95 %MAR)

Maint. Highflow = 2.210 (6.27 %MAR)

Monthly Distributions (Mill. cu. m.)

Distribution Type : S.Cape(wet)

Month	Natural Flows			Modified Flows (IFR)				
				Low	flows	High	Flows	Total
Flows	Mean	SD	CV	Maint.	Drought	Maint.	Maint.	
Oct	3.923	3.309	0.844	0.545	0.172	0.368	0.913	
Nov	4.021	4.600	1.144	0.160	0.083	0.368	0.529	
Dec	3.040	3.778	1.243	0.087	0.064	0.000	0.087	
Jan	2.582	3.003	1.163	0.087	0.064	0.368	0.455	
Feb	2.371	2.866	1.209	0.151	0.078	0.368	0.519	
Mar	3.753	3.847	1.025	0.160	0.086	0.368	0.529	
Apr	3.155	3.288	1.042	0.234	0.166	0.368	0.602	
May	2.662	3.567	1.340	0.420	0.172	0.000	0.420	
Jun	1.604	1.556	0.971	0.410	0.166	0.000	0.410	
Jul	1.754	1.844	1.052	0.317	0.086	0.000	0.317	
Aug	2.896	4.093	1.413	0.423	0.172	0.000	0.423	
Sep	3.495	3.969	1.136	0.391	0.083	0.000	0.391	

Table 11.4 Rule tables for D-Category EWRs at Maa 2

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.677	0.620	0.571	0.521	0.434	0.367	0.278	0.184	0.114	0.084
Nov	0.432	0.374	0.327	0.286	0.217	0.184	0.140	0.096	0.063	0.049
Dec	0.057	0.057	0.056	0.054	0.049	0.043	0.036	0.029	0.026	0.024
Jan	0.249	0.246	0.239	0.222	0.194	0.154	0.109	0.072	0.048	0.037
Feb	0.321	0.318	0.309	0.290	0.254	0.202	0.144	0.093	0.062	0.041
Mar	0.304	0.302	0.296	0.283	0.257	0.216	0.162	0.108	0.067	0.049
Apr	0.363	0.361	0.356	0.342	0.316	0.271	0.211	0.149	0.102	0.082
May	0.281	0.280	0.276	0.267	0.248	0.215	0.169	0.120	0.083	0.067
Jun	0.296	0.296	0.293	0.286	0.271	0.245	0.203	0.148	0.097	0.054
Jul	0.219	0.219	0.217	0.212	0.201	0.180	0.147	0.102	0.059	0.036
Aug	0.295	0.295	0.292	0.285	0.271	0.244	0.202	0.148	0.096	0.069
Sep	0.270	0.269	0.265	0.255	0.234	0.198	0.147	0.094	0.053	0.035
Reserve Flows without High Flows										
Oct	0.368	0.367	0.361	0.346	0.318	0.270	0.206	0.140	0.090	0.068
Nov	0.113	0.113	0.111	0.107	0.099	0.086	0.069	0.051	0.039	0.033
Dec	0.057	0.057	0.056	0.054	0.049	0.043	0.036	0.029	0.026	0.024
Jan	0.058	0.057	0.056	0.054	0.049	0.043	0.035	0.029	0.026	0.024
Feb	0.110	0.110	0.107	0.101	0.091	0.076	0.060	0.045	0.036	0.033
Mar	0.110	0.109	0.107	0.103	0.096	0.083	0.067	0.051	0.038	0.033
Apr	0.164	0.163	0.161	0.156	0.147	0.132	0.111	0.089	0.072	0.065
May	0.281	0.280	0.276	0.267	0.248	0.215	0.169	0.120	0.083	0.067
Jun	0.296	0.296	0.293	0.286	0.271	0.245	0.203	0.148	0.097	0.054
Jul	0.219	0.219	0.217	0.212	0.201	0.180	0.147	0.102	0.059	0.036
Aug	0.295	0.295	0.292	0.285	0.271	0.244	0.202	0.148	0.096	0.069
Sep	0.270	0.269	0.265	0.255	0.234	0.198	0.147	0.094	0.053	0.035
Natural Duration curves										
Oct	3.427	2.584	1.826	1.277	1.057	0.810	0.582	0.452	0.291	0.138
Nov	3.754	2.481	1.860	1.177	0.856	0.594	0.463	0.367	0.235	0.112
Dec	2.602	1.893	1.430	0.904	0.687	0.568	0.392	0.261	0.105	0.049
Jan	2.382	1.471	1.019	0.792	0.605	0.504	0.317	0.205	0.075	0.037
Feb	2.352	1.472	1.145	0.794	0.575	0.463	0.347	0.248	0.153	0.041
Mar	3.379	2.087	1.676	1.292	0.982	0.792	0.366	0.254	0.138	0.052
Apr	2.890	1.825	1.431	1.049	0.818	0.617	0.498	0.336	0.193	0.089
May	2.165	1.471	0.978	0.646	0.534	0.407	0.321	0.198	0.157	0.075
Jun	1.501	0.992	0.640	0.513	0.444	0.390	0.235	0.162	0.108	0.054
Jul	1.620	1.030	0.680	0.594	0.418	0.299	0.250	0.168	0.142	0.101
Aug	2.935	1.206	0.960	0.672	0.568	0.478	0.340	0.273	0.202	0.093
Sep	3.225	2.149	1.516	0.934	0.721	0.590	0.486	0.336	0.220	0.166

AEC: C-CATEGORY
Table 11.5 Summary table for C-Category EWRs at Maa 2

Ecological Category = C							
Total IFR	=	10.579	(30.01 %MAR)				
Maint. Lowflow	=	3.356	(9.52 %MAR)				
Drought Lowflow	=	1.832	(5.19 %MAR)				
Maint. Highflow	=	7.223	(20.49 %MAR)				
Monthly Distributions (Mill. cu. m.)							
Distribution Type : S.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	3.923	3.309	0.844	0.545	0.172	0.368	0.913
Nov	4.021	4.600	1.144	0.160	0.415	1.576	1.736
Dec	3.040	3.778	1.243	0.087	0.087	0.000	0.087
Jan	2.582	3.003	1.163	0.087	0.064	0.368	0.455
Feb	2.371	2.866	1.209	0.151	0.078	0.368	0.519
Mar	3.753	3.847	1.025	0.160	0.086	1.576	1.736
Apr	3.155	3.288	1.042	0.234	0.166	2.966	3.200
May	2.662	3.567	1.340	0.420	0.172	0.000	0.420
Jun	1.604	1.556	0.971	0.410	0.166	0.000	0.410
Jul	1.754	1.844	1.052	0.288	0.172	0.000	0.288
Aug	2.896	4.093	1.413	0.423	0.172	0.000	0.423
Sep	3.495	3.969	1.136	0.391	0.083	0.000	0.391

Table 11.6 Rule tables for C-Category EWRs at Maa 2

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.590	0.534	0.486	0.440	0.362	0.309	0.237	0.162	0.106	0.082
Nov	1.451	1.208	1.016	0.860	0.607	0.532	0.434	0.334	0.235	0.112
Dec	0.045	0.045	0.045	0.044	0.042	0.040	0.037	0.034	0.033	0.032
Jan	0.211	0.209	0.202	0.189	0.166	0.133	0.096	0.065	0.047	0.037
Feb	0.268	0.266	0.259	0.243	0.215	0.173	0.125	0.084	0.059	0.041
Mar	0.789	0.784	0.768	0.732	0.663	0.552	0.366	0.254	0.138	0.052
Apr	1.485	1.479	1.431	1.049	0.818	0.617	0.498	0.336	0.193	0.089
May	0.214	0.213	0.211	0.204	0.191	0.168	0.137	0.103	0.077	0.066
Jun	0.217	0.217	0.215	0.211	0.201	0.183	0.156	0.120	0.086	0.054
Jul	0.146	0.146	0.145	0.143	0.138	0.129	0.114	0.095	0.076	0.066
Aug	0.217	0.217	0.215	0.210	0.201	0.183	0.155	0.120	0.085	0.067
Sep	0.206	0.205	0.202	0.195	0.179	0.153	0.116	0.077	0.047	0.034
Reserve Flows without High Flows										
Oct	0.281	0.280	0.276	0.266	0.245	0.211	0.166	0.118	0.082	0.067
Nov	0.088	0.088	0.090	0.094	0.101	0.112	0.127	0.143	0.154	0.112
Dec	0.045	0.045	0.045	0.044	0.042	0.040	0.037	0.034	0.033	0.032
Jan	0.046	0.045	0.045	0.043	0.040	0.036	0.031	0.027	0.025	0.024
Feb	0.087	0.086	0.085	0.081	0.074	0.063	0.051	0.041	0.035	0.033
Mar	0.084	0.084	0.082	0.080	0.075	0.066	0.056	0.044	0.036	0.033
Apr	0.125	0.125	0.124	0.121	0.115	0.105	0.093	0.079	0.069	0.065
May	0.214	0.213	0.211	0.204	0.191	0.168	0.137	0.103	0.077	0.066
Jun	0.217	0.217	0.215	0.211	0.201	0.183	0.156	0.120	0.086	0.054
Jul	0.146	0.146	0.145	0.143	0.138	0.129	0.114	0.095	0.076	0.066
Aug	0.217	0.217	0.215	0.210	0.201	0.183	0.155	0.120	0.085	0.067
Sep	0.206	0.205	0.202	0.195	0.179	0.153	0.116	0.077	0.047	0.034
Natural Duration curves										
Oct	3.427	2.584	1.826	1.277	1.057	0.810	0.582	0.452	0.291	0.138
Nov	3.754	2.481	1.860	1.177	0.856	0.594	0.463	0.367	0.235	0.112
Dec	2.602	1.893	1.430	0.904	0.687	0.568	0.392	0.261	0.105	0.049
Jan	2.382	1.471	1.019	0.792	0.605	0.504	0.317	0.205	0.075	0.037
Feb	2.352	1.472	1.145	0.794	0.575	0.463	0.347	0.248	0.153	0.041

Mar	3.379	2.087	1.676	1.292	0.982	0.792	0.366	0.254	0.138	0.052
Apr	2.890	1.825	1.431	1.049	0.818	0.617	0.498	0.336	0.193	0.089
May	2.165	1.471	0.978	0.646	0.534	0.407	0.321	0.198	0.157	0.075
Jun	1.501	0.992	0.640	0.513	0.444	0.390	0.235	0.162	0.108	0.054
Jul	1.620	1.030	0.680	0.594	0.418	0.299	0.250	0.168	0.142	0.101
Aug	2.935	1.206	0.960	0.672	0.568	0.478	0.340	0.273	0.202	0.093
Sep	3.225	2.149	1.516	0.934	0.721	0.590	0.486	0.336	0.220	0.166

11.3 MOERAS RIVER (Moe 1 and Moe 2)

The two Moeras River sites, Moe 1 (PES = D Category) and Moe 2 (PES = C Category) are upstream of confluence with the Maalgate River. They are also devoid of any gauging stations and cannot be assessed using the Desktop Version 2, as they are essentially wetlands. For this reason it was decided to use the Maalgate site at the DWAF gauging weir for the Reserve determination site, i.e., Maa 2. – See Section 11.2.



Figure 11.4 Moeras River at Molendrif (Moe 1)



Figure 11.5 Moeras River at Moeras (Moe 2)

11.4 GWAING RIVER (Gwa 1)

Only a D-Category determination was done for the Gwaing River, as the river flow through the outskirts of Blanco is in an E-Category, largely as a result of non-flow related issues, such as development in the riparian zone, alien tree infestations, hard engineers and pollution.

PES = E-Category.



Figure 11.6 Gwaing River at R102 (Gwa 1)

REC: D-CATEGORY

Table 11.7 Summary table for D-Category EWRs at Gwa 1

Desktop Version 2, Generated on 6/7/2007

Summary of Desktop (Version 2)

Total Runoff : Runoff : GGwain

Annual Flows (Mill. cu. m or index values):

MAR = 16.798

S.Dev. = 9.294

CV = 0.553

Q75 = 0.240

Q75/MMF = 0.171

BFI Index = 0.340

CV(JJA+JFM) Index = 2.608

Ecological Category = D

Total IFR = 2.665 (15.87 %MAR)

Maint. Lowflow = 1.613 (9.60 %MAR)

Drought Lowflow = 0.947 (5.64 %MAR)

Maint. Highflow = 1.053 (6.27 %MAR)

Monthly Distributions (Mill. cu. m.)

Distribution Type : S.Cape(wet)

Month	Natural Flows			Modified Flows (IFR)			
	Mean	SD	CV	Low flows		High Flows	Total Flows
				Maint.	Drought	Maint.	Maint.
Oct	1.868	1.817	0.973	0.260	0.107	0.175	0.435
Nov	1.904	2.532	1.330	0.076	0.076	0.175	0.252
Dec	1.299	2.051	1.579	0.041	0.031	0.000	0.041
Jan	1.091	1.592	1.459	0.041	0.031	0.175	0.217
Feb	1.079	1.566	1.451	0.072	0.061	0.175	0.247
Mar	1.947	2.066	1.062	0.076	0.076	0.175	0.252
Apr	1.583	1.767	1.117	0.111	0.107	0.175	0.287
May	1.303	1.955	1.501	0.200	0.107	0.000	0.200
Jun	0.746	0.805	1.079	0.195	0.107	0.000	0.195
Jul	0.833	1.009	1.212	0.151	0.076	0.000	0.151
Aug	1.435	2.244	1.563	0.202	0.107	0.000	0.202
Sep	1.712	2.148	1.255	0.186	0.061	0.000	0.186

Table 11.8 Rule tables for D-Category EWRs at Gwa 1

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.322	0.296	0.272	0.249	0.208	0.178	0.137	0.095	0.063	0.049
Nov	0.206	0.179	0.156	0.137	0.106	0.092	0.075	0.057	0.043	0.037
Dec	0.027	0.027	0.027	0.025	0.023	0.020	0.017	0.014	0.012	0.012
Jan	0.119	0.117	0.114	0.106	0.092	0.073	0.052	0.034	0.023	0.019
Feb	0.153	0.152	0.148	0.139	0.124	0.101	0.075	0.053	0.039	0.025
Mar	0.145	0.144	0.141	0.136	0.125	0.108	0.085	0.061	0.044	0.030
Apr	0.173	0.172	0.170	0.164	0.152	0.133	0.106	0.079	0.059	0.035
May	0.134	0.134	0.132	0.128	0.120	0.105	0.085	0.063	0.048	0.034
Jun	0.141	0.141	0.140	0.137	0.131	0.119	0.081	0.054	0.046	0.031
Jul	0.105	0.105	0.104	0.102	0.097	0.089	0.075	0.056	0.039	0.030
Aug	0.141	0.141	0.139	0.136	0.130	0.118	0.100	0.077	0.054	0.041
Sep	0.129	0.128	0.127	0.122	0.113	0.097	0.074	0.051	0.033	0.025
Reserve Flows without High Flows										
Oct	0.176	0.175	0.172	0.166	0.153	0.132	0.103	0.074	0.051	0.042
Nov	0.054	0.054	0.053	0.052	0.050	0.046	0.041	0.035	0.031	0.030
Dec	0.027	0.027	0.027	0.025	0.023	0.020	0.017	0.014	0.012	0.012
Jan	0.028	0.027	0.027	0.026	0.023	0.020	0.017	0.014	0.012	0.012
Feb	0.053	0.052	0.051	0.050	0.046	0.041	0.035	0.030	0.027	0.025
Mar	0.052	0.052	0.052	0.050	0.048	0.044	0.039	0.034	0.030	0.029
Apr	0.078	0.078	0.077	0.075	0.072	0.066	0.058	0.050	0.044	0.035
May	0.134	0.134	0.132	0.128	0.120	0.105	0.085	0.063	0.048	0.034
Jun	0.141	0.141	0.140	0.137	0.131	0.119	0.081	0.054	0.046	0.031
Jul	0.105	0.105	0.104	0.102	0.097	0.089	0.075	0.056	0.039	0.030
Aug	0.141	0.141	0.139	0.136	0.130	0.118	0.100	0.077	0.054	0.041
Sep	0.129	0.128	0.127	0.122	0.113	0.097	0.074	0.051	0.033	0.025
Natural Duration curves										
Oct	1.803	1.363	0.829	0.676	0.478	0.291	0.168	0.131	0.082	0.049
Nov	1.983	1.316	0.829	0.513	0.266	0.154	0.131	0.104	0.073	0.042
Dec	1.322	0.821	0.482	0.287	0.172	0.149	0.112	0.082	0.049	0.030
Jan	1.228	0.698	0.355	0.213	0.161	0.138	0.090	0.067	0.037	0.026
Feb	1.236	0.715	0.484	0.227	0.157	0.128	0.099	0.079	0.054	0.025
Mar	1.800	1.120	0.881	0.721	0.541	0.448	0.127	0.075	0.049	0.030
Apr	1.431	0.880	0.664	0.517	0.424	0.324	0.193	0.127	0.077	0.035
May	1.131	0.773	0.463	0.329	0.213	0.146	0.090	0.063	0.052	0.034
Jun	0.799	0.455	0.301	0.247	0.201	0.135	0.081	0.054	0.046	0.031
Jul	0.866	0.526	0.355	0.198	0.146	0.108	0.078	0.056	0.049	0.041
Aug	1.523	0.642	0.474	0.336	0.261	0.172	0.119	0.082	0.063	0.041
Sep	1.640	1.053	0.637	0.463	0.359	0.255	0.174	0.112	0.066	0.058

11.5 SWART RIVER (Sw 1)

The Garden Route Dam is situated on the Swart River just upstream of Reach Sw 1 (referred to as Sw 2 in Brown, 2005). The location is significant because the ecological condition of the Swart River is markedly lower in the section downstream of the dam, viz. B/C-Category

upstream (Dr C. Brown, pers. obs.) and D-Category downstream of the dam. The two facts are not unrelated, and the presence of the dam is a major contributing factor in the decline in ecological condition (see Brown, 2005 for more detail). Other contributing factors include: encroachment of alien vegetation (partly related to a reduction in floods) and manual manipulation of the river channel (mainly associated with roads). Only a D-Category determination was done for the Swart River, as it was the opinion of the specialists that additional flow would not necessarily translate into better ecological condition.

PES = D-Category.



Figure 11.7 Swart River at Old George-Knysna Road (Sw 1)

REC: D-CATEGORY

Table 11.9 Summary table for D-Category EWRs at Sw 1

Desktop Version 2, Generated on 6/7/2007

Total Runoff : Runoff : SSwart

Annual Flows (Mill. cu. m or index values):

MAR	=	12.987
S.Dev.	=	5.655
CV	=	0.435
Q75	=	0.340
Q75/MMF	=	0.314
BFI Index	=	0.392
CV(JJA+JFM) Index	=	2.054

Ecological Category = D

Total IFR	=	1.827	(14.07 %MAR)
Maint. Lowflow	=	1.558	(12.00 %MAR)
Drought Lowflow	=	1.558	(12.00 %MAR)
Maint. Highflow	=	0.268	(2.07 %MAR)

Monthly Distributions (Mill. cu. m.)

Distribution Type : S.Cape(wet)

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High	Flows Total
Flows	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.410	1.085	0.770	0.172	0.172	0.000	0.172
Nov	1.410	1.487	1.054	0.139	0.139	0.000	0.139
Dec	1.083	1.216	1.122	0.122	0.122	0.000	0.122
Jan	0.946	0.988	1.044	0.073	0.073	0.000	0.073
Feb	0.881	0.945	1.072	0.110	0.110	0.000	0.110
Mar	1.358	1.250	0.921	0.099	0.099	0.134	0.234
Apr	1.169	1.091	0.933	0.160	0.160	0.134	0.294
May	1.001	1.213	1.212	0.143	0.143	0.000	0.143
Jun	0.631	0.562	0.891	0.117	0.117	0.000	0.117
Jul	0.708	0.699	0.988	0.122	0.122	0.000	0.122
Aug	1.097	1.367	1.246	0.161	0.161	0.000	0.161
Sep	1.292	1.339	1.036	0.141	0.141	0.000	0.141

Table 11.10 Rule tables for D-Category EWRs at Sw 1

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.116	0.116	0.115	0.113	0.108	0.100	0.089	0.077	0.069	0.052
Nov	0.098	0.098	0.097	0.095	0.090	0.083	0.074	0.064	0.057	0.031
Dec	0.081	0.080	0.079	0.077	0.072	0.065	0.058	0.051	0.041	0.015
Jan	0.049	0.049	0.048	0.046	0.043	0.039	0.035	0.031	0.028	0.015
Feb	0.081	0.080	0.079	0.077	0.072	0.065	0.058	0.051	0.047	0.017
Mar	0.139	0.138	0.136	0.131	0.121	0.106	0.086	0.065	0.050	0.026
Apr	0.185	0.184	0.182	0.176	0.165	0.147	0.122	0.096	0.077	0.039
May	0.096	0.096	0.095	0.093	0.089	0.083	0.074	0.064	0.057	0.030
Jun	0.084	0.084	0.084	0.083	0.080	0.076	0.069	0.059	0.042	0.015
Jul	0.084	0.084	0.084	0.083	0.080	0.076	0.069	0.060	0.051	0.041
Aug	0.113	0.113	0.112	0.110	0.107	0.101	0.092	0.079	0.068	0.037
Sep	0.098	0.097	0.097	0.095	0.091	0.084	0.075	0.066	0.058	0.055
Reserve Flows without High Flows										
Oct	0.116	0.116	0.115	0.113	0.108	0.100	0.089	0.077	0.069	0.052
Nov	0.098	0.098	0.097	0.095	0.090	0.083	0.074	0.064	0.057	0.031
Dec	0.081	0.080	0.079	0.077	0.072	0.065	0.058	0.051	0.041	0.015
Jan	0.049	0.049	0.048	0.046	0.043	0.039	0.035	0.031	0.028	0.015
Feb	0.081	0.080	0.079	0.077	0.072	0.065	0.058	0.051	0.047	0.017
Mar	0.068	0.068	0.067	0.066	0.062	0.058	0.051	0.045	0.040	0.026
Apr	0.112	0.112	0.111	0.109	0.104	0.096	0.085	0.074	0.066	0.039
May	0.096	0.096	0.095	0.093	0.089	0.083	0.074	0.064	0.057	0.030
Jun	0.084	0.084	0.084	0.083	0.080	0.076	0.069	0.059	0.042	0.015
Jul	0.084	0.084	0.084	0.083	0.080	0.076	0.069	0.060	0.051	0.041
Aug	0.113	0.113	0.112	0.110	0.107	0.101	0.092	0.079	0.068	0.037
Sep	0.098	0.097	0.097	0.095	0.091	0.084	0.075	0.066	0.058	0.055
Natural Duration curves										
Oct	1.169	0.933	0.676	0.497	0.411	0.317	0.239	0.190	0.119	0.052
Nov	1.277	0.895	0.660	0.440	0.332	0.231	0.181	0.135	0.085	0.031
Dec	0.904	0.620	0.534	0.358	0.254	0.213	0.164	0.105	0.041	0.015
Jan	0.814	0.541	0.396	0.310	0.250	0.202	0.123	0.082	0.030	0.015
Feb	0.823	0.575	0.455	0.310	0.223	0.194	0.149	0.107	0.070	0.017
Mar	1.169	0.762	0.624	0.515	0.396	0.336	0.157	0.116	0.063	0.026
Apr	0.965	0.633	0.532	0.417	0.343	0.258	0.201	0.150	0.085	0.039
May	0.777	0.582	0.362	0.265	0.217	0.183	0.134	0.082	0.063	0.030
Jun	0.575	0.397	0.274	0.216	0.204	0.166	0.096	0.066	0.042	0.015
Jul	0.668	0.429	0.291	0.235	0.175	0.131	0.090	0.071	0.056	0.041
Aug	1.045	0.545	0.388	0.284	0.235	0.205	0.153	0.108	0.082	0.037
Sep	1.146	0.791	0.559	0.374	0.289	0.251	0.197	0.154	0.093	0.066

11.6 SILVER RIVER (Si 1)

The bridge on old Knysna –George Road is situated on the Silver River just within the Reach Si 1, with typical tannin rich dark waters of the acidic system. The location is significant because of the presence of nearby gauging weir and also a variety of substrates present (i.e. Bedrock, boulders and cobble bed). The hydrology and macroinvertebrates were in very good conditions. The most widespread tree species was the exotic invasive *Acacia melanoxylon* (blackwood). The underlying geology is Bokkeveld Group shale. The contributing factors to the current B-Category were mainly encroachment of alien vegetation, and unstable geomorphology. It was the opinion of the specialists that additional flow would not necessarily translate into better ecological condition. For this reason, the Reserves have been determined (using the desktop), for a C and B- categories, with the latter the Recommended Ecological Category and the former an Alternative Ecological Category.

PES = B-Category.

REC: B-CATEGORY.

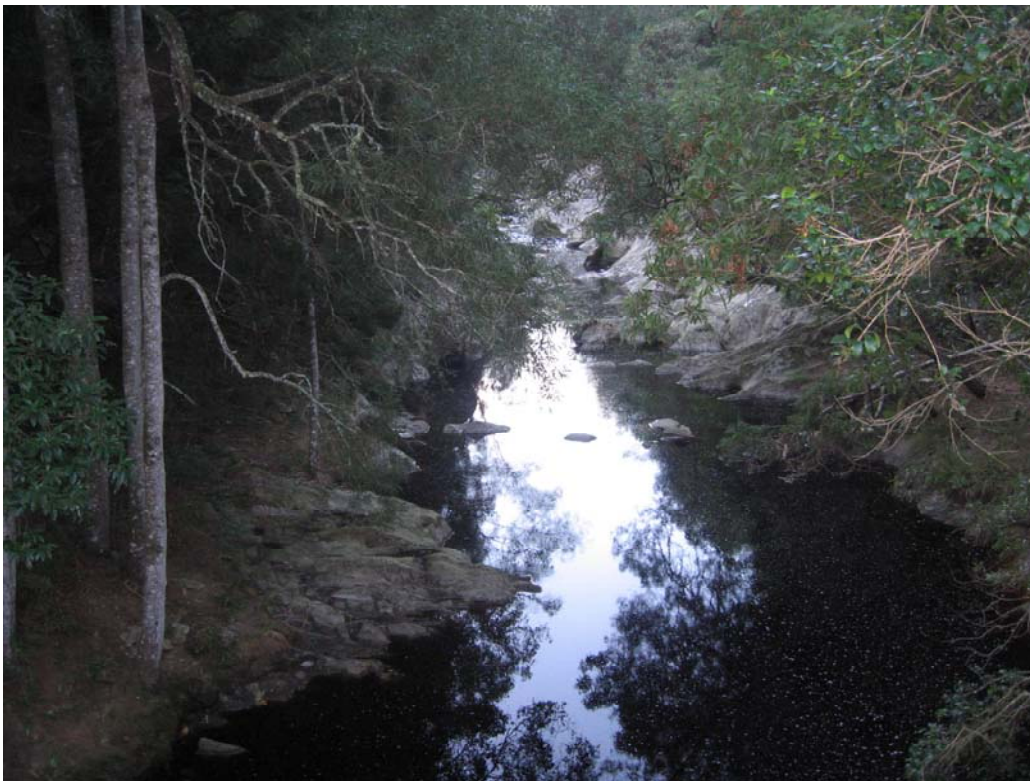


Figure 11.8 Silver River at Old George-Knysna Road (Si 1)

Table 11.11 Summary table for B-Category EWRs at Si 1

Desktop Version 2, Generated on 6/7/2007							
Summary of Desktop (Version 2)							
Total Runoff : Runoff : SSilve							
Annual Flows (Mill. cu. m or index values):							
MAR	=		7.908				
S.Dev.	=		3.493				
CV	=		0.442				
Q75	=		0.200				
Q75/MMF	=		0.303				
BFI Index	=		0.375				
CV(JJA+JFM) Index	=		2.079				
Ecological Category = B							
Total IFR	=		3.168	(40.06 %MAR)			
Maint. Lowflow	=		1.959	(24.77 %MAR)			
Drought Lowflow	=		0.949	(12.00 %MAR)			
Maint. Highflow	=		1.209	(15.29 %MAR)			
Monthly Distributions (Mill. cu. m.)							
Distribution Type : S.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total
Flows	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.862	0.669	0.777	0.206	0.105	0.759	0.964
Nov	0.862	0.920	1.068	0.176	0.085	0.000	0.176
Dec	0.657	0.753	1.145	0.159	0.074	0.000	0.159
Jan	0.572	0.609	1.065	0.145	0.045	0.000	0.145
Feb	0.533	0.582	1.092	0.138	0.067	0.000	0.138
Mar	0.825	0.772	0.936	0.173	0.061	0.082	0.254
Apr	0.712	0.674	0.947	0.176	0.098	0.082	0.258
May	0.611	0.748	1.225	0.170	0.087	0.000	0.170
Jun	0.385	0.344	0.894	0.145	0.071	0.000	0.145
Jul	0.430	0.426	0.991	0.136	0.074	0.000	0.136
Aug	0.671	0.845	1.259	0.166	0.098	0.082	0.248
Sep	0.790	0.828	1.048	0.169	0.086	0.206	0.375

Table 11.12 Rule tables for B-Category EWRs at Si 1

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.717	0.571	0.411	0.299	0.246	0.186	0.123	0.086	0.071	0.034
Nov	0.088	0.087	0.083	0.074	0.061	0.047	0.039	0.034	0.033	0.019
Dec	0.077	0.075	0.070	0.061	0.048	0.037	0.031	0.029	0.026	0.011
Jan	0.070	0.068	0.061	0.048	0.033	0.023	0.019	0.017	0.017	0.011
Feb	0.074	0.073	0.068	0.059	0.047	0.036	0.031	0.029	0.028	0.012
Mar	0.118	0.116	0.109	0.094	0.072	0.050	0.036	0.028	0.026	0.015
Apr	0.124	0.123	0.118	0.108	0.092	0.072	0.056	0.046	0.042	0.023
May	0.082	0.081	0.079	0.073	0.064	0.053	0.043	0.036	0.033	0.019
Jun	0.072	0.072	0.070	0.066	0.059	0.050	0.041	0.033	0.027	0.012
Jul	0.066	0.065	0.064	0.062	0.058	0.052	0.044	0.036	0.031	0.022
Aug	0.153	0.138	0.125	0.111	0.091	0.076	0.061	0.049	0.042	0.022
Sep	0.284	0.239	0.202	0.167	0.118	0.090	0.066	0.050	0.043	0.042
Reserve Flows without High Flows										
Oct	0.099	0.098	0.095	0.088	0.076	0.062	0.050	0.043	0.040	0.034
Nov	0.088	0.087	0.083	0.074	0.061	0.047	0.039	0.034	0.033	0.019
Dec	0.077	0.075	0.070	0.061	0.048	0.037	0.031	0.029	0.026	0.011
Jan	0.070	0.068	0.061	0.048	0.033	0.023	0.019	0.017	0.017	0.011
Feb	0.074	0.073	0.068	0.059	0.047	0.036	0.031	0.029	0.028	0.012
Mar	0.083	0.082	0.077	0.068	0.053	0.039	0.029	0.024	0.023	0.015
Apr	0.088	0.087	0.084	0.078	0.068	0.057	0.047	0.041	0.038	0.023
May	0.082	0.081	0.079	0.073	0.064	0.053	0.043	0.036	0.033	0.019
Jun	0.072	0.072	0.070	0.066	0.059	0.050	0.041	0.033	0.027	0.012
Jul	0.066	0.065	0.064	0.062	0.058	0.052	0.044	0.036	0.031	0.022
Aug	0.080	0.080	0.078	0.074	0.068	0.059	0.050	0.042	0.038	0.022
Sep	0.085	0.084	0.081	0.075	0.065	0.054	0.044	0.037	0.034	0.033
Natural Duration curves										
Oct	0.717	0.571	0.411	0.299	0.246	0.190	0.146	0.116	0.071	0.034
Nov	0.783	0.544	0.401	0.270	0.197	0.139	0.108	0.081	0.050	0.019
Dec	0.553	0.385	0.321	0.213	0.149	0.127	0.097	0.060	0.026	0.011
Jan	0.497	0.325	0.235	0.187	0.149	0.123	0.075	0.049	0.019	0.011
Feb	0.500	0.343	0.273	0.186	0.132	0.116	0.087	0.066	0.041	0.012
Mar	0.717	0.463	0.377	0.306	0.235	0.198	0.093	0.067	0.037	0.015
Apr	0.594	0.390	0.320	0.251	0.208	0.154	0.120	0.089	0.050	0.023
May	0.474	0.351	0.217	0.161	0.134	0.108	0.082	0.049	0.037	0.019
Jun	0.347	0.243	0.162	0.131	0.120	0.100	0.058	0.039	0.027	0.012
Jul	0.403	0.258	0.183	0.146	0.108	0.078	0.056	0.045	0.034	0.022
Aug	0.638	0.329	0.239	0.172	0.142	0.123	0.093	0.067	0.052	0.022
Sep	0.706	0.478	0.347	0.228	0.174	0.154	0.120	0.093	0.058	0.042

AEC: C-CATEGORY

Table 11.13 Summary table for C-Category EWRs at Si 1

Desktop Version 2, Generated on 6/7/2007

Summary of Desktop (Version 2) estimate for Quaternary Catchment

Area :

Total Runoff : Runoff : SSilve

Annual Flows (Mill. cu. m or index values):

MAR = 7.908

S.Dev. = 3.493

CV = 0.442

Q75 = 0.200

Q75/MMF = 0.303

BFI Index = 0.391

CV(JJA+JFM) Index = 2.079

Ecological Category = C

Total IFR = 2.477 (31.32 %MAR)

Maint. Lowflow = 1.739 (21.99 %MAR)

Drought Lowflow = 0.927 (11.72 %MAR)

Maint. Highflow = 0.738 (9.33 %MAR)

Monthly Distributions (Mill. cu. m.)

Distribution Type : S.Cape(wet)

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High	Flows Total
Flows	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.862	0.669	0.777	0.172	0.100	0.206	0.378
Nov	0.862	0.920	1.068	0.202	0.082	0.082	0.283
Dec	0.657	0.753	1.145	0.159	0.071	0.000	0.159
Jan	0.572	0.609	1.065	0.145	0.059	0.000	0.145
Feb	0.533	0.582	1.092	0.138	0.059	0.000	0.138
Mar	0.825	0.772	0.936	0.173	0.059	0.082	0.254
Apr	0.712	0.674	0.947	0.196	0.082	0.082	0.278
May	0.611	0.748	1.225	0.129	0.087	0.000	0.129
Jun	0.385	0.344	0.894	0.092	0.071	0.000	0.092
Jul	0.430	0.426	0.991	0.096	0.074	0.000	0.096
Aug	0.671	0.845	1.259	0.120	0.098	0.082	0.202
Sep	0.790	0.828	1.048	0.117	0.086	0.206	0.323

Table 11.14 Rule tables for C-Category EWRs at Si 1

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.261	0.230	0.205	0.183	0.145	0.127	0.101	0.075	0.055	0.034
Nov	0.180	0.167	0.155	0.143	0.121	0.105	0.083	0.060	0.043	0.019
Dec	0.083	0.082	0.080	0.076	0.069	0.058	0.046	0.036	0.026	0.011
Jan	0.077	0.076	0.074	0.070	0.062	0.052	0.040	0.031	0.019	0.011
Feb	0.080	0.079	0.077	0.073	0.066	0.056	0.044	0.033	0.027	0.012
Mar	0.127	0.126	0.124	0.119	0.109	0.092	0.071	0.049	0.033	0.015
Apr	0.142	0.142	0.140	0.134	0.124	0.108	0.085	0.062	0.044	0.023
May	0.066	0.066	0.065	0.064	0.061	0.056	0.049	0.041	0.035	0.019
Jun	0.049	0.049	0.049	0.048	0.047	0.044	0.040	0.035	0.027	0.012
Jul	0.048	0.048	0.048	0.048	0.046	0.044	0.040	0.035	0.031	0.022
Aug	0.126	0.116	0.108	0.100	0.087	0.081	0.071	0.059	0.047	0.022
Sep	0.239	0.208	0.183	0.161	0.125	0.110	0.089	0.067	0.050	0.042
Reserve Flows without High Flows										
Oct	0.089	0.089	0.088	0.085	0.080	0.072	0.061	0.050	0.042	0.034
Nov	0.109	0.109	0.107	0.103	0.095	0.083	0.067	0.050	0.038	0.019
Dec	0.083	0.082	0.080	0.076	0.069	0.058	0.046	0.036	0.026	0.011
Jan	0.077	0.076	0.074	0.070	0.062	0.052	0.040	0.031	0.019	0.011
Feb	0.080	0.079	0.077	0.073	0.066	0.056	0.044	0.033	0.027	0.012
Mar	0.091	0.090	0.088	0.085	0.078	0.067	0.053	0.038	0.028	0.015
Apr	0.105	0.104	0.103	0.099	0.093	0.081	0.066	0.050	0.038	0.023
May	0.066	0.066	0.065	0.064	0.061	0.056	0.049	0.041	0.035	0.019
Jun	0.049	0.049	0.049	0.048	0.047	0.044	0.040	0.035	0.027	0.012
Jul	0.048	0.048	0.048	0.048	0.046	0.044	0.040	0.035	0.031	0.022
Aug	0.062	0.062	0.062	0.061	0.059	0.056	0.052	0.046	0.040	0.022
Sep	0.062	0.062	0.061	0.060	0.057	0.053	0.047	0.040	0.036	0.033
Natural Duration curves										
Oct	0.717	0.571	0.411	0.299	0.246	0.190	0.146	0.116	0.071	0.034
Nov	0.783	0.544	0.401	0.270	0.197	0.139	0.108	0.081	0.050	0.019
Dec	0.553	0.385	0.321	0.213	0.149	0.127	0.097	0.060	0.026	0.011
Jan	0.497	0.325	0.235	0.187	0.149	0.123	0.075	0.049	0.019	0.011
Feb	0.500	0.343	0.273	0.186	0.132	0.116	0.087	0.066	0.041	0.012
Mar	0.717	0.463	0.377	0.306	0.235	0.198	0.093	0.067	0.037	0.015
Apr	0.594	0.390	0.320	0.251	0.208	0.154	0.120	0.089	0.050	0.023
May	0.474	0.351	0.217	0.161	0.134	0.108	0.082	0.049	0.037	0.019
Jun	0.347	0.243	0.162	0.131	0.120	0.100	0.058	0.039	0.027	0.012
Jul	0.403	0.258	0.183	0.146	0.108	0.078	0.056	0.045	0.034	0.022
Aug	0.638	0.329	0.239	0.172	0.142	0.123	0.093	0.067	0.052	0.022
Sep	0.706	0.478	0.347	0.228	0.174	0.154	0.120	0.093	0.058	0.042

11.7 NOETSIE RIVER

Taken in its totality, the PES of the Noetsie River is a B Category. However, there are sections of the river that are in a high A/B Category. For this reason, the Reserve has been determined (using the desktop), for a C-, B- and an A/B Category, with the latter the REC. The results are slightly HIGHER (%MAR) than previously recommended (*viz.* 51% for an A Category). The reason for this is that – here, the Desktop has been calibrated using the outputs from the Intermediate Reserve Determination study (using Ka 1 and Gou 1) whereas previously there were no studies that could be used to calibrate the Desktop for this region, thus the extrapolated values were from outside the study area. The main difference between the results lies in the recognition, of the extremely strong perennial nature of the systems. The Reserve is for the whole river, i.e., compliance should be monitored at the head of the estuary.

PES = B-Category overall, but with A-A/B in large (middle) reaches.

REC: A/B-CATEGORY

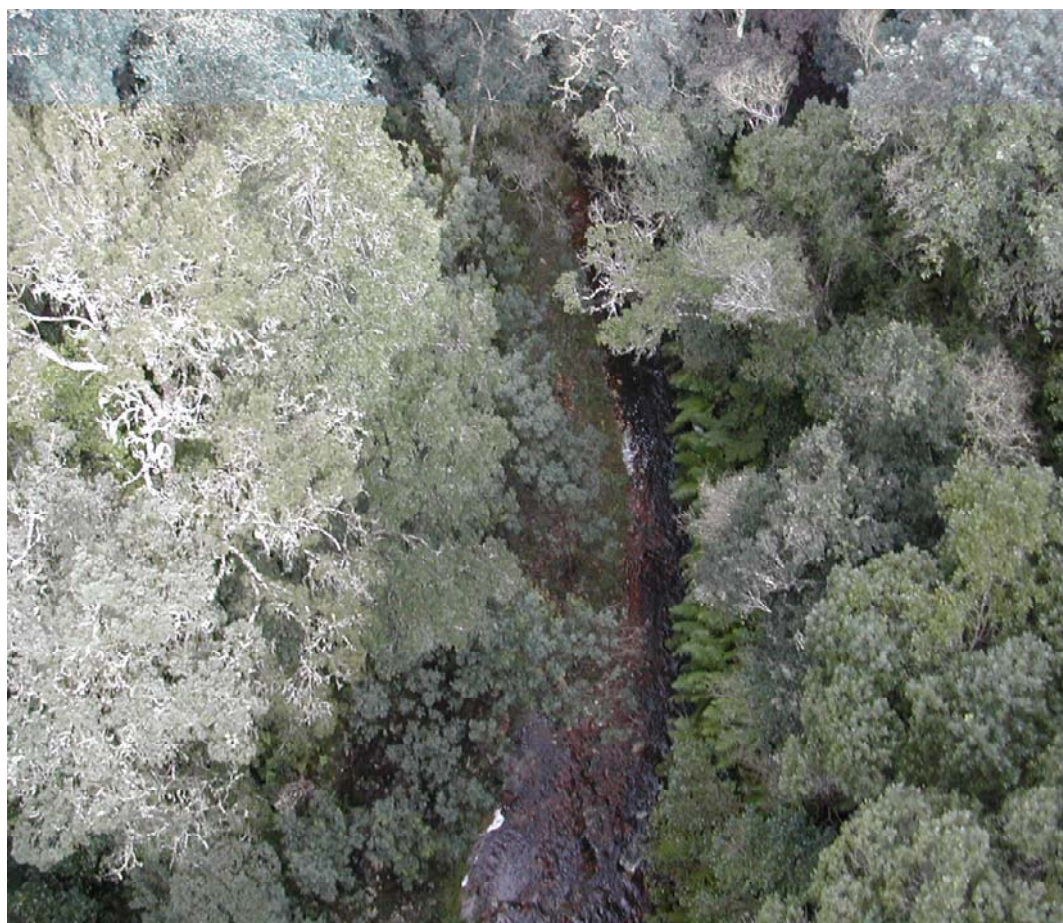


Figure 11.9 Noetsie River – middle reaches

Table 11.15 Summary table for A/B-Category EWRs for the Noetsie River

Desktop Version 2, Generated on 8/15/2007							
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :							
Total Runoff : Runoff : NNoets							
Annual Flows (Mill. cu. m or index values):							
MAR	=		6.398				
S.Dev.	=		3.033				
CV	=		0.474				
Q75	=		0.240				
Q75/MMF	=		0.450				
CV(JJA+JFM) Index	=		1.760				
Ecological Category = A/B							
Total IFR	=		3.837	(59.97 %MAR)			
Maint. Lowflow	=		1.801	(28.15 %MAR)			
Drought Lowflow	=		0.831	(12.99 %MAR)			
Maint. Highflow	=		2.036	(31.82 %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	0.844	0.586	0.694	0.205	0.064	0.000	0.205
Nov	0.695	0.426	0.613	0.186	0.062	0.273	0.460
Dec	0.493	0.427	0.865	0.154	0.064	0.090	0.243
Jan	0.339	0.264	0.780	0.128	0.038	0.000	0.128
Feb	0.269	0.200	0.742	0.116	0.058	0.273	0.389
Mar	0.310	0.285	0.921	0.154	0.128	0.376	0.530
Apr	0.363	0.391	1.078	0.186	0.087	0.656	0.842
May	0.499	0.722	1.446	0.167	0.077	0.000	0.167
Jun	0.448	0.362	0.808	0.124	0.062	0.000	0.124
Jul	0.518	0.484	0.935	0.128	0.064	0.000	0.128
Aug	0.755	0.825	1.092	0.128	0.064	0.000	0.128
Sep	0.866	0.739	0.853	0.124	0.062	0.367	0.491

Table 11.16 Rule tables for A/B-Category EWRs for the Noetsie River

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.092	0.092	0.091	0.090	0.087	0.081	0.071	0.055	0.036	0.024
Nov	0.201	0.201	0.200	0.196	0.189	0.175	0.150	0.112	0.065	0.036
Dec	0.105	0.105	0.104	0.102	0.097	0.088	0.073	0.054	0.036	0.028
Jan	0.057	0.057	0.057	0.055	0.053	0.048	0.039	0.029	0.019	0.015
Feb	0.181	0.149	0.116	0.103	0.087	0.079	0.070	0.058	0.045	0.036
Mar	0.202	0.153	0.123	0.101	0.082	0.075	0.060	0.060	0.045	0.030
Apr	0.216	0.162	0.143	0.116	0.104	0.089	0.077	0.066	0.054	0.039
May	0.074	0.074	0.074	0.073	0.071	0.067	0.060	0.050	0.037	0.029
Jun	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.044	0.034	0.024
Jul	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.044	0.034	0.024
Aug	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.044	0.034	0.024
Sep	0.332	0.296	0.266	0.240	0.215	0.173	0.149	0.112	0.068	0.039
Reserve Flows without High Flows										
Oct	0.092	0.092	0.091	0.090	0.087	0.081	0.071	0.055	0.036	0.024
Nov	0.086	0.086	0.085	0.084	0.081	0.076	0.067	0.053	0.035	0.024
Dec	0.069	0.069	0.068	0.067	0.064	0.059	0.050	0.039	0.029	0.024
Jan	0.057	0.057	0.057	0.055	0.053	0.048	0.039	0.029	0.019	0.015
Feb	0.057	0.057	0.057	0.056	0.054	0.050	0.043	0.035	0.028	0.024
Mar	0.069	0.069	0.069	0.068	0.067	0.066	0.060	0.058	0.045	0.030
Apr	0.086	0.086	0.085	0.084	0.082	0.078	0.070	0.058	0.043	0.034
May	0.074	0.074	0.074	0.073	0.071	0.067	0.060	0.050	0.037	0.029
Jun	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.044	0.034	0.024
Jul	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.044	0.034	0.024
Aug	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.044	0.034	0.024
Sep	0.057	0.057	0.057	0.056	0.055	0.052	0.047	0.039	0.030	0.024
Natural Duration curves										
Oct	0.635	0.411	0.340	0.265	0.235	0.209	0.187	0.183	0.153	0.108
Nov	0.490	0.355	0.316	0.247	0.216	0.197	0.162	0.150	0.131	0.093
Dec	0.310	0.228	0.194	0.172	0.142	0.131	0.112	0.105	0.082	0.063
Jan	0.220	0.142	0.131	0.123	0.105	0.093	0.082	0.071	0.060	0.045
Feb	0.190	0.149	0.116	0.103	0.087	0.079	0.070	0.058	0.045	0.037
Mar	0.202	0.153	0.123	0.101	0.082	0.075	0.060	0.060	0.045	0.030
Apr	0.216	0.162	0.143	0.116	0.104	0.089	0.077	0.066	0.054	0.039
May	0.366	0.202	0.157	0.131	0.112	0.097	0.082	0.071	0.060	0.034
Jun	0.351	0.239	0.185	0.154	0.131	0.120	0.100	0.077	0.058	0.039
Jul	0.314	0.231	0.205	0.183	0.149	0.127	0.116	0.105	0.078	0.052
Aug	0.568	0.310	0.265	0.224	0.198	0.172	0.149	0.131	0.108	0.075
Sep	0.737	0.424	0.324	0.274	0.228	0.208	0.181	0.166	0.143	0.085

AEC: B-CATEGORY
Table 11.17 Summary table for B-Category EWRs for the Noetsie River

Desktop Version 2, Generated on 8/15/2007							
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :							
Total Runoff : Runoff : NNoets							
Annual Flows (Mill. cu. m or index values):							
MAR	=	6.398					
S.Dev.	=	3.033					
CV	=	0.474					
Q75	=	0.240					
Q75/MMF	=	0.450					
BFI Index	=	0.542					
CV(JJA+JFM) Index	=	1.760					
Ecological Category = B							
Total IFR	=	3.378	(52.80 %MAR)				
Maint. Lowflow	=	1.585	(24.77 %MAR)				
Drought Lowflow	=	0.682	(10.65 %MAR)				
Maint. Highflow	=	1.793	(28.03 %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	0.844	0.586	0.694	0.166	0.064	0.614	0.780
Nov	0.695	0.426	0.613	0.143	0.062	0.000	0.143
Dec	0.493	0.427	0.865	0.128	0.060	0.000	0.128
Jan	0.339	0.264	0.780	0.117	0.025	0.000	0.117
Feb	0.269	0.200	0.742	0.112	0.054	0.332	0.444
Mar	0.310	0.285	0.921	0.140	0.049	0.066	0.206
Apr	0.363	0.391	1.078	0.143	0.062	0.549	0.692
May	0.499	0.722	1.446	0.137	0.064	0.000	0.137
Jun	0.448	0.362	0.808	0.117	0.058	0.000	0.117
Jul	0.518	0.484	0.935	0.110	0.060	0.000	0.110
Aug	0.755	0.825	1.092	0.135	0.064	0.066	0.201
Sep	0.866	0.739	0.853	0.137	0.062	0.166	0.303

Table 11.18 Rule tables for B-Category EWRs for the Noetsie River

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.325	0.325	0.322	0.265	0.235	0.209	0.187	0.176	0.098	0.048
Nov	0.066	0.066	0.065	0.065	0.063	0.059	0.053	0.043	0.032	0.024
Dec	0.057	0.057	0.057	0.056	0.054	0.050	0.043	0.034	0.026	0.023
Jan	0.052	0.052	0.052	0.051	0.048	0.043	0.035	0.024	0.014	0.010
Feb	0.190	0.149	0.116	0.103	0.087	0.079	0.070	0.058	0.045	0.037
Mar	0.089	0.089	0.089	0.087	0.082	0.075	0.060	0.053	0.033	0.021
Apr	0.216	0.162	0.143	0.116	0.104	0.089	0.077	0.066	0.054	0.039
May	0.061	0.061	0.061	0.060	0.059	0.055	0.050	0.041	0.031	0.024
Jun	0.054	0.054	0.054	0.053	0.052	0.051	0.048	0.042	0.032	0.022
Jul	0.049	0.049	0.049	0.049	0.048	0.047	0.044	0.039	0.031	0.023
Aug	0.104	0.099	0.095	0.091	0.087	0.079	0.073	0.062	0.045	0.027
Sep	0.188	0.172	0.158	0.145	0.133	0.112	0.097	0.075	0.048	0.031
Reserve Flows without High Flows										
Oct	0.074	0.074	0.074	0.073	0.071	0.066	0.059	0.047	0.033	0.024
Nov	0.066	0.066	0.065	0.065	0.063	0.059	0.053	0.043	0.032	0.024
Dec	0.057	0.057	0.057	0.056	0.054	0.050	0.043	0.034	0.026	0.023
Jan	0.052	0.052	0.052	0.051	0.048	0.043	0.035	0.024	0.014	0.010
Feb	0.055	0.055	0.055	0.054	0.052	0.048	0.042	0.033	0.026	0.023
Mar	0.062	0.062	0.062	0.061	0.059	0.055	0.049	0.039	0.026	0.019
Apr	0.066	0.066	0.065	0.065	0.063	0.059	0.053	0.043	0.032	0.024
May	0.061	0.061	0.061	0.060	0.059	0.055	0.050	0.041	0.031	0.024
Jun	0.054	0.054	0.054	0.053	0.052	0.051	0.048	0.042	0.032	0.022
Jul	0.049	0.049	0.049	0.049	0.048	0.047	0.044	0.039	0.031	0.023
Aug	0.060	0.060	0.060	0.059	0.058	0.056	0.053	0.046	0.035	0.024
Sep	0.063	0.063	0.063	0.062	0.060	0.057	0.051	0.042	0.031	0.024
Natural Duration curves										
Oct	0.635	0.411	0.340	0.265	0.235	0.209	0.187	0.183	0.153	0.108
Nov	0.490	0.355	0.316	0.247	0.216	0.197	0.162	0.150	0.131	0.093
Dec	0.310	0.228	0.194	0.172	0.142	0.131	0.112	0.105	0.082	0.063
Jan	0.220	0.142	0.131	0.123	0.105	0.093	0.082	0.071	0.060	0.045
Feb	0.190	0.149	0.116	0.103	0.087	0.079	0.070	0.058	0.045	0.037
Mar	0.202	0.153	0.123	0.101	0.082	0.075	0.060	0.060	0.045	0.030
Apr	0.216	0.162	0.143	0.116	0.104	0.089	0.077	0.066	0.054	0.039
May	0.366	0.202	0.157	0.131	0.112	0.097	0.082	0.071	0.060	0.034
Jun	0.351	0.239	0.185	0.154	0.131	0.120	0.100	0.077	0.058	0.039
Jul	0.314	0.231	0.205	0.183	0.149	0.127	0.116	0.105	0.078	0.052
Aug	0.568	0.310	0.265	0.224	0.198	0.172	0.149	0.131	0.108	0.075
Sep	0.737	0.424	0.324	0.274	0.228	0.208	0.181	0.166	0.143	0.085

Table 11.19 Summary table for C-Category EWRs for the Noetsie River

Desktop Version 2, Generated on 8/15/2007

Summary of Desktop (Version 2) estimate for Quaternary Catchment

Area :

Total Runoff : Runoff : NNoets

Annual Flows (Mill. cu. m or index values):

MAR = 6.398

S.Dev. = 3.033

CV = 0.474

Q75 = 0.240

Q75/MMF = 0.450

BFI Index = 0.542

CV(JJA+JFM) Index = 1.760

Ecological Category = C

Total IFR = 2.004 (31.32 %MAR)

Maint. Lowflow = 1.407 (21.99 %MAR)

Drought Lowflow = 0.673 (10.51 %MAR)

Maint. Highflow = 0.597 (9.33 %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	0.844	0.586	0.694	0.139	0.064	0.166	0.306
Nov	0.695	0.426	0.613	0.163	0.062	0.066	0.229
Dec	0.493	0.427	0.865	0.128	0.057	0.000	0.128
Jan	0.339	0.264	0.780	0.117	0.038	0.000	0.117
Feb	0.269	0.200	0.742	0.112	0.046	0.000	0.112
Mar	0.310	0.285	0.921	0.140	0.038	0.066	0.206
Apr	0.363	0.391	1.078	0.159	0.062	0.066	0.225
May	0.499	0.722	1.446	0.105	0.064	0.000	0.105
Jun	0.448	0.362	0.808	0.075	0.058	0.000	0.075
Jul	0.518	0.484	0.935	0.077	0.060	0.000	0.077
Aug	0.755	0.825	1.092	0.097	0.064	0.066	0.164
Sep	0.866	0.739	0.853	0.095	0.062	0.166	0.261

Table 11.20 Rule tables for C-Category EWRs for the Noetsie River

Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.147	0.147	0.146	0.143	0.138	0.128	0.111	0.084	0.052	0.031
Nov	0.118	0.118	0.117	0.115	0.112	0.104	0.090	0.069	0.043	0.027
Dec	0.065	0.065	0.064	0.063	0.060	0.055	0.047	0.036	0.026	0.022
Jan	0.059	0.059	0.059	0.058	0.055	0.049	0.041	0.029	0.019	0.015
Feb	0.063	0.063	0.062	0.061	0.058	0.053	0.044	0.034	0.024	0.019
Mar	0.102	0.102	0.101	0.100	0.082	0.075	0.060	0.056	0.033	0.017
Apr	0.116	0.116	0.115	0.113	0.104	0.089	0.077	0.066	0.043	0.027
May	0.054	0.054	0.054	0.054	0.052	0.050	0.045	0.038	0.029	0.024
Jun	0.042	0.042	0.041	0.041	0.041	0.040	0.038	0.034	0.028	0.022
Jul	0.042	0.042	0.042	0.041	0.041	0.040	0.038	0.034	0.028	0.022
Aug	0.096	0.092	0.088	0.084	0.080	0.072	0.067	0.058	0.042	0.027
Sep	0.176	0.159	0.145	0.133	0.122	0.102	0.089	0.069	0.046	0.031
Reserve Flows without High Flows										
Oct	0.072	0.072	0.072	0.071	0.069	0.065	0.058	0.046	0.033	0.024
Nov	0.088	0.088	0.087	0.086	0.083	0.078	0.068	0.053	0.036	0.024
Dec	0.065	0.065	0.064	0.063	0.060	0.055	0.047	0.036	0.026	0.022
Jan	0.059	0.059	0.059	0.058	0.055	0.049	0.041	0.029	0.019	0.015
Feb	0.063	0.063	0.062	0.061	0.058	0.053	0.044	0.034	0.024	0.019
Mar	0.073	0.073	0.072	0.071	0.068	0.064	0.055	0.041	0.025	0.015
Apr	0.085	0.085	0.085	0.084	0.081	0.076	0.067	0.052	0.035	0.024
May	0.054	0.054	0.054	0.054	0.052	0.050	0.045	0.038	0.029	0.024
Jun	0.042	0.042	0.041	0.041	0.041	0.040	0.038	0.034	0.028	0.022
Jul	0.042	0.042	0.042	0.041	0.041	0.040	0.038	0.034	0.028	0.022
Aug	0.053	0.053	0.052	0.052	0.051	0.050	0.047	0.041	0.033	0.024
Sep	0.051	0.051	0.051	0.050	0.049	0.047	0.043	0.036	0.029	0.024
Natural Duration curves										
Oct	0.635	0.411	0.340	0.265	0.235	0.209	0.187	0.183	0.153	0.108
Nov	0.490	0.355	0.316	0.247	0.216	0.197	0.162	0.150	0.131	0.093
Dec	0.310	0.228	0.194	0.172	0.142	0.131	0.112	0.105	0.082	0.063
Jan	0.220	0.142	0.131	0.123	0.105	0.093	0.082	0.071	0.060	0.045
Feb	0.190	0.149	0.116	0.103	0.087	0.079	0.070	0.058	0.045	0.037
Mar	0.202	0.153	0.123	0.101	0.082	0.075	0.060	0.060	0.045	0.030
Apr	0.216	0.162	0.143	0.116	0.104	0.089	0.077	0.066	0.054	0.039
May	0.366	0.202	0.157	0.131	0.112	0.097	0.082	0.071	0.060	0.034
Jun	0.351	0.239	0.185	0.154	0.131	0.120	0.100	0.077	0.058	0.039
Jul	0.314	0.231	0.205	0.183	0.149	0.127	0.116	0.105	0.078	0.052
Aug	0.568	0.310	0.265	0.224	0.198	0.172	0.149	0.131	0.108	0.075
Sep	0.737	0.424	0.324	0.274	0.228	0.208	0.181	0.166	0.143	0.085

11.8 COMMENTS ON THE EXISTING RAPID III RESERVE FOR THE MOORDKUIL RIVER

The Rapid III Ecological Reserve determination for the Moordkuil River was conducted in 2001, and resulted in the following:

PES: B/C
Reserve: 26.22% nMAR.

When the same site was visited during this study in 2007, the PES was estimated as a D. This was largely because of (apparently fairly recent) mechanical damage to the riparian zone, and the high prevalence of alien species in the remaining riparian vegetation.

There are two main issues that arise with respect to the Ecological Reserve at this site:

- The results obtained in the current (2007) study suggest that, the 26.22% previously recommended is about right for maintenance of a B/C category. Of the sites considered in this study, GB 1 is probably the closest to the Moordkuil site and would be the one used for calibration of the Desktop. Were this to be the case, the recommended Ecological Reserve for maintaining a B/C would be in the region of 27%.
- The PES has obviously declined in the six years separating the two studies. This decline appears to have been driven by non-flow related factors. Nonetheless, it points to a failure to maintain current condition, viz. a B/C in 2001. In this regard every effort should be made to restore the river banks, reestablish a buffer area, remove the alien invasives and regain a B/C category river.

With respect to Point 1 above, please note that these figures are exclusive of floods with a return period of two years or greater, but these are required if this river is to be maintained in a B/C Category.

With respect to Point 2 above, it may be tempting to suggest that the Reserve should be decreased to that required to maintain a D-Category⁸⁶. It is the opinion of the specialists in this study (2007) that this would be counter-productive and damaging to efforts to implement the requirements of the National Water Act in other catchments (and indeed in the rest of the Klein Brak Catchment).

Please also note (E. van Niekerk, BKS, pers. comm.): The Category B/C EWR was signed-off by the DG. The hydrology and the seasonal flow distribution were however considerably changed by the Outeniqua Study because of an error in the WR90 data as a result of an inappropriate raingauge used by the WR90-study team. The signed-off EWR (based on the incorrect hydrology) requires that the flood be released in the low flow season (August) instead of November, which might have an unnecessary high impact on the yield and diversion to Klipheuwel Dam without any benefit to the river. This problem should be addressed by the RDM-Chief Directorate.

⁸⁶ The valoume of water associated with this was not determined but would probably be in the region of 17% nMAR.

12 SUMMARY RESULTS FOR RAPID RESERVE DETERMINATIONS

The summary results of REC for the Rapid EWR sites are provided in Table 12.1.

Table 12.1 The annual estimates of the Reserves for the REC for each Rapid EWR site

Method	River	Site	Portion of the EWR	PES	EIS	REC	Method/ Calculation Notation	MCMa ⁻¹	%nMAR	MCMa ⁻¹	%nMAR
								(incl. ≥1:2 year floods)		(excluding ≥1:2 year floods ⁸⁷)	
Rapid I/II (Desktop Model)	Gwaing	Gwa 1	MAINTENANCE TOTAL (Volume)	E	H	D	Calibrated Desktop			2.7	16%
	Maalgate	Maa 2	MAINTENANCE TOTAL (Volume)	D	H	D	Calibrated Desktop			5.6	16%
	Moeras	Moe 1	MAINTENANCE TOTAL (Volume)	D	H	D	Maa 2 site was used for the Reserve determination site (see Section 11.3)				
	Swart	Sw 1	MAINTENANCE TOTAL (Volume)	D	H	D	Calibrated Desktop			1.8	14%
	Silver	Si 1	MAINTENANCE TOTAL (Volume)	B	VH	B	Calibrated Desktop			3.2	40%
	Noetsie	Noe 1	MAINTENANCE TOTAL (Volume)	B	VH	A/B	Calibrated Desktop			3.8	60%
Review	Moordkuil	Moo 1	MAINTENANCE TOTAL (Volume)	D	H	B/C	Rapid III			8.9	26.2%

13 WATER QUALITY RESERVE

A general description of water quality (WQ) and delineation of the rivers studied at intermediate level into water quality sub-units (WQSUs) is provided in the Sub-study 2, Delineation Report (RDM/ K10-K30,K40E/00/CON/0207) for this project. Found in the same document are also background information on the climate, hydrology and other aspects of the area.

13.1 METHODS

13.1.1 General approach used

At present there is a relatively well-developed method (*albeit* that the documentation is scattered) for determining the WQ EWR at the Intermediate and Comprehensive level. For Rapid Reserves of all levels, WQ is not usually considered and there are no established methods (Scherman, P., CES, *pers. com.* March 2007). The approach used here was to assess the WQ situation for all study rivers (irrespective of the study level) as far as the available data would permit. As there is a limited number of monitoring stations in the catchment (and no water quality data were collected during the project), water quality was described for as much of the river system as possible (rather than just at the EWR sites). However, only the Groot Brak, Malgas, Kaaimans and Goukamma Rivers were delineated into water quality sub-units (see Section 3.3 of Sub-study 2, Report 2: Delineation Report (RDM/ K10-K30,K40E/00/CON/0207)). A resource unit is defined as a length of river for which a single description of water quality can be given.

Concurrent with the timing of this project, Dr Scherman was commissioned by the DWAF to streamline the methodology for undertaking the water quality component for all levels of EWR determinations. This work was not finalised at the time of writing this report. Thus the methods used to derive the Reference conditions (RC), Present Ecological State (PES), and Recommended Ecological Category (REC), unless otherwise stated, were taken from DWAF (Sept 2007 *in prep.*), Kleynhans, Louw, Thirion *et al.* (2006), or as described in DWAF (2006). Inconsistencies and uncertainties still existed in the WQ method, but care was taken to ensure that, as far as possible, the correct procedure was followed.

13.1.2 Availability of water quality data

A list of the DWAF water quality monitoring stations that are either situated on the rivers of concern, or are located on adjacent river systems (and can be used to infer water quality) is given in Sub-study 2, Delineation Report (RDM/ K10-K30,K40E/00/CON/0207). Of note is either the complete absence of monitoring stations or only a limited length of record for the upper Groot Brak River above the Wolwedans Dam and for the Goukamma River. Figure 13.1 shows the location of the DWAF WQ monitoring stations and the EWR sites used in the study.

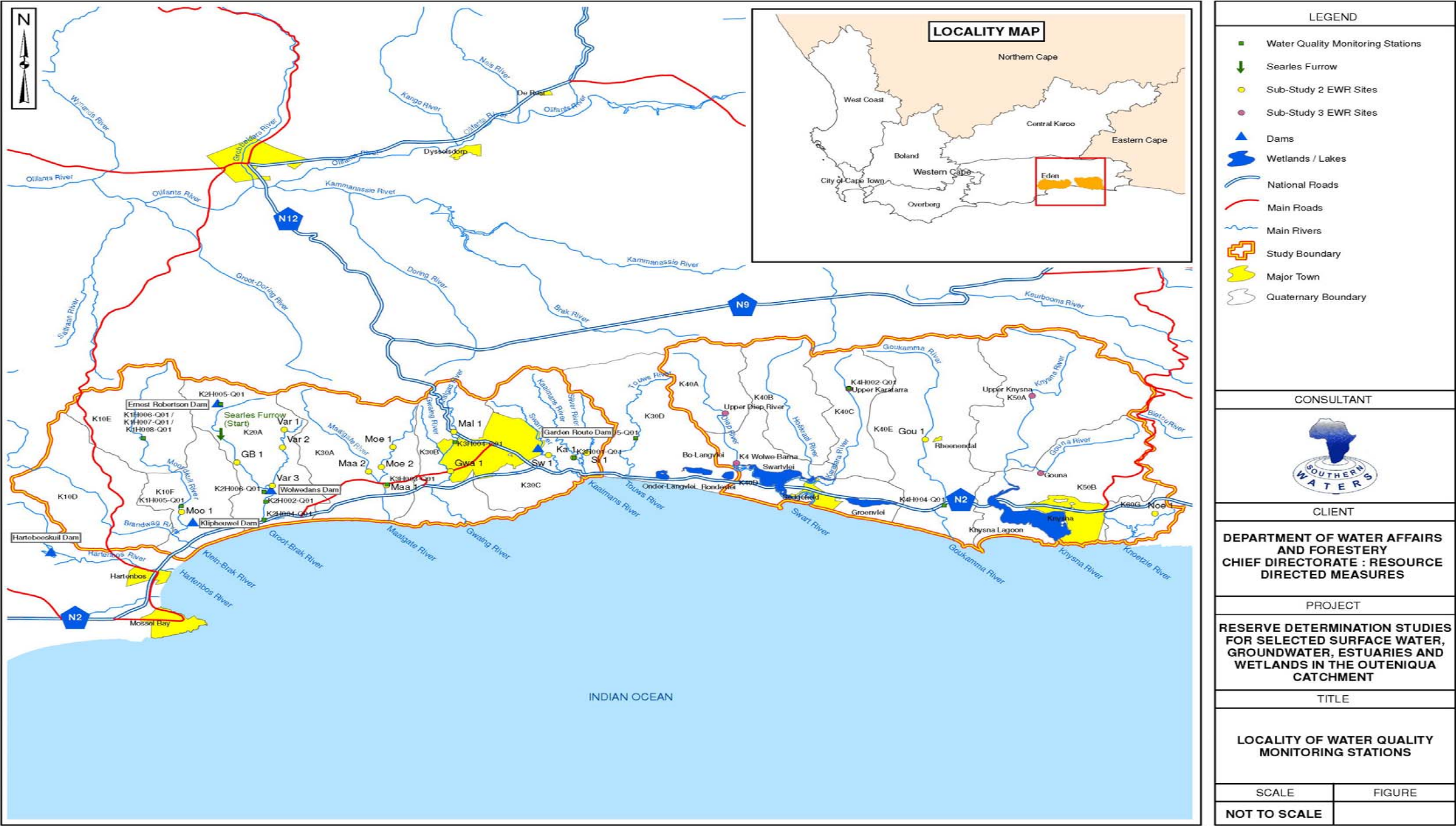


Figure 13.1 Map of EWR sites and water quality monitoring stations

In addition to the sites shown in Figure 13.1, several other locations were used to infer water quality in the study rivers and are listed in Table 13.1.

Table 13.1 Availability of water quality data from the DWAF monitoring stations (additional stations from adjoining catchments)

Water quality monitoring station	Location	Coordinates	Data available
Rooi River			
K3H002-Q01	@ George (located in upper mountainous reaches, above the city). Possible Reference site.	33°56'00"S 22°27'44"E	1978 – present ⁸⁸ . Weekly to monthly sampling (with gap from 1983 - 1987). Standard variables ⁸⁹ . n = 817. ⁹⁰
K3H007-Q01	@ DWAF regional office in George	33°58'20"S 22°26'29"E	1995 – present. Weekly to monthly sampling. Standard variables. n = 316
Karatara River			
K4H002-Q01	@ Karatara forest reserve. Possible Reference site.	33°52'52"S 22°50'19"E	1971 – present. Weekly to monthly sampling. Standard variables. n = 673

The standard suite of WQ variables was investigated (subject to the availability of data) as listed in DWAF (2007 *in prep.*). The following water quality variables are included either quantitatively or qualitatively:

- MgSO₄ (mg/L)
- Na₂SO₄ (mg/L)
- MgCl₂ (mg/L)
- CaCl₂ (mg/L)
- NaCl (mg/L)
- Total inorganic nitrogen (TIN) in mg/L
- Soluble Reactive Phosphorus (SRP) in mg/L
- pH
- Water temperature (°C)
- Dissolved oxygen (DO) in (mg/L
- Turbidity (NTU)
- EC (mS/m)

⁸⁸ Data were available up until October 2006.

⁸⁹ Standard suite of variables (Ca, Mg, K, Na, Cl, F, Si, SO₄, NH₄, NO₃+NO₂, PO₄, TAL) – excludes, TP, KN, Temp, Turbidity.

⁹⁰ Sample size (n) given for EC (the most frequently measured variable). n for other variables equal to or less than n for EC.

- Chlorophyll a (Chl a) as periphyton algae (mg/m²)
- Chlorophyll a as phytoplankton algae (µg/L)
- Toxic substances

No in-stream toxicity testing was undertaken. Chlorophyll a samples were also not taken, because during both field trips flow was high and (in the case of the June 2007 visit) water temperatures were low. Thus the overall algal biomass was expected to be low and it was considered that once-off samples would not be particularly useful in assessing the trophic state (Ewart-Smith, J., FRU, *pers. com.* 2007). Furthermore, neither of the above variables is obligatory for Reserve Determinations (DWAF 2007 *in prep.*). Qualitative assessments were made at the sites for the presence of algae.

13.1.3 Analysis of the water quality data

Water quality data were manipulated according to the method set out in DWAF (2007 *in prep.*). The benchmark values given in Table 13.2 and Table 13.3 were used to rate the status of individual water quality variables. The overall WQ status was obtained using the Physico-chemical Driver Assessment Index (PAI) Ecstatus model (Kleynhans *et al.* 2006) in the case of WQSUs that contained an EWR site. For WQSUs that did not encompass an EWR site, expert judgment was used to assess the overall classification. This approach was used because input is required from the invertebrate and fish specialists in order for the WQ variables to be ranked and the PAI model to be completed (Scherman, P. *pers com.* Dec 2007), but only the EWR sites were assessed for biological condition, rather than the entire river length as was required for water quality.

Confidence in the statistical parameters of the data set (i.e. sample size, standard deviation) for each water quality variable was expressed by the power statistic G-power where applicable. In addition, confidence in the monitoring site used to represent the PES (and sometimes RC) in terms of its location and length of data is also reported.

PROBLEMS ENCOUNTERED

During the course of this project, in addition to an unconsolidated method for assessing WQ, problems were encountered with the format of the WMS water quality data supplied by the DWAF. For this reason the data were first checked visually and then compared with statistical parameter values calculated from the data set (from the start date to the end of 2006) with the corresponding values given for the relevant station on the DWAF website given below:

<http://www.dwaf.gov.za/iwqs/wms/data/000key.htm>

Table 13.2 Boundary values used to describe water quality, excluding salts, in terms of Category and Rating (adapted from DWAF 2007 in prep.)

Category	Rating (for Ecstatus model)	Upper boundary value per category	
		TIN (mg/L) – 50 th %ile	PHYTOPLANKTON Chl a (µg/L) – 50 th %ile
A	0	≤ 0.25	<10
A/B		0.5	
B	1	0.75	10 – 15
B/C		1.0	
C	2	2.0	15 – 20
C/D		3.0	
D	3	4.0	20 – 30
E/F	4	> 4.0	> 30
		SRP or PO4 (mg/L) – 50 th %ile	PERIPHYTON Chl a (mg/m ²) – 50 th %ile
A	0	≤ 0.005	< 1.7
A/B		0.012	
B	1	0.02	1.7 - 12
B/C		0.025	
C	2	0.058	12 - 21
C/D		0.091	
D	3	0.125	21 - 84
E/F	4	>0.125	> 84
		pH – 5% th ile and 95 th %ile	TEMPERATURE (°C) – 10 th %ile and 90 th %ile
A	0	6.5 – 8.00	Nat temp range
B	1	5 th percentile: 6.00 – 6.24 95 th percentile: 8.37 – 8.69	Nat temp range
C	2	5 th percentile: 5.00 – 5.23 95 th percentile: 9.05 – 9.36	Vary by no more than 2°C
D	3	5 th percentile: 5.46 – 5.7 95 th percentile: 8.56 – 10.00	Vary by no more than 4°C
E	4	< 5.00	Vary by no more than 4°C
F	5	-	Vary by no more than 5°C to max of 30°C
		Dissolved oxygen (mg/L) - 5 th %tile	BIOLOGICAL INDICATOR (ASPT)
A	0	>8	7
A/B			6.67
B	1	7	6.34
B/C			6
C	2	6	5.67
C/D			5.34
D	3	4	5
E	4	2	
E/F			<5
F	5	<2	

Table 13.3 Boundary values used to describe salts in terms of Category and Rating (from DWAF 2007 in prep.)

PES rating	Deviation from reference condition	Water quality category	MgSO ₄ (mg/L)	Na ₂ SO ₄ (mg/L)	MgCl ₂ (mg/L)	CaCl ₂ (mg/L)	NaCl (mg/L)
0	No change	A	16	20	15	21	45
1	Small change	B	23	33	30	57	191
2	Moderate change	C	28	38	36	69	243
3	Large change	D	37	51	51	105	389
4	Serious change	E	45	64	66	141	535
5	Extreme change	F	>45	>64	>66	>141	>535

In all cases, the values were found to be the same. For the above reason (and due to other problems concerning incompatibilities between the data format and requirements for TEACHA) the DWAF software “TEACHA” could not be used to calculate the theoretical concentration of salts from the concentrations of constituent ions. Instead salinity was assessed from an examination of the electrical conductivity (EC) values for the relevant monitoring station. Elevated salinity is not a problem in the WQSUs and it was considered that this was a reasonable approach. Note that the method has not been adequately tested and that these resultant estimates are therefore low confidence assessments (DWAF 2006). There is also an inconsistency in that only three categories are delineated in the method developed to assess salinity using EC rather than individual salts (DWAF 2004), viz. Natural, Good and Fair, whereas six categories are required for the PAI (0 – 5, or A – F). This problem was circumvented by extrapolation as shown in Table 13.4. A further consequence of problems with the WMS data is that G-power could not be used to calculate the confidence in the data for Total Inorganic Nitrogen (TIN).

Table 13.4 Boundary values used to describe Electrical Conductivity (EC) quality in terms of Category and Rating

Original Category	New Category	Rating	Boundary values for Electrical Conductivity (mS/m)
Natural:	A	0	≤ 30
Good:	B	1	≤55
Upper Fair:	C	2	≤85
Lower Fair:	D	3	>85
Poor:	E/F	4	-

DETERMINATION OF THE REFERENCE CONDITION

The reference condition water quality was derived by means of one of the following approaches:

- using historic data, i.e., collected prior to major impacts in the catchment, for the site in question.
- using data extrapolated from a similar site on another river.
- where no suitable data were available, using the default rating values for the natural ("A") Category (Table 13.2 and Table 13.3).

DETERMINATION OF THE PRESENT ECOLOGICAL STATE

The Present Ecological State water quality was derived using one, or a combination of, the following approaches:

- Using present-day data for a site located in the WQSU in question.
- Using data extrapolated from a similar (in terms of surrounding landuse) river from an adjacent catchment.
- Using biological indicator data (for invertebrates and algae) to infer water quality and then using the appropriate rating values as set out in Table 3.1.

13.2 WATER QUALITY ASSESSMENT – INTERMEDIATE LEVEL

13.2.1 General comments

The results of the WQ Present Ecological State (PES) assessments are summarised in Table 13.6 to 13.17 and Table 13.20 to 13.23. The results are presented first for each WQSU for the rivers studied at an Intermediate level, and then for the rivers studied at a Rapid level. Note that the assessment tables that are currently available for pH are not applicable to the Cape because of the naturally acidic waters (DWAF 2007 *in prep.*), thus pH values are noted in the summary tables, but no category is given. It is not expected that a change in pH will be problematic at the sites in question. Furthermore there was a change in the manner in which the DWAF measured pH in 1989, consequently values measured after this period are usually approximately 1 unit higher than for the same site before 1989. This means that reference condition pH values calculated from pre-1989 data can be misleading and thus were not included.

It was noted in Section 13.1.3 that salinity was assessed from an examination of the electrical conductivity values. In general salinity was not a major water quality impact and for most WQSU, median EC was found to be in a "Natural" category (i.e. lower than 30 mS/m), except for: Groot Brak, WQSU 3 (downstream of Wolwedans Dam, which is influenced by the tides); the lower Gwaing River (WQSU 3), and the lower Maalgate River.

For most of the sites, SRP (phosphate) levels for the Reference Condition (RC) were higher than $\leq 0.005\text{mg/l}$, the boundary value for the "Natural" or "A" category river. This indicates that impacts had already occurred in the river and nutrient levels were elevated from natural. For many sites this is very likely, for example, for K1H005-WQ01 Moordkuil @ Banff the earliest data are from 1976 when farming activity was already well established in the

catchment. However, for some sites, for instance K3H001-Q01 Kaaimans River @ Barbierskraal where the catchment is largely pristine, SRP concentrations were also higher than the boundary value for the natural category. This suggests that the boundary value of $\leq 0.005 \text{ mg/l}$ SRP may well be too conservative. For all cases where the RC values did not fall within the “A” category, the values for the PES were adjusted according to the procedure prescribed in DWAF 2007 (*in prep.*) If the PES values were adjusted it was noted in the relevant PES table.

Conversely, Total Inorganic Nitrogen (TIN) was in an “A” or “A/B” category for all the sites despite known water quality impacts at some sites. Thus, it is possible that the boundary values for this variable are too lenient.

13.2.2 Groot Brak River

GROOT BRAK RIVER WQSU 1 AND 2: FROM SOURCE TO LEVEL 1 ECOREGION BOUNDARY

PES categories and overall site assessment for Groot Brak WQSU 1 and 2 are provided in Table 13.6. The two WQSUs were combined because of similar landuse in the area, and similar river morphology (deeply incised channel, with steep, forested sides). Landuse in the regions is natural fynbos - especially around the source (the Perdeberg) and on the high altitude areas, with forestry on the lower slopes. There are no DWAF water quality monitoring sites and no River Health Programme (RHP) data for these two WQSUs, which make it difficult to establish the PES. Limited data are available for sites in the adjacent catchment (Moordkuil tributary 1, 2 and 3 at Ruitersbos). These data, however, were not used to infer the PES, since there are several plantations in the Groot River (Groot Brak River) catchment, and very few in the Ruitersbos catchment.

There are limited data for the outflow from the Ernest Robertson dam (K2H005-Q01; 1983 - 1996), which are summarised below. These data are not strictly representative of the water quality in the river but were used to infer the general water quality with a low level of confidence. Comparison of the values given in Table 13.2 to Table 13.4 indicates that water quality is good and in line with what could be expected from a high-altitude catchment with low landuse impacts, viz. EC and TIN levels are low and the pH is acidic (due to the fynbos vegetation). The levels of SRP are higher than expected (“C” Category), however, which may be attributed to the location of the dam.

Table 13.5 Summary statistics for K2H005 (Outflow from Ernest Robertson dam)

	EC (mS/m)	pH	TIN (mg/L)	SRP (mg/L)
Median	9.4	4.62	0.11	0.042
n	29	28	28	29

Table 13.6 PES categories and overall site assessment for Groot Brak WQSU 1 & 2

RIVER	Groot Brak River		WATER QUALITY MONITORING POINTS	
WQSU	WQSU 1 + 2		RC	Default boundary tables for “A” category river
EWR SITE	None		PES	Groot Brak R. @ Ernest Robertson dam - K2H005-Q01 (1983 – 1996; n = 29)
Confidence assessment		Very low because extrapolated from outflow from a dam, and not current data.		
Water Quality Constituents			Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄			No data
	Na ₂ SO ₄			
	MgCl ₂			
	CaCl ₂			
	NaCl			
	CaSO ₄			
Nutrients (mg/L)	SRP (mg/l)		0.042	Unreliable data used
	TIN (mg/l)		<0.25	A category
Physical Variables	pH (5 th – 95 th %)		4.62	Naturally acidic
	Temperature			No data
	Dissolved oxygen			Expected to be high
	Turbidity (NTU)			Expected to be low
	Electrical conductivity (mS/m)		<30	A category
Response variables	Chl a: periphyton			No data
	Chl a: phytoplankton			No data
	Macroinvertebrates (ASPT)			No data
	Fish community score			No data
Toxics				No data – expected to be minimal
OVERALL SITE CLASSIFICATION			A/B (from expert judgement)	

GROOT BRAK RIVER WQSU 3: FROM LEVEL 1 ECOREGION BOUNDARY TO THE INFLOW TO THE WOLWEDANS DAM

PES categories and overall site assessment for Groot Brak WQSU 3 are provided in Table 13.7. The Groot Brak EWR site is located in this WQSU. This river reach is similar to that above in that the river channel is deeply incised with steep wooded banks. There is more intense landuse in this area with dryland agriculture and irrigated pastures, sheep, dairy and crops. There is no DWAF monitoring station in this reach and no RHP site on the Groot Brak River. The Varing River (which also flows into the Wolwedans Dam and has similar landuse in the catchment) has an overall Ecostatus = Fair (water quality = Good). The two rivers are likely to be similar in terms of WQ. On visiting the EWR site in March and June 2007, the water was humic acid-stained (i.e. brown in colour), slightly turbid with no obvious signs of algae. Because there is no water quality monitoring station in this reach, data were extrapolated from the adjoining catchment (K1H005-WQ01 Moordkuil @ Banff).

Table 13.7 PES categories and overall site assessment for Groot Brak WQSU 3 (*Boundary adjusted)

RIVER		Groot Brak River		WATER QUALITY MONITORING POINTS	
WQSU		WQSU 3		RC	Moordkuil R. @ Banff - K1H005 (1979 – 1982 n = 91)
EWR SITE		GB 1		PES	K1H005 (2002 – 2006 n = 51)
Confidence assessment			Medium. NB: Because extrapolated from another catchment. Biological data support inferred water quality		
Water Quality Constituents			RC value	PES Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄			No data	
	Na ₂ SO ₄				
	MgCl ₂				
	CaCl ₂				
	NaCl				
	CaSO ₄				
Nutrients (mg/L)	SRP	0.006*	0.029	Category = C. Increase in trend	
	TIN	0.04	0.06	Category = A. Trend stable	
Physical Variables	pH (5 th – 95 th %)	Not calculated	6.6 – 7.9		
	Temperature			No data, but not considered to be problem variables, as not downstream of a major dam.	
	Dissolved oxygen				
	Turbidity (NTU)			Slightly turbid on site visits in March and June 2007 (but after heavy rains).	
	Electrical conductivity (mS/m)	40	30	Slight decrease in trend	
Response variables	Chl a: periphyton			No data. Visual inspection March and June – no obvious signs of algae.	
	Chl a: phytoplankton				
	Macroinvertebrates (ASPT)	-	A	Natural; ASPT = 8.0; SASS = 192 (this study)	
	Fish community score	-	C	This study	
Toxics				No data. Possibly some pesticides from agriculture.	
OVERALL SITE CLASSIFICATION			B (from PAI model)		

This water quality monitoring station (K1H005-WQ01 Moordkuil @ Banff) has a good set of long-term data (n = 443, from 1976 to 2007) and was used to set both Reference Condition and the PES. This was considered to be a feasible approach since landuse in the two catchments is similar (i.e. dry-land agriculture, some irrigated pasture and crops, with no major areas of habitation). The SASS scores for both the Groot Brak (EWR 1) and Moordkuil

(at Banff) obtained during the present study are in a river integrity category = A (Magoba, R. Southern Waters, pers. comm.; DWAF 2007). Despite the fairly extensive farming in the region, the well-wooded slopes of the river channels are likely to be protecting the river from return-flows. Thus nutrients and pesticide levels are expected to be low and the SASS scores support this inference. There are no known point sources of pollution upstream.

GROOT BRAK RIVER WQSU 4: FROM THE OUTFLOW OF WOLWEDANS DAM TO GROOT BRAK VILLAGE

PES categories and overall site assessment for Groot Brak WQSU 4 are provided in Table 13.8. As noted in the Delineation Report (DWAF 2007), the Wolwedans Dam was completed in 1990 and is a bottom-release system. There have been complaints from residents in the Groot Brak village of turbid water smelling of hydrogen sulphide. As a consequence, releases have been made from the dam on occasion to dilute poor water quality. There is fairly extensive irrigated agriculture upstream of the village, and increasing infrastructure development (mostly housing). Two DWAF water quality monitoring stations are located in this WQSU namely; K2H006-Q01 and K2H002-Q01. The former site is located at the outflow from the dam and thus was not used. The second station (K2H002-Q01 Groot Brak at Wolwedans) is located downstream of the dam and upstream of the village and is thus suitably located to establish water quality for this reach. In addition the sample size for K2H002-Q01 is 870 and data have been collected since 1970. Thus data from this site were used to set both the reference condition and the PES.

GROOT BRAK RIVER WQSU 5: FROM GROOT BRAK VILLAGE TO ESTUARY MOUTH

As noted earlier, this WQSU was included in the assessment in order to supply data as input to the Estuarine RDM study. This reach of the river is within the tidal influence. The results will be presented in the Estuary RDM Report for the study.

13.2.3 Malgas and Gwaing rivers

The Gwaing River was divided into three WQSUs. The upper most unit (WQSU 1) extends from the source in the Outeniqua mountains to just above the quarry in Witfontein forestry area. The second from the quarry to the confluence with the Rooi River. Lastly, WQSU 3 extends from the Rooi River confluence to the Indian Ocean.

MALGAS RIVER WQSU 1: FROM THE SOURCE TO WITFONTEIN QUARRY

PES categories and overall site assessment for Malgas River WQSU 1 are provided in Table 13.9. Landuse in this area is primarily natural fynbos with pine plantations in the lower reaches. The Montague Pass follows the course of the river (named the “Keur” in this region) for several kilometers, but does not exert a major impact on water quality, since the banks are steep and heavily wooded with natural vegetation. There is no DWAF monitoring station for this river reach, and thus the RC and PES were extrapolated from the neighboring Rooi River catchment (K3H002- Q01), which is also located in the mountains.

Table 13.8 PES categories and overall site assessment for Groot Brak WQSU 4
 (*Boundary adjusted)

RIVER	Groot Brak		WATER QUALITY MONITORING POINTS	
WQSU	4		RC	Groot Brak R. @ Wolwedans - K2H002-Q01 (1976 – 1978; n = 68)
EWR SITE	None		PES	K2H002 (2002 – 2006; n = 57)
Confidence assessment		Very good. Monitoring station located in WQSU, above point source of village. Data collected from > 15 years before dam construction		
Water Quality Constituents		RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄			No data
	Na ₂ SO ₄			
	MgCl ₂			
	CaCl ₂			
	NaCl			
	CaSO ₄			
Nutrients (mg/L)	SRP	0.016*	0.037	Category = C. Trend increasing
	TIN	0.04	0.075	Category = A. Trend increasing
Physical Variables	pH (5 th – 95 th %)		6.8 – 8.1	Based on Monitoring station located in WQSU, above point source of village
	Temperature		No data	May be a problem considering downstream of dam. Requires monitoring
	Dissolved oxygen		No data	
	Turbidity (NTU)		No data	
	Electrical conductivity (mS/m)	30	52	Category = B. Trend increasing
Response variables	Chl a: periphyton			No data
	Chl a: phytoplankton			No data
	Macroinvertebrates (ASPT)			No data
	Fish community score			No data
Toxics				No data
OVERALL SITE CLASSIFICATION		B/C (expert judgement)		

Table 13.9 PES categories and overall site assessment for Malgas River WQSU 1 (*Expert judgment)

RIVER	Malgas River (Keur River)		WATER QUALITY MONITORING POINTS		
WQSU	WQSU 1		RC	Rooi R. @ George K3H002-Q01 ('77 – '79 n = 84)	
EWR SITE	None		PES	K3H002-Q01 ('01 – '06 n = 65)	
Confidence assessment		Low. NB: extrapolated from an adjacent catchment			
Water Quality Constituents			RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄				No data
	Na ₂ SO ₄				
	MgCl ₂				
	CaCl ₂				
	NaCl				
	CaSO ₄				
Nutrients (mg/L)	SRP		0.014	≤0.014*	Category = A
	TIN		0.04	≤0.25*	Category = A
Physical Variables	pH (5 th – 95 th %)			3.7 – 6.7	Naturally acidic
	Temperature				No data but expected to be natural as little development in upstream catchment.
	Dissolved oxygen				
	Turbidity (NTU)				
	Electrical conductivity (mS/m)		16	17	Category = A
Response variables	Chl a: periphyton				No data
	Chl a: phytoplankton				
	Macroinvertebrates				Good (RHP)
	Fish community score				Natural (RHP)
Toxics					No data
OVERALL SITE CLASSIFICATION			A (from expert judgement)		

Two issues of concern were the slightly elevated TIN values for the PES at K3H002-Q01 (2001 – 2006 median TIN = 0.39 mg/L, category “B”; n = 65) and the elevated phosphate both for the RC and the PES (2001 – 2006 median SRP = 0.034 mg/L, category “C”; n = 49). The reason for this could not be determined. From the low transformation of land in the Malgas/Keur catchment, water quality for this reach is expected to be largely natural and typical of a mountain stream in the fynbos region i.e. cold, well-oxygenated water, humic-stained, low pH, low nutrients and low electrical conductivity. Thus the PES was extrapolated from K3H002-Q01, but the value for TIN and SRP was adjusted to an “A” category value as given in the default ratings table (Table 2). This assumption is supported by the available biomonitoring data. Scott (2006) recorded an ASPT value of 7.3 for the Keur in 2006; Douglas (2005) an ASPT value of 8.2 in winter and 6.4 in summer. The RHP monitoring site at Keur Bridge also records the site as having natural water quality. The trend in water quality variables could not be determined since the data used for the PES assessment was extrapolated from another site.

MALGAS RIVER WQSU 2: FROM THE WITFONTEIN QUARRY TO THE CONFLUENCE WITH THE ROOI RIVER

PES categories and overall site assessment for Malgas River WQSU 2 are provided in Table 13.10. WQSU 2 extends from the quarry, asphalt manufacture and cement-mixing site, which is just above the EWR site at Ou Brug. There are extensive pine plantations in this area. Further down stream is the village of Blanco with areas of formal and low economic housing, followed by Fancourt golf estate and then intensive agriculture. There is a DWAF monitoring station (K3H004-Q01 Malgas R. @ Blanco) with a good set of data from 1967 to the present. This site is located further downstream from the EWR site, at Blanco and is considered to be a reliable data source for assessing the water quality downstream of the village. Water quality at the EWR site itself which is located in the most upstream portion of the WQSU, can only be inferred from expert judgment and is likely to be better than below the village. A visual inspection at the EWR site indicated fairly extensive growth of filamentous algae in still-water areas caused by the construction of the road. There was also visibly poor water quality (turbid with phytoplankton) at the site – although this appeared to be a fairly localized impact. Nevertheless, the SASS scores for the EWR site were high with an ASPT = 8.2 indicating an “A” category (Magoba R. Southern Waters, *pers. com.* 2007).

An examination of the data available from the earliest years was made for K3H004-Q01 (Malgas R. @ Blanco) to examine its suitability to set the RC. The median values for all water quality variables were in the “A” category (for 1977 – 1981; EC = 12 mS/m; TIN = 0.06 mg/L; n = 158). However, the median SRP value was relatively high (0.015 mg/L) i.e. a “B” category. This may indicate that even during the mid 1970’s there was some pollution in the river. As a consequence, the default boundary values (Table 2) were used for the RC, rather than data from K3H004-Q01. The data from K3H004-Q01 indicate that nutrient levels and electrical conductivity are increasing at this site.

Table 13.10 PES categories and overall site assessment for Malgas River WQSU 2

RIVER	Malgas River		WATER QUALITY MONITORING POINTS			
WQSU	WQSU 2		RC	Default values		
EWR SITE	Mal 1		PES	Malgas R. @ Blanco - K3H004-Q01 ('01 – '06 n = 53)		
Confidence assessment		Good for the overall WQSU. Low for the EWR Site.				
Water Quality Constituents			RC Value	PES Value	Category/Comment	G-power (Confidence)
Inorganic salts (mg/L)	MgSO ₄					No data
	Na ₂ SO ₄					
	MgCl ₂					
	CaCl ₂					
	NaCl					
	CaSO ₄					
Nutrients (mg/L)	SRP		≤0.005	0.038	Category = C. Trend increasing.	0.116 (Low)
	TIN		≤0.25	0.413	Category = A/B. Trend increasing	
Physical Variables	pH (5 th – 95 th %)			4.3 – 7.2	Naturally acidic.	0.84 (High)
	Temperature		16.3 (50%ile)	-	No PES data. Not expected to be a problem since no dam upstream	
	Dissolved oxygen					
	Turbidity (NTU)				No data. Could be a problem due to quarry	
	Electrical conductivity (mS/m)		<30	15	Category = A. Trend = slight increase	0.64 (Medium)
Response variables	Chl a: periphyton				No data	No data (but visual inspection at EWR site indicated localised problem).
	Chl a: phytoplankton				No data	
	Macroinvertebrates				A category; ASPT = 8.2, SASS = 164 (this study)	
	Fish community score				C/D (this study)	
Toxics					No data. Possible toxicity from quarry/cement/asphalt works, outflows from village and agricultural return flows	
OVERALL SITE CLASSIFICATION			B (from PAI model). Likely to be better at EWR site itself.			

MALGAS/GWAING RIVER WQSU 3: FROM THE ROOI RIVER CONFLUENCE TO THE ESTUARY

PES categories and overall site assessment for Malgas/Gwaing River WQSU 3 are provided in Table 13.11. The storm water from most of George decants into the lower Rooi River (also known as the “Camphersdrift River”) and ultimately into the Gwaing. Other impacts are leachate from the refuse area (recently closed) and from the Wastewater Treatment Works located just south of the R102 (in the upper reaches of this WQSU), and run-off from the airport. Landuse in the lower reaches is intense agriculture (dairy, vegetables). There is no DWAF monitoring station in this WQSU, however there is a RHP monitoring site at the N2 Bridge. The water quality status according to the RHP is “poor.” Furthermore there have been reports recently in the local newspaper of offensive smells from the Gwaing River downstream of the Wastewater Treatment Works. Water quality is likely to improve slightly along the length of the sub-unit, but because of intense agriculture, will remain impacted.

Table 13.11 PES categories and overall site assessment for Malgas River WQSU 3

RIVER		Malgas River	WATER QUALITY MONITORING POINTS		
WQSU		WQSU 3	RC	Default values	
EWR SITE		None	PES	No DWAF monitoring station	
Confidence assessment		Low for RC as default values used. Medium for the PES as no monitoring station, but supported by biomonitoring data and (limited) supplementary data.			
Water Quality Constituents			RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄				No data
	Na ₂ SO ₄				
	MgCl ₂				
	CaCl ₂				
	NaCl				
	CaSO ₄				
Nutrients (mg/L)	SRP		≤0.005	1.4 mg/L	Category = F
	TIN		≤0.25		Category = D
Physical Variables	pH (5 th – 95 th %)				
	Temperature				No data. Likely to be a problem with low DO and elevated turbidity
	Dissolved oxygen				
	Turbidity (NTU)				
	Electrical conductivity (mS/m)		<30	49	
Response variables	Chl a: periphyton				No data
	Chl a: phytoplankton				
	Macroinvertebrates (ASPT)				RHP = “Poor water quality”
	Fish community score				
Toxics					No data, but likely to be a problem
OVERALL SITE CLASSIFICATION			D/E (expert judgement)		

Data (Table 13.12) were obtained from George Municipality, which monitors water quality at selected river sites. Samples were taken at the N2 Bridge over the Gwaing River (in close

proximity to the RHP site) and downstream of the Wastewater Treatment Works. Water quality is monitored monthly, however, only the data for 2007 were available at the time of the project (Surujlal, S. George Municipality, *pers. com.* 2007).

Table 13.12 Median values of various water quality variables for the Gwaing River Jan – Dec 2007 (n = 11 for each variable)

pH	EC (mS/m)	NO ₃ ⁻² (mg/L N)	PO ₄ ⁻² (mg/L P)
7.02	49	1.35	1.4
-	“Good” (B category)	N/A	F category (i.e. >0.125)

It can be seen from Table 13.12 that neither electrical conductivity nor nitrate is particularly elevated in this WQRU. The median value of EC for 2007 is less than 55 mS/m and thus is within a “Good” B category (Table 13.4). The boundary values given in Table 13.2 are for *TIN* – i.e. NO₃⁻², NO₂⁻ and ammonium *combined* and if one considers that the lower “D” boundary value is 4.0 mg/L, the value of 1.35 mg/L for NO₃⁻² is not excessive. The level of phosphate, however, is of concern with the median values exceeding the F category boundary (0.125 mg/L) and this is likely to cause serious eutrophication in the lower Gwaing River, especially if flows are decreased. No data were available for any toxic substances. The likelihood of this being a problem in this river reach is high due to the presence of the Wastewater Treatment Works, storm water, possible leachate from the refuse tip, and pesticides from agriculture.

13.2.4 Kaaimans River

KAAIMANS WQSU 1: FROM SOURCE TO EDGE OF MOUNTAINOUS AREA

PES categories and an overall site assessment for the Kaaimans River WQSU 1 are provided in Table 13.13. The Kaaimans River rises in the Outeniqua mountains and flows south through indigenous fynbos. The upper catchment has few or no impacts. The forested, foothill area starts at approximately 33° 56' 33" S 22° 31' 44"E, just north of Saasveld College. There is no DWAF monitoring station in this WQSU. There is a RHP site, however, which records the water quality of this reach as “natural.” The water quality for this WQSU is expected to be similar to that of the upper Malgas (Keur R.) and thus typical of a mountain stream in the fynbos region i.e. cold, well-oxygenated water, humic-stained, low pH, low nutrients and low electrical conductivity. Because of the lack of a monitoring station, the default boundary values were used to define the RC. The PES was defined in the same manner as for WQSU 1 for the Malgas (Keur R.).

Table 13.13 PES categories and overall site assessment for Kaaimans River WQSU 1 (*expert judgment)

RIVER		Kaaimans River		WATER QUALITY MONITORING POINTS	
WQSU		WQSU 1		RC	Rooi R. @ George K3H002-Q01 ('77 – '79 n = 84)
EWR SITE		None		PES	K3H002-Q01 ('01 – '06 n = 65)
Confidence assessment		Low. NB: extrapolated from an adjacent catchment			
Water Quality Constituents			RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄				No data
	Na ₂ SO ₄				
	MgCl ₂				
	CaCl ₂				
	NaCl				
	CaSO ₄				
Nutrients (mg/L)	SRP		0.014	≤0.014*	Category = A
	TIN		0.04	≤0.25*	Category = A
Physical Variables	pH (5 th – 95 th %)			3.7 – 6.7	Naturally acidic.
	Temperature				No data but expected to be natural as little development in upstream catchment.
	Dissolved oxygen				
	Turbidity (NTU)				
	Electrical conductivity (mS/m)		16	17	Category = A
Response variables	Chl a: periphyton				No data
	Chl a: phytoplankton				No data
	Macroinvertebrates (ASPT)				Category = A (RHP)
	Fish community score				No data
Toxics					No data. Unlikely to be a problem
OVERALL SITE CLASSIFICATION			A (expert judgement)		

KAAIMANS WQSU 2: FROM EDGE OF MOUNTAINOUS AREA TO CONFLUENCE WITH THE SWART RIVER

PES categories and overall site assessment for the Kaaimans River WQSU 2. WQSU 2 flows through the lower foothills of the Outeniqua Mountains and across the narrow coastal plain. The river channel is deeply incised virtually the entire length of this section and up to the coast, with steep, wooded hillsides. The EWR site lies in this WQSU. The catchment is largely natural with indigenous forests and fynbos. The Kaaimans is considered to be “a largely pristine river,” although there is limited agricultural activity (dairy) in this area and some plantations can be found. A RHP monitoring site is located in this reach of the river. Invertebrates and water quality are recorded as being “natural” at this site.

Table 13.14 PES categories and overall site assessment for Kaaimans River WQSU 2 (*boundary value recalibrated)

RIVER		Kaaimans River		WATER QUALITY MONITORING POINTS		
WQSU		WQSU 2		RC	Kaaimans R. @ Barbierskraal - K3H001-Q01 ('77 – '81; n = 175)	
EWR SITE		Ka1		PES	K3H001-Q01 ('01 – '06; n = 56)	
Confidence assessment		High for both the RC and PES, because the monitoring station is in the WQSU, has a good length of data, and because there is little land transformation in the catchment.				
Water Quality Constituents			RC Value	PES Value	Category/Comment	G-power (Confidence)
Inorganic salts (mg/L)	MgSO ₄					No data
	Na ₂ SO ₄					
	MgCl ₂					
	CaCl ₂					
	NaCl					
	CaSO ₄					
Nutrients (mg/L)	SRP		0.011	0.028*	Category = B. Trend = slight increase	0.122 (Low)
	TIN		0.04	0.061	Category = A. Very slight increase in trend	
Physical Variables	pH (5 th – 95 th %)			4.4 – 7.4	Naturally acidic waters	0.87 (High)
	Temperature				No data. Unlikely to be a problem	
	Dissolved oxygen					
	Turbidity (NTU)				No data. Visual inspection = low turbidity. Unlikely to be a problem	
	Electrical conductivity (mS/m)		16	17	A Category. Trend = stable	0.87 (High)
Response variables	Chl a: periphyton				No data. Visual inspection = no excessive algal growth	
	Chl a: phytoplankton					
	Macroinvertebrates				A category; ASPT = 8.0, SASS = 175 (this study). Natural (RHP)	
	Fish community score				B	
Toxics					No data, but unlikely to be a problem	
OVERALL SITE CLASSIFICATION			A (calculated from PAI model)			

The DWAF monitoring station K3H001-Q01 (Kaaimans River @ Barbierskraal) is located in this reach. It has a long length of data collected on a regular basis and therefore is very useful for establishing both the RC and PES.

KAAIMANS WQSU 3: FROM THE SWART RIVER CONFLUENCE TO THE SEA

This WQSU is very short (less than 1 km) and is estuarine and thus outside the scope of this project. There is no DWAF monitoring station in this reach.

13.2.5 Goukamma River

GOUKAMMA RIVER WQSU 1: FROM SOURCE TO EDGE OF MOUNTAINOUS AREA

PES categories and overall site assessment for Goukamma River WQSU 1 are provided in Table 13.15. WQSU 1 on the Goukamma River extends from the source in the Outeniqua Mountains to the edge of the forested region (approximately 33° 52' S, 22° 56' E). The river is called the “Homtini” in these reaches. The catchment is a conservation area with pristine fynbos. There is no DWAF monitoring station in this WQSU, but there is a RHP site, a little further downstream in WQSU that records water quality as being natural. Water quality is expected to be comparable with that of the Keur (upper Malgas) and upper Kaaimans, typical of a mountain stream in the fynbos region i.e. cold, well-oxygenated water, humic-stained, low pH, low nutrients and low electrical conductivity. Thus the same approach (and RC and PES values) for the water quality variables was used as for the Keur and upper Kaaimans Rivers.

GOUKAMMA WQSU 2: FROM EDGE OF MOUNTAINOUS AREA TO UPPER LIMIT OF TIDAL INFLUENCE

PES categories and overall site assessment for Goukamma River WQSU 2 are provided in Table 13.16. WQSU 2 stretches from the edge of mountainous/forested area to the upper limit of tidal influence (at approximately the N2 Bridge). Landuse in the upper reaches (Homtini R.) is largely conservation areas with indigenous forests and forestry plantations. There are possibly localized impacts from the small village of Rhenendal (Van Staden, DWAF, *pers. com.* and interview with local resident) such as sewage inflows from the village. There is also some agricultural activity (dairy, vegetables) around Rhenendal. Although there is no DWAF monitoring station in this WQSU, RHP monitoring is done. The overall ecostatus for the upper Homtini is good with both the invertebrate and water quality assessments in the “natural” category. The invertebrate assessment for the current study at the EWR site was a “B” category, largely as a result of reduced habitat types rather than any WQ impacts (Magoba, R. *pers. com.* 2008).

Data were used from the adjacent Karatara catchment (monitoring station K4H002-Q01 Karatara R @ Karatara State Forest). The Goukamma and Karatara Rivers are comparable in terms of landuse and the topology of the catchment (deeply incised channels with densely forested sides). Monitoring station K4H002-Q01 is located fairly high up in the catchment, just below the mountainous area and above the settlement of Karatara. The water quality for this monitoring station is good for all variables except for phosphate (“C” category). This value is higher than would be expected for both the Karatara and Goukamma Rivers and may be a consequence of the forestry activities in the catchment (or, as discussed previously, over-conservative boundary values for phosphate).

Table 13.15 PES categories and overall site assessment for Goukamma River WQSU 1 (expert judgment)

RIVER		Goukamma River	WATER QUALITY MONITORING POINTS			
WQSU		WQSU 1	RC	Rooi R. @ George K3H002-Q01 ('77 – '79 n = 84)		
EWR SITE		None	PES	K3H002-Q01 ('01 – '06 n = 65)		
Confidence assessment		Low to medium because no DWAF monitoring station. However unimpacted catchment and likely to be similar to other mountain streams.				
Water Quality Constituents			RC Value	PES Value	Category/Comment	
Inorganic salts (mg/L)	MgSO ₄				No data	
	Na ₂ SO ₄					
	MgCl ₂					
	CaCl ₂					
	NaCl					
	CaSO ₄					
Nutrients (mg/L)	SRP		0.014	≤0.014*	A category.	
	TIN		0.04	≤0.25*	A category.	
Physical Variables	pH (5 th – 95 th %)			3.7 – 6.7	Naturally acidic.	
	Temperature				No data but expected to be natural as little development in upstream catchment.	
	Dissolved oxygen					
	Turbidity (NTU)					
	Electrical conductivity (mS/m)		16	17	A category.	
Response variables	Chl a: periphyton				No data	
	Chl a: phytoplankton				No data	
	Macroinvertebrates				No data	
	Fish community score				No data	
Toxics					No data.	
OVERALL SITE CLASSIFICATION			A (expert judgement)			

Table 13.16 PES categories and overall site assessment for Goukamma River WQSU 2 (boundary value recalibrated)

RIVER		Goukamma River	WATER QUALITY MONITORING POINTS			
WQSU	WQSU 2		RC	Karatara R. @ Karatara State Forest K4H002-Q01 ('71 – '76; n = 107)		
EWR SITE	Gou 1		PES	K4H002-Q01 ('01 – '06; n = 51)		
Confidence assessment		Low, the monitoring station is in an adjacent catchment.				
Water Quality Constituents			RC Value	PES Value	Category/Comment	G-power (Confidence)
Inorganic salts (mg/L)	MgSO ₄					No data
	Na ₂ SO ₄					
	MgCl ₂					
	CaCl ₂					
	NaCl					
	CaSO ₄					
Nutrients (mg/L)	SRP		0.018	0.048*	Category = C. Trend = increasing	0.232 (Low)
	TIN		0.11	0.11	Category = A. Trend = stable	
Physical Variables	pH (5 th – 95 th %)			3.8 – 6.4	Naturally acidic waters	0.781 (Medium)
	Temperature				No data. Unlikely to be a problem	
	Dissolved oxygen					
	Turbidity (NTU)				No data. Visual inspection = low turbidity	
	Electrical conductivity (mS/m)		10	12	Category = A. Trend = stable	0.997 (High)
Response variables	Chl a: periphyton				No data. Visual inspection = no excessive algal growth	
	Chl a: phytoplankton					
	Macroinvertebrates				B ^{&91} category; ASPT = 7.2, SASS = 143 (this study). Natural (RHP)	
	Fish community score				C (this study)	
Toxics					No data, but unlikely to be a problem	
OVERALL SITE CLASSIFICATION			A (PAI model)			

GOUKAMMA WQSU 3: FROM UPPER LIMIT OF TIDAL INFLUENCE TO THE SEA

PES categories and overall site assessment for Goukamma River WQSU 3 are provided in Table 13.17. The upper limit of the tidal influence as given in the 1:50 000 topographical map for the region is roughly at the N2 Bridge (9 km from the mouth). Although this lowest WQSU is in the estuarine reaches of the river, water quality is assessed here in order to provide input to the estuarine component of the study. In the lower reaches (below the N2)

⁹¹ Likely to be an "A" category if suitable habitat available (Magoba, R. Southern Waters, *pers. com.* 2008)

there is intensive dairy farming. Goukamma Nature Reserve lies further downstream at the estuary. A DWAF monitoring station K4H004-Q01@ Buffels Vermaak is present at the uppermost boundary of the WQSU (located at the N2 Bridge). Unfortunately only 11 months of data were collected at this site (1998 -1999; n = 11). Thus the confidence in this assessment is low.

The limited results from this monitoring station (Table 13.18) show that TIN and SRP are relatively low (A and B category respectively). Electrical conductivity is high – but this is likely to be a consequence of the tidal influence and should be disregarded. The quality of the water from upstream (WQSU 2) is good. However, there is intense dairy farming in WQSU 3 (downstream of K4H004-Q01), which is expected to increase the nutrient levels in this reach.

Table 13.17 PES categories and overall site assessment for Goukamma River WQSU 3

RIVER		Goukamma River	WATER QUALITY MONITORING POINTS		
WQSU		WQSU 3	RC	Default values	
EWR SITE		None	PES	Goukamma R. @ Buffels Vermaak K4H004-Q01 ('98 – '99; n=11) + expert judgement	
Confidence assessment		Low due to limited length of monitoring			
Water Quality Constituents			RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	MgSO ₄				No data
	Na ₂ SO ₄				
	MgCl ₂				
	CaCl ₂				
	NaCl				
	CaSO ₄				
Nutrients (mg/L)	SRP		≤0.005	0.02	B category
	TIN		≤0.25	0.07	A category
Physical Variables	pH (50 th %)			7.1	No reliable data
	Temperature				
	Dissolved oxygen				
	Turbidity (NTU)			1	Low
	Electrical conductivity (mS/m)		<30	43	Likely to be high due to tidal influence
Response variables	Chl a: periphyton			No data, but not expected to be a problem	
	Chl a: phytoplankton				
	Macroinvertebrates (ASPT)			No data	
	Fish community score			No data	
Toxics					No data, but not likely to be a major problem.
OVERALL SITE CLASSIFICATION			B (expert judgement)		

Table 13.18 Summary statistics for K4H004 (Goukamma R. @ Buffels Vermaak)

	EC	pH	TIN (mg/L)	SRP (mg/L)	TP (mg/L)	Turbidity (NTU)	Temp °C
Median	43 ^{*92}	7.07	0.07	0.02	0.03	1.00	23
n	11	11	11	11	11	12	7

13.2.6 Consequences of flow changes for water quality

The generic list used to predict changes in water quality following flow manipulation in DRIFT is given in Table 13.19. DRIFT requires that specialists' made prediction of component (i.e. water quality) change in different flow levels. A maximum of ten elements (i.e water quality variables) are required into the DRIFT entry sheet. The geomorphologist, botanist and invertebrate specialist predictions were considered when predicting the changes in water quality following flow manipulation.

Table 13.19 Generic list and information used to predict changes in water quality with changes in flow using DRIFT

Generic list (Element)	Comments on ratings for flood responses	
pH	Note: All are standard variables that need to be assessed during the WQ component of a Reserve Determination	pH is an important system characteristic. Rivers in the Outeniqua region are acidic and thus support adapted fauna.
Salinity		Salinity is also an important characteristic of an aquatic ecosystem. The study rivers have low salinities in the reference condition, and thus is an important sign of impact.
Nutrients		Nutrients (phosphorus and nitrogen) enrichment is one of the most important impacts to aquatic resources world-wide. Therefore, it is important to assess the levels of these nutrients.
Temperature		Temperature is important because of its direct impact on fauna, and also affecting the rate of chemical and biochemical reactions.
Dissolved oxygen		Low dissolved oxygen levels result in the death of fish (and if levels remain low – of other organisms). Thus it is important to take this variable into account. Note there is a strong (inverse) correlation with temperature.
Toxic substances		With increasing development, industrial and agricultural activity in a catchment the likelihood of toxic substances (e.g. pesticides, heavy metals) being found in rivers increased. Even at low concentrations these can have a severe impact on all forms of life.
Turbidity		Turbidity (water clarity/suspended sediments) is an important variable that can impact on fauna. High turbidities can cause smothering of organisms, prevent finding of food by fish and cause other impacts.

⁹² Salinity high due to tidal influence

13.3 WATER QUALITY ASSESSMENT – RAPID LEVEL

13.3.1 Moordkuil River

The Moordkuil River rises in the Outeniqua Mountains and joins with the Klein Brak system on the coastal plain. Landuse in this catchment is similar to that of the Groot Brak i.e. natural fynbos and plantations in the up-land areas, and dry-land agriculture, some irrigated pasture and crops further downstream. The only major areas of habitation along the river are at the coast. There are limited data for three adjacent small tributaries of the Moordkuil (K1H006-Q01; K1H007-Q01 and K1H003-Q01 – tributary 1, 2 and 3 @ Ruiterbos) in the Outeniqua Mountain region. All the data were collected on the same sampling date and are from 1985 – 1988. All values were very similar and thus the median of each sampling occasion was taken and used for the PES assessment (Table 13.20). These data, although not recent, indicate little or no impacts on water quality.

Table 13.20 PES categories and overall site assessment for the upper Moordkuil River

RIVER		Upper Moordkuil	WATER QUALITY MONITORING POINTS	
WQSU		N/A	RC	Default boundary tables for “A” category river
EWR SITE		-	PES	Tributaries 1 -3 @ Ruiterbos K1H006; K1H007; K1H008 (1985 – 1988; n = 42)
Confidence assessment		Moderate because data not recent		
Water Quality Constituents			Value	Category/Comment
Nutrients (mg/L)	SRP		0.01	Category =A/B (TP = 0.015 mg/L)
	TIN		0.1	Category = A
Physical Variables	pH (5 th – 95 th %)		3.9 – 5.0	Naturally acidic
	Temperature			No data
	Dissolved oxygen			Expected to be high (un-impacted)
	Turbidity (NTU)			Expected to be low (un-impacted)
	Electrical conductivity (mS/m)		9	Category = A
Response variables	Chl a: periphyton			No data
	Chl a: phytoplankton			No data
	Macroinvertebrates (ASPT)			No data
	Fish community score			No data
Toxics				No data – but expected to be minimal
OVERALL SITE CLASSIFICATION			A (from expert judgement)	

Landuse in the upper catchment is not considered to have changed greatly from when the data were collected, and thus are expected to be representative of the PES. The data are typical of a mountain stream in the fynbos region, with acidic waters and low conductivity. Of interest are the slightly elevated phosphate levels (median value of 0.01 mg/L). This may be

a result of forestry activity in the area, or conversely that the SRP levels in the catchment are naturally higher than the default value of 0.005 mg/L.

There is a DWAF monitoring station (K1H005-WQ01 Moordkuil @ Banff) on the floodplain with a good set of long-term data (n = 443, from 1976 to present), which was used to set both the reference condition and the present state for the lower part of the river (Table 13.21). The SASS scores the Moordkuil (at Banff) obtained during the present study as a river integrity class = A (Magoba, R. Southern Waters, *pers. com.* 2007).

Table 13.21 PES categories and overall site assessment for the lower Moordkuil River (boundary values recalculated)

RIVER		Lower Moordkuil	WATER QUALITY MONITORING POINTS	
WQSU	N/A		RC	Moordkuil R. @ Banff K1H005 (1979 – 1982 n = 91)
EWR SITE	Moo 1		PES	K1H005 (2002 – 2006 n = 51)
Confidence assessment		Good. Monitoring station with good length of data. Biological data support water quality data		
Water Quality Constituents		RC value	PES Value	Category/Comment
Nutrients (mg/L)	SRP	0.006*	0.029	Category = C. Increase in trend
	TIN	0.04	0.06	Category = A. Trend stable
Physical Variables	pH (5 th – 95 th %)	Not calculated	6.6 – 7.9	
	Temperature			No data, but not considered to be problem variables, as not downstream of a major dam.
	Dissolved oxygen			
	Turbidity (NTU)			No data
	Electrical conductivity (mS/m)	40	30	Slight decrease in trend
Response variables	Chl a: periphyton			No data.
	Chl a: phytoplankton			
	Macroinvertebrates (ASPT)	-	A	Natural; ASPT = 7.3; SASS = 175 (this study)
	Fish community score	-	D	This study
Toxics				No data. Possibly some pesticides from agriculture.
OVERALL SITE CLASSIFICATION		B (from expert judgement)		

13.3.2 Moeras/Maalgate River

The PES categories and overall site assessment for the Moeras and Maalgate Rivers are provided in Table 13.22. The upper catchment is comprised of natural vegetation in the source areas and forestry in the foothills draining the mountain slopes. The Witels and Moeras Rivers join to become the Maalgate River. There is intensive agriculture in the foothills and on the coastal plain (vegetables, hops, dairy). Excessive abstraction has been

reported to occur in this area. The rivers are heavily invaded by alien vegetation particularly black wattle. There is a DWAF monitoring station (K3H003 Maalgate River @ Noetze Kamma) located just below the confluence of the Moeras and Witels Rivers (on the Maalgate) to the west of the George airport. There is also a RHP monitoring site in this reach that records overall Ecstatus as “poor” and water quality as “fair”. The assessment given below is for both the Moeras and Maalgate Rivers, which are expected to be similar in terms of water quality. The RC was set using the default boundary values for an “A” category since examination of the data for K3H003-Q01 indicated that even the earliest data indicated elevated SRP levels (time period 1977 – 1981, n = 145, median for SRP = 0.019mg/L). Through expert judgment water quality is expected to be in a “C” category for the Maalgate River.

Table 13.22 PES categories and overall site assessment for the Moeras and Maalgate Rivers

RIVER		Moeras/Maalgate River		WATER QUALITY MONITORING POINTS	
WQSU		N/A		RC	Default boundary tables for A category river
EWR SITE		Moe 1 & Maa 2		PES	Maalgate R. @ Noetze Kamma K3H003 ('02 – '06; n = 52)
Confidence assessment			Good.		
Water Quality Constituents				Value	Category/Comment
Nutrients (mg/L)	SRP		0.019	Category = B (TP = 0.015 mg/L)	
	TIN		0.1	Category = A	
Physical Variables	pH (5 th – 95 th %)		5.7 – 7.7	Naturally acidic	
	Temperature			No data. May be impacted (by abstraction)	
	Dissolved oxygen			No data. May be impacted (due to excessive abstraction)	
	Turbidity (NTU)			No data. Site visit indicated not elevated.	
	Electrical conductivity (mS/m)		63	Category = C	
Response variables	Chl a: periphyton			No data. Site visit indicated extensive periphyton	
	Chl a: phytoplankton			No data	
	Macroinvertebrates (ASPT)			D (present study) Fair (RHP)	
	Fish community score			D (present study)	
Toxics				No data – expected to be pesticides from intensive agricultural activity	
OVERALL SITE CLASSIFICATION				C (from expert judgement)	

13.3.3 Swart River

The upper reaches of the Swart River (both upstream and downstream of the small George Dam) flow through mountainous fynbos areas and water quality is expected to be largely natural. In the lower foothill regions there is forestry (both plantations and indigenous forests) and the river flows into the Garden Route Dam. The lower portion of the Swart River is influenced by the reduced flow from the Garden Route Dam (Magoba, R. Southern Waters, *pers. com.* 2007). There are extensive plantations and farming activities (dairy, vegetables)

in this region. Housing density is also increasing. The Swart River joins the Kaaimans River approximately 1km from the sea (at the N2 road-crossing) within the tidal reach. There is no DWAF monitoring station for the Swart River, although monitoring is carried out in the reservoir (K3R002). These data were not considered to be representative of the instream water quality and were not used in this study. Because of the landuse activities in the lower Swart River and the reduced flows it is expected that water quality will be impacted. There are no data for this river, however, nor is there a similar system from which data can be extrapolated. Thus it is not possible to assess the PES quantitatively. The PES for invertebrates for this study found an integrity score of “B”. It is considered that water quality for the low Swart River (below the Garden Route Dam) is also likely to be in a “B” category or lower.

13.3.4 Silver River

The PES categories and overall site assessment for the Silver River are provided in Table 13.23. The Silver River flows into the Kaaimans River and landuse in the catchment of both rivers is comparable and the water quality of the two rivers is likely to be similar. Thus the values obtained for the Kaaimans River were used for the Silver River. The biomonitoring data obtained on this project supports an overall WQ of “A” or “B” category.

The Silver River joins the Kaaimans River in this WQSU. The landuse in the catchment of the Silver River is comparable to that in the Kaaimans River, and thus largely un-impacted, it is considered that the water quality of the two rivers will be similar (there are no WQ data for the Silver River). This assumption is supported by biomonitoring data. Scott (2006) records ASPT scores for the Silver River sampled in autumn 2006, 2004 and 2003 ranging from 6.7 – 7.1. Magoba (in DWAF 2007) found the Kaaimans River to be in an “A” category and the Silver in a “B” category with regard to invertebrates. Thus water quality in the Silver River can be inferred as also largely natural. Because of the similarity in the WQ for the two rivers, the reaches of the Kaaimans River, both upstream and downstream of the confluence with the Silver River were included in the same WQSU.

13.3.5 Noetsie River

The catchment of the Noetsie River is very small. Landuse in the upper catchment is largely indigenous, with housing (on a golf estate) in the down-stream reach at the coast. There is no DWAF monitoring station and no RHP site on this river. Invertebrate sampling during the current study indicated a low ASPT 5.3 (Magoba, R. Southern Waters, *pers. com.* 2007) – although this may well be due to poor habitat rather than water quality impairment. There have been reports of high sediment loads in the lower reaches due to construction activities on the Golf estate. The lack of data meant it was not possible to assess the PES water quality.

Table 13.23 PES categories and overall site assessment for the Silver River

RIVER		Silver River	WATER QUALITY MONITORING POINTS		
WQSU		N/A	RC	Kaaimans R. @ Barbierskraal K3H001-Q01 ('77 – '81; n = 175)	
EWR SITE		Si 1	PES	K3H001-Q01 ('01 – '06; n = 56)	
Confidence assessment		Low – medium. NB: extrapolated from adjacent catchment. But landuse similar in both catchments and biomonitoring data supports the results.			
Water Quality Constituents			RC Value	PES Value	Category/Comment
Nutrients (mg/L)	SRP		0.011	0.028*	Category = B
	TIN		0.04	0.061	Category = A
Physical Variables	pH (5 th – 95 th %)			4.4 – 7.4	Naturally acidic waters
	Temperature				No data. Unlikely to be a problem
	Dissolved oxygen				
	Turbidity (NTU)				No data. Visual inspection = low turbidity. Unlikely to be a problem
	Electrical conductivity (mS/m)		16	17	Category = A
Response variables	Chl a: periphyton				No data. Visual inspection = no excessive algal growth
	Chl a: phytoplankton				
	Macroinvertebrates				Category = B (this study).
	Fish community score				No data
Toxics					No data, but unlikely to be a problem
OVERALL SITE CLASSIFICATION			A/B (from expert judgement)		

*Boundary value recalibrated

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APPENDIX A: RAPID III RESERVE FOR THE VARING RIVER AND SUGGESTIONS FOR MANAGEMENT OF THE RIVER ECOSYSTEM

A1 INTRODUCTION

The Varing River was not originally highlighted as a key river for Reserve determination in Sub-study 2; however, a license application was received for an in-channel dam on the Varing River subsequent to the completion of the river EWRs for the Groot Brak and associated systems. The Varing River was then included in the study as part of Variation Order 1 because it was cost effective for team members to visit the river and undertake the required ecoclassification tasks while they are busy with other tasks related to the area. The Reserve was determined using the Desktop model and calibrated using Intermediate level information from the Groot Brak River. The sub-tasks that comprised the study were:

- Task VO1.1.1: Review of desktop information and incorporation of the Varing River into the delineations already undertaken for the Groot Brak and associated systems.
- Task VO1.1.2 A 5-hour field trip to the Varing River, in order to undertake a Present Ecological Status (PES) assessment and Ecoclassification. The specialists attending the field visit were:
- | | |
|----------------------------|----------------------------------|
| EWR Coordination: | Dr Cate Brown |
| Geomorphology: | Mark Rountree (also wetlands) |
| Vegetation: | Dr Charlie Boucher |
| Fish: | Dr Stephen Lamberth |
| Invertebrates: | Rembu Magoba |
| Client representative: | Retha Stassen |
| BKS representative: | Estelle van Niekerk |
| Londoloza representatives: | Kirstin Botha
Eugene Matthews |
- The data gathered were used to:
- complete Ecoclassification datasheets for the disciplines provided above;
 - undertake a rapid PES assessment for floodplain wetlands using Wetland-IHI;
 - compare the recorded discharge with those recommended for the EWRs.
- Task VO1.1.3 A 4-hour specialist meeting to undertake Ecoclassification and to determine the Ecological Water Requirements (EWR) determination. The Desktop model was run, and adjusted where necessary.
- Task VO1.1.4 The results of the above tasks were written up and are presented in this appendix.

In addition to the work contracted in the Variation Order, the team compiled a set of considerations and recommendations with respect to the proposed dam in the upper Varing River. These are presented in Section A.7.

A.2 STUDY AREA AND EWR SITES

The Varing River is a tributary of the Groot Brak River (Quaternary catchment K20A). It no longer joins the Groot Brak River, however, as both of these systems now flow into the Wolwedans Dam. The sites visited (EWR Sites Var 1 and 2, and additional site) and the location of the site where the hydrological data are provided (EWR Sites Var 2 and 3) are presented in Figure A.1.

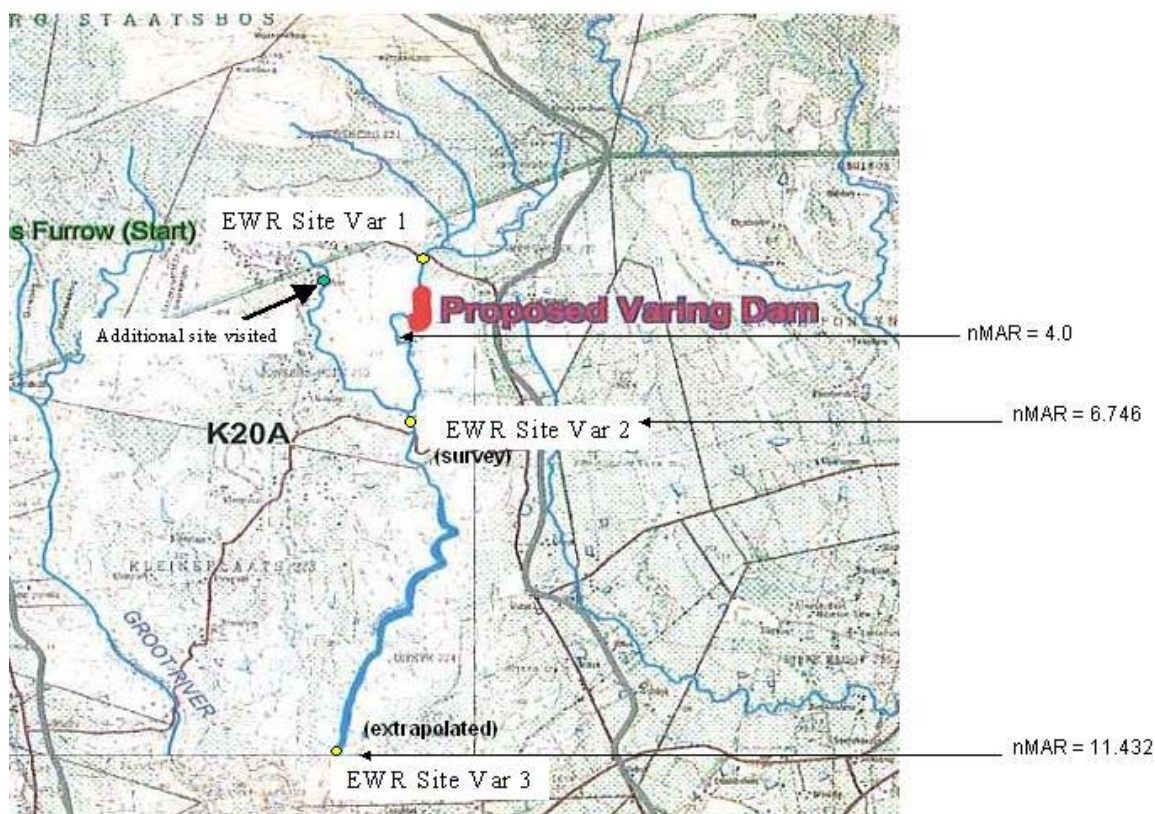


Figure A.1 Map showing the Varing River, and the location of three EWR sites, and one additional site. Sites Var 1, Var 2 and the additional site were visited as part of the fieldwork. EWR data are presented for EWR sites VAR 2 and 3.

The Google image of the upstream area, i.e., between EWR Sites Var 1 and Var 2 is presented in Figure A.2.



Figure A.2 Google image of the upstream area, i.e., between EWR Sites Var 1 and Var 2.

A.3 GENERAL DESCRIPTION OF CONDITION AND ECOCLASSIFICATION

Ecoclassification for the Varing River was undertaken using:

Geomorphology:	GAI (Level IV)
Vegetation:	VEGRAI
Macroinvertebrates:	MIRAI
Fish:	FRAI.

Prior to farming in the area, the Varing River was probably dominated by palmiet and other wetland vegetation. Palmiet is an ecosystem engineer – it binds the sediment on the floor (valley bottoms and banks) of wetlands and river channels. Historically, this weakly channelled wetland area was characterised by organic rich (peat) sedimentary layers. Abstraction and upstream afforestation activities, however, have reduced lowflows in the river system way below those that would have occurred naturally, which has resulted in the desiccation of the wetland and allowed terrestrial exotic vegetation to encroach into the wetland.

The channel is incised and scoured and both are having a negative effect on the instream vegetation, which is not no longer able to trap sediments. Channel incision and the resultant drop in water levels associated with a lower bed level, has led to further desiccation of the lower zone of the riparian vegetation, and an increase in colonisation of the zone by forest trees, both indigenous and exotic. The drop in water levels associated with a lower bed has

also led to the upper zone and floodplain *Cliffortia* and palmiet marshes drying out and concomitant invasions of the area by woody exotics. The presence of these species in the marsh will increase their propensity to burn as well as increase fire temperatures. They also lead to increased shading, of which the indigenous marsh species are intolerant. These two factors, viz. more frequent, hotter fires and shading will have accelerate the decline in the marshes, and will eventually result in some indigenous forest species, in addition to exotic invasive species, moving into the drying lateral marshes.

The geomorphology PES is a D Ecological Category, which means that this reach has been largely modified, i.e. that “a large loss of natural habitat, biota and basic ecosystem functions” has occurred in the system (Kleynhans *et al.*, 2006). Given that the Reference State of the system was a wetland, it is important to note that the GAI (Level IV) results were verified using the geomorphology assessment module of the Wetland Index of Habitat Assessment (DWAF, 2007c; see below).

The flow at EWR Site Var 2 at the time of the site visit (15.04.2008) was $0.009 \text{ m}^3\text{s}^{-1}$ (i.e., less than the 95th percentile under natural conditions), with almost all of the flow being contributed by the small tributary entering the Varing from the northwest immediately upstream of the site.

The vegetation PES is a low C Ecological Category. Apart from the changes in vegetation described above, lateral farming intrusion into the riparian zone has also had a negative effect on the system, which is currently in a steep negative trajectory floristically. Loss of lateral marshes will lead to progressively lower flows during dry seasons as the ability of the catchment to absorb and retain floodwater reduces. This negative process started with (pine) afforestation of upland fynbos heathlands.

The overall macroinvertebrate ecological category (EC) is a C. The dominant habitat is slow flowing water and, hence, backswimmers dominate the invertebrate samples. The Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO) group, the presence of which is indicative of good conditions, was poorly represented at the site. The macroinvertebrates assemblage recorded at sites may be more the result of a lack of suitable habitats (i.e. fast flowing water, aquatic and marginal vegetation, less gravel and cobbles) and siltation, than of water quality issues. The sampled taxa were in low abundances with an exception of Elmidae⁹³, which dominated the samples. SASS scores and average score per taxon (ASPT) are generally lower than expected for the river. These scores indicates moderately impoverished river conditions, and hence the allocation of an ecological category C.

⁹³ Elmidae species are generally mobile and can easily move to more suitable habitats. That they were sampled in large abundance relative to less mobile species, suggests that the availability of suitable habitats varies in time and space.

Table A.1 SASS and ASPT scores for site Var 1 and Var 2 on the Varing River

	Var 1	Var 2
SASS score	93	72
No. of taxa	14	13
ASPT	6.6	5.5

The indigenous fish assemblage of the Varing River was expected to comprise the small-bodied *P. afer*, *Sandelia capensis* and *G. zebratus*, and the catadromous eel *A. mossambica*. The river goby, *Glossogobius callidus*, also occurs in the Groot Brak catchment and prior to the construction of the Wolwedans Dam, was likely to have occurred further upstream, including the lower reaches of the Varing River. The confluence of the Varing and Groot Brak rivers was inundated by the Wolwedans Dam and as was the case for the Groot Brak River, the pools and temperatures in the lower reaches of the Varing River are expected to be conducive to the alien largemouth bass *M. salmoides* and smallmouth bass, *M. dolomieu*, moving upstream from the dam, especially in the summer months.

Var 1 was sampled visually and using hand-nets. Approximately 20 *G. zebratus* were seen and 8 caught over a 100 m stretch of the stream. All of these fish were amongst cobble as instream and marginal vegetation was extremely limited at the site. The cobble was also embedded, which further limited refuge. A shallow slow-flowing side channel had extensive filamentous algae growth but no *G. zebratus* were caught or seen. No other species were seen at this site and overall low numbers of fish are likely because of the lack of marginal or instream vegetation, substrate or depth refuge. Eels, *A. mossambica*, if able to traverse the dam, may travel through this site to deep pools further upstream. *S. capensis* and *P. afer* are also likely to occur here.

Var 2 was sampled with hand and cast-nets. No fish were caught with the cast-net and only two *G. zebratus* with the handnets. Prior to the deterioration of water quality, the pools in this reach would have been ideal for *A. mossambica*. As was the case with the Groot Brak River, the paucity of smaller bodied individuals in the river may partly be due to the presence of the aliens, *M. salmoides* and *M. dolomieu*, and/or two large floods in the 18 months prior to sampling⁹⁴.

The FRAI scored the Varing River fish assemblage in an upper C but this may have been an overestimation resulting from difficulties in entering the cover metrics specifically the %weight and ratings in the adjusted field and the fact that the observed and habitat derived frequency of occurrence could not be given a 0 score if a species was absent. (Dr Lamberth's opinion was that the assemblage was in a D Category).

⁹⁴ The affect of these floods on fish would have been exacerbated by channel incision. Whole-scale erosion and the lack of instream refuges.

Table A.2 PES, EIS and REC for the Varing River

Component of the riverine ecosystem	PES		EIS	Recommended Ecological Category
	Category	Trajectory		
Hydrology	D	Negative	<i>High EIS</i> , because of the support it provides to the Groot Brak Estuary and the fact that it is an important corridor through farmland for wildlife.	C/D
Water quality	C	Negative		
Geomorphology	D	Negative		
Riparian vegetation	C	Negative		
Macroinvertebrates	C	Negative		
Fish	C/D	Negative		
PRESENT ECOSTATUS	C/D	Negative		

The major factors contributing to the PES of the Varing River were:

- incision of the river channel (flow related);
- water levels associated with lower bed levels;
- extreme erosion, particularly of peat beds;
- poor water quality associated with upstream farming activities;
- die-back of riparian and instream vegetation as a result of above affects;
- drying out and invasion of marshes by exotic species.

A.4 WETLAND INDEX OF HABITAT INTEGRITY

Wetlands are amongst the most impacted and degraded of all ecological systems, and global assessments indicate that the majority of remaining wetlands are degraded or under threat of degradation (Finlayson and Spiers, 1999).

Wetland index of habitat integrity (Wetland-IHI, DWAF, 2007c) was determined using desktop information and field verification from two sites, and drives around the catchment.

The Wetland-IHI assesses four main components of the ecosystem, namely:

- alteration to vegetation due to land use activities in the wetland;
- alteration to the natural hydrology (flooding regime) due to catchment as well as on-site activities;
- alteration to the geomorphology of the site due to catchment as well as on-site activities;
- alteration to the water quality aspects of the river due to upstream catchment activities.

The reach assessed was between the road crossings that are upstream and downstream of the wetland reach in the upper portion of the Varing River (Figure A.2).

The overall score for the habitat integrity of the Varing wetland is in a “C/D” Ecological Category (Table A.3), which means that this wetland is moderately to largely modified. The individual components assessed are described below.

Table A.3 Results from the assessment of Wetland Habitat Integrity

OVERALL PRESENT ECOLOGICAL STATE (PES) SCORE					
	Ranking	Weighting	Score	Confidence Rating	PES Category
DRIVING PROCESSES:		100	2.0		
Hydrology	1	100	2.2	3.8	D
Geomorphology	2	100	2.2	3.4	D
Water Quality	3	60	1.4	3.7	C
WETLAND LANDUSE ACTIVITIES:		80	2.1	2.4	
Vegetation Alteration Score	1	90	2.1	2.4	C/D
Weighting needs to consider the sensitivity of the type of wetland (e.g.: nutrient poor wetlands will be more sensitive to nutrient loading)					
OVERALL SCORE:			2.1		
PES %			58.9	Confidence Rating	
PES Category:			C/D	1.1	

Vegetation Alteration (C/D category): The vegetation of the wetland has been significantly altered from natural, with the biggest impacts being extensive infestation of exotic trees and other plants (such as bracken fern and brambles), some vegetation clearing and localised infilling along the edges of the floodplain. Some pockets of near natural vegetation appear to remain in more inaccessible areas of the reach (Figure A.3).



Figure A.3 Pockets of more natural vegetation (on left) remain within the Varing wetland reach, but much of the reach is heavily infested with exotic invasive tree species (right).

Hydrology (D category): Lowflows have been seriously reduced by abstraction for irrigation and afforestation. The most significant effect, however, has been the indirect impact of the incision of the channel, which has resulted in a local lowering of the water table and subsequent desiccation of the lateral edges of the former wetland along the valley bottom (as illustrated in Figure A.4), and increased competency of the now incised channel, resulting in a reduced frequency of overbank (flood zone) inundation, causing further desiccation of the wetland, and so on.

Water Quality (C category): There are a number of impacts on water quality in the Varing River. The main ones are increased turbidity, arising primarily from the extensive eroding cut banks; increased fluctuations in temperature, arising from reduced lowflows (less temperature buffering) and the degradation of fringing marginal vegetation; increased nutrients and salts, from agricultural runoff from the catchment, and; increased pH levels, which are partly a result of agricultural runoff but also a result of a change in the vegetation.

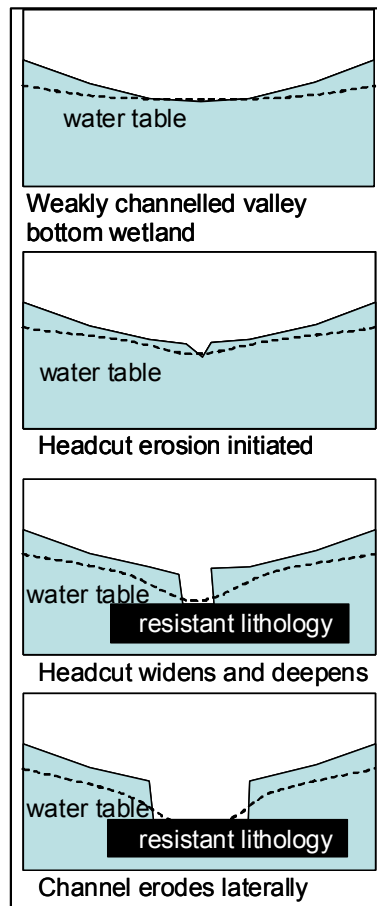


Figure A.4 A diagrammatic representation of the process of incision and lateral desiccation of wetland systems in valley bottoms – essentially lowering of the local water table due to drainage as a result of the incised channel.

A.5 EWR DETERMINATIONS – EWR SITE VAR 2

EWRs have been determined (using the calibrated desktop), for a C/D (REC), C (AEC 1) and D (AEC 2) categories.

REC: C/D-CATEGORY

Table A.4 Summary table for C/D-Category EWRs for the Varing River at EWR Site Var 2

Desktop Version 2, Generated on 4/16/2008							
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area:							
Annual Flows (Mill. cu. m or index values):							
MAR	=	6.746					
S.Dev.	=	3.044					
CV	=	0.451					
Q75	=	0.150					
Q75/MMF	=	0.267					
BFI Index	=	0.389					
CV(JJA+JFM) Index	=	2.222					
Ecological Category = C/D							
Total IFR	=	1.412	(20.93 %MAR)				
Maint. Lowflow	=	0.828	(12.28 %MAR)				
Drought Lowflow	=	0.426	(6.32 %MAR)				
Maint. Highflow	=	0.583	(8.65 %MAR)				
Monthly Distributions (Mill. cu. m.)							
Distribution Type : W.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			Total Flows
	Mean	SD	CV	Low flows		High Flows	
				Maint.	Drought	Maint.	Maint.
Oct	0.736	0.602	0.818	0.079	0.059	0.081	0.160
Nov	0.784	0.872	1.112	0.082	0.039	0.072	0.154
Dec	0.583	0.681	1.168	0.073	0.029	0.000	0.073
Jan	0.497	0.577	1.159	0.066	0.029	0.000	0.066
Feb	0.449	0.538	1.198	0.062	0.027	0.000	0.062
Mar	0.736	0.734	0.997	0.075	0.032	0.000	0.075
Apr	0.615	0.622	1.011	0.073	0.031	0.000	0.073
May	0.498	0.649	1.303	0.067	0.030	0.049	0.116
Jun	0.298	0.288	0.965	0.057	0.029	0.023	0.079
Jul	0.347	0.360	1.039	0.055	0.041	0.082	0.138
Aug	0.559	0.731	1.307	0.066	0.041	0.041	0.107
Sep	0.643	0.698	1.086	0.073	0.039	0.236	0.309

Table A.5 Rule tables for C/D-Category EWRs for the Varing River at EWR Site Var 2

Desktop Version 2, Generated on 4/16/2008											
Summary of IFR rule curves (Desktop Version 2) for:											
Total Runoff: Runoff: RRunof											
Regional Type: W.Cape(wet)											
Ecological Category = C/D											
Data are given in m ³ /s mean monthly flow											
Month	% Points										
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%	
Oct	0.088	0.088	0.088	0.086	0.084	0.078	0.069	0.054	0.037	0.022	
Nov	0.089	0.089	0.088	0.087	0.084	0.078	0.067	0.051	0.031	0.018	
Dec	0.043	0.043	0.042	0.042	0.040	0.036	0.030	0.022	0.015	0.007	
Jan	0.039	0.039	0.038	0.037	0.036	0.032	0.027	0.020	0.007	0.004	
Feb	0.040	0.040	0.040	0.039	0.037	0.034	0.028	0.021	0.014	0.004	
Mar	0.046	0.046	0.046	0.045	0.044	0.041	0.036	0.028	0.018	0.007	
Apr	0.046	0.046	0.046	0.045	0.044	0.041	0.036	0.028	0.018	0.008	
May	0.065	0.065	0.065	0.063	0.061	0.057	0.049	0.030	0.022	0.013	
Jun	0.050	0.050	0.050	0.049	0.048	0.046	0.042	0.027	0.019	0.008	
Jul	0.091	0.085	0.080	0.075	0.071	0.056	0.049	0.034	0.022	0.015	
Aug	0.070	0.068	0.065	0.062	0.060	0.054	0.050	0.042	0.030	0.017	
Sep	0.223	0.200	0.180	0.163	0.135	0.100	0.089	0.062	0.042	0.025	
Reserve Flows without High Flows											
Oct	0.049	0.049	0.048	0.048	0.047	0.044	0.040	0.034	0.027	0.022	
Nov	0.052	0.052	0.052	0.051	0.049	0.046	0.041	0.032	0.022	0.015	
Dec	0.043	0.043	0.042	0.042	0.040	0.036	0.030	0.022	0.015	0.007	
Jan	0.039	0.039	0.038	0.037	0.036	0.032	0.027	0.020	0.007	0.004	
Feb	0.040	0.040	0.040	0.039	0.037	0.034	0.028	0.021	0.014	0.004	
Mar	0.046	0.046	0.046	0.045	0.044	0.041	0.036	0.028	0.018	0.007	
Apr	0.046	0.046	0.046	0.045	0.044	0.041	0.036	0.028	0.018	0.008	
May	0.041	0.041	0.041	0.040	0.039	0.036	0.032	0.025	0.017	0.011	
Jun	0.038	0.038	0.038	0.038	0.037	0.035	0.033	0.027	0.019	0.008	
Jul	0.036	0.036	0.036	0.036	0.035	0.034	0.032	0.028	0.022	0.015	
Aug	0.043	0.043	0.043	0.043	0.042	0.040	0.038	0.032	0.024	0.016	
Sep	0.046	0.046	0.046	0.045	0.044	0.041	0.037	0.029	0.021	0.015	
Natural Duration curves											
Oct	0.605	0.500	0.366	0.280	0.209	0.153	0.108	0.082	0.045	0.022	
Nov	0.775	0.532	0.374	0.235	0.170	0.116	0.081	0.062	0.039	0.019	
Dec	0.493	0.351	0.276	0.190	0.146	0.108	0.067	0.041	0.015	0.007	
Jan	0.497	0.291	0.190	0.153	0.116	0.097	0.052	0.034	0.007	0.004	
Feb	0.463	0.298	0.236	0.128	0.103	0.079	0.062	0.033	0.025	0.004	
Mar	0.698	0.429	0.347	0.280	0.239	0.131	0.078	0.041	0.022	0.007	
Apr	0.667	0.370	0.270	0.208	0.174	0.131	0.100	0.062	0.023	0.008	
May	0.392	0.273	0.190	0.138	0.093	0.078	0.063	0.030	0.022	0.015	
Jun	0.274	0.177	0.131	0.093	0.085	0.066	0.046	0.027	0.019	0.008	
Jul	0.302	0.202	0.142	0.116	0.090	0.056	0.049	0.034	0.022	0.015	
Aug	0.545	0.269	0.205	0.146	0.112	0.090	0.071	0.056	0.034	0.019	
Sep	0.590	0.421	0.255	0.197	0.135	0.100	0.089	0.062	0.042	0.035	

AEC: C -CATEGORY

Table A.6 Summary table for C -Category EWRs for the Varing River at EWR Site Var 2

Desktop Version 2, Generated on 8/6/2008 Summary of Desktop (Version 2) estimate for Quaternary Catchment Area : Total Runoff : Runoff : RRunof							
Annual Flows (Mill. cu. m or index values):							
MAR	=		6.746				
S.Dev.	=		3.044				
CV	=		0.451				
Q75	=		0.150				
Q75/MMF	=		0.267				
BFI Index	=		0.365				
CV(JJA+JFM) Index	=		2.222				
Ecological Category = C							
Total IFR	=		1.692	(25.08 %MAR)			
Maint. Lowflow	=		1.048	(15.53 %MAR)			
Drought Lowflow	=		0.413	(6.12 %MAR)			
Maint. Highflow	=		0.644	(9.55 %MAR)			
Monthly Distributions (Mill. cu. m.)							
Distribution Type : S.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			
	Mean	SD	CV	Low flows		High Flows	Total Flows
				Maint.	Drought	Maint.	Maint.
Oct	0.736	0.602	0.818	0.101	0.059	0.089	0.190
Nov	0.784	0.872	1.112	0.104	0.039	0.080	0.184
Dec	0.583	0.681	1.168	0.093	0.029	0.000	0.093
Jan	0.497	0.577	1.159	0.083	0.029	0.000	0.083
Feb	0.449	0.538	1.198	0.079	0.027	0.000	0.079
Mar	0.736	0.734	0.997	0.095	0.029	0.000	0.095
Apr	0.615	0.622	1.011	0.093	0.031	0.000	0.093
May	0.498	0.649	1.303	0.084	0.029	0.054	0.138
Jun	0.298	0.288	0.965	0.071	0.029	0.025	0.096
Jul	0.347	0.360	1.039	0.069	0.032	0.091	0.160
Aug	0.559	0.731	1.307	0.083	0.040	0.045	0.128
Sep	0.643	0.698	1.086	0.092	0.039	0.260	0.353

Table A.7 Rule tables for C -Category EWRs for the Varing River at EWR Site Var 2

Desktop Version 2, Generated on 8/6/2008										
Summary of IFR rule curves (Desktop Version 2) for :										
Total Runoff : Runoff : RRunof										
Regional Type : S.Cape(wet)										
Ecological Category = C										
Data are given in m ³ * 10 ⁶ monthly flow volume										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.339	0.303	0.274	0.247	0.201	0.176	0.143	0.108	0.081	0.060
Nov	0.325	0.293	0.265	0.238	0.193	0.165	0.128	0.090	0.061	0.049
Dec	0.130	0.129	0.125	0.118	0.105	0.086	0.065	0.046	0.035	0.020
Jan	0.118	0.117	0.114	0.107	0.095	0.078	0.059	0.044	0.020	0.010
Feb	0.110	0.109	0.106	0.100	0.089	0.074	0.056	0.040	0.031	0.010
Mar	0.134	0.133	0.130	0.125	0.115	0.098	0.077	0.054	0.038	0.020
Apr	0.128	0.128	0.126	0.121	0.112	0.097	0.076	0.055	0.039	0.020
May	0.179	0.178	0.176	0.170	0.157	0.135	0.104	0.072	0.047	0.037
Jun	0.127	0.127	0.125	0.123	0.117	0.106	0.088	0.066	0.044	0.020
Jul	0.200	0.200	0.199	0.194	0.185	0.150	0.130	0.090	0.060	0.040
Aug	0.209	0.195	0.182	0.169	0.147	0.134	0.113	0.086	0.061	0.047
Sep	0.709	0.606	0.523	0.453	0.336	0.260	0.220	0.148	0.093	0.069
Reserve Flows without High Flows										
Oct	0.139	0.139	0.137	0.134	0.126	0.114	0.097	0.079	0.066	0.060
Nov	0.146	0.146	0.143	0.138	0.127	0.110	0.087	0.065	0.048	0.040
Dec	0.130	0.129	0.125	0.118	0.105	0.086	0.065	0.046	0.035	0.020
Jan	0.118	0.117	0.114	0.107	0.095	0.078	0.059	0.044	0.020	0.010
Feb	0.110	0.109	0.106	0.100	0.089	0.074	0.056	0.040	0.031	0.010
Mar	0.134	0.133	0.130	0.125	0.115	0.098	0.077	0.054	0.038	0.020
Apr	0.128	0.128	0.126	0.121	0.112	0.097	0.076	0.055	0.039	0.020
May	0.115	0.115	0.113	0.110	0.102	0.089	0.071	0.052	0.037	0.031
Jun	0.097	0.097	0.096	0.094	0.090	0.082	0.070	0.053	0.038	0.020
Jul	0.094	0.094	0.093	0.092	0.088	0.081	0.070	0.055	0.041	0.033
Aug	0.114	0.114	0.113	0.111	0.106	0.098	0.084	0.067	0.051	0.042
Sep	0.126	0.126	0.124	0.120	0.113	0.099	0.081	0.061	0.046	0.040
Natural Duration curves										
Oct	1.620	1.340	0.980	0.750	0.560	0.410	0.290	0.220	0.120	0.060
Nov	2.010	1.380	0.970	0.610	0.440	0.300	0.210	0.160	0.100	0.050
Dec	1.320	0.940	0.740	0.510	0.390	0.290	0.180	0.110	0.040	0.020
Jan	1.330	0.780	0.510	0.410	0.310	0.260	0.140	0.090	0.020	0.010
Feb	1.120	0.720	0.570	0.310	0.250	0.190	0.150	0.080	0.060	0.010
Mar	1.870	1.150	0.930	0.750	0.640	0.350	0.210	0.110	0.060	0.020
Apr	1.730	0.960	0.700	0.540	0.450	0.340	0.260	0.160	0.060	0.020
May	1.050	0.730	0.510	0.370	0.250	0.210	0.170	0.080	0.060	0.040
Jun	0.710	0.460	0.340	0.240	0.220	0.170	0.120	0.070	0.050	0.020
Jul	0.810	0.540	0.380	0.310	0.240	0.150	0.130	0.090	0.060	0.040
Aug	1.460	0.720	0.550	0.390	0.300	0.240	0.190	0.150	0.090	0.050
Sep	1.530	1.090	0.660	0.510	0.350	0.260	0.230	0.160	0.110	0.090

AEC: D -CATEGORY

Table A.8 Summary table for D -Category EWRs for the Varing River at EWR Site Var 2

Desktop Version 2, Generated on 8/6/2008

Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :

Total Runoff : Runoff : RRunof

Annual Flows (Mill. cu. m or index values):

MAR = 6.746

S.Dev. = 3.044

CV = 0.451

Q75 = 0.150

Q75/MMF = 0.267

BFI Index = 0.365

CV(JJA+JFM) Index = 2.222

Ecological Category = D

Total IFR = 1.202 (17.82 %MAR)

Maint. Lowflow = 0.619 (9.18 %MAR)

Drought Lowflow = 0.416 (6.17 %MAR)

Maint. Highflow = 0.583 (8.65 %MAR)

Monthly Distributions (Mill. cu. m.)

Distribution Type : S.Cape(wet)

Month	Natural Flows			Modified Flows (IFR)			
	Mean	SD	CV	Low flows		High Flows	Total Flows
				Maint.	Drought	Maint.	Maint.
Oct	0.736	0.602	0.818	0.059	0.054	0.081	0.140
Nov	0.784	0.872	1.112	0.061	0.040	0.072	0.134
Dec	0.583	0.681	1.168	0.055	0.029	0.000	0.055
Jan	0.497	0.577	1.159	0.049	0.029	0.000	0.049
Feb	0.449	0.538	1.198	0.047	0.027	0.000	0.047
Mar	0.736	0.734	0.997	0.056	0.029	0.000	0.056
Apr	0.615	0.622	1.011	0.055	0.031	0.000	0.055
May	0.498	0.649	1.303	0.050	0.029	0.049	0.099
Jun	0.298	0.288	0.965	0.042	0.029	0.023	0.065
Jul	0.347	0.360	1.039	0.041	0.040	0.082	0.124
Aug	0.559	0.731	1.307	0.049	0.040	0.041	0.090
Sep	0.643	0.698	1.086	0.054	0.039	0.236	0.290

Table A.9 Rule tables for D -Category EWRs for the Varing River at EWR Site Var 2

Desktop Version 2, Generated on 8/6/2008										
Summary of IFR rule curves (Desktop Version 2) for :										
Total Runoff : Runoff : RRunof										
Regional Type : S.Cape(wet)										
Ecological Category = C										
Data are given in m ³ * 10 ⁶ monthly flow volume										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.339	0.303	0.274	0.247	0.201	0.176	0.143	0.108	0.081	0.060
Nov	0.325	0.293	0.265	0.238	0.193	0.165	0.128	0.090	0.061	0.049
Dec	0.130	0.129	0.125	0.118	0.105	0.086	0.065	0.046	0.035	0.020
Jan	0.118	0.117	0.114	0.107	0.095	0.078	0.059	0.044	0.020	0.010
Feb	0.110	0.109	0.106	0.100	0.089	0.074	0.056	0.040	0.031	0.010
Mar	0.134	0.133	0.130	0.125	0.115	0.098	0.077	0.054	0.038	0.020
Apr	0.128	0.128	0.126	0.121	0.112	0.097	0.076	0.055	0.039	0.020
May	0.179	0.178	0.176	0.170	0.157	0.135	0.104	0.072	0.047	0.037
Jun	0.127	0.127	0.125	0.123	0.117	0.106	0.088	0.066	0.044	0.020
Jul	0.200	0.200	0.199	0.194	0.185	0.150	0.130	0.090	0.060	0.040
Aug	0.209	0.195	0.182	0.169	0.147	0.134	0.113	0.086	0.061	0.047
Sep	0.709	0.606	0.523	0.453	0.336	0.260	0.220	0.148	0.093	0.069
Reserve Flows without High Flows										
Oct	0.139	0.139	0.137	0.134	0.126	0.114	0.097	0.079	0.066	0.060
Nov	0.146	0.146	0.143	0.138	0.127	0.110	0.087	0.065	0.048	0.040
Dec	0.130	0.129	0.125	0.118	0.105	0.086	0.065	0.046	0.035	0.020
Jan	0.118	0.117	0.114	0.107	0.095	0.078	0.059	0.044	0.020	0.010
Feb	0.110	0.109	0.106	0.100	0.089	0.074	0.056	0.040	0.031	0.010
Mar	0.134	0.133	0.130	0.125	0.115	0.098	0.077	0.054	0.038	0.020
Apr	0.128	0.128	0.126	0.121	0.112	0.097	0.076	0.055	0.039	0.020
May	0.115	0.115	0.113	0.110	0.102	0.089	0.071	0.052	0.037	0.031
Jun	0.097	0.097	0.096	0.094	0.090	0.082	0.070	0.053	0.038	0.020
Jul	0.094	0.094	0.093	0.092	0.088	0.081	0.070	0.055	0.041	0.033
Aug	0.114	0.114	0.113	0.111	0.106	0.098	0.084	0.067	0.051	0.042
Sep	0.126	0.126	0.124	0.120	0.113	0.099	0.081	0.061	0.046	0.040
Natural Duration curves										
Oct	1.620	1.340	0.980	0.750	0.560	0.410	0.290	0.220	0.120	0.060
Nov	2.010	1.380	0.970	0.610	0.440	0.300	0.210	0.160	0.100	0.050
Dec	1.320	0.940	0.740	0.510	0.390	0.290	0.180	0.110	0.040	0.020
Jan	1.330	0.780	0.510	0.410	0.310	0.260	0.140	0.090	0.020	0.010
Feb	1.120	0.720	0.570	0.310	0.250	0.190	0.150	0.080	0.060	0.010
Mar	1.870	1.150	0.930	0.750	0.640	0.350	0.210	0.110	0.060	0.020
Apr	1.730	0.960	0.700	0.540	0.450	0.340	0.260	0.160	0.060	0.020
May	1.050	0.730	0.510	0.370	0.250	0.210	0.170	0.080	0.060	0.040
Jun	0.710	0.460	0.340	0.240	0.220	0.170	0.120	0.070	0.050	0.020
Jul	0.810	0.540	0.380	0.310	0.240	0.150	0.130	0.090	0.060	0.040
Aug	1.460	0.720	0.550	0.390	0.300	0.240	0.190	0.150	0.090	0.050
Sep	1.530	1.090	0.660	0.510	0.350	0.260	0.230	0.160	0.110	0.090

A.6 EWR DETERMINATIONS – EWR SITE VAR 3 (Extrapolation)

EWRs have been determined (using the calibrated desktop), for a C/D (REC), C (AEC 1) and D (AEC 2) categories (Extrapolation to inflow to Wolwedans Dam).

REC: C/D -CATEGORY

Table A.10 Summary table for C/D -Category EWRs for the Varing River at EWR Site Var 3

Desktop Version 2, Generated on 4/17/2008							
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :							
Total Runoff : Runoff : VVarin							
Annual Flows (Mill. cu. m or index values):							
MAR	=	11.432					
S.Dev.	=	5.159					
CV	=	0.451					
Q75	=	0.250					
Q75/MMF	=	0.262					
BFI Index	=	0.389					
CV(JJA+JFM) Index	=	2.220					
Ecological Category = C/D							
Total IFR	=	2.392	(20.93 %MAR)				
Maint. Lowflow	=	1.404	(12.28 %MAR)				
Drought Lowflow	=	0.722	(6.32 %MAR)				
Maint. Highflow	=	0.989	(8.65 %MAR)				
Monthly Distributions (Mill. cu. m.)							
Distribution Type : W.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			
	Mean	SD	CV	Low flows		High Flows	Total Flows
				Maint.	Drought	Maint.	Maint.
Oct	1.248	1.021	0.819	0.134	0.100	0.137	0.271
Nov	1.328	1.477	1.112	0.139	0.066	0.123	0.261
Dec	0.989	1.155	1.168	0.124	0.050	0.000	0.124
Jan	0.844	0.977	1.158	0.112	0.050	0.000	0.112
Feb	0.760	0.912	1.199	0.106	0.045	0.000	0.106
Mar	1.247	1.244	0.998	0.127	0.054	0.000	0.127
Apr	1.041	1.054	1.012	0.124	0.053	0.000	0.124
May	0.842	1.100	1.306	0.113	0.050	0.083	0.196
Jun	0.507	0.487	0.962	0.096	0.048	0.038	0.134
Jul	0.588	0.611	1.038	0.094	0.070	0.139	0.233
Aug	0.948	1.237	1.306	0.112	0.070	0.070	0.181
Sep	1.091	1.185	1.086	0.123	0.066	0.400	0.523

Table A.11 Rule tables for C/D -Category EWRs for the Varing River at EWR Site Var
3

Desktop Version 2, Generated on 4/17/2008										
Summary of IFR rule curves (Desktop Version 2) for :										
Total Runoff : Runoff : VVarin										
Regional Type : W.Cape(wet)										
Ecological Category = C/D										
Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.150	0.150	0.149	0.146	0.142	0.133	0.117	0.092	0.062	0.041
Nov	0.150	0.150	0.149	0.147	0.142	0.131	0.113	0.086	0.052	0.031
Dec	0.073	0.073	0.072	0.070	0.067	0.061	0.050	0.037	0.022	0.011
Jan	0.065	0.065	0.065	0.063	0.061	0.055	0.046	0.034	0.015	0.007
Feb	0.068	0.068	0.068	0.066	0.063	0.057	0.048	0.035	0.024	0.008
Mar	0.078	0.078	0.077	0.076	0.074	0.069	0.060	0.047	0.031	0.011
Apr	0.078	0.078	0.078	0.077	0.074	0.069	0.061	0.047	0.031	0.015
May	0.110	0.110	0.109	0.108	0.104	0.096	0.083	0.052	0.038	0.022
Jun	0.085	0.085	0.085	0.084	0.082	0.079	0.072	0.046	0.035	0.015
Jul	0.154	0.144	0.136	0.128	0.120	0.097	0.082	0.056	0.041	0.026
Aug	0.119	0.114	0.110	0.105	0.101	0.092	0.085	0.072	0.051	0.029
Sep	0.378	0.339	0.305	0.276	0.228	0.170	0.150	0.104	0.069	0.042
Reserve Flows without High Flows										
Oct	0.082	0.082	0.082	0.081	0.079	0.075	0.069	0.058	0.046	0.038
Nov	0.088	0.088	0.087	0.086	0.083	0.078	0.069	0.054	0.037	0.026
Dec	0.073	0.073	0.072	0.070	0.067	0.061	0.050	0.037	0.022	0.011
Jan	0.065	0.065	0.065	0.063	0.061	0.055	0.046	0.034	0.015	0.007
Feb	0.068	0.068	0.068	0.066	0.063	0.057	0.048	0.035	0.024	0.008
Mar	0.078	0.078	0.077	0.076	0.074	0.069	0.060	0.047	0.031	0.011
Apr	0.078	0.078	0.078	0.077	0.074	0.069	0.061	0.047	0.031	0.015
May	0.069	0.069	0.069	0.068	0.066	0.062	0.054	0.042	0.028	0.019
Jun	0.065	0.065	0.064	0.064	0.063	0.060	0.055	0.046	0.033	0.015
Jul	0.062	0.062	0.061	0.061	0.060	0.058	0.054	0.048	0.037	0.026
Aug	0.073	0.073	0.073	0.072	0.071	0.068	0.064	0.055	0.041	0.026
Sep	0.078	0.078	0.078	0.077	0.074	0.070	0.062	0.050	0.035	0.026
Natural Duration curves										
Oct	1.027	0.848	0.620	0.474	0.355	0.261	0.183	0.142	0.078	0.041
Nov	1.312	0.903	0.633	0.397	0.289	0.197	0.139	0.104	0.066	0.031
Dec	0.833	0.597	0.470	0.325	0.246	0.183	0.116	0.071	0.022	0.011
Jan	0.840	0.493	0.325	0.261	0.198	0.164	0.090	0.060	0.015	0.007
Feb	0.781	0.504	0.397	0.219	0.178	0.132	0.103	0.058	0.041	0.008
Mar	1.184	0.728	0.590	0.474	0.403	0.220	0.131	0.067	0.037	0.011
Apr	1.130	0.625	0.459	0.351	0.293	0.220	0.170	0.104	0.042	0.015
May	0.665	0.463	0.321	0.231	0.161	0.131	0.105	0.052	0.041	0.022
Jun	0.463	0.301	0.224	0.158	0.143	0.112	0.081	0.046	0.035	0.015
Jul	0.515	0.343	0.239	0.198	0.149	0.097	0.082	0.056	0.041	0.026
Aug	0.926	0.455	0.347	0.246	0.190	0.153	0.119	0.093	0.060	0.030
Sep	1.003	0.710	0.432	0.336	0.228	0.170	0.150	0.104	0.069	0.058

AEC: C -CATEGORY

Table A.12 Summary table for C -Category EWRs for the Varing River at EWR Site Var 3

Desktop Version 2, Generated on 4/17/2008							
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :							
Total Runoff : Runoff : VVarin							
Annual Flows (Mill. cu. m or index values):							
MAR	=		11.432				
S.Dev.	=		5.159				
CV	=		0.451				
Q75	=		0.250				
Q75/MMF	=		0.262				
BFI Index	=		0.389				
CV(JJA+JFM) Index	=		2.220				
Ecological Category = C							
Total IFR	=		2.867	(25.08 %MAR)			
Maint. Lowflow	=		1.776	(15.53 %MAR)			
Drought Lowflow	=		0.700	(6.12 %MAR)			
Maint. Highflow	=		1.091	(9.55 %MAR)			
Monthly Distributions (Mill. cu. m.)							
Distribution Type : W.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			
	Mean	SD	CV	Low flows		High Flows	Total Flows
				Maint.	Drought	Maint.	Maint.
Oct	1.248	1.021	0.819	0.171	0.100	0.151	0.322
Nov	1.328	1.477	1.112	0.177	0.066	0.135	0.312
Dec	0.989	1.155	1.168	0.158	0.050	0.000	0.158
Jan	0.844	0.977	1.158	0.141	0.050	0.000	0.141
Feb	0.760	0.912	1.199	0.133	0.045	0.000	0.133
Mar	1.247	1.244	0.998	0.161	0.050	0.000	0.161
Apr	1.041	1.054	1.012	0.157	0.053	0.000	0.157
May	0.842	1.100	1.306	0.143	0.050	0.091	0.234
Jun	0.507	0.487	0.962	0.120	0.048	0.042	0.162
Jul	0.588	0.611	1.038	0.118	0.054	0.154	0.271
Aug	0.948	1.237	1.306	0.141	0.068	0.077	0.218
Sep	1.091	1.185	1.086	0.156	0.066	0.441	0.597

Table A.13 Rule tables for C -Category EWRs for the Varing River at EWR Site Var 3

Desktop Version 2, Generated on 4/17/2008										
Summary of IFR rule curves (Desktop Version 2) for :										
Total Runoff : Runoff : VVarin										
Regional Type : W.Cape(wet)										
Ecological Category = C										
Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.156	0.156	0.155	0.153	0.148	0.138	0.121	0.095	0.064	0.041
Nov	0.157	0.157	0.156	0.154	0.148	0.138	0.119	0.089	0.054	0.031
Dec	0.080	0.080	0.079	0.077	0.073	0.066	0.054	0.039	0.022	0.011
Jan	0.071	0.071	0.071	0.069	0.066	0.060	0.050	0.036	0.015	0.007
Feb	0.075	0.075	0.074	0.072	0.069	0.062	0.051	0.038	0.025	0.008
Mar	0.084	0.084	0.083	0.082	0.079	0.074	0.064	0.049	0.031	0.011
Apr	0.084	0.084	0.084	0.082	0.080	0.074	0.065	0.050	0.032	0.015
May	0.115	0.115	0.114	0.112	0.108	0.101	0.087	0.052	0.039	0.022
Jun	0.087	0.087	0.086	0.085	0.084	0.080	0.073	0.046	0.035	0.015
Jul	0.165	0.155	0.145	0.136	0.128	0.097	0.082	0.056	0.041	0.026
Aug	0.127	0.122	0.117	0.112	0.107	0.097	0.089	0.075	0.052	0.029
Sep	0.415	0.372	0.335	0.303	0.228	0.170	0.150	0.104	0.069	0.044
Reserve Flows without High Flows										
Oct	0.089	0.089	0.088	0.087	0.085	0.081	0.073	0.061	0.047	0.038
Nov	0.095	0.095	0.094	0.093	0.090	0.084	0.074	0.058	0.038	0.026
Dec	0.080	0.080	0.079	0.077	0.073	0.066	0.054	0.039	0.022	0.011
Jan	0.071	0.071	0.071	0.069	0.066	0.060	0.050	0.036	0.015	0.007
Feb	0.075	0.075	0.074	0.072	0.069	0.062	0.051	0.038	0.025	0.008
Mar	0.084	0.084	0.083	0.082	0.079	0.074	0.064	0.049	0.031	0.011
Apr	0.084	0.084	0.084	0.082	0.080	0.074	0.065	0.050	0.032	0.015
May	0.074	0.074	0.074	0.073	0.070	0.066	0.057	0.045	0.029	0.019
Jun	0.067	0.067	0.066	0.066	0.065	0.062	0.057	0.046	0.034	0.015
Jul	0.063	0.063	0.063	0.063	0.061	0.059	0.055	0.047	0.034	0.021
Aug	0.076	0.076	0.076	0.075	0.074	0.071	0.066	0.056	0.041	0.026
Sep	0.084	0.084	0.084	0.082	0.080	0.075	0.066	0.053	0.036	0.026
Natural Duration curves										
Oct	1.027	0.848	0.620	0.474	0.355	0.261	0.183	0.142	0.078	0.041
Nov	1.312	0.903	0.633	0.397	0.289	0.197	0.139	0.104	0.066	0.031
Dec	0.833	0.597	0.470	0.325	0.246	0.183	0.116	0.071	0.022	0.011
Jan	0.840	0.493	0.325	0.261	0.198	0.164	0.090	0.060	0.015	0.007
Feb	0.781	0.504	0.397	0.219	0.178	0.132	0.103	0.058	0.041	0.008
Mar	1.184	0.728	0.590	0.474	0.403	0.220	0.131	0.067	0.037	0.011
Apr	1.130	0.625	0.459	0.351	0.293	0.220	0.170	0.104	0.042	0.015
May	0.665	0.463	0.321	0.231	0.161	0.131	0.105	0.052	0.041	0.022
Jun	0.463	0.301	0.224	0.158	0.143	0.112	0.081	0.046	0.035	0.015
Jul	0.515	0.343	0.239	0.198	0.149	0.097	0.082	0.056	0.041	0.026
Aug	0.926	0.455	0.347	0.246	0.190	0.153	0.119	0.093	0.060	0.030
Sep	1.003	0.710	0.432	0.336	0.228	0.170	0.150	0.104	0.069	0.058

AEC: D -CATEGORY

Table A.14 Summary table for D -Category EWRs for the Varing River at EWR Site Var 3

Desktop Version 2, Generated on 4/17/2008							
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area :							
Total Runoff : Runoff : VVarin							
Annual Flows (Mill. cu. m or index values):							
MAR	=	11.432					
S.Dev.	=	5.159					
CV	=	0.451					
Q75	=	0.250					
Q75/MMF	=	0.262					
BFI Index	=	0.389					
CV(JJA+JFM) Index	=	2.220					
Ecological Category = D							
Total IFR	=	2.038	(17.82 %MAR)				
Maint. Lowflow	=	1.049	(9.18 %MAR)				
Drought Lowflow	=	0.706	(6.17 %MAR)				
Maint. Highflow	=	0.989	(8.65 %MAR)				
Monthly Distributions (Mill. cu. m.)							
Distribution Type : W.Cape(wet)							
Month	Natural Flows			Modified Flows (IFR)			
	Mean	SD	CV	Low flows		High Flows	Total Flows
				Maint.	Drought	Maint.	Maint.
Oct	1.248	1.021	0.819	0.100	0.091	0.137	0.237
Nov	1.328	1.477	1.112	0.104	0.067	0.123	0.226
Dec	0.989	1.155	1.168	0.093	0.050	0.000	0.093
Jan	0.844	0.977	1.158	0.084	0.050	0.000	0.084
Feb	0.760	0.912	1.199	0.079	0.045	0.000	0.079
Mar	1.247	1.244	0.998	0.095	0.050	0.000	0.095
Apr	1.041	1.054	1.012	0.092	0.053	0.000	0.092
May	0.842	1.100	1.306	0.085	0.050	0.083	0.168
Jun	0.507	0.487	0.962	0.071	0.048	0.038	0.110
Jul	0.588	0.611	1.038	0.070	0.068	0.139	0.209
Aug	0.948	1.237	1.306	0.083	0.068	0.070	0.153
Sep	1.091	1.185	1.086	0.092	0.066	0.400	0.492

Table A.15 Rule tables for D -Category EWRs for the Varing River at EWR Site Var 3

Desktop Version 2, Generated on 4/17/2008										
Summary of IFR rule curves (Desktop Version 2) for :										
Total Runoff : Runoff : VVarin										
Regional Type : W.Cape(wet)										
Ecological Category = D										
Data are given in m ³ /s mean monthly flow										
Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.151	0.151	0.150	0.147	0.143	0.133	0.117	0.091	0.060	0.040
Nov	0.150	0.150	0.149	0.147	0.142	0.132	0.114	0.086	0.053	0.031
Dec	0.064	0.064	0.064	0.062	0.060	0.054	0.045	0.034	0.022	0.011
Jan	0.058	0.058	0.057	0.056	0.054	0.049	0.042	0.032	0.015	0.007
Feb	0.061	0.061	0.060	0.059	0.056	0.051	0.043	0.033	0.023	0.008
Mar	0.071	0.071	0.070	0.069	0.067	0.063	0.055	0.043	0.028	0.011
Apr	0.071	0.071	0.071	0.070	0.067	0.063	0.056	0.044	0.030	0.015
May	0.109	0.109	0.108	0.107	0.103	0.096	0.082	0.052	0.038	0.022
Jun	0.084	0.084	0.083	0.083	0.081	0.077	0.071	0.046	0.035	0.015
Jul	0.150	0.140	0.131	0.124	0.116	0.097	0.082	0.056	0.041	0.026
Aug	0.114	0.110	0.105	0.101	0.096	0.087	0.081	0.069	0.049	0.028
Sep	0.370	0.331	0.298	0.269	0.228	0.170	0.150	0.104	0.069	0.042
Reserve Flows without High Flows										
Oct	0.075	0.075	0.074	0.073	0.072	0.068	0.062	0.053	0.041	0.034
Nov	0.080	0.080	0.079	0.078	0.076	0.071	0.063	0.051	0.036	0.026
Dec	0.064	0.064	0.064	0.062	0.060	0.054	0.045	0.034	0.022	0.011
Jan	0.058	0.058	0.057	0.056	0.054	0.049	0.042	0.032	0.015	0.007
Feb	0.061	0.061	0.060	0.059	0.056	0.051	0.043	0.033	0.023	0.008
Mar	0.071	0.071	0.070	0.069	0.067	0.063	0.055	0.043	0.028	0.011
Apr	0.071	0.071	0.071	0.070	0.067	0.063	0.056	0.044	0.030	0.015
May	0.063	0.063	0.063	0.062	0.060	0.056	0.050	0.039	0.027	0.019
Jun	0.060	0.060	0.060	0.060	0.058	0.056	0.052	0.044	0.032	0.015
Jul	0.057	0.057	0.057	0.057	0.056	0.054	0.051	0.045	0.035	0.026
Aug	0.068	0.068	0.068	0.067	0.066	0.064	0.060	0.052	0.039	0.026
Sep	0.071	0.071	0.070	0.069	0.068	0.064	0.057	0.046	0.034	0.026
Natural Duration curves										
Oct	1.027	0.848	0.620	0.474	0.355	0.261	0.183	0.142	0.078	0.041
Nov	1.312	0.903	0.633	0.397	0.289	0.197	0.139	0.104	0.066	0.031
Dec	0.833	0.597	0.470	0.325	0.246	0.183	0.116	0.071	0.022	0.011
Jan	0.840	0.493	0.325	0.261	0.198	0.164	0.090	0.060	0.015	0.007
Feb	0.781	0.504	0.397	0.219	0.178	0.132	0.103	0.058	0.041	0.008
Mar	1.184	0.728	0.590	0.474	0.403	0.220	0.131	0.067	0.037	0.011
Apr	1.130	0.625	0.459	0.351	0.293	0.220	0.170	0.104	0.042	0.015
May	0.665	0.463	0.321	0.231	0.161	0.131	0.105	0.052	0.041	0.022
Jun	0.463	0.301	0.224	0.158	0.143	0.112	0.081	0.046	0.035	0.015
Jul	0.515	0.343	0.239	0.198	0.149	0.097	0.082	0.056	0.041	0.026
Aug	0.926	0.455	0.347	0.246	0.190	0.153	0.119	0.093	0.060	0.030
Sep	1.003	0.710	0.432	0.336	0.228	0.170	0.150	0.104	0.069	0.058

A.7 EXPLANATION OF THE EWRS AND SUGGESTIONS FOR IMPROVED MANAGEMENT OF THE RIVER ECOSYSTEM

The changes that have occurred in the Varing River may have been initiated by reduced lowflows in the system but they cannot be reversed (at least not in the short-term) using flow alone. Furthermore, the knock-on effects of these changes are serving to accelerate the process of degradation, and the ecological condition of the Varing River is in a steep negative trajectory. In time, the wetlands will dry out further, alien invasion will increase and the natural vegetation will all but disappear from the system. The result will be a further decline in lowflows (even in the absence of abstraction) and an increase in flood peaks and flood damage, partly because there will be fewer wetlands to attenuate floodwaters but also because the channel will become clogged with alien trees. Interestingly, this clogging of the channel by trees, and the resultant trapping of sediments, will eventually (over hundreds of years) start the reversal of the process, but not before a serious (additional) decline in river condition and reduction in river services (of which lowflows are probably the most valued by farmers at present).

The declining condition of the Varing River has several implications for both flow and catchment management, and affect, *inter alia*, the recommendations for ecological water requirements, and the evaluation, from an entirely ecological perspective, of the proposal to build an in-channel dam in the upper reaches of the river.

As far as the recommendations for ecological water requirements are concerned, no large floods (Class III, IV or inter-annual floods) have been motivated for, since these large events would further scour out the system and accelerate the negative trajectory of change. An extensive period of moderate flows, combined with increased low flows, would facilitate some recovery of the incised channel through increased vegetation cover, bank stabilisation and bed aggradation. Given the nature of the catchment, however, these larger floods are likely to continue to occur, and indeed will probably increase in magnitude. Hence the concern expressed earlier that reinstating flow alone would not reverse the ongoing decline in system condition.

In order to halt the decline in condition, and possibly reverse it in places, some channel engineering, such as construction of gabions or other in-channel obstructions, will be required. These obstructions, provided they are designed and placed appropriately, will serve to slow the flow of water through the channel and will trap sediments, which will raise the bed and provide habitat for the palmiet to re-established. They will also elevate the water levels and reverse some of the lateral desiccation of the wetland, as well as to improve the opportunity for bed aggradation and in-channel vegetation re-establishment. This channel engineering will also need to be accompanied by removal of the trees that have invaded the marshes and river corridors and, ideally, should also be accompanied by the reinstatement of riparian buffer zones, which will provide some protection from poor quality agricultural runoff. Farmers should also be encouraged to catch nutrient-rich runoff from their farms and to redistribute these onto pastures before they are allowed to flow into the Varing River.

Note: These rehabilitation measures could be done with the assistance, both expertise and financial, of Working for Wetlands.

A7.1 Comments on the proposed in-channel farm dam

The construction of an in-channel dam on the Varing River could either exacerbate or ameliorate the current degradation of the river system, depending on its exact location, its design, care taken in its construction and its operation.

In order for it to ameliorate the current degradation of the river system, the following would be required:

Location:

The dam should be located upstream of its current proposed position, i.e., upstream of the small tributary entering from the northeast.

Design:

The dam should have multiple bottom outlets that are designed in such a manner that flow from them is distributed across a wide area as concentrated flow paths will result in erosion and a lowering of the bed, etc.

The same applied to flood spills over the dam wall. The spillway should be designed in such as to avoid a concentration of flows during floods.

Low-level cross-channel gabions should be constructed upstream and downstream of the dam for a distance of c. 250 m, as necessitated by the current extent of incision of the channel in the affected reach.⁹⁵

Construction:

An Environmental Management Plan should be developed for the construction phase, and an Environmental Control Officer should supervise the construction.

Operation:

Initially, the dam will need to release the full Ecological Reserve lowflow maintenance requirement, regardless of lowflow inflow to the dam, i.e., some of the storage capacity should be used to ensure that the Reserve would be met.

Table A.16 Summary results for the Varing River EWR Sites

Site	Location		nMAR	PES	EIS	REC
	Latitude	Longitude				
Var 1	33°93.747'	22°24.226'	4.0	Not considered for EWR study		
Var 2	33°57.467'	22°14.410'	6.746	CD	High	CD
Var 3	34°05.630'	22°13.448'	11.432	D	High	CD

⁹⁵ The EWR team did not visit the site of the proposed dam.