APPENDIX K

RAPID ECOLOGICAL RESERVE METHODOLOGY (RERM) III

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EXECUTIVE SUMMARY

INTRODUCTION

IWR Source-to-Sea was requested to undertake a Rapid determination of the Ecological Water Requirements (quantity) at level III (Rapid III Ecological Reserve Methodology (RERM III)) for the Diep River, quaternary catchment K90D. A site (EWR 7) was selected approximately 2 km from the confluence with the Kromme River. This study was conducted to complement the Kromme / Seekoei Reserve Determination study.

BACKGROUND

Rapid Ecological Reserve Methodology (RERM)

Broadly the RERM III comprises the following steps:

- Undertaking a site visit to determine the Present Ecological State (PES), assessing the Ecological importance and Sensitivity (EIS) and deriving the Ecological Category (EC).
- Estimating the Ecological Reserve using the Desktop Reserve Method (DWAF, 1999) (referred to as the DRM) for the Ecological Category (EC) set during the site visit.
- Verifying whether the DRM estimates are acceptable during the site visit.
- Adjusting the DRM estimate if required.
- Reporting on the site visit and the results generated during the site visit. Note that the duration for the whole RERM for one river stretch is limited to approximately two days. A detailed report providing explanations of methodologies and rationale for the answers is therefore not provided. The report consists of a set of tables that are completed on site and serves only to provide results.

This RERM included a hydraulic component and is therefore a RERM at level III.

ECOLOGICAL CATEGORIES

The categories provided for EWR 7 are summarised below.

EWR site	IHI[1]	RHI[2]	Aquatic invertebrates	Fish	Riparian vegetation	Ecostatus PES	EIS	REC	Alternative scenario
EWR 7	C	E	C	C	E	C/D	Moderate	C/D	D

(1) Instream Habitat Integrity
(2) Riparian Habitat Integrity

SUMMARY OF RESULTS

The results for EWR 7 sites are summarised in the following table as a percentage of the virgin Mean Annual Runoff (MAR).

EWR site	EC	Maintenance low flows (%)	Drought low flows (%)	High flows (%)	Long term mean of VMAR (%)
EWR 7	C/D	9.32	1.88	13.9	23.09
	D	5.91	1.88	15.44	22.36

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ASPT	Average Score Per Taxon
BBM	Building Block Methodology
DRM	Desktop Reserve Method or Model
DWAF	Department of Water Affairs and Forestry
Eald	Elevation above local datum
EIS	Ecological Importance and Sensitivity
EC	Ecological Category
EWR	Ecological Water Requirement
FD	Fast Deep
FS	Fast Shallow
IFR	Instream Flow Requirement
IPC	Iron Peg in Concrete
MAR	Mean Annual Runoff
MCM	Million Cubic Meters
MRK	Mark (painted)
MV	Marginal vegetation
MVIC	Marginal vegetation in current
NMMM	Nelson Mandela Metropolitan Municipality
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RERM	Rapid Ecological Reserve Method
RQS	Resource Quality Services
SASS	South African Scoring System
SD	Shallow Deep
SI	Social Importance
SIC	Stones in current
SOOC	Stones out of current
SPATSIM	Spatial and Time Series Information Modelling Software
SS	Shallow Slow

1 INTRODUCTION

1.1 Background

IWR Source-to-Sea was requested to undertake a Rapid determination of the Ecological Water Requirements (EWR) (quantity) at level III (Rapid III Ecological Reserve Methodology (RERM III)) for the Diep River.

The Rapid III study forms part of the Kromme/Seekoei Catchments Reserve Determination Study, and was undertaken as a variation order to the current contract.

1.2 Study area and level of Reserve required

The study area focussed on the K90D Kromme catchment. The river traverses two quaternary catchments (K90C, upstream; and K90D downstream). The level of Ecological Reserve required is not applicable as this investigation is not in reaction to a license. A decision was made that the most cost-effective investigation will be to follow the Rapid Ecological Reserve Method (RERM) (Level III) and the study supplemented the Reserve determination studies on the Kromme and Seekoei rivers.

1.3 Scope of the report

This report deals with the Ecological Reserve (Quantity) only. All reference to EWRs are relevant to quantity only. Methods and approaches are not described; as they are available in various RDM documents (e.g. DWAF, 1999). Due to the time constraints associated with the RERM methods, the report only provides the results of a site visit and workshop (9 March 2005) during which EWRs for different Ecological Categories were quantified. The report associated with a Rapid determination is therefore a summary report concentrating on results only. The results are presented in a standard format.

1.4 Study objectives

The objective of this study was to recommend an Ecological Category (EC) for the river reach under investigation and an associated EWR that will achieve the recommended category using the Rapid III Ecological Reserve Methodology (RERM III). If accepted, this will become the quantity component of the Ecological Reserve.

2 K90D: DIEP RIVER

2.1 River reach

The river reach that was investigated to select an EWR site was in the Diep River in quaternary catchment K90D. The area falls in the Level I Ecoregion South Eastern Coastal belt (Figure K-1), and in 20.03 Level II.

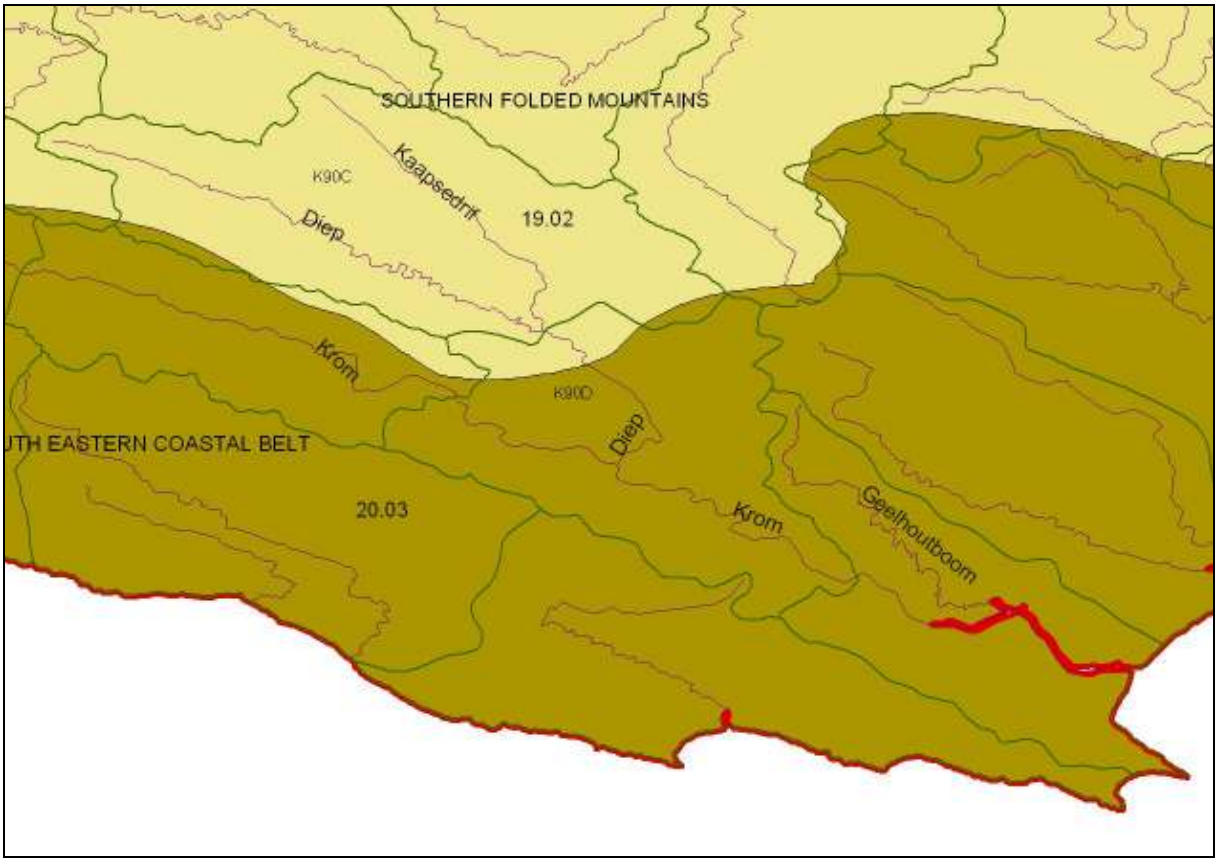

Figure K–1 Study area: Ecoregion South Eastern Coastal belt

2.2 EWR site

Mr Flip de Wet of Eastern Cape DWAF assessed various potential EWR sites on 8 March 2005. He accompanied the team on 9 March and the best option was selected for the purpose of hydraulic analysis and field verification. EWR 7 is located in the Diep River in the K90D quaternary catchment. The site is located downstream of a road bridge, approximately 2 km upstream of the confluence with the Kromme River. The co-ordinates of the site are:

S 34° 01.322
E 24° 35.557

The site is characterised by a short (7.5 m long) riffle composed predominantly of large cobbles and small boulders. Pools occur upstream and downstream of the riffle, with the depth in the upstream pool in excess of 1 m at the time of the site visit. A mid-channel bar vegetated with Palmiet exists immediately upstream of the riffle, with divided flows at medium to high discharges.

The site is illustrated in Figure K-2.

Figure K–2 Diep River (0.061 m^3/s, 9/03/05)

The suitability of the EWR site to provide the physical clues to verify or adjust the DRM output was evaluated according to the criteria listed in Table K-1. The evaluation (0 - 5 with 0 = no confidence and 5 = high confidence) reflects the different specialists' confidence in the EWR site to provide sufficient indicators to verify the Desktop Reserve Model (DRM).

Table K-1 EWR site evaluation table

Component	Evaluation	Advantages	Disadvantages
Fish	4	Wide range of habitats (all except for Fast Deep) present.	No Fast Deep habitats. Insufficient overhanging and marginal vegetation.
Aquatic invertebrates	3	Plentiful SOOC and SIC habitat present with adequate marginal vegetation.	Infestation of the Wattle (changes substrate availability). Gravel, sand, mud habitat difficult to sample. SIC and SOOC large, embedded and difficult to sample.
Hydraulics	2		Non-uniform flow over short riffle 'step' feature. Riffle will drown-out at medium to high flows (approximately 0.3 m^3/s). Difficult to determine reduction in flow resistance from site calibrated value as influence of control becomes drowned out at higher discharges. Influence of channel blockages, channel form, and pool/riffle/rapid sequences on flow resistance.

2.3 Ecoclassification

2.3.1 Available information

Fish
The national data base for fish per quaternary catchment as set up for the Ecological Importance and Sensitivity (EIS) for Kromme and other tributaries was available. Only one record from the Diep River itself exists. A specific survey was undertaken by Dr Bok on 9 March 2005.

Confidence: 2

Aquatic Invertebrates
Information from one survey, collected on 9 March 2005 during flood conditions is available.

Confidence: 2

Hydraulics
Only one data set collected during low flow conditions was available.

Confidence: 2

Hydrology
The hydrology as provided as part of the Kromme/Seekoei Catchments Reserve Determination Study study was compared to WRSM90. The hydrology was sufficiently similar to run the Desktop Reserve Model (DRM) with WRSM90 data. The confidence is low due to the general lack of any gauges in the system to calibrate data.

Confidence: 2

2.3.2 Reference conditions

Fish
The following indigenous fish species are expected under reference conditions:

Pseudobarbus afer	*Sandelia capensis*
Gilchristella aestuaria	*Anguilla mossambica*
Anguilla marmorata	*Anguilla bicolor bicolor*

Aquatic Invertebrates
The following taxa are expected under reference conditions.

Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Hydracarina, Baetidae, Caenidae, Heptageniidae, Leptophlebiidae, Chlorocyphidae, Coenagriidae, Aeshnidae, Gomphidae, Libellulidae, Belastomatidae, Corixidae, Gerridae, Hydrtometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Hydropsychidae, Philopotamidade, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Ceratopogonidae, Culicidae, Dixidae, Ephydridae, Muscidae, Psychodidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Lymnaeidae, Physidae, Corbiculidae.

SASS5 score: 200
ASPT: 6

Hydrology
The Virgin (WRSM90) Mean Annual Runoff (MAR) at the EWR site is 17.67 MCM. This was determined as follows: The MAR at K90C is 13.58 MCM. The site in K90D represents 24% of the MAR of the quaternary catchment (calculated using the sub-quaternary MAR scaling from

SPATSIM), which equates to 4.095 MCM. The MAR at the site is therefore the sum of the K90C MAR and 24% of K90D, i.e. 17.67 MCM.

2.3.3 PES

The following water quality information listed in Table K-2 was considered when assessing the habitat integrity (provided by the water quality team of the Kromme-Seekoei Reserve study).

Table K-2 Water quality information

RIVER	Diep River	**Water Quality Monitoring Points**	
WQSU	6	**RC**	Default boundary tables
EWR SITE	7	**PES**	WQ6 (n=4)
Water Quality Constituents		**Value**	Category / Comment
Inorganic salts (mg/L)	$MgSO_4$	-	An assessment of inorganic salts could not be undertaken as the data from the NMMM laboratories were not compatible with the salt model.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.245	E/F (Poor)
	TIN	0.01	A (Natural)
Physical variables	pH (5^{th}-95^{th}%)	6.8 - 7.2	A (Natural)
	Temperature	-	No data available, but not considered a problem water quality variable as the site is not downstream of a dam, and thermal and dissolved oxygen impacts are not expected.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	No data
	Electrical conductivity (mS/m)	40.7	A/B (Upper Good)
Response variable	Chl-a: periphyton	184.3	E/F (Poor)
	Chl-a: phytoplankton	0.913	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score	6.13 (Oct 03)	B (Good)
	Fish community score	-	No data
Toxics	Fluoride (mg/L)	0.07	A (Natural)
OVERALL SITE CLASSIFICATION FOR WATER QUALITY		**B/C**	

2.3.4 Habitat integrity

Instream Habitat Integrity: **Category C (Attachment D)**

- The score for the Instream Habitat Integrity is 70.6% (Category C: 60 - 80%).
- The major modifying determinants for the Instream Habitat Integrity are water abstraction, flow and channel modification.

Riparian Habitat Integrity: **Category E (Attachment D)**

- The score for the Riparian Habitat Integrity is 30.2% (Category E: 20 - 40%).
- The major modifying determinants for the Riparian Habitat Integrity are linked to the presence of extensive black Wattle infestation and the effects associated with their presence.

2.3.5 Fish (C) (Attachment B)

Species found during the survey were:

Micropterus dolomieu/salmoides *Lepomis macrochirus*
Tilapia sparrmanii *Glossogobius callidus* (indigenous)

PES	Causes	Sources	Flow/Non flow related
C	Alien species	-	Non flow related
	Lack of migration	Downstream barriers	Non flow related
	Reduced marginal vegetation	Black Wattle	Non flow related
	Increased sedimentation	Black Wattle	Non flow related
	Reduced low flows	Upstream abstraction	Flow related

2.3.6 Aquatic Invertebrates (C) (Attachment C)

SASS5 score: 146
ASPT: 5.6

PES	Causes	Sources	Flow/Non Flow related
C	Reduced low flows.	Upstream abstraction	Non Flow Related
	Reduced marginal vegetation.	Black Wattle	Non Flow Related
	Increased sedimentation.	Black Wattle	Non Flow Related
	Reduced water quality.	Upstream dairy farming	Non Flow Related

2.3.7 Ecostatus (C/D)

The Ecoclassification as part of the Rapid III process requires the Ecostatus to be calculated as an average between the Habitat Integrity, fish and aquatic invertebrate scores. The average indicated an Ecostatus of a D category. Although the Instream Habitat Integrity category was a C Ecostatus was scored a D due to the E category assigned to riparian vegetation status due to the presence of alien vegetation, i.e. not flow related causes. Specialists indicated that the instream C category was more representative of the river. The Ecostatus model was therefore adjusted to add a weighting to the instream category resulting in an overall C/D category for Ecostatus (Table K-3).

Table K-3 Summary of the PES categories for EWR 7

	PES	REC	ALTERNATE EC (DOWN)
DRIVER COMPONENTS			
HABITAT INTEGRITY	C	C	D
RIPARIAN INTEGRITY	E	D	D
RESPONSE COMPONENTS			
FISH	C	C	D
AQUATIC INVERTEBRATES	C	C	D
INSTREAM	C	C	D
RIPARIAN VEGETATION	E	D	D
ECOSTATUS	C/D	C/D	D

2.3.8 Ecological Importance and Sensitivity (EIS)

The evaluation for EIS is Moderate due to the possible presence of Red Data fish species. A summary of the EIS is available in Attachment E. Note that EIS is assessed for present state only, as required by RERM.

2.3.9 Range of Ecological Categories

Recommended Ecological Category (REC)
The REC is to maintain the PES, i.e. a C/D Ecostatus. The riparian vegetation of an E category should be addressed, but this can only be done by eradicating the alien vegetation and not by manipulating flows (i.e. implement a Working for Water programme). Note that the Diep River has no effect on the Kromme River as it runs directly into Impofu Dam. Impact is therefore on the yield of the dam rather than the estuary below the dam.

Alternative Ecological Categories
Improving the Ecostatus was not considered as it was considered unrealistic at the resolution of this study and information available at a Rapid level of determination. It must be noted that addressing the riparian vegetation issue, i.e. the eradication of black Wattle, should improve the Ecostatus without any manipulation of flows.

One category down from the Ecostatus was considered, i.e. a D Ecostatus. Under these conditions the fish and aquatic invertebrates Ecological Categories will decrease from a C to a D category.

The hypothetical conditions for the D Ecostatus were set as follows:

- Lower low flows due to increased abstractions.
- Increased water quality issues associated with nutrient levels (particularly peryphyton and the decreased flows.

2.4 Flow requirement results

The proportional differences between the Desktop Reserve Model results and that generated at EWR 1 in the Kromme River must be used to provide a Desktop estimate for the Diep River site. EWR 1 in the Kromme River was set for a C REC and the Diep River at a C/D REC. To be able to use the Kromme River C category results, the C REC at EWR 1 first had to be modified to be applicable for a C/D EC at EWR 1. Then the Desktop C/D results at EWR 1 could be compared to the extrapolated (higher confidence) C/D results at EWR 1 and these proportions used to provide a Desktop flow result for the Diep River site with a C/D REC. The step by step procedure was as follows:

- Desktop % of VMAR at EWR 1 for a C category
- Desktop % of VMAR at EWR 1 for a C/D category
- Determine ratio between the Desktop % of a C and C/D category
- Obtain the % of VMAR at EWR 1 for at a C category as determined during the Kromme Intermediate study.
- Adjust the % of VMAR for the C category with the ratio to extrapolate the Kromme Intermediate C results to a C/D results.
- Determine the scaling factor required to establish the VMAR at the Diep River site (The Diep River site comprised 50% of the VMAR at EWR 1)
- Run the Desktop model and adjust the VMAR to 50% of the EWR 1 VMAR.
- Adjust the volumes of the Maintenance Low flows, Drought flow and High flows to represent the % of the MAR as for the EWR 1 C/D results.
- Those results are provided to specialists to check their adequacy. The process is summarised in the table below.

EWR site	EC	Comment	MLF	DLF	HF
EWR 1	C	Desktop	7.89%	2.99%	11.3%
EWR 1	C/D	Desktop	5.55%	2.99%	10.1%
RATIO		*Desktop*	*0.7*	*1*	*0.89*
EWR 1	C	Set requirements	13.76%	1.93%	16%
EWR 1	C/D	Extrapolated from requirements (using Desktop ratio)	9.6%	1.9%	14.2%
EWR Diep	C/D	Extrapolated from Kromme study	9.6%	1.9%	14%
EWR Diep	C/D	Final % after adjusting Desktop	9.3%	1.9%	14%

(1) MLF: Maintenance Low Flows
(2) DLF: Drought Low Flows
(3) HF: High flows
%: % of VMAR

The D Desktop category was determined following the same approach.

A Desktop Reserve Model C/D category was generated using trends determined during the Comprehensive study at EWR 1 in the Kromme River as follows:

The Desktop C percentages of the virgin MAR at EWR 1 was as follows:
Drought low flows: 2.99% Maintenance low flows: 7.89% High flows: 11.3%

The Desktop C/D percentages of the virgin MAR at EWR 1 was as follows:
Drought low flows: 2.99% Maintenance low flows: 5.55% High flows: 10.1%

The ratio between the Desktop Reserve Model C and C/D category at EWR 1 was as follows:
Drought low flows: 1 Maintenance low flows: 0.7 High flows: 0.89

This ratio was adjusted by 50% as the MAR at EWR 1 is double that of the Diep River EWR 7 site:

Drought low flows: 0.5 Maintenance low flows: 0.35 High flows: 0.45

The C percentages of the virgin MAR as set by specialists at EWR 1 during the Comprehensive study was as follows:

Drought low flows: 1.93% Maintenance low flows: 13.76% High flows: 16%

The EWR 1 data was then adjusted using the applicable ratio to represent a Diep River C/D category adjusted from Comprehensive data. The D Desktop category was determined following the same approach.

These results were then tested by the ecologists and both the C/D and D categories results were accepted. The following motivations were supplied:

2.4.1 Fish

C/D category motivation
The indigenous fish present (*P. afer*) only use shallow riffle areas for spawning, while all other indigenous species, including *G. callidus* and *S. capenis,* need sufficient depths over riffles for movement between habitats. All indigenous species were small, less than 12 cm in length. The indigenous fish in this reach normally frequent shallow slow (SS) and shallow deep (SD) areas found in pools under cover among marginal and aquatic vegetation and under rocks and cobbles. These habitats will be marginally impacted by reduced low flows.

Maximum depths of 10 cm are suitable for migration through riffles for small indigenous fish species, *P. afer* and *S. capensis*. These depths will be provided by the flows envisaged. Migrations as well as spawning events usually take place at or after high flows after rains, when sediment in riffles is flushed out. Thus the given depths at various flows will be adequate for fish movement.

Maintenance flows in the wet season provide sufficient depths (25 cm) for spawning and in dry season for movements over riffles (20 cm). Drought flows will provide enough depth (a mean of 6 cm) for movement of small fish through riffles.

No movement or breeding normally takes place during drought situations. More critical is the maintenance of water quality in pools and keeping pools topped up – 1 l/s will probably achieve this.

It is apparent that depths in riffle areas are not that sensitive in terms on impacts on fish in this reach.

D category motivation
Maintenance flows in the wet season provide sufficient depths (a maximum of 23.2 cm, mean 7.5 cm) for spawning and movement through riffles and in the dry season, for movements over riffles (maximum of 16.5 cm, mean 6.3 cm). Drought flows will provide enough depth (mean of 5.9 cm) for movement of small fish through riffles.

2.4.2 Aquatic Invertebrates

C/D category motivation

Maintenance wet season flow of 0.077 m^3/s

Discharge	0.077
Max Depth	Up to 0.28
Ave Depth	Up to 0.1
Ave velocity	Up to 0.19 m/s
Max velocity	Up to 55 m/s
% Slow shallow	82
% Fast Shallow	18

At these flows the riffle will provide similar habitat to the present conditions (0.061 m^3/s). Maximum flow depth increases by only 4 cm from current conditions, which will increase inundation of marginal vegetation, providing for additional surface area for colonisation. Marginal vegetation in current (MVIC) habitat will increase slightly. The average velocity is in the region of 0.19 m/s which is only marginally different from present conditions (0.18 m/s); the distribution of flow types therefore varies only marginally from present conditions. The aquatic invertebrate community is unlikely to alter.

Maintenance dry season flow of 0.035 m^3/s

Discharge	0.034
Max Depth	0.2
Ave Depth	0.07
Ave velocity	0.17
Max velocity	0.5
% Slow shallow	87
% Fast Shallow	13

At these flows, the maximum depth is decreased from 24 cm to 20 cm. A loss of 4 – 7 cm depth will result in a loss of flow over the top and forward face of boulders in the riffle, i.e. under these conditions; flow over the upper surface of many of the rocks in the riffle will be lost. The sides and undersides of riffles will however still be inundated, with average velocities of 0.17m/s, which are only marginally reduced from the present. The only taxa likely to be lost under these conditions are simuliids, which have a preference for the surface of rocks in flow areas. There will only be marginal effects on the aquatic invertebrate community.

Drought flows of 0.025 m^3/s

Discharge	0.025
Max Depth	> 0.16
Ave Depth	> 0.06
Ave velocity	> 0.15
Max velocity	> 0.45
% Slow shallow	Approx 92
% Fast Shallow	Approx 8

At present, the Diep River ceases to flow on occasion (Flip de Wet, DWAF Cradock *pers.comm.*), which suggests there must be a slow reduction in flow and flow depth to result in this condition.

The aquatic invertebrate community collected on site must be sufficiently resilient to withstand these conditions, and it is thus assumed that the majority of less sensitive taxa present will survive depth and flow reductions represented by this drought flow scenario. However, it is likely that as flows reduce to this value, taxa with a preference for moderate and high flows will relocate or disappear (Simuliidae, Philopotamidae, Gyrinidae). Water temperatures are likely to rise and water quality deteriorate, resulting in a loss of taxa with a requirement for high quality water (Heptageniidae, Dixidae, Veliidae, Gerridae).

Drought flows of 0.001 m^3/s

Discharge	0.001
Conditions	Trickle flow through riffle.

Pool and Stones-out-of-current (SOOC) habitats will endure during these conditions, while marginal vegetation (MV) and stones-in-current (SIC) habitats are likely to be lost. The aquatic invertebrate fauna will be reduced significantly. As a no-flow situation apparently occurs sporadically under present conditions, the present aquatic invertebrate community is sufficiently resilient to endure a trickling flow situation. It is likely that the presence of more sensitive taxa during higher flows is related to the life-cycle adaptations (e.g. locality and resilience of eggs).

D motivation:

Maintenance flow of 0.055 m^3/s

Discharge	0.055
Max Depth	0.22
Ave Depth	0.07
Ave velocity	0.17
Max velocity	0.52
% Slow shallow	90
% Fast Shallow	10

At these flows, the maximum depth is decreased from 24 cm to 22 cm, with an average depth of 7 cm. This represents a maximum loss of 2 cm depth over the riffle. On average however, a larger amount of depth will be lost over the top and forward face of boulders. The sides and undersides of riffles will however still be inundated, with average velocities of 0.17 m/s, which are only marginally reduced from the present. The only taxa likely to be lost under these conditions are simuliids, which have a preference for the surface of rocks in flow areas. There is still 10% of Fast Shallow water in this area. There will only be marginal effects on the aquatic invertebrate community.

Maintenance flow of 0.018 m^3/s

Discharge	0.018
Max Depth	0.16
Ave Depth	0.06
Ave velocity	0.15
Max velocity	0.45
% Slow shallow	92
% Fast Shallow	8

At present, the Diep River ceases to flow on occasion (Flip de Wet, DWAF Cradock *pers.comm.*). There is a slow reduction in flow and flow depth to result in this condition. The aquatic invertebrate

community collected on site must be sufficiently resilient to withstand these conditions, and it is thus assumed that the majority of less sensitive taxa present will survive depth and flow reductions represented by this drought flow scenario. However, it is likely that as flows reduce to this state, taxa with a preference for moderate and high flows will relocate or disappear (Simuliidae, Philopotamidae, Gyrinidae). Water temperatures are likely to rise and water quality deteriorate, resulting in a loss of taxa with a requirement for high quality water (Heptageniidae, Dixidae, Veliidae, Gerridae).

2.4.3 IFR table and assurance rules for a C/D REC

The results represent a long term mean of 23.09% of the virgin MAR.

Desktop Version 2, Printed on 2005/03/10
Summary of IFR estimate for: Diep WRSM90 Flows
Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	17.684
S.Dev.	=	15.661
CV	=	0.886
Q75	=	0.312
Q75/MMF	=	0.212
BFI Index	=	0.255
CV(JJA+JFM) Index	=	4.537

REC = C/D

Maint. Lowflow	=	1.648 (9.32 %MAR)
Maint. Highflow	=	2.457 (13.90 %MAR)
Total Maint. IFR	=	4.105 (23.22 %MAR)
Drought Lowflow	=	0.333 (1.88 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : S.Karoo

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.791	0.997	0.471	0.070	0.020	0.081	0.151
Nov	0.664	0.685	0.398	0.063	0.015	0.084	0.147
Dec	0.353	0.332	0.351	0.042	0.005	0.000	0.042
Jan	0.286	0.806	1.051	0.035	0.001	0.000	0.035
Feb	0.250	0.580	0.962	0.035	0.001	0.000	0.035
Mar	0.412	1.255	1.136	0.038	0.002	0.000	0.038
Apr	0.360	0.664	0.713	0.038	0.002	0.000	0.038
May	0.616	1.556	0.943	0.042	0.005	0.000	0.042
Jun	0.519	0.943	0.700	0.053	0.010	0.084	0.137
Jul	0.570	1.032	0.676	0.063	0.015	0.081	0.144
Aug	0.856	1.543	0.673	0.077	0.025	0.348	0.425
Sep	1.032	2.084	0.779	0.070	0.025	0.252	0.322

Desktop Version 2, Printed on 2005/03/10
Summary of IFR rule curves for: Diep WRSM90 Flows
Determination based on defined BBM Table with site specific assurance rules.
REC = C/D

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

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.278	0.249	0.223	0.196	0.151	0.126	0.093	0.060	0.036	0.029
Nov	0.204	0.201	0.194	0.182	0.162	0.133	0.097	0.060	0.033	0.025
Dec	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jan	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Feb	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Mar	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
Apr	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
May	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jun	0.258	0.228	0.201	0.175	0.131	0.107	0.078	0.048	0.026	0.019
Jul	0.267	0.238	0.212	0.186	0.142	0.117	0.086	0.054	0.031	0.024
Aug	0.847	0.728	0.564	0.486	0.369	0.304	0.223	0.141	0.080	0.062
Sep	0.635	0.548	0.473	0.404	0.286	0.236	0.175	0.112	0.066	0.052
Reserve flows without High Flows										
Oct	0.109	0.107	0.104	0.098	0.088	0.074	0.056	0.038	0.024	0.021
Nov	0.098	0.096	0.093	0.088	0.078	0.065	0.048	0.032	0.019	0.016
Dec	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jan	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Feb	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Mar	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
Apr	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
May	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jun	0.082	0.081	0.078	0.073	0.065	0.054	0.039	0.025	0.014	0.010
Jul	0.098	0.096	0.093	0.088	0.078	0.065	0.048	0.032	0.019	0.016
Aug	0.119	0.118	0.114	0.108	0.097	0.082	0.063	0.044	0.030	0.026
Sep	0.109	0.107	0.104	0.098	0.089	0.076	0.059	0.042	0.029	0.026

Natural Duration curves

Oct	1.613	0.870	0.695	0.598	0.505	0.452	0.374	0.287	0.233	0.141
Nov	1.632	0.934	0.552	0.457	0.427	0.351	0.316	0.266	0.206	0.131
Dec	0.952	0.583	0.360	0.262	0.228	0.199	0.160	0.126	0.102	0.058
Jan	0.369	0.262	0.194	0.141	0.107	0.092	0.073	0.068	0.053	0.024
Feb	0.436	0.194	0.145	0.129	0.097	0.075	0.054	0.043	0.032	0.022
Mar	0.627	0.287	0.209	0.190	0.107	0.087	0.068	0.044	0.034	0.015
Apr	0.793	0.351	0.236	0.181	0.146	0.121	0.085	0.065	0.040	0.020
May	1.380	0.656	0.374	0.233	0.165	0.121	0.102	0.068	0.058	0.019
Jun	1.014	0.598	0.437	0.286	0.246	0.186	0.141	0.110	0.065	0.045
Jul	1.050	0.651	0.428	0.384	0.326	0.272	0.243	0.185	0.155	0.053
Aug	2.206	0.899	0.564	0.486	0.394	0.340	0.282	0.243	0.199	0.136
Sep	1.662	1.165	0.713	0.608	0.482	0.387	0.311	0.256	0.216	0.146

2.4.4 IFR table and assurance rules for a D REC

The results represent a long term mean of 22.36% of the virgin MAR.

Desktop Version 2, Printed on 2005/03/10
Summary of IFR estimate for: Diep WRSM90 Flows
Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	17.684
S.Dev.	=	15.661
CV	=	0.886
Q75	=	0.312
Q75/MMF	=	0.212
BFI Index	=	0.255
CV(JJA+JFM) Index	=	4.537

ERC = D

Maint. Lowflow	=	1.046 (5.91 %MAR)
Maint. Highflow	=	2.730 (15.44 %MAR)
Drought Lowflow	=	0.333 (1.88 %MAR)
Total Maint. IFR	=	3.776 (21.35 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : S.Karoo

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.791	0.997	0.471	0.050	0.020	0.090	0.140
Nov	0.664	0.685	0.398	0.045	0.015	0.093	0.138
Dec	0.353	0.332	0.351	0.023	0.005	0.000	0.023
Jan	0.286	0.806	1.051	0.018	0.001	0.000	0.018
Feb	0.250	0.580	0.962	0.018	0.001	0.000	0.018
Mar	0.412	1.255	1.136	0.018	0.002	0.000	0.018
Apr	0.360	0.664	0.713	0.020	0.002	0.000	0.020
May	0.616	1.556	0.943	0.025	0.005	0.000	0.025
Jun	0.519	0.943	0.700	0.030	0.010	0.093	0.123
Jul	0.570	1.032	0.676	0.040	0.015	0.090	0.130
Aug	0.856	1.543	0.673	0.055	0.025	0.387	0.442
Sep	1.032	2.084	0.779	0.055	0.025	0.280	0.335

Desktop Version 2, Printed on 2005/03/10
Summary of IFR rule curves for : diep WRSM90 Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : S.Karoo ERC = D

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

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.281	0.249	0.220	0.193	0.146	0.121	0.091	0.060	0.037	0.030
Nov	0.214	0.211	0.204	0.191	0.170	0.140	0.101	0.063	0.034	0.026
Dec	0.042	0.042	0.040	0.038	0.034	0.028	0.020	0.012	0.007	0.005
Jan	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Feb	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Mar	0.033	0.032	0.031	0.029	0.026	0.021	0.015	0.008	0.004	0.002
Apr	0.037	0.036	0.035	0.032	0.029	0.023	0.016	0.009	0.004	0.002
May	0.046	0.045	0.044	0.041	0.036	0.030	0.022	0.013	0.007	0.005
Jun	0.250	0.218	0.189	0.163	0.117	0.097	0.071	0.045	0.026	0.020
Jul	0.262	0.231	0.203	0.176	0.130	0.108	0.080	0.052	0.031	0.025
Aug	0.910	0.777	0.564	0.486	0.386	0.318	0.234	0.148	0.085	0.066
Sep	0.686	0.590	0.507	0.432	0.302	0.250	0.184	0.118	0.069	0.055
Reserve flows without High Flows										
Oct	0.092	0.091	0.088	0.083	0.075	0.064	0.049	0.034	0.024	0.020
Nov	0.083	0.081	0.079	0.074	0.067	0.056	0.042	0.029	0.018	0.015
Dec	0.042	0.042	0.040	0.038	0.034	0.028	0.020	0.012	0.007	0.005
Jan	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Feb	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Mar	0.033	0.032	0.031	0.029	0.026	0.021	0.015	0.008	0.004	0.002
Apr	0.037	0.036	0.035	0.032	0.029	0.023	0.016	0.009	0.004	0.002
May	0.046	0.045	0.044	0.041	0.036	0.030	0.022	0.013	0.007	0.005
Jun	0.055	0.054	0.053	0.050	0.045	0.037	0.028	0.019	0.012	0.010
Jul	0.074	0.072	0.070	0.066	0.060	0.050	0.039	0.027	0.018	0.015
Aug	0.101	0.100	0.097	0.092	0.083	0.071	0.056	0.040	0.029	0.025
Sep	0.101	0.100	0.097	0.092	0.083	0.071	0.056	0.040	0.029	0.025
Natural Duration curves										
Oct	1.613	0.870	0.695	0.598	0.505	0.452	0.374	0.287	0.233	0.141
Nov	1.632	0.934	0.552	0.457	0.427	0.351	0.316	0.266	0.206	0.131
Dec	0.952	0.583	0.360	0.262	0.228	0.199	0.160	0.126	0.102	0.058
Jan	0.369	0.262	0.194	0.141	0.107	0.092	0.073	0.068	0.053	0.024
Feb	0.436	0.194	0.145	0.129	0.097	0.075	0.054	0.043	0.032	0.022
Mar	0.627	0.287	0.209	0.190	0.107	0.087	0.068	0.044	0.034	0.015
Apr	0.793	0.351	0.236	0.181	0.146	0.121	0.085	0.065	0.040	0.020
May	1.380	0.656	0.374	0.233	0.165	0.121	0.102	0.068	0.058	0.019
Jun	1.014	0.598	0.437	0.286	0.246	0.186	0.141	0.110	0.065	0.045
Jul	1.050	0.651	0.428	0.384	0.326	0.272	0.243	0.185	0.155	0.053
Aug	2.206	0.899	0.564	0.486	0.394	0.340	0.282	0.243	0.199	0.136
Sep	1.662	1.165	0.713	0.608	0.482	0.387	0.311	0.256	0.216	0.146

3 REFERENCES

Department of Water Affairs and Forestry. 1999. *Resource Directed Measures for Protection of Water Resources - Volume 3: River Ecosystems. Version 1.0.* DWAF Private Bag X313, Pretoria, 0001.