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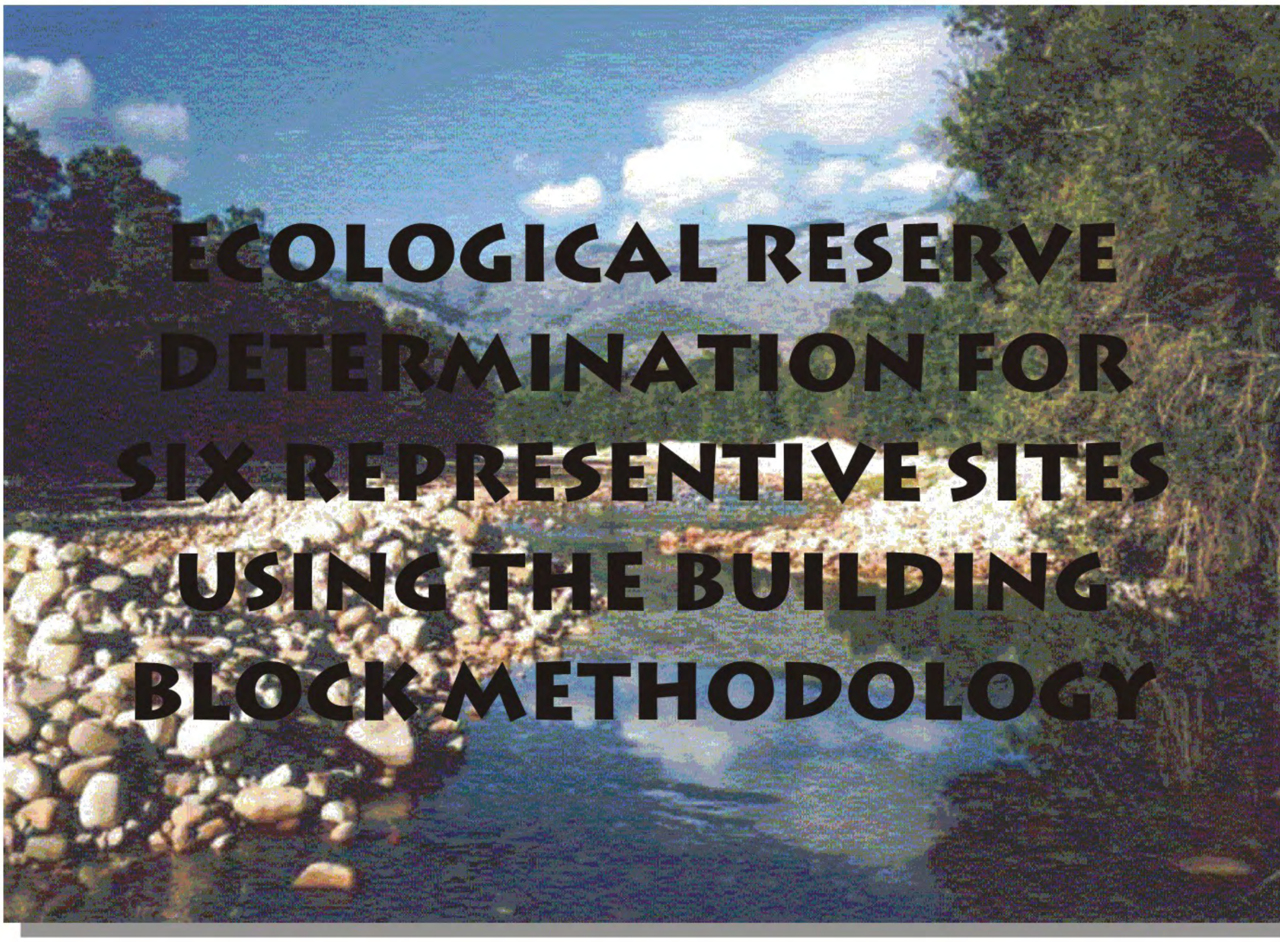
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE OF WATER RESOURCES PLANNING

BREEDE RIVER BASIN STUDY



ECOLOGICAL RESERVE DETERMINATION FOR SIX REPRESENTIVE SITES USING THE BUILDING BLOCK METHODOLOGY

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DEPARTMENT OF
WATER AFFAIRS AND FORESTRY

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FINAL

MAY 2003

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TITLE	**:**	**Ecological Reserve Determination for Six Representative Sites Using the Building Block Methodology**
AUTHORS	**:**	**C A Brown and D Louw**
PROJECT NAME	**:**	**Breede River Basin Study**
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Approved for Southern Waters Ecological Research and Consulting CC

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BREEDE RIVER BASIN STUDY

ECOLOGICAL RESERVE DETERMINATION FOR SIX REPRESENTATIVE SITES USING THE BUILDING BLOCK METHODOLOGY

EXECUTIVE SUMMARY

INTRODUCTION

Reserve Determinations Undertaken for the Breede River Basin Study

Environmental sustainability forms one of the cornerstones of the National Water Act. In recognition of this, and to provide the information that would be required to ascertain the availability of water at particular locations in the Breede River catchments and to set a Preliminary Reserve in the Breede Water Management Area, a considerable portion of Study resources was directed toward determining the ecological water requirements of the aquatic ecosystems in the catchments of the Breede River.

Reserve determinations were carried out for the following components of the Reserve :

- Riverine water quantity. (The subject of this report.)
- Riverine water quality, documented in Reports PH 00/00/3402 *Ecological Reserve Determination (Water Quality)*, and PH 00/00/3602 *Ecological Reserve Determination (Water Quality) – Recalculation of the Water Quality Reserve*.
- The Breede River Estuary, documented in Report PH 00/00/1102 *Intermediate Determination of Resource Directed Measures for the Breede River Estuary.*
- The Papenkuils Wetland, documented in Report PH 00/00/1402 *Papenkuils Wetland Intermediate (Ecological) Reserve Determination (Low Confidence).*
- Groundwater, documented in Report PH 00/00/1202 *Groundwater Reserve Determination.*

The geographical spread and confidence levels of the determinations were planned to deliver, as far as present knowledge and available resources permitted, Reserve determinations commensurate with the management needs of the Breede River catchments. The Study findings represent scientific estimates of the ecological water requirements of the aquatic ecosystems in the Breede River catchments. The socio-economic implications of the implementation of Reserves at the recommended levels (Ecological Management Categories) should therefore be carefully considered prior to the setting of a preliminary Reserve. Before a comprehensive Reserve can be set, a separate stakeholder consultation process must first take place.

Numerous interrelations exist between the different components of the Reserve in the Breede River Basin. These had to be taken into account to provide an accurate reflection of current and future water availability. This information will also be required when setting a Preliminary Reserve, and to manage the system accordingly. Relatively simple integration procedures were therefore developed during the course of the Study, and the findings of this work are reported on in the *Main Report* of the Study (Report PH 00/00/3102)

Very little experience has thus far been gained in the implementation and management of Reserves in South Africa, and little is known about the effectiveness of the ecological water requirements (EWRs) in achieving the recommended ecological management categories. In recognition of the limited experience available, further study work was approved to explore the implications that the system-wide implementation of recommended EWRs may have on water availability in the Basin. This work is also documented in the *Main Report*.

Background to the Reserve Determination for River Quantity

The biophysical component of the Reserve Determination for River Quantity was conducted according to the RDM requirements for a Comprehensive Reserve Determination, using the Building Block Methodology (BBM).

IFR Sites

Reserve determinations were conducted for six representative sites distributed throughout the Breede River Basin. The number of sites was limited by time and financial constraints.

At the Planning Meeting (April 2000), the participants agreed that the IFR sites were expected to fulfil several criteria, namely:

- they should be representative of as many rivers within the catchment as possible;
- they should be downstream of proposed major water resource developments;
- they should correspond to "key management points" within the Breede River Basin;
- they should be near DWAF gauging weirs.

It was also agreed that six IFR sites could not possibly meet all of the above criteria for the whole catchment. Thus, the sites eventually chosen represent those sections of the river perceived to be most important at a basin planning level.

The six sites chosen (and used) were:

IFR SITE 1: Breede River downstream of Witbrug on the farm Mooiplaas.
IFR SITE 2: Molenaars River downstream of DWAF gauging weir.
IFR SITE 3: Breede River upstream of Le Chasseur.
IFR SITE 4: Breede River downstream of Felix Unite camp on the Farm Ou Werf.
IFR SITE 5: Riviersonderend at Greyton Campsite.
IFR SITE 6: Baviaans River upstream of DWAF weir.

The Hex River was not included in the BRBS, and a separate Intermediate Reserve Determination was undertaken for the rivers in that catchment.

Components of the riverine ecosystem addressed in the study:

The following aspects of the riverine ecosystem were addressed as part of the Reserve Determination:

- Hydrology (daily average flows; summary statistics are provided in Table E.1)
- Hydraulics
- Sedimentology/geomorphology
- Water quality
- Riparian and instream vegetation
- Macroinvertebrates
- Fish

A considerable quantity of data were collected during the course of this study, and several of the specialists spent additional time and energy collecting data in excess of their Terms of Reference. Notwithstanding this effort, the specialist's responses to the *confidence* they had in their assessments were *mainly moderate, and in some instances low*. Some uncertainties also arose from the difficulty in accurately modelling low flow hydraulics.

TABLE E.1: SUMMARY HYDROLOGICAL STATISTICS FOR THE IFR SITES

IFR SITE	NATURALISED MAR (million m^3/a)	PRESENT DAY MAR (million m^3/a)	SUMMER IRRIGATION RELEASES ?
1	333	287	Yes
2	158	131	No
3	1 210	763	Yes
4	1 720	1 059	No
5	347	94	Yes
6	The hydrology for IFR Site 6 appeared to contain several inconsistencies. Eventually, it was decided not to use the data provided, and to rather determine the IFR without reference to the hydrological data, and back-check once these inconsistencies had been resolved.		No

The "Maintenance Lowflows" and "Maintenance Highflows" and the "Reserve MARs" presented below are based on the following:

- The volumes for "Maintenance Lowflows" and "Maintenance Highflows" were generated as part of the BRBS IFR Study (Building Block Application). The volumes given were calculated from the hydraulic cross-sections at each IFR site, and the original depth and flow requirements therefore take precedence over the volume requirements in the event of any hydraulic queries.

- The "Reserve MARs" at each site were generated by running the BRBS IFR Study data mentioned above through the Desktop Model (V1) using the IFR Rule Tables in the Model and the long-term flow records at the various sites to generate the IFR Time Series Tables. It is quite likely that the long-term percentage for the "Reserve MAR" (IFRs) generated through the Desktop Model will differ from the sum of the Maintenance Lowflows and Highflows Table. The extent to which these differ is dependent on *inter alia*, the length (and accuracy) of the hydrological record used, the Assurance of Maintenance Lowflows used, and on the relationships determined for the Hydrological Region in which each IFR Site is situated.

IFR SITE 1: BREEDE RIVER AT MOOIPLAAS

Target reach: From Witbrug to the confluence with the Wit River.

River condition

The Present Ecological Status (PES), Ecological Sensitivity and Importance and the short- and long-term trajectories of change for IFR Site 1 are presented in Figure E.1.

EIS rating: Moderate.

Confidence: High.

Determinants: Presence of rare and endangered species; presence of diverse habitat types and refugia; importance for migration.

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	D	0	D	D	MODERATE	
Water quality	B (flag)	-	C	C		B
Geomorphology	D/E	0	D/E	D/E		D/E → D
Riparian veg	D/E	-	E	E/F		D/E → D
Fish	D/E	-	E	F		D/E → D
Aquatic inverts	D/E	0	D/E	D/E		D
Ecostatus	D/E	0	D/E	E		D/E
					Long term EC	D

(flag) Concern based on landuse information or inconsistency between the bio-assessment and the water chemistry (i.e biota in a lower class)

Figure E.1: Summary of PES and EC for IFR Site 1

The Ecostatus EC (for which the Reserve was determined) was a D Class.

Summary of Attainability

The most important causes and origins affecting the river reach represented by IFR Site 1 are: *non-flow related*: presence of alien fish and vegetation species; mechanical changes to the floodplain and river channel resulting in a modified river; irrigation return flows and sewage impacting on water quality; and flow related: abstraction resulting in river drying up in summer due to agriculture.

Reinstating summer low flows at IFR Site 1 will achieve a D Class for aquatic invertebrates and riparian vegetation. However, realistically, if a D Class is to be achieved, non-flow related impacts, such as mechanical disturbance to the channel and presence of alien fish species, will also need to addressed.

Recommended Reserve

A summary of recommended volumes of water required to met the Reserve for a D Class at IFR Site 1 are provided below:

Naturalised MAR:	333 million m^3/a
Present day MAR:	287 million m^3/a
Reserve MAR (D):	**103 million m^3/a (30.9 % naturalized MAR)**
Maintenance Lowflows (D):	42.8 million m^3/a (12.9 % naturalized MAR)
Maintenance Highflows (D):	41.4 million m^3/a (12.4 % naturalized MAR).

Average daily discharge, depth and velocities are provided for each month of the year.

Scenarios

No scenarios were produced for IFR Site 1. The reason for this is that the PES is an E Class, and the recommended EC Class (D Class) will be difficult to achieve as it is dependent on the correction of non-flow related impacts.

IFR SITE 2: MOLENAARS RIVER

Target reach: Molenaars River from the confluence with the Elands River to the confluence with the Tierkloof River.

River condition

The Present Ecological Status (PES), Ecological Sensitivity and Importance and the short- and long-term trajectories of change for IFR Site 2 are presented in Figure E.2.

EIS rating:	Very high.
Confidence:	High.
Determinants:	Presence of rare and endangered species; presence of intolerant biota (water quality); species/taxon richness; presence of diverse habitat types, refugia and habitats sensitive to quality changes; conservation and natural areas.

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	A/B	0	A/B	A/B	VERY HIGH	
Water quality	A/B	0	A/B	A/B		A/B
Geomorphology	B	0	B	B		B
Riparian veg	B/C	+	B/C	B		B
Fish	E	0	E	E		E
Aquatic inverts	A/B	0	A/B	A/B		A/B
Ecostatus	B	0	B	B		B
					Long term EC	B

Figure E.2: Summary of the PES and EC classes for IFR Site 2

The Ecostatus EC (for which the Reserve was determined) was a B Class.

Summary of Attainability

The most important causes and origins affecting the river reach represented by IFR Site 2 are *non-flow related*, namely: presence of alien fish and vegetation species; presence of the N1; trout farming (effluent and alien fish); increased fire frequency. Notwithstanding these, the river is presently in an excellent state. It would be difficult to improve the current condition. The attainable ecological class could be maintained with minimal to no risk of moving to a lower class.

Recommended Reserve

A summary of recommended volumes of water required to meet the Reserve for a B Class at IFR Site 2 are provided below:

Naturalised MAR:	158 million m^3/a
Present day MAR:	131 million m^3/a
Reserve MAR (B):	**78.5 million m^3/a (49.7 % naturalized MAR)**
Maintenance Lowflows (B):	45.3 million m^3/a (28.7 % naturalized MAR)
Maintenance Highflows (B):	35.4 million m^3/a (22.4 % naturalized MAR).

Average daily discharge, depth and velocities are provided for each month of the year.

Scenarios

The results for a Class B Ecostatus were used to calibrate the Desktop Model, which was used to generate results for a Class C Ecostatus for IFR Site 2:

Maintenance Lowflows (C):	26.3 million m^3/a (16.6 % naturalized MAR)
Maintenance Highflows (C):	29.6 million m^3/a (18.8 % naturalized MAR)

Confidence

Overall Confidence: High

IFR SITE 3: BREEDE RIVER AT LE CHASSEUR

Target reach: Breede River from Moordkuil to Bonnievale.

River condition

The Present Ecological Status (PES), Ecological Sensitivity and Importance and the short- and long-term trajectories of change for IFR Site 3 are presented in Figure E.3.

EIS rating: Moderate.
Confidence: High.
Determinants: Presence of rare and endangered species; presence of diverse habitat types and refugia; importance for migration.

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	C/D	0	C/D	C/D	MODERATE	
Water quality	B (flag)	0	B	B		B
Geomorphology	C	0	C	C		C
Riparian veg	C	-	C	D		C
Fish	D	-	D/E	E		D
Aquatic inverts	D	0	D	D		D
Ecostatus	C/D	-	C/D	D		C/D
					Long term EC	C/D

(flag) Concern based on landuse information or inconsistency between the bio-assessment and the water chemistry

Figure E.3: Summary of the PES and EC classes for IFR Site 3

The Ecostatus EC (for which the Reserve was determined) was a C/D Class.

Summary of Attainability

The most important causes and origins affecting the river reach represented by IFR Site 3 are: *non-flow related:* Presence of alien fish and vegetation species; manipulation of the floodplain; return flows from agriculture; and *flow-related:* turbid releases from Brandvlei Dam; unseasonal releases from Brandvlei Dam.

The major issue in this section is the increased summer base flows, lack of flow variability and the associated turbid water from Brandvlei Dam. If this problem can be addressed, the maintenance of the PES of a C/D Class should be possible.

Recommended Reserve

A summary of recommended volumes of water required to met the Reserve for a C/D Class at IFR Site 3 are provided below:

Naturalised MAR:	1210 million m^3/a
Present day MAR:	763 million m^3/a
Reserve MAR (C/D):	**539 million m^3/a (44.6 % naturalized MAR)**
Maintenance Lowflows (C/D):	249 million m^3/a (20.6 % naturalized MAR)
Maintenance Highflows (C/D):	215 million m^3/a (17.8 % naturalized MAR).

Average daily discharge, depth and velocities are provided for each month of the year.

Scenarios

The results for a Class C/D Ecostatus were used to calibrate the Desktop Model, which was used to generate results for a Class C and D Ecostatus for IFR Site 3:

Maintenance Lowflows (C):	328 million m^3/a (27.1 % naturalized MAR)
Maintenance Highflows (C):	212 million m^3/a (17.5 % naturalized MAR)
Maintenance Lowflows (D):	249 million m^3/a (20.6 % naturalized MAR)
Maintenance Highflows (D):	215 million m^3/a (17.7 % naturalized MAR)

Confidence

Overall Confidence: Moderate.

IFR SITE 4: LOWER BREEDE

Target Reach: Breede River from confluence with the Buffeljags River to the head of the estuary.

River condition

The Present Ecological Status (PES), Ecological Sensitivity and Importance and the short- and long-term trajectories of change for IFR Site 4 are presented in Figure E.4.

EIS rating:	High.
Confidence:	High.
Determinants:	Important for migration route; conservation and natural areas.

The Ecostatus EC (for which the Reserve was determined) was a B/C Class.

Summary of Attainability

The most important causes and origins affecting the river reach represented by IFR Site 4 are *non-flow related*, namely: presence of alien fish and vegetation species; return flows from agriculture (sediments and nutrients).

If measures to mitigate these, such as the creation of buffer riparian zones and overall improved catchment management, were implemented then the negative trajectory for vegetation and geomorphology could be halted.

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	C	0	C	C	VERY HIGH	
Water quality	C	-	C	C		B
Geomorphology	B	-	B	B/C		B
Riparian veg	C	-	C	C/D		C
Fish	C	0	C	C		C
Aquatic inverts	C	0	C	C		B/C
Ecostatus	C	0	C	C		B/C
					Long term EC	B/C

Figure E.4: Summary of PES and EC for IFR Site 4

Recommended Reserve

A summary of recommended volumes of water required to met the Reserve for a B/C Class at IFR Site 4 are provided below:

Naturalised MAR: 1720 million m^3/a
Present day MAR: 1059 million m^3/a
Reserve MAR (B/C): 582 million m^3/a (33.8 % naturalized MAR)
Maintenance Lowflows (B/C): 376 million m^3/a (21.9 % naturalized MAR)
Maintenance Highflows (B/C): 176 million m^3/a (10.2 % naturalized MAR).

Average daily discharge, depth and velocities are provided for each month of the year.

Scenarios

The results for a Class B/C Ecostatus were used to calibrate the Desktop Model, which was used to generate results for a Class B and C Ecostatus for IFR Site 4:

Maintenance Lowflows (B): 511 million m^3/a (29.7% naturalized MAR)
Maintenance Highflows (B): 176 million m^3/a (10.2% naturalized MAR)
Maintenance Lowflows (C): 300 million m^3/a (17.4% naturalized MAR)
Maintenance Highflows (C): 147 million m^3/a (8.5% naturalized MAR).

Reserve MAR (B): 623 million m^3/a (36.2 % naturalized MAR)
Reserve MAR (C): 452 million m^3/a (26.3 % naturalized MAR)

Confidence

Overall Confidence: Moderate.

IFR Site 5: RIVIERSONDEREND at Greyton

Target Reach: Riviersonderend from confluence with the Baviaans River to the town of Riviersonderend.

River condition

The Present Ecological Status (PES), Ecological Sensitivity and Importance and the short- and long-term trajectories of change for IFR Site 5 are presented in Figure E.5.

EIS rating: High.

Confidence: High.

Determinants: Rare and endangered species, species and taxon richness, diversity of habitat types and refugia, sensitivity to flow related water quality changes, migration routes.

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	E	0	E	E	HIGH	
Water quality	B (flag)	-	B	B/C		B
Geomorphology	E	-	E	E/F		E → D
Riparian veg	E	-	E	E/F		E/D → D
Fish	E	-	E	F		E/D → D
Aquatic inverts	C/D	-	D	E		C/D
Ecostatus	E	-	E	E/F		D/E
					Long term EC	D

(flag) Concern based on landuse information or inconsistency between the bio-assessment and the water chemistry (i.e. biota in a lower class than chemistry)

Figure E.5: Summary of the PES and EC classes for IFR Site 5

Summary of Attainability

The most important causes and origins affecting the river reach represented by IFR Site 5 are *flow related*, namely lack of floods and environmental releases from Theewaterskloof compounded by abstraction for irrigation. Non-flow related impacts (most post-Theewaterskloof construction) include the presence of alien fish and vegetation species and considerable mechanical disturbance to the channel.

The recommended Reserve will not be sufficient on its own to accomplish a D Class status, and will need to be accompanied by extensive mechanical intervention, and removal of alien trees.

Recommended Reserve

A summary of recommended volumes of water required to met the Reserve for a D Class at IFR Site 5 are provided below:

Naturalised MAR: 347 million m^3/a

Present day MAR: 93.5 million m^3/a

Reserve MAR (C/D): 134 million m^3/a (38.6 % naturalized MAR)

Maintenance Lowflows (C/D): 67.2 million m^3/a (19.3 % naturalized MAR)

Maintenance Highflows (C/D): 41.0 million m^3/a (11.8 % naturalized MAR).

Average daily discharge, depth and velocities are provided for each month of the year.

Scenarios

Scenarios lower than a Class D should not be considered (DWAF 1999), and given the difficulties associated with provided IFR releases for the Riviersonderend (i.e., the presence of Theewaterskloof Dam, which is the main water supply for Cape Town), it was deemed unrealistic to provide scenarios for conditions better that D Class, as these would undoubtedly require more water than that recommended for a D Class river.

Confidence

Overall Confidence: Moderate.

IFR 6 : BAVIAANS RIVER UPSTREAM OF THE DWAF GAUGING WEIR

Target reach: Baviaans River from dam to the town of Genadendal.

River condition

The Present Ecological Status (PES), Ecological Sensitivity and Importance and the short- and long-term trajectories of change for IFR Site 6 are presented in Figure E.6.

EIS rating: Very high.
Confidence: High.
Determinants: Presence of rare, endangered and unique species as well as intolerant biota. Important refugia and habitats that are sensitive to flow and flow related water quality changes.

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	B	0	B	B		
Water quality	A/B	-	A/B	A/B	HIGH	A/B
Geomorphology	B	0	B	B		B
Riparian veg	C	+	B/C	B		B
Fish	A/B	0	A/B	A/B		A/B
Aquatic inverts	A/B	0	A/B	A/B		A/B
Ecostatus	B	0	B	B		B
					Long term EC	B

Figure E.6: Summary of the PES and EC for IFR Site 6

Summary of Attainability

The most important causes and origins affecting the river reach represented by IFR Site 6 are *flow related*: Abstraction in summer for purposes of Genadendal and environment *and non-flow related: grazing*.

Recommended Reserve

Problems with the hydrological information emerged at the IFR Workshop. We had considerable difficulties with IFR Site 6, Baviaans River, as the biophysical information suggested that the hydrological data from the DWAF gauging weir was underestimating flow in the river. Subsequent discussions between Ninham Shand, DWAF and Prof Albert Rooseboom confirmed this. Thus, in an effort to keep the process going forward, the specialists determined the IFR without reference to the hydrological data. This means that the standard back checking for consistency was NOT undertaken.

A summary of recommended volumes of water required to met the Reserve for a B Class at IFR Site 6 are provided below:

Naturalised MAR: Unknown
Present day MAR: Unknown
Reserve MAR (C/D): 8.5 million m^3/a (% naturalized MAR unknown) *
Maintenance Lowflows (C/D): 5.9 million m^3/a (19.3 % naturalized MAR)
Maintenance Highflows (C/D): 2.6 million m^3/a (11.8 % naturalized MAR).

* Based on the Maintenance Lowflows and Highflows in the absence of reliable hydrological data.

Average daily discharge, depth and velocities are provided for each month of the year.

Without the correct hydrology it was not possible to provide the IFR rules and the IFR flow sequence for IFR Site 6. However, the flood requirements for a Class C and D river are provided in the report and calculation of the scenarios according to the process described in Section 6 would be a relatively simple task once the hydrology were available.

Confidence
Overall Confidence: Low-moderate.

SUMMARY OF RESERVE RECOMMENDATIONS FOR BRBS

SITE	PRESENT CATEGORY	RECOM-MENDED CATEGORY	PERIOD	NATURAL MAR	PRESENT MAR	INSTREAM FLOW REQUIREMENT	
				(million m^3/a)	(million m^3/a)	(million m^3/a)	% Natural MAR
1. Upper Breede River d/s of Witbrug (Mooiplaas)	D/E	D	1961-1990	333	287	103	31
2. Molenaars River d/s of gauging weir	B	B	1969-1990	158	131	79	50
3. Middle Breede River u/s of Le Chasseur	C/D	C/D	1980-1990	1210	763	539	45
4. Lower Breede River on the Farm Ou Werf	C	B/C	1927-1990	1720	1059	582	34
5. Riviersonderend at Greyton Camp Site	E	D	1964-1993	347	94	134	39
6. Baviaans River, i.e. tributary of the Riviersonderend	B	B	Low confidence determination			8.5	

KEY:
A = Natural　B = Largely natural with few modifications　C = Moderately modified
D = Largely modified　E = Seriously modified　F = Critically modified

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1 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

In October 1999, Southern Waters Ecological Research and Consulting cc ("Southern Waters") was appointed by a joint-venture comprising MBB, Ninham Shand, and Jakoet & Associates to undertake the determination of the water quantity component of the Ecological Reserve for the main rivers within the Breede River Basin.

The study was conducted as part of the wider Breede River Basin Study (BRBS), which was commissioned by the Department of Water Affairs and Forestry (DWAF) in August 1999. The MBB-Shand-Jakoet joint-venture was the lead consultant for the Basin Study.

The Terms of Reference (TOR) for Southern Waters' portion of the study are provided below.

As a separate, but related exercise, the Water Research Commission (WRC) and DWAF agreed to fund a dual application of methodologies on the Breede River, namely, the Building Block Methodology (BBM) and DRIFT. A team of IFR specialists from IWR Environmental agreed to assist with this dual application, and they took a considerable share of the responsibility for facilitation of the BBM portion of the exercise. The IWRE team consisted of:

- Prof. Jay O’Keeffe.
- Ms Delana Louw.
- Prof. Caroline Palmer.
- Prof. Denis Hughes.

The Southern Waters project management team consisted of:

Dr Jackie King	Chairperson.
Dr Cate Brown	Team Leader and Ecological Reserve Determination Process Coordinator.
Ms. Justine Fowler	Assistant Ecological Reserve Determination Coordinator.

The disciplines represented on the specialist team, and the names and organisations of the people responsible for each are provided in Table 1.1.

1.2 OBJECTIVES AND TERMS OF REFERENCE

1.2.1 Outline Description of Work Packages and Associated Tasks

The main objectives of the aquatic ecosystem component of the Breede River Basin Study are to:

- assess the present condition of the aquatic ecosystems within the Breede River Basin area.
- determine the ecological reserve for the key river reaches and principal wetlands.
- assess the possible impacts on aquatic ecosystems associated with several identified water development options.
- recommend future action with respect to the sustainable utilisation of the BRBS aquatic ecosystems.

TABLE 1.1 : DISCIPLINES AND SPECIALISTS REPRESENTED ON THE BRBS ECOLOGICAL RESERVE TEAM FOR THE RIVERS

DISCIPLINES	SPECIALISTS	COMPANY
Data Management	J. Fowler	Southern Waters
Hydrology	J. van Rensburg G. Howard	Ninham Shand Ninham Shand
Hydraulics	Prof A. Rooseboom M. Barnard	University of Stellenbosch
Habitat Mapping	J. Fowler	Southern Waters
Sedimentology/Geomorphology	Prof A. Rooseboom	Stellenbosch University
Chemistry (water quality)	N. Roussouw	Ninham Shand
Botany	Dr C. Boucher E. Rode	Stellenbosch University
Macroinvertebrate ecology	B. Paxton Dr C. Brown	Southern Waters Southern Waters
Fish	S. Lamberth	Marine and Coastal Management

In order to meet these objectives, the project was divided into two complementary phases.

PHASE 1: PRELIMINARY ASSESSMENTS

Task 1 A classification of the riverine ecosystems in the catchment on the basis of their natural features.

Task 2 A preliminary assessment of the characteristics and PRESENT ECOLOGICAL STATE of the aquatic ecosystems within the Breede River Basin, through a once-off visit to representative parts of the system.

Task 3 Identification, through the literature, discussion with relevant specialists and the results from the once-off visit, of key conservation areas and diversity hotspots.

Task 4 Identification of the ECOLOGICAL CLASS for rivers in the Breede River Basin.

Task 5 A Rapid Estimate of the ecological reserve for rivers of the Breede River Basin, in accordance with the requirements of the RDM Manual Version 1.0.

Task 6 Identification of areas/systems requiring more detailed study in Phase 2.

Task 7 BBM Planning Meeting for a Comprehensive Methodology (DWAF, 1999).

These tasks were documented in the Preliminary Report (March 2000).

PHASE 2: DETAILED STUDIES

Task 1	Ecological Reserve Determination for six key river reaches using the Comprehensive Methodology.
Task 2	Input to the Public Participation Process aimed at deciding on future Management Classes, and thus the Ecological Reserve, for key rivers in the Breede River basin.
Task 3	Intermediate Ecological Reserve Assessment of the Papenkuils Wetlands.
Task 4	Detailed assessments of the possible impacts of individual yet-to-be-named water development options, including interbasin transfers, on aquatic ecosystems.

Related activities within the BRBS were:

Water Quality Reserve Determination (rivers):	Ninham Shand.
Estuarine Reserve Determination:	CSIR.
Groundwater Reserve Determination:	Groundwater Consulting.
Papenkuils Wetland Reserve Determination:	Southern Waters.

Note: At the specific request of the client Department of Water Affairs, the Reserve Determination activities undertaken for this study EXCLUDED Stakeholder Participation.

1.3 SCOPE OF THE REPORT

This report documents Task 1, *viz*., Ecological Reserve Determination for six key river reaches using the BBM Comprehensive methodology.

1.4 TIMING OF KEY ACTIVITIES

The following are key dates for the aquatic ecosystem component of the BRBS:

30 September 1999:	Start of project.
January 2000:	Data collection for Preliminary Phase.
15-20 March 2000:	Determination of the Rapid Reserve.
31 March 2000:	Completion of Preliminary Phase report.
13 April 2000:	Planning Meeting for Detailed Phase (see Appendix 1).
April 2000 – March 2001:	Data collection for Detailed Phase.
March 2001:	Completion of the specialists reports for Hydrology and Hydraulics.
April 2001:	Completion of specialist reports for the Ecological Reserve Determination (water quantity).
May 2001:	Compilation of the Workshop Starter Document.
June 2001:	Workshop for Ecological Reserve Determination (water quantity) – Klaas Voogds, Robertson.
August 2001:	Completion of Detailed Phase reports.

2. THE ECOLOGICAL RESERVE AND RESOURCE CLASSIFICATION SYSTEM

2.1 INTRODUCTION

The National Water Act (No. 36 of 1998) (NWA) is based on the central guiding principles of sustainability and equity (NWA: Chapter 1). Sustainability of resource use is to be ensured by the implementation of resource protection measures (NWA: Chapter 3), including the application of the ecological Reserve, the quality, quantity and reliability of water required to maintain the ecological functioning of aquatic ecosystems (Principle 7, National Water Policy, DWAF, 1997; Section 1, Definitions, NWA).

Note: In this report "the Reserve" refers specifically to the ecological Reserve.

Theoretically a range of levels of resource use, resource protection, and ecosystem health are possible. Thus, it is necessary to classify the condition (ecosystem health) of each water resource for which the Reserve is to be determined. The classification system describes levels of ecosystem health, and uses these to derive 'tolerable' degrees of risk to ecosystem health, and levels of acceptable use of the resource. The volume and quality of water allocated to the ecological Reserve is thus dependant on the level of classification afforded a particular water resource.

In the ecological Reserve determination procedure (DWAF 1999 - Volume 3), the classification of Ecological Class comprises 3 steps of the 7-step procedure. In Step 3, the historical, natural, or best estimate of the natural state is described. In Step 4, the present ecological state (PES) is described and classified, and in Step 5, a class toward which management objectives could realistically (in ecological terms) be aimed is recommended (Figure 2.1). This classification is termed the "Ecological Class"* or EC.

* Note, this refers ONLY to ecological considerations and is not (necessarily) the same as the Management Class. The Ecological Class was previously referred to as the Ecological Management Class.

2.2 POLICY, LAW AND PROCESS

Classification is explained in the following extract from the White Paper on a National Water Policy for South Africa (Department of Water Affairs and Forestry, April 1997):

"6.3.3 Resource Protection
A national resource protection classification system will be introduced. Through a process of consensus-seeking among water users and other stakeholders, the level of protection for a resource will be decided by setting objectives for each aspect of the Reserve (water quality, quantity and assurance, habitat structure, and living organisms). The objectives for each aspect of the Reserve will show what degree of change or impact is considered acceptable and unlikely to damage a water resource beyond repair. Resources will be grouped into a number of protection classes, with each class representing a certain level of protection. Where a high level of protection is required, the objectives will be strict, demanding a low risk of damage and the

use of great caution. In other cases, the need for short to medium term use may be more pressing and the need for protection lower. Some resources may already need action to restore them to a healthy state, and, in future, no resources should be allowed to become irreversibly degraded."

The legal provision for the concept of classification in the NWA is summarised as follows:

Resource Protection:
The intention of the new law is to protect all water resources which, from the definitions in Section 1, include rivers, springs, natural channels, wetlands, lakes, dams, surface water, estuaries, aquifers or other underground water and includes the bed and banks where relevant. The aim is to protect all components of the whole ecosystem, i.e. water, biota, riparian zones and sediments.

Chapter 3 of the National Water Act - Protection of Water Resources - describes how resource protection will be achieved by:

- the establishment of a system for classifying water resources (resource classification);
- the determination of:
  - the class of significant water resources.
  - resource quality objectives (water quantity, water quality, habitat and biotic integrity).
  - the Reserve.

DWAF defined methods to classify the resource and quantify the ecological Reserve. A 7-step procedure was formulated to determine the ecological Reserve, which included the classification of the resource. The specific steps of the 7-step procedure that deals with the classification of the Resource are Steps 3 - 5 (Figure 2.1).

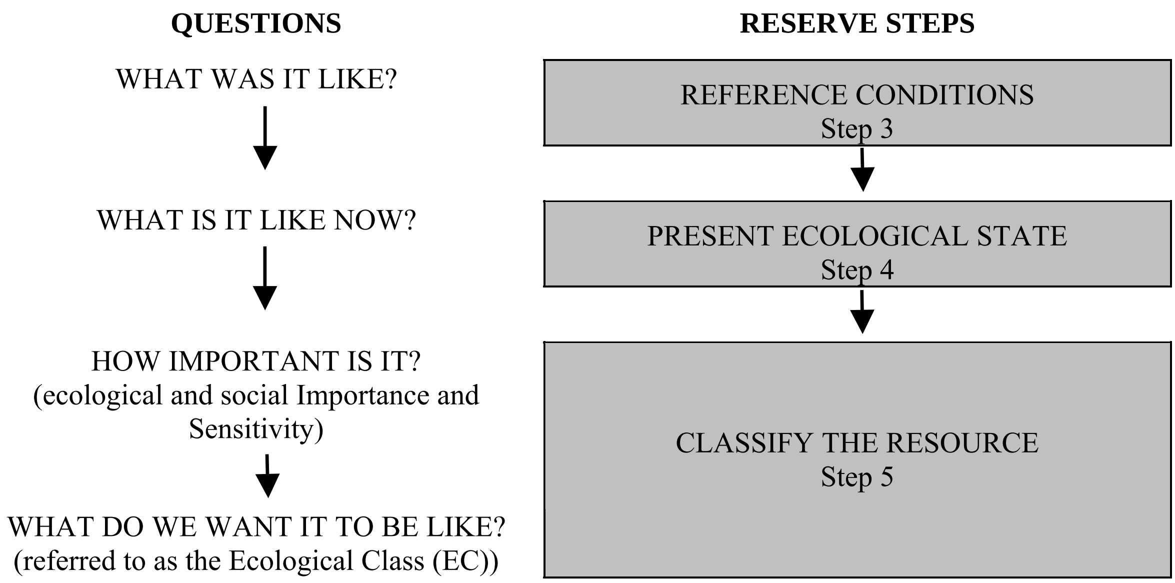

Figure 2.1 : Steps in the Ecological Reserve Determination Procedure that pertain to the classification of the resource

2.3 ECOLOGICAL MANAGEMENT CLASS

The Ecological Class (EC) concept (Step 5, Figure 2.1) is detailed in Volume 8 of the Resource Directed Measures (RDM) documentation (DWAF 1999). A system has been developed which provides a generic description of the ecological target for a water resource, expressed as Classes A to D, where Class A represents virtually unmodified, natural conditions (usually the reference conditions), and Class D represents a high degree of modification from natural conditions (conditions of maximum resource-use). "*Under current thinking (DWAF 1999), Class D is the lowest ecological class where resource use is deemed to be sustainable. Classes E and F are deemed to be ecologically unsustainable (degraded and degrading). Since sustainability is a guiding principle, the NWA precludes selection of Classes E and F for the EC.*"

The EC for a particular water resource is determined in relation to the Present Ecological State (PES) Class (A to F); the Ecological Importance and Sensitivity (EIS) of the resource, and possible improvements in resource quality, given that "some prior impacts or modifications may not be practically reversible due to technical, social or economic constraints" (DWAF 1999 - Volume 8). The EC may be set at the same level as the PES, or may be set as an improved class, but may not normally be set at a lower class than the present state, since this would suggest a deliberate intention to allow the resource to degrade. However, ecological considerations can be over-ruled by an executive, political decision to meet urgent social and/or economic needs.

Once the EC is determined, it becomes the overall target for the long-term protection and management of the resource, and the flow-related recommendations made in the Reserve determination processes are designed to maintain or improve the resource in the specified class.

Because the EC is a generic target, specific objectives have to be set for each resource, so that the particular characteristics of the resource are taken into account in the designated EC.

2.4 METHODS FOR DETERMINING THE RESERVE

A suite of methods is available for use in Reserve determination, each method associated with a different level of confidence in the results. The choice of methods is dependent on a number of factors such as:

- the degree to which the catchment is already utilised (DWAF 1999).
- the sensitivity and importance of the catchment (DWAF 1999).
- the potential impact of the proposed water use (DWAF 1999).
- logistic constraints.

The available methods include:

- Rapid Ecological Reserve Methodology (RERM).
- Intermediate Ecological Reserve Method (IERM).
- Comprehensive Ecological Reserve Method (CERM).

The IERM and CERM use more detailed information bases, take more time and cost more than does a RERM, but have the advantage of increased levels of confidence in the results arising from their use. The Building Block Methodology (BBM) - see 4.1 following - is the currently accepted approach for the CERM.

Methods for determining the EC differ for the various methods of Reserve determination (DWAF 1999 - Volume 2). As yet, no formal detailed method exists for determining the EC in a CERM study. A method was however developed for the recent Comprehensive Reserve determination for the Olifants River (North) and a similar process was adopted for the BRBS (see Section 3).

3. THE PROCESS FOLLOWED TO PROVIDE EC RECOMMENDATIONS

Table 3.1 shows a sequence of questions addressed during the EC process, where the left column illustrates simple questions, and the equivalent more technical version is given in the right column.

TABLE 3.1 : THE SEQUENCE OF ACTIONS REQUIRED FOR PROVIDING TECHNICAL INFORMATION ON THE EC

What did the river look like in the past ?	1 DETERMINE REFERENCE CONDITIONS
Relative to how it looked in the past, what does the look like now ?	2. DETERMINE PES (Class A-F)
Is the river changing, and if so how ? How severely ? How fast ?	3. DETERMINE TRAJECTORY OF CHANGE (FOR EACH COMPONENT WITH REASONS) IF THE STATUS QUO IS MAINTAINED Trajectory (None, negative, positive) Short term and/or long term (Class A - F)
What is the main cause for the change ?	4. DETERMINE CRITICAL CAUSE FOR THE FOR THE PES and/ or the trajectory OF CHANGE and GIVE THE ORIGIN OF THE CAUSE
What is the origin of the cause ?	
How ecologically and socially important is the river ?	5. DETERMINE IMPORTANCE and SENSITIVITY CATEGORIES (Low, Moderate, High, Very High) AND STATE CONFIDENCE IN EVALUATIONS.
What would the ecological aims be for the river ?	6. CONSIDERING THE IMPORTANCE AND THE **PRESENT** ECOLOGICAL STATE; SHOULD THE PES BE IMPROVED (if so, by how much) OR MAINTAINED (NOTE: MAINTAINING THE PES COULD STILL REQUIRE RESTORATION MANAGEMENT, DEPENDING ON THE TRAJECTORY OF CHANGE). (Class A - D)
Can the main cause realistically be addressed to achieve the ecological aims ?	7. DETERMINE WHAT WOULD BE REQUIRED TO ADDRESS THE CAUSES OF CHANGE 8. DETERMINE HOW DIFFICULT IT WOULD BE TO ADDRESS THE CAUSE. (RESTORATION/REVERSIBILITY POTENTIAL - easy, reasonable, difficult, very difficult). PROVIDE REASONS.
What is an achievable EC for the river ?	9. CONSIDERING THE ECOLOGICAL AIMS, AND THE DIFFICULTY OF ACHIEVING THE AIMS, DETERMINE THE ECOLOGICAL CLASS FOR EACH COMPONENT

The way in which the above questions were addressed is described in the flow-diagram below (Figure 3.1, DWAF 2000). The steps in the flow-diagram are discussed in numerical order.

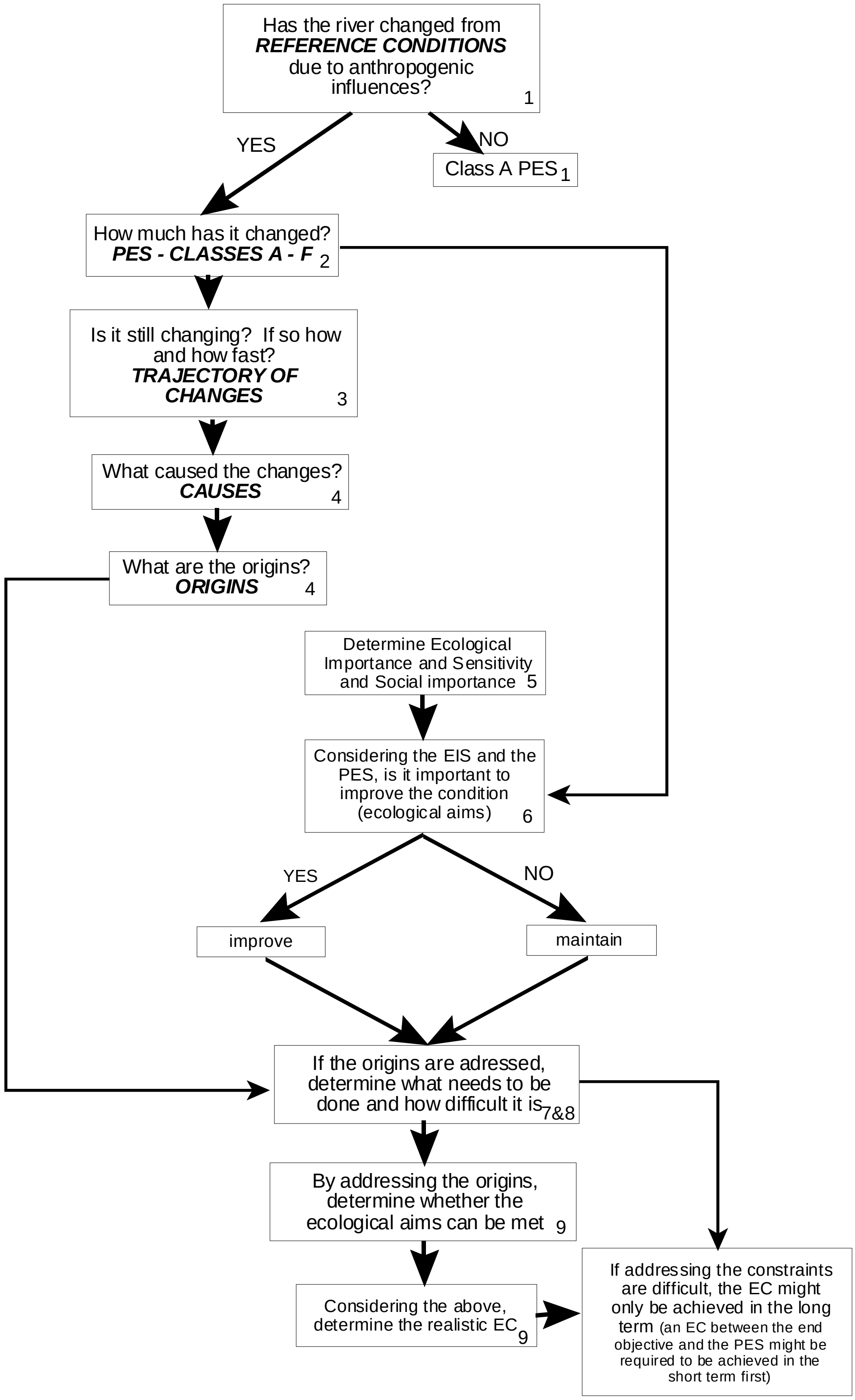

Figure 3.1 : Flow diagram illustrating the information generated to determine the EC

1. ***Has the river changed from reference conditions as a result of human interference ?***

   Detailed guidelines are provided in DWAF (1999, Volume 8) for the determination of reference conditions for both quantity and quality aspects of a Reserve determination. The reference condition describes the natural condition prior to anthropogenic change. Historical information and data, and/or data from similar minimally impacted sites elsewhere are used to describe the reference conditions for the channel, hydrology, biota and water quality. Often, the reference condition does not represent the pristine condition of a river, but a best estimate of a minimally impaired baseline state (the lack of data on pristine rivers being one reason for this). If the river is deemed to be unchanged relative to its reference condition, then its *present ecological state* can be described as Class A, which denotes that it is a natural or minimally impacted state, and thus the PES is the same as the reference condition. If the condition of river is deemed to differ from its reference condition, Step 2 is followed.

2. ***How much has the condition of the river changed (Classes B - F) ?***

   The PES is either the same as the reference condition (see 1) or described as being degraded relative to the reference condition. The range of PES Classes below A, *viz*. B-F, represent the extent of degradation from reference condition. For a CERM, the PES is expressed separately for each component of the river ecosystem, namely, general (habitat integrity), biophysical (fish, riparian vegetation, aquatic invertebrates and geomorphology) and water quality (chemistry) integrity. Integration of these different PES ratings is not required but in this study (and in most similar studies) an overall score, referred to the Ecological Class, is provided. This is simply a consensus evaluation of combined PES scores, arrived at through discussion at the specialist meeting, and is used to determine the Ecological Class.

3. ***Is it still changing, if so, how, and how fast (Trajectory and rate of change) ?***

   The Trajectory of Change describes the direction of change in river condition, *viz*. positive (improving), negative (degrading) or stable. The rate of change is provided as the PES Classes predicted for the short term (< 5 years) and the long term (> 20 years). The trajectory and rate of change are described for each of the components for which a PES is determined.

4. ***What has caused the changes in river condition (if any) and what are the origins of the causes ?***

   The impacts on river condition are listed as 'causes' and their origins described. For example, where sediment that originates from over-grazed fields impacts on the condition of riverine habitat by clogging interstitial spaces, the proximal **cause** of that impact would be sedimentation and its **origin** would be overgrazing. Thus, a distinction is made between the proximal cause of an impact (e.g., unnaturally high salinities in the river water) and its origin (e.g., elevated salt concentrations as a result of irrigation return-flows).

   Both cause and origin are designated as being either flow (i.e., can be remedied through flow manipulations) or non-flow related.

TABLE 3.2 DEFINITIONS OF GENERIC PES CATEGORIES.

CATEGORY	DESCRIPTION
A	Natural; • The resource base has not been decreased; • The resource capability has not been exploited
B	Largely natural with few modification; • The resource base has been decreased to a small extent; • A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified; • The resource base has been decreased to a moderate extent; • A change of natural habitat and biota has occurred, but the basic ecosystem functions are predominantly unchanged.
D	Largely modified; • The resource base has been decreased to a large extent; • Large changes in natural habitat, biota and basic ecosystem functions have occurred.
E	Seriously modified; • The resource base has been seriously decreased; • The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically modified; • The resource base has been critically decreased; • Modifications have reached a critical level and the resource has been modified completely with an almost total loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

5. Determine the Ecological Importance and Sensitivity (EIS) and Social Importance (SI)

EIS: The ecological importance of a river is an expression of its contribution towards ecological diversity and functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance (resistance) and to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration in the assessment of ecological importance and sensitivity (DWAF 1999 - Volume 3).

SI: Specific methods to determine the social importance of a river have not yet been designed. During the IERM, a simple set of questions is asked in an effort to determine the dependency of people in the area on a healthy functioning river, and to assess the cultural and tourism potential of the river. Where such questions are put to ecologists (as was the case in this study) the resultant SI scores must be viewed as having an extremely low confidence.

EIS and SI are used to set the EC. The following 'rules' apply:

- If the EIS is High or Very High, the EC is set as an improvement of the PES.
- If the EIS and the SI are Low or Moderate, the EC is set as equal to the PES.
- If the EIS is Low or Moderate, but the SI is High or Very High, the EC is set as an improvement of the PES.

6. ***Considering the EIS, SI and PES, determine the ecological aims for the river***
If the EIS or SI are high or very high, the EC is as an improvement of the PES, however, before finalising the EC, it is necessary to consider the practicality of achieving such an improvement – see Step 7.

7. ***If the origins are addressed, what needs to be done and how difficult is it ?***
The recommended EC should be realistically attainable. Thus, problems in catchment that would need to be addressed to ensure that the ecological aims are achieved must be identified. To the extent possible within the reserve project, the specialists identify the potential problems, identify the actions to remedy them and provide an opinion on the degree of difficulty to do so. Such assessments provided in this report are *per force* preliminary indications as they often require subjective evaluations on technical possibilities by ecological specialists.

8. ***Assessing the difficulty of addressing the origin of critical causes***
Each impact on each component of the river ecosystem should be assessed in terms of the perceived difficulty (in terms of current financial, social and political constraints) of reducing it and achieving an overall restoration of the river (DWAF 1999 - Volume 8). It is acknowledged that within this assessment, some changes to rivers may be regarded as irreversible within the limits of time and effort (including financial resources) required to achieve them.

   Several causes of change are landscape-based, and even immediate improvements in management practice would not show immediate improvements in river condition. Thus, short term and long term objectives may need to be set (see below).

9. ***Recommend attainable EC***
The outcome of the above 9-step process is a recommended or target EC, which is used as the focus condition at the BBM workshop. The target EC is often divided into a short-term and a long-term objective.

   This is not the final EC for the river.

   The Minister of Water Affairs and Forestry (or his delegated authority) decides on the final EC (or Ecological or Resource Management Class – EMC) after public consultation and considering, socio-economic information from various other sectors, in addition to ecological concerns. The final Reserve is then integrated into the Resource Quality Objectives for the river.

4. QUANTIFYING THE RESERVE: STEP 6

The volume and distribution of water required to meet the Reserve; referred to here as the instream flow requirements (IFR) must be quantified for the target EC.

In the BRBS, the standard Building Block Methodology (BBM, King and Louw 1998) was used to determine the Reserve. The BBM is the currently accepted Comprehensive Ecological Reserve Methodology (DWAF 1999).

4.1 STANDARD BBM (extracts from King and Louw 1998)

The BBM caters for the almost universal reality in South Africa of having rapidly to provide scientific guidance on such flows for a river in cases where biological data and understanding of the functioning of the river are limited. However, the methodology works equally well in data-rich situations.

"The BBM depends on available knowledge and expert opinion, gleaned from experienced river scientists in a structured 4-day meeting. Limited new data of a specific nature are gathered to facilitate the process. Relevant data on the river are prepared in a way that specialist workshop participants can easily understand and quickly begin to use. Scientists typically involved in the specialist meeting, all with specific roles, are those with specialist knowledge of the river or similar rivers in terms of the fish, aquatic invertebrates, riparian vegetation, river importance, habitat integrity, fluvial geomorphology, local hydraulics, water chemistry and social dependence on the riverine ecosystem. Hydrological and hydraulic modellers provide data inputs and facilitate the workshop process by answering questions and producing additional data as requested. The specialist meeting output, reached by consensus, is a quantitative description in space and time of a flow regime that should facilitate maintenance of the river ecosystem in some predetermined desired future state (now called the EC).

In the methodology the following assumptions are made.

The biota associated with a river can cope with those low-flow conditions that naturally occur in it often, and may be reliant on higher-flow conditions that naturally occur in it at certain times. This assumption reflects the thinking that the flows that are a normal characteristic of a specific river, no matter how extreme, variable or unpredictable they may be, are ones to which the riverine species characteristic of that river are adapted and on which they may be reliant. On the other hand, flows that are not characteristic of that river will constitute an atypical disturbance to the riverine ecosystem and could fundamentally change its character.

Identification of what are felt to be the most important components of the natural flow regime and their incorporation as part of the modified flow regime will facilitate maintenance of the natural biota and natural functioning of the river.

Certain kinds of flow influence channel geomorphology more than others. Identification of such flows and their incorporation into the modified flow regime will aid maintenance of the natural channel structure and diversity of physical biotopes.

The flows incorporated into the modified flow regime will constitute the instream flow requirement (IFR) for the river. The IFR describes, in space and time, the minimum amount of water that it is felt will facilitate maintenance of the river at some pre-defined desired state.

The recommended flows are identified and their magnitudes, timing and duration decided upon in the BBM specialist meeting. Initially, thought is focussed on the characteristic features of the natural flow regime of the river. The most important of these are usually: degree of perenniality, magnitude of base flows in the dry and wet season, magnitude, timing and duration of floods in the wet season and small pulses of higher flow, or freshes, that occur in the drier months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired state of the river, and thus should not be eradicated during development of the river's water resources. The described parts of each flow component are considered the building blocks that create the IFR, each being included because it is understood to perform a required ecological or geomorphological function. The first building block, or low-flow component, defines the required perenniality or non-perenniality of the river, as well as the timing of wet and dry seasons. Subsequent building blocks add essential higher flows."

4.2 APPLICATION OF THE STANDARD BBM AT THE IFR WORKSHOP

Flows are determined for maintenance periods (those flows that will maintain the system at the EMC during years other than drought years) and for drought periods (flows that allow only for survival of the most critical components of the ecosystem). The same procedure is used to determine maintenance and drought flows.

The sequence of actions followed during a standard BBM specialist meeting is as follows:

1. The assurances of maintenance and drought flows are determined based on the hydrological characteristics of the system.
2. Using observed or simulated daily hydrological data for the IFR site or a nearby representative site, the months with the highest and lowest low flows (base flows), respectively, are selected.
3. The maintenance and drought low flow values required to facilitate the target EC at the IFR site are determined for the months selected, and are used as the upper and lower limits of the range of low flows. These values are accompanied by motivations from each of the specialists for the values specified (see 4).
4. For each component of the river ecosystem, the specialist responsible describes the physical parameters (e.g., water level, velocity, depth) required with motivations. For components where flows lower than the required flows would be insufficient to meet the target EC, the motivations are denoted at primary motivations. For components where flows lower than the required flows would suffice to meet the target EC, the motivations are denoted at secondary motivations.
5. Once the low flows have been determined, they are (usually) compared with the hydrological record to check for anomalies, such as possible unrealistically low or high recommendations. Normal or average hydrological years are utilised to check maintenance flows and the driest years are used to check drought flows.

6. The low flows for the remaining months are interpolated by following the shape of the natural annual hydrograph. The low flows are specified as discharge ($m^3 s^{-1}$).
7. High flow events are also determined and motivated for. High flows refer to small, medium and large floods. The high flows are specified in $m^3 s^{-1}$ where the specified flow refers to a daily average peak. The instantaneous peak for these events would therefore be somewhat higher than the discharge provided.
8. The duration of each high flow is specified in days, with the shape of the flood hydrograph based on the shape of the natural hydrograph. The specified peaks include the low (base) flow portion of the total flow, thus, when the volumes of the high flows are calculated, it is necessary to exclude the low flow volume, which is already provided for in the lowflow recommendations (see 3).
9. Each high flow event is assigned to a specific month of the year. This designation is only used as a guide and all the high flows should be linked to a natural climatic trigger, viz. a high flow event will only be provided in conjunction with a natural event in the system.
10. Once the high flows have been determined, they are also compared with the hydrological record to check for anomalies, such as possible unrealistically low or high recommendations.
11. Together the low and high flows constitute the design IFR, which is then modelled against the hydrological record (using the assurances determined in 1) to produce the final IFR results, i.e., IFR flow sequence (see 12).
12. The IFR model or the Hughes DSS (DWAF 1999) are used to link the design IFR to natural triggers in an historical time series. The IFR model is used when daily data are available and affords the specialists the opportunity to view the IFR flow sequence set against the historic time series. This allows them to assess the frequency of drought and maintenance flows and whether they are satisfied that the flows they have recommended will meet the target EC. The model output is in a format suitable for linking with the Water Resources Yield Model (WRYM).
13. If no daily data are available, the Hughes DSS is used to undertake a similar exercise, but based on monthly data.
14. Once the design IFR for the target EC is finalized an evaluation of the overall confidence in the results is done. This takes into account the influence of constraints on time, data (quality and availability) and knowledge, and the inherent unpredictability of natural ecosystems, to arrive at a narrative evaluation of the confidence that can be attached to the final results.
15. As a final step, the parameters of the design IFR are used to 'regionally-calibrate' the Hughes DSS (DWAF, 1999), which (where appropriate) is then used to generate the IFR sequences that would result in either a one-class improvement and degradation of the target EC. Hence if the target EC is a Class C, then an IFR sequence to facilitate maintenance of a Class B or a Class D condition may be generated.

5. INFORMATION BASE

5.1 IFR SITES

Southern Waters' Preliminary Report (March 2000) provided a list of potential IFR stretches (and possible IFR sites within these) based on their Present Ecological Status and engineering considerations. At the BBM Planning Meeting (April 2000), the participants agreed that the IFR sites were expected to fulfil several criteria, namely:

- they should be representative of as many rivers within the catchment as possible.
- they should be downstream of proposed major water resource developments.
- they should correspond to "key management points" within the Breede River Basin.

It was also agreed that six IFR sites could not possibly meet all of the above criteria for the whole catchment.

In addition, given the size of the Breede River mainstream, and the inherent difficulties in recording discharge at high flows, it was imperative that, where possible, the IFR sites be situated near a DWAF hydrological gauging weir.

Thus, four IFR stretches were selected that were considered to meet all the criteria (Figure 5.1), and therefore were seen as of paramount importance. A further four IFR stretches, each of which met some but not all of the criteria, were selected, and it was decided to choose two of these as IFR stretches on the basis of the results of a site selection visit.

The locations for the four recommended IFR stretches were (Figure 5.1):

- Breede River mainstream, in the vicinity of Witbrug, Michell's Pass.
- Molenaars River, upstream of the proposed Ouplaas Dam.
- Breede River mainstream, immediately downstream of Papenkuils Wetland.
- Riversonderend mainstream, upstream of Riviersonderend Town.

The locations for the four alternate IFR stretches (Figure 5.1) were (the criteria that each stretch met is given in brackets):

- Breede River mainstream, upstream of the confluence with the Riversonderend (management area/characteristics).
- Breede River mainstream, downstream of the confluence with the Buffeljags River (management area/characteristics).
- On one of the tributaries of the middle Breede River feeding in from the north (management area/characteristics).
- On one of the mountain streams feeding into the Riversonderend from the Riversonderend Mountains, probably on the Baviaans River near Genadendal (characteristics).

5.1.1 Site Selection Visit and Team

The site selection visit took place on 19 and 20 April 2000. The following team members took part in the visit:

Dr Cate Brown:	study leader and macroinvertebrates.
Prof Albert Rooseboom:	hydraulics and geomorphology.
Dr Charlie Boucher:	botany.
Mr Steve Lambert:	fish.
Ms Justine Fowler:	habitat mapping.
Mr Bruce Paxton:	macroinvertebrates.
Mr Robin Pharoah:	surveying.

A total of 18 potential IFR sites were visited, of which the most promising are listed in Table 5.1. The majority of the sites were rejected on the basis of poor ecological condition, specifically poor riparian vegetation, poor fish habitat and anticipated difficulties with hydraulic measurements that would severely reduce the confidence in the Reserve determination.

5.1.2 Location of the IFR Sites

The following six sites were chosen (and used) as BRBS IFR sites (Figure 5.1):

IFR SITE 1:	Breede River downstream of Witbrug on the farm Mooiplaas.
IFR SITE 2:	Molenaars River downstream of DWAF gauging weir.
IFR SITE 3:	Breede River upstream of Le Chasseur.
IFR SITE 4:	Breede River downstream of Felix Unite camp on the Farm Ou Werf.
IFR SITE 5:	Riviersonderend at Greyton Campsite.
IFR SITE 6:	Baviaans River upstream of DWAF weir.

5.2 FISH (S. LAMBERTH - STARTER DOCUMENT VOLUME 1)

The fish report focuses on the effects of flow on the broad-scale characteristics of the fish assemblages in the Breede River Basin.

Twenty-two species of fish have been recorded from the Breede River Basin, half of which occur naturally and are either southern African and/or Southwestern Cape endemics. Four species, namely the witvis *Barbus andrewi*, Burchell's redfin *Pseudobarbus burchelli*, Cape kurper *Sandelia capensis* and Cape galaxies *Galaxias zebratus* are endemic to the southwestern Cape. *Barbus andrewi* is confined to the Breede and Berg River systems whereas *P. burchelli* occurs only in the Breede River and smaller adjacent catchments. *Sandelia capensis* and *G. zebratus* occur throughout the south.

TABLE 5.1 : SHORTLIST OF POTENTIAL SITES COMPLIED DURING THE SITE SELECTION VISIT. * = RECOMMENDED IFR SITE

IFR STRETCH	IFR SITE	DESCRIPTION	
Breede River mainstream, in the vicinity of Witbrug, Michell's Pass	*Breede River in Michell's Pass upstream of the confluence with the Wit Els River*	Potential as an IFR site: Overall condition: Access: Habitat availability: Hydraulics: Water quality: Vegetation: Fish: Macroinvertebrates:	Limited but possible. Problems will arise from a lack of confidence in the quality of data obtainable from the site. Poor, past alien infestation evident and considerable clearing ongoing in the catchment. Good. Cascades and pools, with occasional runs. Fairly representative of the Breede River in Michell's Pass. Could not easily be extrapolated to the Breede River downstream of Witbrug. No gauging weir, therefore hydraulics problematic, but possible. Fair. Poor. Only one bank could be used for IFR assessment, and this bank was comprised of a rocky out crop. Fair. Fair but impaired by water quality.
	*Breede River downstream of Witbrug on the farm Mooiplaas (c. 2 km upstream of confluence with the Wit River)**	Potential as an IFR site: Overall condition: Access: Habitat availability: Hydraulics: Water quality: Vegetation: Fish: Macroinvertebrates:	Limited but possible. Problems will arise from a lack of confidence in the quality of data obtainable from the site. Probably more valuable than the Michell's Pass site from a management perspective, and certainly no worse a candidate as an IFR site. Poor, extensive cultivation in the floodplain. Also the Breede River upstream of this site is dry in summer (as a result of abstractions) but the river flows all year round at this site because of contributions from the Sandspruit River. Also, the farmer informed us that the banks of the river at the site had not been disturbed since *c.* 1955. Little chance of finding a site in better condition in this reach. Good. Pools and runs, plus a short gravel riffle. Fairly representative of the Breede River in between Witbrug and the N1. Problematic but possible. Lack of a nearby gauging weir. Poor. Poor, but some indigenous elements are present. Poor, but some suitable habitat. Farmer reported that Witvis occur. Fair to poor.
Molenaars River, upstream of the proposed Ouplaas Dam	*Molenaars River downstream of DWAF gauging weir**	Potential as an IFR site: Overall condition: Access: Habitat availability: Hydraulics: Water quality: Vegetation: Fish: Macroinvertebrates:	Good. Highly recommended. Good, although the N1 impinges on the one bank. Good. Excellent. Riffle, runs, pools. Representative on foothill rivers in the Breede River Basin, specifically the Wit River. Good. Good. Good. Good. Excellent.
Breede River mainstream, immediately downstream of Papenkuils Wetland AND Breede River mainstream, just upstream of the confluence with the Riversonderend (management area/ characteristics)	*Breede River upstream of La Chasseur**	Potential as an IFR site: Overall condition: Access: Habitat availability: Hydraulics: Water quality: Vegetation: Fish: Macroinvertebrates:	Fair to good. Fair. Good. Fair to good. Runs and at least one rapid/riffle section. Fairly representative of the river in this stretch, with a riffle/cascade habitat, which is likely to be the most sensitive to flow changes. Good, *c.* 1.5 km upstream of a DWAF weir. Fair to poor. Fair, sufficient cues for an IFR assessment. Fair to poor. Habitats are limiting but it is likely that the Breede River in this reach is dominated by alien species. Fair to poor. Likely to be mainly marginal vegetation invertebrates. Limited from an IFR perspective.

IFR STRETCH	IFR SITE	DESCRIPTION
	Breede River at the Abbey	Potential as an IFR site: Poor, mainly because of the hydraulic difficulties. However, the site was good from a fish habitat perspective. Overall condition: Poor. Access: Good. Habitat availability: Good. Varied fish habitat. Hydraulics: Very poor. No weir and very difficult to accurately measure Q. Water quality: Fair to poor. Vegetation: Poor, insufficient for IFR assessment. Fish: Good. Excellent fish habitat. However it is likely that the Breede River in this reach is dominated by alien species. Macroinvertebrates: Good.
Breede River mainstream, downstream of the confluence with the Buffeljags River	*Breede River downstream of Felix Unite camp on the Farm Ou Werf*	Potential as an IFR site: Fair to good. Overall condition: Poor. Access: Good. Habitat availability: Good. Varied fish habitat. Representative of the river in this stretch, with the added advantage of having riffle/cascade habitat, which is likely to be the most sensitive to flow changes. Hydraulics: Fair. No nearby weir but Q measurements are possible because of a constriction of the channel just upstream of the site. Water quality: Fair to poor. Vegetation: Fair to good, sufficient for IFR assessment. Fish: Good. Excellent fish habitat. However it is likely that the Breede River in this reach is dominated by alien species. Macroinvertebrates: Fair.
On one of the tributaries of the middle Breede River feeding in from the north	Vink, Nuy, Klaas Voogs and Hoop Rivers, others visited during preliminary visit	Almost without exception, these rivers are severely degraded and have levees constructed on both banks. It is the opinion of the IFR Team that it would be a waste of resources to undertake a comprehensive IFR determination for these rivers. It is suggested that future IFR/Reserve studies consider applying a no-more-than intermediate level determinations to these rivers.
Riversonderend mainstream, upstream of RSE Town	Several sites visited	None of the sites visited was ideally suited to an IFR site. However, the site below would probably provide sufficient data for a low/medium-confidence Reserve assessment.
	Riviersonderend at Greyton Campsite	Potential as an IFR site: Poor to fair. Overall condition: Poor to fair. However the site was in considerably better condition than the other sites visited. Access: Good. Habitat availability: Fair. Deep pools, with Palmiet and gravel riffles. Representative of the Riviersonderend upstream of Riviersonderend Town, with fair indications of pre-Theewaterskloof characteristics. Hydraulics: Fair. No nearby weir but Q measurements are possible. Water quality: Fair to poor. Vegetation: Poor, unlikely to provide useful information above the Wetbank Zone because of alien invasion. Fish: Fair. However it is likely that the Breede River in this reach is dominated by alien species. Macroinvertebrates: Fair.
Baviaans River (mountain stream) near Genadendal. Site selection was limited to the Baviaans River because it was crucial to be near a DWAF weir. Several sites on the river were visited and eventually a site upstream of the DWAF weir in the mountain reserve was selected. The other sites were too heavily impacted to provide useful IFR data.	*Baviaans River upstream of DWAF weir**	Potential as an IFR site: Good. Overall condition: Good. Some upstream abstraction. Access: Good. Habitat availability: Good. Runs, riffle pool. Likely to be representative of the mountain streams draining into Riviersonderend from the Riviersonderend Mountains. Hydraulics: Good. DWAF weir just downstream of the site. Water quality: Good. Vegetation: Good. Some alien species. Fish: Good. Macroinvertebrates: Good.

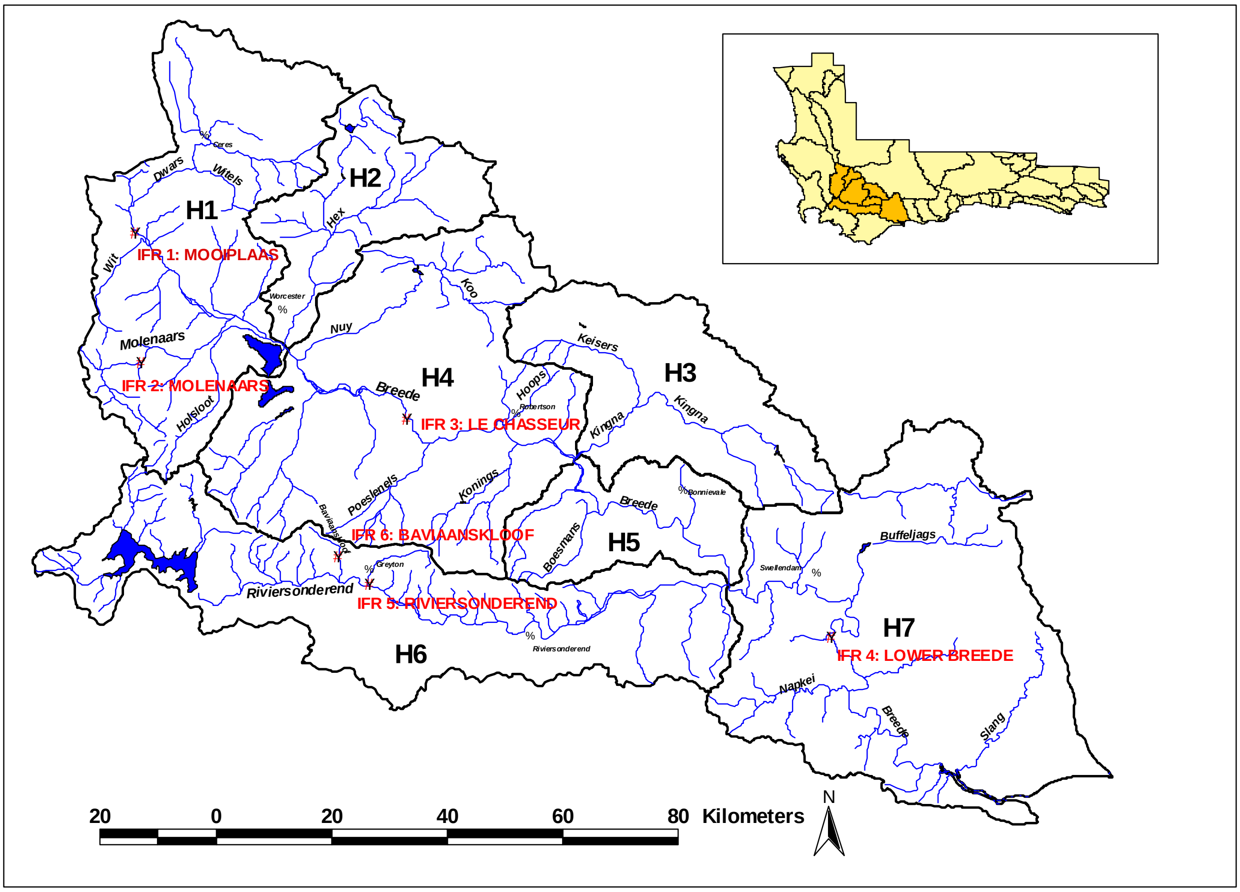

Figure 5.1 : IFR sites selected in the Breede River catchment

Western Cape although the taxonomic status of the latter is under review with the prospect of at least two new genera. The indigenous species include three obligate catadromous eels, these being the longfin eel *Anguilla mossambica*, the Madagascan mottled eel *A. marmorata* and the African mottled eel *A. bengalensis labiata*. *Anguilla mossambica* and *A. bengalensis* are confined to the west Indian Ocean and southern Africa whereas *A. marmorata* is distributed throughout the tropical regions of the Indo-Pacific.

The remaining indigenous species are the facultative catadromous freshwater mullet *Myxus capensis* and three "estuarine vagrants" Cape moony *Monodactylus falciformis*, flathead mullet *Mugil cephalus* and estuarine round-herring *Gilchristella aestuaria*. *Gilchristella aestuaria* can live and breed in freshwater and a thriving population exists after being introduced to Brandvlei Dam.

Introduced aliens are:

Micropterus dolomieu - Smallmouth bass
Micropterus salmoides - Largemouth bass
Oncorhynchus mykiss - Rainbow trout
Salmo trutta - Brown trout
Lepomis macrochirus - Bluegill sunfish
Tinca tinca - Tench

Cyprinus carpio - Carp
Carassius auratus - Goldfish
Oreochromis mossambicus - Mozambique tilapia
Tilapia sparrmanii - Banded tilapia
Clarias gariepinus - Sharptooth catfish.

5.3 AQUATIC INVERTEBRATES (B. PAXTON - STARTER DOCUMENT VOLUME 1)

The aquatic macroinvertebrate report focuses on the effects of flow on the broad-scale characteristics of the macroinvertebrate assemblages and on and the importance of a dynamic flow regime for aquatic ecosystems, including a review of the pertinent scientific literature. In addition, individual key taxa are identified and their microhabitat preferences described using the data collected.

Standard ecological descriptors are used to characterise the macroinvertebrate assemblage of each of the six sites in terms of taxon composition, relative abundance and diversity. Rank-abundance curves are presented as a descriptor of taxon dominance at each site. Key habitats are identified (marginal vegetation, pools and riffles) and the characteristic taxa associated with them described. Microhabitat preferences are described by means of Substratum-Velocity-Depth (SVD) histograms, based on the assumption that utilisation of microhabitats by invertebrates can be described by the modal range of their distribution across a particular physical habitat gradient.

The key habitat types, dominant particle sizes, geomorphological sub-zones, typical macroinvertebrate fauna and information required from other disciplines for each habitat are provided in Table 5.2.

5.4 RIPARIAN VEGETATION (C. BOUCHER - STARTER DOCUMENT VOLUME 1)

The general vegetation of the area belongs to the Fynbos Biome except for the Worcester-Bonnievale section, which is located in part of the Succulent Karoo Biome. More precisely, variations of the moist to arid Mountain Fynbos (Campbell 1985, Low and Rebelo 1996) occur in the mountains while Central Mountain Renosterveld occurs in the valleys formed by the Breede River and its tributaries from Ceres to Worcester and South Coast Renosterveld from Barrydale to Port Beaufort (Low and Rebelo 1996). The description of the vegetation below is subdivided into two sections:

1. A general description of the vegetation found along the Breede River and its tributaries, the Molenaars River and Riviersonderend, as well as a tributary of the Riviersonderend, the Baviaans River.
2. An outline of the phenological rhythms of selected riparian plants.

The vegetation at each IFR Site was categorised into the different lateral zones along key transects, and profile diagrams showing the lateral zones, their distance and height ranges were roughly determined in the field using a vertex hypsometer and more precisely by indicating the location of each boundary to the land surveyor.

Soils collected from each zone were sieved into size fractions and tested for acidity.

The phenological part of the botanical study was designed to obtain site-specific information about the annual phenological rhythms of selected riparian plants to determine variations in their responses to different water levels. Selection was based on the obligatory presence of the species at a minimum of two IFR sites, but preferably at more. They had to represent different growth forms. The examples had to serve as representatives of different lateral zones. All the longitudinal zones had to be represented albeit not by the same species.

The following typical riparian plants in this region were selected for study: *Acacia karroo* (IFR Sites 3 and 4; located in the Flood-plain Region Tree-shrub Zone), *Brabejum stellatifolium* (IFR Sites 1, 2 and 6; located in the Mountain Stream and Foothill Region Tree-shrub Zone), *Cyperus textilis* (IFR Sites 2 and 4; located in the Flood-plain Region Wetbank Zone), *Juncus lomatophyllus* (IFR Sites 5 and 6; located in the Mountain to Foothill Region Wetbank Zone) and *Salix mucronata* (IFR Sites 1, 2, 3, 4 and 5; located in the Mountain Stream, Foothill and Flood-plain Region in the Wetbank Zone).

5.5 FLUVIAL GEOMORPHOLOGY (A. ROOSEBOOM - STARTER DOCUMENT VOLUME 1)

This report serves to provide the information required for determining the IFR for rivers in terms of sediment transportation and geomorphology. Large- and small-scale geomorphological changes are brought about by changes in sediment supply, as well as changes in sediment transporting capacity. Such changes can occur in the short as well as the long term. In order to be able to quantify potential changes and the measures required to counter unacceptable changes, it is necessary to gather certain data as well as to establish certain relationships. The key components of this study are:

I. the different sources of sediment and their yields.
II. the sediment transporting capacity of river flows.
III. the characteristics of the sediments being transported, as well as the bed materials.

TABLE 5.2 : DEFINITION OF HABITAT TYPES, DOMINANT PARTICLE SIZES, GEOMORPHOLOGICAL SUB-ZONES, TYPICAL MACROINVERTEBRATE FAUNA AND INFORMATION REQUIRED FROM OTHER DISCIPLINES FOR EACH HABITAT

HABITAT TYPE	PARTICLE SIZE	GEOMORPHOLOGICAL SUB-ZONE	TYPICAL MACROINVERTEBRATE TAXA	INFORMATION REQUIRED FROM OTHER DISCIPLINES
Riffle	Cobble and boulder (64 – 250 mm and >250 mm)	Mountain streams and foothill (cobble bed)-	- Ephemeroptera: Ephemerellidae (*Ephemerellina* spp., *Lestagella* spp.), Leptophlebiidae, (*Castanophlebia* spp., Adenophlebia spp., Aprionyx spp.), Baetidae (*Baetis* spp.), Heptageniidae (*Afronurus* spp.) - Diptera: Simuliidae, Blephariceridae - Plecoptera: Notonemeuridae - Tricoptera: Hydropsychidae (*Cheumatopsyche* spp.) - Megaloptera: Corydalidae (*Platychauloides* sp.) - Coleoptera: Elmidae, Hydraenidae Helodidae (King, 1981)	Qs capable of turning over cobbles and boulders (sedimentologist). Qs capable of flushing sand and debris from interstitial spaces (sedimentologist). Qs that inundate habitat (hydraulician, habitat mapper).
Backwater/pool	Sand, gravel, cobble and boulder (all size ranges)	All	- certain Chironomidae - Oligochaeta - Hemiptera: Corixidae - Coleoptera: Gyrinidae - Cased Trichopter (Petts and Greenwood, 1985)	Qs capable of turning over cobbles and boulders to 10 cm. Qs capable of flushing sand and debris from interstitial spaces (sedimentologist). Qs capable of replacing poorly oxygenated groundwater from the hyporheic zone with oxygenated water Sub-surface flows, which flush deep hyporheos (geohydrologist).
Hyporheos.	Sand, gravel, cobble and boulder (all size ranges)	Mountain streams and foothill (cobble bed)-	- "Permanent" fauna: e.g. specialised copepods, mites and ostracods that complete their entire lifecycle within the hyporheos. - "Occasional" fauna: e.g., larvae and nymphs from the surface benthos that take up residence for part of their lifecycle or to escape disturbance events (Williams and Hynes, 1974)	
Marginal and aquatic		All	- Ephemeroptera: Leptophlebiidae (Castanophlebia spp.) Baetidae (*Baetis* spp., *Afroptilum* spp.) - Trichoptera: Leptoceridae Athripsodes sp.) - Odonata: Coenagrionidae: (*Pseudagrion* spp.) - Hemiptera: Gerridae, Veliidae, Corixidae - Coleoptera: Gyrinidae, Dytiscidae - Gastropoda: Lymnaeidae, Physidae, Ancylidae (King, 1981)	Flow regime required to maintain marginal and aquatic plant communities (botanist).
Sand beds	0.06 – 2 mm	Foothill (gravel bed) and Lowland	- Ephemeroptera: Caenidae - Odonata: Gomphidae, Corduliidae (Davies and Day, 1998)	Qs capable of flushing organic material from sand beds and of transporting or depositing sand (sedimentologist).
Burrows in mudbanks	< 0. 06 mm	Foothill (gravel bed) and Lowland-	- Ephemeroptera: Caenidae - Odonata: Gomphidae, Corduliidae (Davies and Day, 1998)	Qs that inundate habitat and maintain the saturation levels in the banks (hydraulician, habitat mapper).

Included in the geomorphological report is the habitat-mapping report (authored by J. Ewart-Smith), which provides an overview of the IFR sites in terms of channel morphology, the distribution of different-size substrata and the distribution of different flow types at a minimum of three markedly different discharges. In addition, areas of different hydraulic conditions (called hydraulic habitats) within the site are delineated and, for each of these, depth and velocity readings are provided for at least three discharges.

5.6 HYDRAULICS (STARTER DOCUMENT VOLUME 2)

As in other IFR studies the primary purpose of the calculations undertaken here was to establish a stage-discharge relationship for each cross-section, where the hydraulic characteristics were required. Once the stage-discharge relationship has been established, the other hydraulic parameters such as velocities, flow depths and wetted perimeters can easily be derived.

The stage-discharge relationships were developed using recorded stage levels and measured discharges. Discharges were obtained from DWAF measuring weirs in proximity of the IFR sites in the cases of Molenaars (IFR Site 2), Le Chasseur (IFR Site 3) and Baviaans sites (IFR Site 6). In the case of Mooiplaas (IFR Site 1) and Riviersonderend (IFR Site 5), site discharges were determined by stream gauging. In the case of the lower Breede Site (IFR Site 4), it was not possible to do reliable stream gauging and the local discharges had to be derived from two upstream weirs, one of the Breede River itself (H7H006) and one on the only major tributary between the Breede River weir and the site, the Buffeljags River (H7H013).

The CFP backwater programme developed by Dr MJ Shand was used to relate stages at the different cross-sections for each IFR site. The application of the methodology differed from site to site depending on local conditions and on data availability.

5.7 HYDROLOGY (STARTER DOCUMENT VOLUME 2)

The hydrological information was compiled by Ninham Shand. The details of the models and analyses used are provided in the report. The summary statistics for the IFR Sites are provided in Table 5.3:

TABLE 5.3 : SUMMARY HYDROLOGICAL STATISTICS FOR THE IFR SITES

IFR SITE	NATURALISED MAR (MCM)	PRESENT DAY MAR (MCM)	SUMMER IRRIGATION RELEASES ?
1	333	287	Yes
2	158	131	No
3	1 210	763	Yes
4	1 720	1 059	No
5	347	94	Yes
6	The hydrology for IFR Site 6 appeared to contain several inconsistencies. Eventually, it was decided not to use the data provided, and to rather determine the IFR without reference to the hydrological data, and back-check once these inconsistencies had been resolved.		No

5.8 RESERVE LEVEL OF CONFIDENCE AND INFORMATION AVAILABILITY

A considerable quantity of data were collected during the course of this study, and several of the specialists spent additional time and energy collecting data in excess of their Terms of Reference. Notwithstanding this effort, the specialists' responses to the confidence they had in their assessments were mainly moderate, and in some instance low.

Some uncertainties also arose from the difficulty in accurately modelling low flow hydraulics.

The following should also be noted :

- The data presented in the IFR Tbles for each IFR site, *viz*. depth, flow and volume for "Maintenance Lowflows", "Maintenance Highflows" and "Drought Lowflows, were generated as part of the BRBS IFR Study (Building Block Application). The volumes given were calculated from the hydraulic cross-sections at each IFR site, and the original depth and flow requirements therefore take precedence over the volume requirements in the event of any hydraulic queries.

- The data presented in the IFR Rule Tables and IFR Time Series Tables were generated by running the BRBS IFR Study data sets through the Desktop Model (V1). It is quite likely that the "Reserve MARs" determined as the long-term percentages for the IFR generated through the Desktop Model for the time series of various deviations at the various sites will differ from the sums of the respective Maintenance Lowflows and Highflows in the IFR Tables. The extent to which each differs is dependent on *inter alia*, the length (and accuracy) of the hydrological record used, the Assurance of Maintenance Lowflows used, and on the relationships determined for the Hydrological Region in which each IFR Site is situated.

6. IFR SITE 1: BREEDE RIVER AT MOOIPLAAS

TARGET REACH : FROM WITBRUG TO THE CONFLUENCE WITH THE WIT RIVER

6.1 REFERENCE CONDITIONS

6.1.1 Fish

Four species, namely the witvis *(Barbus andrewi)*, Burchell's redfin *(Pseudobarbus burchelli)* and Cape kurper *(Sandelia capensis)* are endemic to the southwestern Cape. Under natural conditions, these species are likely to have been abundant at IFR Site 1. Other indigenous species likely to have occurred here include three obligate catadromous eels; the longfin eel (*Anguilla mossambica)*, the Madagascan mottled eel *(A. marmorata)* and the African mottled eel *(A. bengalensis labiata)*.

Reference indigenous species list (6 of 6):
Barbus andrewi
Pseudobarbus burchelli
Sandelia capensis
Anguilla mossambica
Anguilla marmorata
Anguilla bengalensis labiata.

6.1.2 Aquatic Invertebrates

Reference conditions for Transitional and Lowland Floodplain rivers are based on data accumulated for the present study including community composition, diversity indices, rank-abundance curves and SASS4 scores. Natural, unmodified conditions are expected to have a SASS4 score = >110 and an ASPT score >7. The community is expected to include a large proportion of sensitive taxa, *viz*. three or more baetids, Leptophlebiidae, Tricorythidae and Limnichidae, with a low relative abundance of Chironimidae and Oligochaeta. Community diversity is expected to be high (*H'* >3) with an even distribution of individuals amongst species, reflected by low gradient rank-abundance curve.

6.1.3 Riparian Vegetation

There should be a clear distinction between the different zones in the riparian vegetation as detailed in Boucher (1998), and Boucher and Tlale (2000). There should be a distinct floodplain.

In summary, these zones should be as follows:

Aquatic vegetation: Instream rooted or floating aquatic vegetation should comprise less than 1% cover.
Wetbank vegetation: New sandy deposits should only be colonised by indigenous herbaceous species, such as *Cyperus textilis* or *Juncus lomatophyllus*, while *Salix mucronata* shrubs should fringe the water throughout. Seedlings of *Salix mucronata* should be present. Fringing *Prionium*

serratum should line the pools while dense *Cyperus textilis* and *Juncus lomatophyllus* should dominate the fringing vegetation of the riffles. The riffles should be clear of vegetation. There should be no bank collapse.

Lower Dynamic Zone: There should be no bank collapse and no invasion of the zone by either woody or herbaceous exotic species.

Tree/shrub zone: The dry bank should be dominated by indigenous woody perennials, including *Brabejum stellatifolium, Metrosideros angustifolia, Morella serrata, Podocarpus elongates* and *Rhus angustifolia*. There should be no alien invasive species. Post-fire recruitment should be dominated by woody indigenous perennials.

Floodplain: Should be 100% intact with back-channels supporting indigenous vegetation and have no invasion by woody exotic species.

6.1.4 Geomorphology

River type: Foothill cobble-bed river.

Natural condition

Active channel well defined, with stable well-vegetated banks. Cobbles not embedded. No bulldozing or artificial manipulation of the bed, banks, floodplain and no channelisation. Natural condition includes a multi-channelled floodplain, with channels that may or may not have held water throughout the year.

Modified reference condition

Irreversible structural changes have taken place at this site. These have taken place due to mechanical infilling of the floodplain, and the normal (natural reference) conditions are not a realistic baseline. Thus, a modified reference condition, without a natural floodplain, is set and the river banks end at mid tree/shrub zone, i.e., banks curtailed.

6.1.5 Water Quality

System variable:

TDS	:	< 45 mg l^{-1}.
pH	:	6.5 – 7.5.
DO	:	80 - 120% saturation.
TSS	:	< 5 mg l^{-1}.
Temperature	:	unmodified.
Nutrients	*:*	PO_4/TP ratio: 0 – 10%. Median $P0_4$: 0.01 mg l^{-1}. TN:TP ratio: > 20:1.
Toxic substances:		Meets the target water quality range for toxic substances as stated in the South African Water Quality Guidelines for Aquatic Ecosystems for 90% of the time, 99% of time less than or equal to chronic effect value, 100% of time less than the acute effect value.

6.1.6 Hydrology

No change to natural distribution flow regime.

6.2 PES, CAUSES AND ORIGIN, TRAJECTORY OF CHANGE

6.2.1 Fish

PES: D/E Class

The fish community at the site is dominated by large mouth, *Micropterus salmoides*, and small mouth, *Micropterus dolomieu*, bass. The eel, *A. mossambica*, and the witvis, *Barbus andrewi*, still occur at the site but in much reduced numbers. Also much of the habitat that would have attracted other indigenous species, such as *Pseudobarbus burchelli* has been removed through infilling.

CAUSES	ORIGINS	NON-/FLOW RELATED
Change in abundances and species composition of indigenous fish species.	Introductions of alien fish species, i.e., bass, trout and blue gills.	Non-flow related
Reduction in fish habitat quality.	Flow manipulations favouring alien species, in particular, bass.	Flow related
	Mechanical infilling of the floodplain and side channels.	Non-flow related

Trajectory of change: Negative (Short term: E Class -Long term: F Class)

Suitable indigenous fish habitat is limited throughout the reach, and alien species have a firm foothold. In addition, there are indications that the indigenous fish may not be in a particularly healthy condition. For instance, Bok and Immelman (1989) obtained 15 000 viable eggs from healthy, sexually mature female witvis, whereas only 200 eggs were found in the gravid female caught at IFR Site 1. This may, however, be an indication that peak spawning had already taken place. According to local reports, *L. macrochirus* were once the most abundant species at this site but they suddenly disappeared about five years ago. The reasons for this are not known but point towards a relatively unstable trajectory of change.

6.2.2 Aquatic Invertebrate

PES: D/E Class

Mooiplaas has a SASS4 score = 69 (reference conditions >110) and ASPT score = 5.3, the second lowest diversity index of all sites (*H'* = 3.31) and a steep rank-abundance curve with the community dominated by Chironimidae. However, the presence of a significant numbers of Leptophlebiidae and four baetid species, suggests that conditions are still tolerable for at least a few sensitive taxa.

CAUSES	ORIGINS	NON-/FLOW RELATED
Reduced habitat quality in river and other refugia due to increased sediment yield. Loss of habitat area through infilling.	Agricultural activities and bulldozing.	Non-flow related
Loss of habitat through embeddedness of cobbles. Increased sediment yield plus retardation of low flows (see geomorphology) and subsequent deposition of finer materials.	Reduced summer low flows due to irrigation abstraction.	Flow related
	Agricultural runoff from surrounding farmland.	Non-flow related

Trajectory of change: None

A 1997 SASS assessment by Dallas (1998) at nearby site yielded a SASS4 score = 61 and an ASPT score = 5.6, which suggest that conditions are stable albeit but largely modified.

6.2.3 Riparian Vegetation

PES: D/E Class

Aquatic vegetation : The density of instream aquatic vegetation, particularly algae and invasion by grasses and sedges is > 40 % during the summer months, as there is little water in the channel. In addition, *Eichhornia crassipes* (water hyacinth) has been recorded in the reach in recent years.

Wetbank vegetation : Sandy deposits are colonised by *Sesbania punicea*. Palmiet is present although it is in poor condition over most of the reach. There is bank collapse in places.

Lower Dynamic Zone : Disturbances of the banks have facilitated the invasion of the *Cliffortia strobilifera*. The shrubland community of the Upper Wetbank and Lower Dynamic Zones is dominated by dense stands of 2.0 m tall shrubs of the exotic invasives *Paraserianthes lophantha* and *Sesbania punicea*.

Tree/shrub zone : The Tree/shrub zone is highly disturbed by fire and terracing, except on the left bank of the upper transect. Unfortunately this latter area is invaded by a dense stand of up to 10 m tall *Acacia mearnsii* and *Eucalyptus camaldulensis* trees.

Back Dynamic Zone: Only remnants of this zone remain, the rest having been destroyed through alien invasion, farming activities (bulldozing) and/or fire.

Floodplain : Completely destroyed by farming activities. Back-channel canals filled in.

CAUSES	ORIGINS	NON-/FLOW RELATED
Destruction of tree shrub zone and the floodplain vegetation.	Farming activities - bulldozing of floodplain and channel: • to create agricultural lands; • in an effort to reduce flooding of agricultural lands in the floodplain	Non-flow related
Low summer flows promote invasion and establishment of alien species (*Eucalyptus* and *Sesbania*) and therefore flooding is less effectual in removing them.	Introduction (natural and planting) and lack of management of alien species.	Non-flow related
	Abstraction for agriculture.	Flow related
Increase in algae due to nutrients and low summer flows.	Farming activities.	Flow related and non-flow related
Presence of *Eichhornia crassipes* (water hyacinth).	Farming activities and irrigation return flows resulting in excessively low flows in summer and artificially high concentrations of nutrients.	Non-flow related

Trajectory of change: Negative (Short term: E Class -Long term: E/F Class)
The presence of invasive aquatic plants in this section is particularly problematic, and if left unchecked would almost certainly result in a decline in the current condition of the system. Also, encroachment of alien trees into the riparian zone is will continue unless actively discouraged.

6.2.4 Geomorphology

PES: D/E Class
Note: The geomorphological class should be interpreted in the context of habitats and not large-scale geomorphology.

CAUSES	ORIGINS	NON-/FLOW RELATED
Infilling of floodplain.	Mechanical creation of agricultural fields.	Non-flow related
Instream morphological units and habitat changes and bank changes.	Instream bulldozing and manipulation of the channel (including banks). Cobble mining.	Non-flow related
Berm for length of river stretch.	Agriculture - prevent flooding of lands.	Non-flow related
Embeddedness and mud deposits - increase in sediment yield.	Agricultural activities.	Non-flow related

Trajectory of change: None
The channel appears to be in equilibrium with its current hydrological regime.

6.2.5 Water Quality

PES: B Class
Water quality data from Witbrug (H1H006Q01) indicate that the river is in a B Class (moderately elevated TDS concentrations and nutrient concentrations). However, this monitoring point is situated quite some distance upstream of the IFR site and just downstream of the confluence with the Witels River, which brings in good quality water. The low SASS scores and large stands of benthic algae observed at the IFR site, indicate the quality to be significantly poorer than that recorded at H1H006Q01. Based on these qualitative observations, it was agreed that water quality at the IFR site is probably at least one class poorer than indicated by the data from H1H006Q01.

CAUSES	ORIGINS	NON-/FLOW RELATED
Increased nutrients.	Effluent return flows from domestic sewage effluent from Ceres.	Non-flow related
Increased TDS.	Irrigation return flows from intensive irrigation agriculture in Ceres area and between Ceres and IFR Site 1.	Non-flow related

Trajectory of change: Negative (Short term: C Class Long term: C Class)

Slight increasing trend in salinity over last 20 years (about 2 mg l^{-1} TDS per year), probably the result of irrigation return flows and evaporation. Moderate increasing trend in PO_4 (about 0.002 mg l^{-1} per year) and in NO_2NO_3-N (about 0.011 mg l^{-1} per year), probably as a result of treated sewage effluent being discharged into the river as well as intensive agriculture in the catchment.

6.2.6 Hydrology

PES: D Class

Flow stops in summer (river used to be perennial), however the flood regime is largely natural. Contributions from relatively undisturbed tributaries are considerable.

6.2.7 Overall PES

PES: D/E Class

The causes and origins are summarised as follows:

Non-flow related
Presence of alien fish and vegetation species.
Mechanical changes to the floodplain and river channel resulting in a modified river.
Irrigation return flows and sewage impacting on water quality.
Flow related
Abstraction resulting in river drying up in summer due to agriculture.

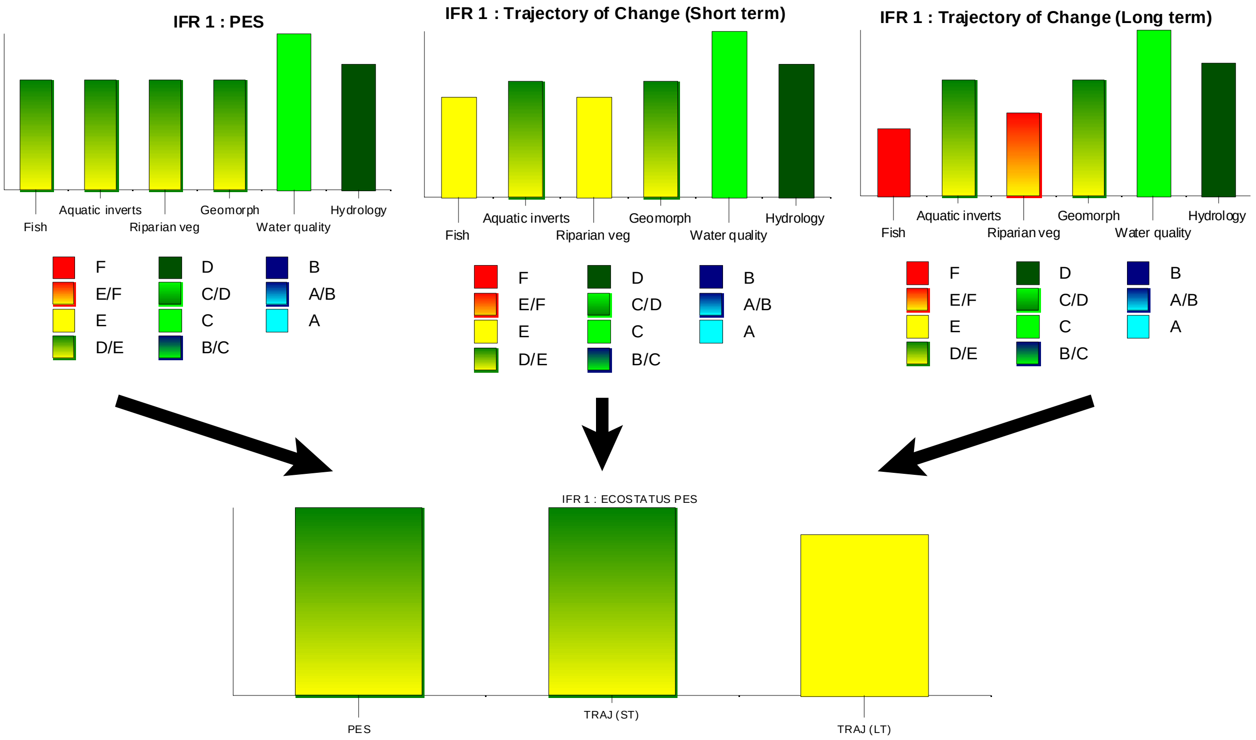

Figure 6.1 : Present Ecological Status (PES)

The information on PES for the different components are summarised in Figure 6.1. The top row of graphs illustrates the classes allocated to the different components. The bottom graph illustrates the component PES values integrated into one value.

Four of the components, i.e., fish, invertebrates, riparian vegetation and geomorphology are in a D/E Class. This includes two drivers, i.e., geomorphology and riparian vegetation. Water quality is in a C Class, but the possibility exists that it is in a lower class taking into account the lack of data upstream of the Witels River and the lower aquatic invertebrate evaluation (D/E Class). Hydrology is in a D Class. Considering the number of non-flow related activities that contribute to the D/E Class, the combined PES should reflect the average condition, i.e., D/E Class. The short-term trajectory for change for two of the components (fish and riparian vegetation) is to an E Class, and their long-term trajectory of change is E and E/F Class, respectively. The overall river condition is expected to be D/E in the short-term and E in the long-term.

6.3 ECOLOGICAL AND SOCIAL IMPORTANCE

The results are attached as Appendix A.

Note that the social evaluation is a guesstimate on the part of ecologists with some local experience of the area and as such must be accorded a LOW confidence rating.

EIS rating: Moderate.
Confidence: High.
Determinants: Presence of rare an endangered species.
Presence of diversity of habitat types and refugia. Important for migration.
Social rating: Low.
Confidence: Low.
Determinants: Some subsistence fishing and recreation.

***AIM*:**
The EIS is moderate, the social importance is low and the PES is very low (D/E Class). The overall trajectory of change is negative and results in an E Class. The aim, in terms of the RDM protocols, would be to improve the system to at least a D Class. The degree of difficulty will dictate whether a D Class is considered to be attainable.

6.4 ATTAINABLE ECOSTATUS CLASS (EC)

6.4.1 Fish

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Alien fish.	Non-flow related	Remove all alien species.	Difficult
Agriculture (flow reduction).	Flow related	Restrictions on summer abstractions.	Difficult
Agriculture (infilling and channel opening and straightening).	Non-flow related	Stop mechanical interference with the river channel and rehabilitate the flood plain.	Very difficult
PES D/E - EC D/E÷D If one does not address the alien fish species, any other mitigation is not going to achieve a D Class for fish. The class can therefore not be achieved by flow related mitigation.			

6.4.2 Aquatic Invertebrates

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Agriculture (flow reduction).	Flow related	Restrictions on summer abstractions.	Difficult
Agriculture (runoff).	Non-flow related	Irrigation and pesticide management.	Reasonable
Agriculture (activities and bulldozing).	Non-flow related	Stop mechanical interference with the river channel and rehabilitate the flood plain.	Very difficult
PES D/E - EC D Addressing the flow related issue, i.e., the summer low flows would be the most important aspect to address and could achieve the EC of a D Class. To halt the negative trajectory of change (resulting in an F Class), some of the non-flow related issue also should be addressed.			

6.4.3 Riparian Vegetation

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Agriculture (irrigation return flows).	Non-flow related	Irrigation and pesticide management.	Reasonable
Agriculture - summer decrease.	Flow related	Restrictions on summer abstractions.	Difficult
Agriculture (activities and bulldozing).	Non-flow related	Stop mechanical interference with the river channel and restore.	Very difficult
Introduction of alien vegetation.	Non-flow related	Management and clearing. (Working for Water).	Reasonable
PES D/E - EC D/E÷D If the flow-related origin, i.e., the decrease in summer base flows, is addressed, this should also indirectly address some of the other problems such as the alien vegetation and irrigation flows. Reinstating summer flow should therefore achieve the improvement to a Class D.			

6.4.4 Geomorphology

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Agricultural activities - mechanical.	Non flow related	Stop mechanical interference with the river channel and restore floodplain.	Very difficult
PES D/E - EC D/E÷D The improvement of the geomorphology could only be in the long term due to the extensive changes to the floodplain.			

6.4.5 Water Quality

The difference between the water quality class and the aquatic invertebrate class indicates that a potential discrepancy exists. This discrepancy could either be because influences on water quality occur between H1H006Q01 and IFR Site 1, or because the water quality data do not include measurements of determinants that could be harmful to the biota.

6.4.6 Summary of Attainability and Ecostatus EC

Addressing the summer low flows will achieve the improvement from an D/E to a D Class for aquatic invertebrates and riparian vegetation. It is doubtful whether the fish class can be improved due to the alien fish species and the difficulty of addressing this problem. In the long term, geomorphology can be improved if the non-flow related issue of the mechanical disturbance to the channel is addressed. To ensure the ecological class of a D, the summer low flows must therefore be addressed; however the non-flow related aspect of the bulldozing will also have to be addressed to ensure that in the long term, the ecostatus EC of a D Class be achieved. Realistically, it will be very difficult to improve the overall status of this river due to the presence of the alien fish and the structural changes that have taken place.

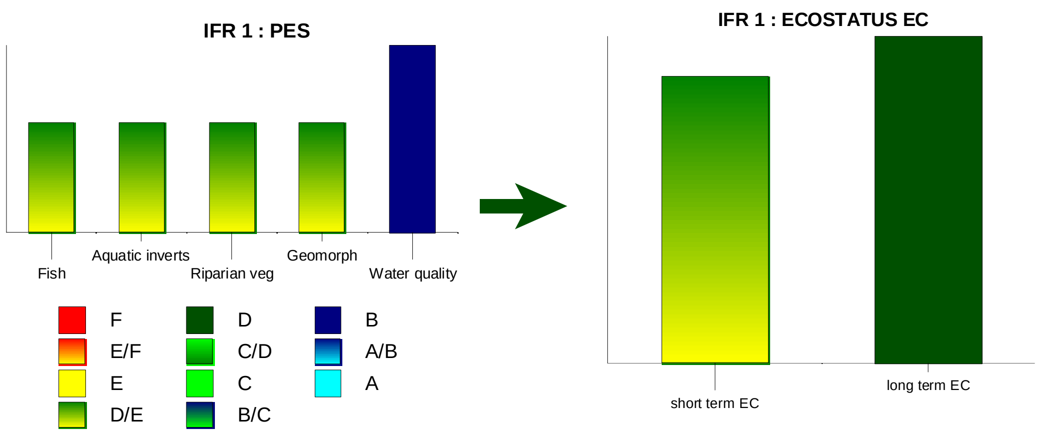

Figure 6.2 : Ecological Class (EC)

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	D	0	D	D	MODERATE	
Water quality	B (flag)	-	C	C		B
Geomorphology	D/E	0	D/E	D/E		D/E → D
Riparian veg	D/E	-	E	E/F		D/E → D
Fish	D/E	-	E	F		D/E → D
Aquatic inverts	D/E	0	D/E	D/E		D
Ecostatus	D/E	0	D/E	E		D/E
					Long term EC	D

(flag) Concern based on landuse information or inconsistency between the bio-assessment and the water chemistry (i.e biota in a lower class)

Figure 6.3 : Summary of PES and EC

6.5 OBJECTIVES

6.5.1 Fish

EC: D/E÷D
General flow objectives: Maintain low flows during summer.
Overall fish objectives: To maintain and enhance populations of the remaining indigenous fish.
Objectives for target/indicator species: Maintain spawning habitat and conditions, flow of aerated water at head of pools for survival of eggs and larvae of *Barbus andrewi*. *B. andrewi* is a serial spawner, breeding continuously throughout summer, and therefore requires flow throughout the summer.

General flow objectives: Maintain winter floods, high flows.
Overall fish objectives: To facilitate dispersal of indigenous species especially out of overpopulated reaches.
Objectives for target/indicator species: Indigenous species most notably the larger *B. andrewi* use floods and high flows for dispersal and may recolonise areas left vacant by alien species some of which are washed downstream in strong winter flows.

General flow objectives: Maintain summer floods, high flows.
Overall fish objectives: To facilitate migration of catadromous species.

Objectives for target/indicator species: Catadromous eels use high flows, in particular summer floods, as cues and a passage to migrate back to the sea. Juveniles use the summer high flows to return to the rivers and to move upstream.

General flow objectives: Maintain summer floods, freshes.
Overall fish objectives: Population control, removal of alien species.
Objectives for target/indicator species: Well-timed floods during spring will aid in the destruction and flushing of nests, eggs and larvae of alien species *L.macrochirus* and *Micropterus* spp., which start breeding earlier than do the indigenous species.

6.5.2 Aquatic Invertebrates

EC: D
General flow objectives: Maintain present flood regime and reinstate summer low flows to achieve EC of D.
General objectives for invertebrate component:

- SASS4 score $ 69 and ASPT score $5.3.
- Community should include at least four baetid species as well as Leptophlebiidae, Hydropsychidae and Hydroptilidae (riffles).
- Community diversity = *H'* 3.3.

Identification of and objectives for target species: Maintenance of above community characteristics rather than focussing on target species.

6.5.3 Riparian Vegetation

EC: D/E →D
Back Dynamic Zone
General flow objectives: No objective as zone has either been destroyed by farming activities or is invaded by dense alien infestations. Non-flow related objective would be to control the construction of infrastructure floodplain in an effort to minimise future flood damage.

Tree-Shrub zone
General flow objectives: Maintain existing plants by depositing silt and debris (1:5 to 1:20 year floods) and to promote seedling and juvenile establishment and maintenance (Require 1:2 year and Class IV floods).
General objectives for vegetation component: Community objective is to reduce stress on plants to restrict alien species invasions.
Identification of and objectives for target species: To restore density of stands of woody species (e.g., *Maytenus oleoides*, *Olea europaea* subsp. *africana, Freylinia lanceolata* and *Cliffortia heterophylla* (as an edge species)) coupled with a campaign to eradicate alien woody vegetation.

Lower Dynamic Zone
General flow objectives: Maintain zone in a healthy state to reduce channel shape change, i.e., steepening and narrowing of banks (1:2 year and Class IV Floods).
General objectives for vegetation component: To prevent the establishment of annuals and woody alien species.

Identification of and objectives for target species: No specific target/indicator species, other than to promote the growth of indigenous herb and to allow for some downward movement of tree and shrub species.

Upper Wetbank Zone

General flow objectives: Maintain the zone to prevent channel shape change (Class II and III floods and 5% winter lowflow).

General objectives for vegetation component: To prevent the establishment of annual and woody alien species.

Identification of and objectives for target species: Salix mucronata and *Metrosideros angustifolia* should be maintained in a healthy condition.

Lower Wetbank Zone

General flow objectives: Maintain zone vegetation (Class I floods; 5-90% winter lowflow and 5-90% summer lowflow levels).

General objectives for vegetation component: Community objective is to ensure zone is wet regularly for fairly long periods in winter (with fluctuations in levels) to allow plants to grow in clear water even while submerged. To ensure that banks will be wetted through capillary action when exposed.

Identification of and objectives for target species: Cyperus textilis, Prionium serratum, Phragmites australis. To allow maintenance and re-establishment of *Prionium serratum* by wetting the substrate periodically (Summer 5-90% lowflow levels) and to prevent invasion of riffle by *Paspalum distichum.*

Aquatic Zone

General flow objectives: Maintain Aquatic Zone (90-99% winter lowflow and 50% summer lowflow).

General objectives for vegetation component: Ensure plants are inundated during most of winter.

Identification of and objectives for target species: Target/indicator species objectives are to prevent algae increase.

6.5.4 Geomorphology

Ideal condition: Re-instatement of secondary channel and flood plain.

Secondary, more achievable aim: To maintain pool, riffle and rapid systems. Sufficient small and large floods are required to achieve this.

Risk: Severe channel deformation during high floods.

6.5.5 Water Quality

EC: B

TDS: Maintain the median summer (Jan – Mar) TDS concentrations < 45 mg l^{-1} (Class A) and for the remaining months, < 300 mg l^{-1} (Class B) for 95% of the time.

Note – at present the recorded values are well below the 300 m l^{-1} value for the B/C Class limits and the 95 percentile was selected to set the winter TDS RQO.

pH: Maintain between current 6 - 7.7 based on the PES pH range.

Dissolved oxygen: Maintain between 80-100% of saturation.
Water temperature: Maintain within 3% of the seasonal variation pattern at reference site.
Nutrients: Median PO_4 concentration < 0.05 mg l^{-1}.

% PO_4:TP ratio <20%.
TN:TP ratio>10:1.
Median NH_3-N<0.015.
Maintain winter NO_2NO_3-N concentrations at < 0.8 mg l^{-1} for 95% of the time and summer concentrations < 0.5 mg l^{-1} for 95% of the time.

Toxic substances: Maintain toxic substances at ≤ CEV for 95% of the time and ≤ AEV for 99% of the time as specified in the SAWQG for aquatic ecosystems.

Flow related objectives: Prevent biofilm formation by maintaining the flows required to slightly move fines and clays (0.93 $m^3 s^{-1}$) and gravel (1.98 $m^3 s^{-1}$).
Non-flow related objectives: Pesticides are a concern as a result of intensive agriculture upstream of site. See objectives for toxic substances.

Note: % low flows provided refer to exceedence values.

6.6 MAINTENANCE FLOW ASSURANCE

The assurance of maintenance low flows during winter is set as a flow that occurs 70% of the time. The assurance of maintenance low flows during summer is set as a flow that will occur 60% of time.

6.7 SEASONAL DISTRIBUTION

July was selected as the highest flow month and February was selected as the lowest flow month.

6.8 IFR RESULTS

6.8.1 Motivations: Low Flows

The specialists' motivations for each flow are provided below.

MAINTENANCE LOW (DRY SEASON, FEBRUARY) 0.4 m^3s^{-1}

Descriptions of flow required:
0.1 m s^{-1} at Cross-section 3 (0.08 actually used). Reinstatement of perenniality. Trickle flow into pool at Cross-section 1.

Primary motivation:

Aquatic invertebrates: At the very bottom of the range for *Afronurus* sp. *Afronurus*' range: 0.1 – 0.4 m s^{-1}, depth range 0.2 – 0.25 m. Population will be stressed but may be able to re-establish (aiming for a D-Class, so cannot suggest much higher).
Source: Invertebrates samples for this study, photos, profile, SVD histograms, available literature.
Riparian vegetation: Maintenance of Wetbank vegetation. To allow *Isolepis prolifer* to reproduce and to reduce algal growth and encroachment by *Paspalum*. Will reduce stress to pool and riffle habitats, in terms of algal growth.
Source: Own data, reports and students studies.

Secondary motivation:

Fish: Sufficient inflow of oxygenated water into pool over cobble gravel area, *B. andrewi* still able to spawn during the summer months.
Source: Breede Study.

Water quality consequences of low flows

The general water quality condition in riffles will be unchanged from the present day. However, poorer water quality (high TDS, high temp and low DO) in pools will be mitigated.

MAINTENANCE LOW (WET SEASON, JULY) 2.20 $m^3 s^{-1}$

Descriptions of flow required:

Velocities: Depth up to 0.19 m at Cross-section 3. 1.95 m deep at Cross-section 1.

Primary motivation:

Riparian vegetation: Moderate velocity, fairly deep, wetted perimeter slightly to moderately reduced. 90% winter baseflow level or 30% summer flow level. Just reaches top of the Lower Wetbank.
Source: Own data, reports, students' studies.
Aquatic invertebrates: At the very bottom of the range for *Demoreptus capensis* conditions of highest occurrence (i.e., velocities of 0.6 – 1.2 m s^{-1}, depth up to 0.25 m) at Cross-section 3. Population will be stressed but may be able to re-establish (aiming for a D-Class, so cannot suggest much higher).
Source: Invertebrate samples for BRBS, photos, profile.

Secondary Motivation:

Fish: Movement between the habitats is restricted, and only possible for smaller and smaller individuals and adults confined to the larger pools except during spates (depth: 0.19 m allowed for but 0.29 m ideal).
Source: Study, literature.

Water quality consequences of low flows

TDS will increase but should still remain in a B class. HOWEVER - it is important to realise that the data used here are from Witbrug - upstream of the site.

DROUGHT LOW (DRY SEASON, FEBRUARY) 0.19 m^3 s^{-1}

Descriptions of flow required:
Trickle flow into pool at Cross-section 1.Maintain perenniality.

Primary motivations:
Fish: Sufficient inflow of oxygenated water into pool over cobble gravel area, *B. andrewi* still able to spawn during the summer months.
Aquatic invertebrates: Some habitat remains as refuge for the remaining individuals.
Source: Invertebrate samples for this study, photos, profile.

Secondary motivations:
Riparian vegetation: All Wetbank plants stressed.
Source: Own data, reports and student's studies.

Water quality consequences of low flows
Similar to present day conditions.

DROUGHT LOW (WET SEASON, JULY) 0.96 m^3 s^{-1}

Descriptions of flow required:
To just reach the bottom of the LWB in Cross-section 3.

Primary motivation:
Riparian vegetation: Lower Wetbank lost 90%. Water reaches to the top of Aquatic Zone. Pool degradation started. Riffle affected moderately.
Source: Own data, reports, students' studies.

Secondary motivations:
Aquatic invertebrates: With a reduction in the range of winter low flows, inundation of these areas is reduced, and the habitat for taxa favouring depositional environments is limited to the margins of the channel. Some reduction in habitat availability and loss of potential hyporheic refuge is expected. This will be exacerbated if the winter within year floods are not provided.
Source: BRBS data, students' studies.
Fish: Maintenance of a trickle into the pool and drift food source. Lower flows will result in food limitation in pools, cannibalism, deterioration in water quality and increase in parasite loads of fish.

Water quality consequences of drought flows
TDS will increase but should still remain in a B class unless the drought conditions are imposed for extended periods. HOWEVER - it is important to realise that the data used here are from Witbrug - upstream of the site.

6.8.2 Motivations: High Flows

Fish:

Class I:

Used for migration, dispersal and recruitment of adults and juveniles. Class I summer floods also alleviate the potential for water quality problems. In general adult indigenous fish species are tolerant of reduced water quality, but if severe, will either curtail or reduce their reproductive output. Parasite loads increase with poor water quality, contributing to a decline in individual and population health. Juvenile fish are more tolerant than adults purely because all their resources are put into growth and don't have to apportion resources between reproduction and maintaining a large body size – as is the case with the adults. Eggs and larvae are susceptible to poor water quality and usually die. Some introduced species continue to reproduce, overpopulating waters with stunted individuals. These species are usually flushed downstream or out of the system with floods.

Class I floods are used for spawning by *P. burchelli*. Reduced floods = more 1 year old fish, which only spawn once. 2 years old fish can spawn twice (every 90 days) and are more fecund.

Class III and IV:

Similar effects to Class I and II floods. Also important for facultative catadromous species and estuarine associated species to migrate in and out of the system.

Aquatic invertebrates:

Class I:

Affects water quality in the river during the dry summer months. Loss of events in the summer would result in a reduction in water quality, which would impact on the more sensitive species.

Class II and III:

Used for dispersal of larvae and/or eggs through downstream drift. These floods also mobilise flood and organic matter into the water column, and prevent localised build-up of organic material or mud on rock surfaces, which would favour different taxa, e.g., oligochaetes.

Class IV and larger:

Required for habitat maintenance, e.g., flushing of interstitial spaces and resetting/ordering of substrata.

Riparian vegetation:

Class I:

Maintains the Lower Wetbank (LWB). Reductions in these floods (together with decrease summer flows have already resulted in increased algal growth in the channel in summer, and encroachment of *Paspalum* into the channel. Delays/non-existence of these floods may also negatively affect growth of plants in the LWB by shortening the period when plants can benefit from these floods.

Class II, III, IV:

- To maintain the Lower Dynamic Zone and reduce the encroachment of aliens. Removal of these floods will result in exotics becoming dense along the margins of the Upper Wetbank

(UWB) and heat from subsequent fires destroy both UWB and Tree Shrub Zone (TSZ) plants.

1:2 and 1:5 floods:

- N/A as zones that would normally be maintained by these floods no longer exist.

Geomorphology

The sediment transporting capacities of the different within-year flood classes at IFR Site 1 are provided below.

CROSS-SECTION	CLASS I	CLASS II	CLASS III	CLASS IV
Section 1	*Deposition*	*Deposition*	Deposition	Slight movement of fine sediments.
Section 2	Deposition	Slight resuspension of fine sediments and gravel	Resuspension of fine sediments, gravel and small cobbles.	Resuspension of fine sediments, gravel and cobbles.
Section 3	Slight movement of *in situ* gravel and cobbles	Movement of *in situ* gravel and cobbles	Movement of *in situ* gravel and small cobbles. Resuspension of embedded sand.	Movement of *in situ* cobbles and smaller sediments. Flushing of embedded sediments.

Water quality consequences:

The Class I floods are sufficient to move fine organics, clays and sand moving slightly. Hence all floods do some work in moving TSS. Water quality expected to remain in a Class B under recommended flood regime, with possible incursions into a Class C during droughts.

TABLE 6.1 : FLOOD REQUIREMENTS FOR IFR 1.

FLOOD CLASS	MONTHLY DISTRIBUTION	SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NUMBER OF EVENTS			DISTR
			NATURAL	PRESENT DAY	D CLASS	
<I	10-4	8.7	Included in I	Included in I	1	10-4
I	10-4	10	7	7	1	10-4
II	5-6	28	3	3	1	5-6
III	8-10	57	3	2	1	8-10
IV	6-9	111	2	2	1	6-9
1 : 2	211					
1 : 5	343					
1 : 10	399					
1 : 20	417					

6.8.3 IFR Table

The results as motivated above are presented in the IFR table below.

TABLE 6.2 : IFR TABLE: IFR 1 - D CLASS

IFR 1: BREEDE RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) MAR (VIRGIN): 332.87 MAR (PRESENT): 287.43										
MONTHS	**MAINTENANCE LOW FLOWS**			**HIGH FLOWS**				**DROUGHT LOW FLOWS**		
	DEPTH[4]	**FLOW**	**VOLUME**	**DEPTH[4]**	**FLOW**	**DURATION**	**VOLUME[1]**	**DEPTH[4]**	**FLOW**	**VOLUME**
	(m)	**(m^3 s^{-1})**	**(10^6 m^3)**	**(m)**	**m^3 s^{-1} Daily average**	**(days)**	**(10^6 m^3)**	**(m)**	**(m^3 s^{-1})**	**(10^6 m^3)**
Oct	0.17	1.90	5.09	0.41	10	3	1.26	0.11	0.83	2.22
Nov	0.13	1.18	3.06					0.09	0.50	1.30
Dec	0.09	0.60	1.61	0.38	8.7	3	1.26	0.06	0.27	0.72
Jan[2]	0.09	0.55	1.47					0.06	0.26	0.70
Feb	0.08	0.40	0.97					0.05	0.19	0.46
Mar	0.09	0.50	1.34					0.05	0.21	0.56
Apr	0.10	0.69	1.79					0.07	0.31	0.80
May	0.12	1.01	2.71	0.70	28	3	4.20	0.08	0.43	1.52
Jun	0.17	1.90	4.93					0.11	0.83	2.15
Jul[3]	0.19	2.20	5.89					0.12	0.96	2.57
Aug	0.22	3.00	8.04	1.44	111	6	24.73	0.14	1.34	3.59
Sep	0.19	2.30	5.96	1.02	57	4	9.93	0.12	1.00	2.59
TOTAL			**42.84**				**41.37**			**18.82**
% OF MAR (VIRGIN)			**12.87**				**12.43**			**5.65**
Long term % OF MAR (VIRGIN): 30.9 % (102.7 MCM)										
1	The volume represents the daily average less the low flows									
2	January was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.									
3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Depths taken from cross-section 3.									

6.8.4 IFR Rule Table

Before the monthly distributions of IFRs can be considered useful for water resource planning and management, it is necessary to determine a basis for deciding when the maintenance (or above) components of the recommended flow should apply and when lower flows (i.e., down to and including the drought recommendations) should apply. During 1997 and 1998, these decisions were made during a number of specialist meetings on the basis of the IFR model which allows a set of rules to be applied and the results visualised by the various specialists through representative time series of IFR modified flows. A similar system has been incorporated into the desktop assessment procedure based on a monthly data and these are referred to as 'Assurance Rules'. They are essentially curves relating to the percentage of time that certain flows will be equalled or exceed in the modified flow regime and can be used in conjunction with the natural time series and associated flow duration curves to generate representative time series of flows required to satisfy the Reserve requirements.

The IFR rule table for IFR 1 is provided in Table 6.3.

TABLE 6.3 : IFR RULE TABLE - D CLASS

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

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.740	3.740	3.715	3.657	3.535	3.294	2.865	2.205	1.408	0.895
Nov	1.938	1.938	1.925	1.896	1.835	1.714	1.498	1.167	0.767	0.509
Dec	1.539	1.539	1.525	1.490	1.413	1.267	0.999	0.729	0.453	0.325
Jan	0.860	0.860	0.853	0.836	0.627	0.545	0.459	0.444	0.327	0.264
Feb	0.625	0.625	0.620	0.608	0.581	0.407	0.349	0.269	0.157	0.111
Mar	0.821	0.821	0.816	0.803	0.777	0.543	0.317	0.274	0.175	0.097
Apr	1.133	1.133	1.126	1.109	1.074	1.005	0.882	0.692	0.463	0.251
May	3.724	3.724	3.696	3.633	3.499	3.235	2.765	2.042	1.169	0.288
Jun	3.328	3.328	3.312	3.278	3.211	3.078	2.825	2.365	1.615	0.846
Jul	3.854	3.854	3.835	3.796	3.718	3.564	3.271	2.738	1.870	0.978
Aug	21.683	19.965	18.424	17.048	15.743	13.218	11.984	9.744	6.089	2.339
Sep	11.214	10.248	9.406	8.657	7.916	6.619	5.689	4.260	2.534	1.422
Natural Duration curves										
Oct	14.516	9.953	8.821	7.274	6.692	5.698	5.276	4.688	4.476	3.805
Nov	6.286	5.930	4.365	3.870	3.370	2.909	2.658	2.402	2.133	1.144
Dec	3.785	2.574	2.224	2.046	1.564	1.311	0.999	0.893	0.833	0.533
Jan	3.381	1.449	1.259	0.903	0.627	0.545	0.459	0.444	0.352	0.296
Feb	2.243	1.345	1.017	0.909	0.585	0.407	0.349	0.269	0.157	0.111
Mar	3.599	2.341	1.809	1.431	0.792	0.543	0.317	0.274	0.175	0.097
Apr	6.331	5.988	5.136	3.338	3.109	2.651	1.988	1.513	1.098	0.251
May	29.198	20.847	10.386	8.787	6.856	6.266	5.036	3.607	2.782	0.288
Jun	61.542	31.693	27.888	23.392	17.623	12.546	9.877	8.044	5.201	2.803
Jul	48.721	36.825	26.086	20.329	19.217	17.776	13.948	9.664	7.066	3.187
Aug	62.907	39.442	29.315	24.579	18.612	14.990	12.479	11.767	10.598	9.260
Sep	30.669	17.852	14.632	13.530	11.682	10.729	7.379	6.939	6.613	4.412

6.8.5 IFR Time Series

The final result of the application of the Desktop model is a representative time series of monthly flow volumes (the same length as that used to represent the natural flow regime) recommended for the quantity component of the Ecological Reserve for the selected ecological class (Table 6.4).

Please refer to the last paragraph of Section 5.8 for an explanation of the reasons for differences between the results in Tables 6.2 and 6.4.

TABLE 6.4 : FINAL RESULTS FOR A TIME SERIES 1969 - 1990 ($10^6 m^3$) - D CLASS

Total Runoff : REGION VI IFR 1
IFR Modified Flow Data Management Class C/D

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1961	9.465	1.900	1.135	1.460	1.471	2.169	2.835	3.131	8.627	10.271	58.076	21.960	122.501
1962	10.018	5.023	3.786	1.950	1.280	0.849	0.651	0.771	6.726	9.199	56.058	16.271	112.581
1963	3.681	4.807	4.040	1.910	1.513	1.300	2.296	6.869	8.620	9.547	53.474	18.747	116.804
1964	9.468	5.023	3.700	1.532	1.513	2.199	2.919	9.900	6.024	5.007	33.900	12.787	93.972
1965	7.673	1.485	1.862	0.743	0.269	2.199	2.836	2.826	7.979	10.306	13.610	11.041	62.830
1966	4.691	1.319	0.870	0.948	0.380	0.260	2.898	8.717	8.627	8.046	29.092	14.746	80.594
1967	9.950	4.990	3.775	1.223	0.361	0.265	2.681	9.974	8.353	10.167	43.703	10.776	106.219
1968	10.018	4.966	4.084	2.294	0.963	0.541	2.698	6.382	3.460	3.355	16.309	23.254	78.325
1969	10.018	5.008	4.109	2.296	1.501	2.119	1.716	9.372	8.470	9.958	47.204	26.564	128.334
1970	9.522	4.915	4.121	2.303	1.425	2.199	2.146	5.442	5.120	10.221	43.541	13.383	104.338
1971	3.772	1.988	0.944	0.822	0.633	0.306	2.025	9.829	7.383	6.124	26.099	15.527	75.453
1972	6.739	3.025	4.046	0.875	0.560	2.185	0.986	1.997	2.192	10.322	37.255	18.510	88.692
1973	9.077	4.609	3.991	1.207	0.780	0.470	0.658	7.406	8.318	7.224	58.076	26.879	128.694
1974	9.988	5.023	4.121	2.303	1.447	1.454	2.938	9.974	7.323	9.630	45.660	6.568	106.427
1975	9.986	4.955	3.863	1.230	1.000	0.740	2.285	5.469	8.627	10.298	9.359	4.399	62.210
1976	5.559	5.023	4.121	2.303	1.513	2.194	2.938	9.974	8.627	10.322	58.076	22.438	133.087
1977	9.796	4.873	4.121	2.284	1.489	2.152	2.911	7.550	2.806	2.620	35.404	25.280	101.286
1978	8.823	3.536	2.311	1.032	1.507	2.082	1.200	9.038	8.542	7.335	34.232	24.379	104.017
1979	10.018	4.756	2.676	2.303	1.405	0.720	2.876	9.820	7.747	4.145	23.134	5.070	74.668
1980	2.738	5.023	4.121	2.303	1.513	2.171	2.605	4.138	4.187	10.048	47.641	29.067	115.553
1981	9.631	5.017	1.212	2.263	0.950	1.833	2.938	8.203	7.301	8.761	6.266	3.685	58.060
1982	9.877	3.430	3.096	1.190	1.513	2.145	1.455	9.974	8.627	10.322	32.097	21.707	105.432
1983	5.906	3.979	1.953	0.706	0.278	2.199	2.785	9.974	6.131	10.237	21.007	29.067	94.223
1984	10.018	4.736	4.121	2.303	1.513	2.199	2.937	9.627	8.543	10.322	52.082	20.517	128.916
1985	9.892	4.442	3.151	1.679	0.984	2.193	2.929	9.940	8.323	10.167	54.572	23.653	131.925
1986	6.906	3.884	1.501	2.239	0.820	0.735	2.488	9.974	8.584	9.268	49.347	17.155	112.901
1987	8.401	2.931	3.932	1.267	0.844	0.741	2.938	8.665	8.497	8.547	30.687	25.826	103.275
1988	8.348	4.237	2.584	1.310	1.487	2.199	2.938	9.731	8.246	9.923	51.059	29.067	131.128
1989	10.018	5.023	4.104	2.267	1.510	1.970	2.938	9.963	8.627	10.322	42.165	8.494	107.400
1990	2.397	2.434	3.393	1.638	0.650	1.162	1.793	9.495	8.607	10.322	41.655	27.957	111.504
Mean	8.080	4.079	3.161	1.673	1.102	1.532	2.374	7.804	7.308	8.745	38.361	18.492	102.712

The IFR time series illustrated for the above 10 years relative to natural and present flows presented in Figure 6.4.

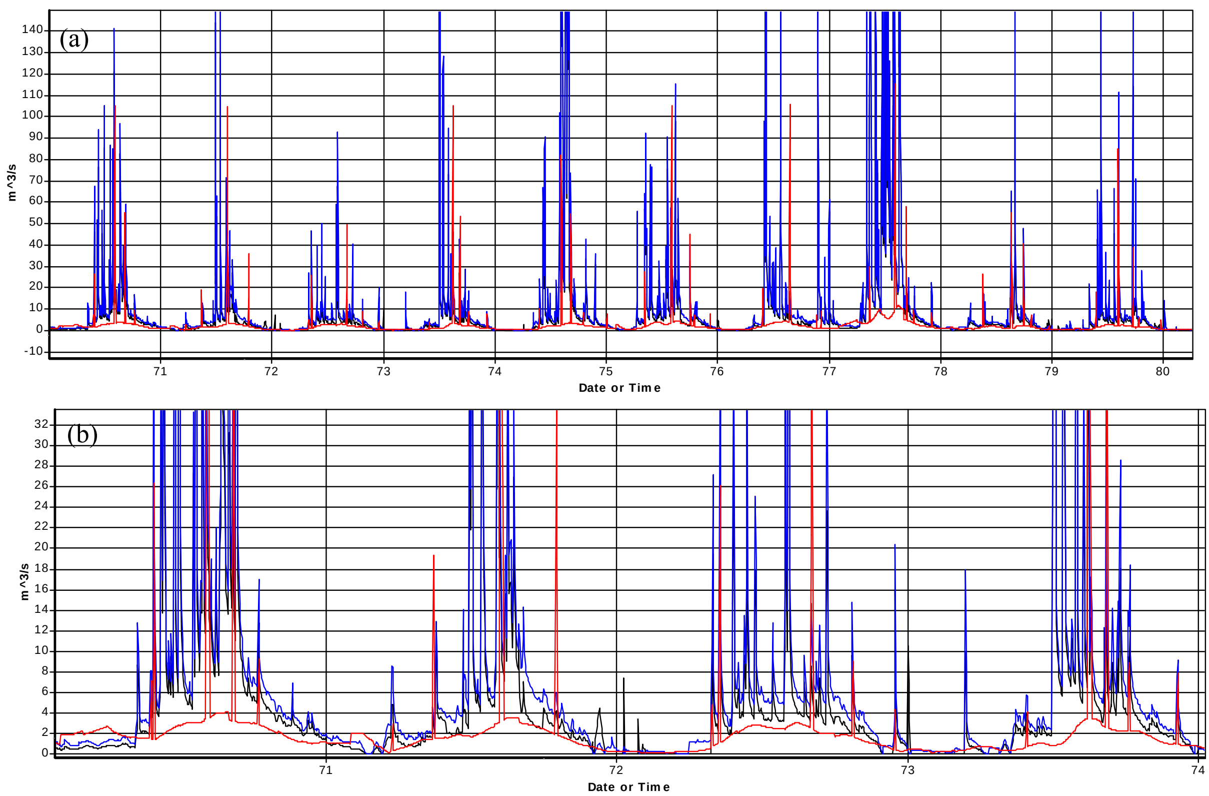

Figure 6.4 : IFR time series between (a) 1970 –1980 (b) 1970 – 1974 (red line = IFR; blue line = Virgin, Black line = Present Day)

7. IFR SITE 2 : MOLENAARS RIVER

TARGET REACH : THE MOLENAARS RIVER FROM THE CONFLUENCE WITH THE ELANDS RIVER TO THE CONFLUENCE WITH THE TIERKLOOF RIVER

7.1 REFERENCE CONDITIONS

7.1.1 Fish

Historically, it is likely that this stretch of river would have had many pools with few, *B. andrewi,* rather than a few large pools with many *Barbus andrewi*. It is also possible that *B. andrewi* migrated up from the Breede River into this area to spawn but the majority are likely to have been resident. *Pseudobarbus burchelli* and *Sandelia capensis* are also likely to have been abundant amongst the cobbles and amongst the emergent vegetation at the end of the pool. *Galaxias zebratus* are likely to have been present but in lesser numbers along the undercut bank and amongst the emergent vegetation.

Reference indigenous species list (6 of 6):
Barbus andrewi
Pseudobarbus burchelli
Sandelia capensis
Galaxias zebratus
Anguilla mossambica
Anguilla marmorata.

7.1.2 Aquatic Invertebrates

Reference conditions for Mountain Streams and Foothill rivers are based on data accumulated for the present study, including community composition, diversity indices, rank-abundance curves and SASS4 scores. Natural, unmodified conditions are expected to yield a SASS4 score = >140 and ASPT score > 8. The community is expected to include a large proportion of sensitive taxa, including three or more baetid species, Notonemeuridae, Leptophlebiidae, Elmidae, Dryopidae, Helodidae and Limnichidae with lower relative abundances of Chironimidae and Oligochaeta. Community diversity is expected to be high (H' >4) with an even distribution of individuals amongst species, reflected by a low gradient rank-abundance curve.

7.1.3 Riparian Vegetation

There should be a clear distinction between the different zones in the riparian vegetation as detailed in Boucher (1998), and Boucher and Tlale (2000). In summary, these zones, and the species that characterise them, should be as follows:

Aquatic vegetation: The density of instream aquatic vegetation should be less than 5% cover. Rocky sills should support *Isolepis digitata*. *I. digitata* should continue to reproduce sexually (flowers). If there are constant high flows in summer, *I. digitata* will not reproduce at all and if the summer flows are consistently average, vegetative reproduction will be dominant. Variable, but low, summer flows will result in flowers and seeds. The water should remain clear to allow photosynthesis to take place even when plants are inundated.

Wetbank vegetation: New sandy deposits should only be colonised by indigenous herbaceous species, such as *Isolepis prolifer*, i.e., without shrubs or trees, although seedlings of *Salix mucronata* and *Metrosideros angustifolia* should be present. *Prionium serratum* clumps with *Metrosideros angustifolia* and *Salix mucronata* shrubs between should be relatively continuous on the stable sand between rocks. There should be no bank collapse.

Lower Dynamic Zone: There should be no bank collapse and no invasion by woody or herbaceous exotic species.

Tree/shrub zone: The dry bank should be dominated by indigenous woody perennial shrubs or short trees. There should be no invasive alien invasive species present. Post-fire recruitment should be dominated by woody indigenous perennials.

Back Dynamic Zone: Should be 100% intact and have no invasion by woody exotic species.

7.1.4 Geomorphology

River type: Foothill cobble-bed river.

The active channel should be well-defined, with stable well-vegetated banks. Cobbles should not be embedded. There should be no bulldozing or artificial manipulation of the bed, banks, floodplain and no channelisation should have taken place.

7.1.5 Water Quality

System variables:

TDS	:	< 45 mg l^{-1}.
pH	:	5.5 – 6.5
DO	:	80 - 120% saturation
TSS	:	< 5 mg l^{-1}.
Temperature	:	unmodified
Nutrients	:	PO_4/TP ratio: 0 – 10%
		Median $P0_4$: < 0.01 mg l^{-1}
		TN:TP ratio: > 20:1.
Toxic substances:		Meets the target water quality range for toxic substances as stated in the South African Water Quality Guidelines for Aquatic Ecosystems for 90% of the time, 99% of time less than or equal to chronic effect value, 100% of time less than the acute effect value.

7.1.6 Hydrology

No significant change to natural distribution flow regime.

7.2 PES, CAUSES AND ORIGIN, TRAJECTORY OF CHANGE

7.2.1 Fish

PES: E Class*

No indigenous fish were recorded during the study. The presence of trout and bass is primarily responsible for the reduction in indigenous species. In general, the fish habitat available in the Molenaars River is in good condition, and would provide ideal habitat for indigenous species should the threat from alien fish be eliminated.

CAUSES	ORIGINS	NON-/FLOW RELATED
Presence of alien fish, primarily trout and bass.	Breeding trout population initially stocked, now augmented by escapees from trout farms.	Non-flow related

* Fish habitat = A/B Class.

Trajectory of change: None

The available fish habitat is good, however, alien species (trout and bass) dominate the system. It is likely that the present situation will remain relatively unchanged should other factors, *viz.,* water abstraction, effluent disposal and alien vegetation encroachment, remain constant.

7.2.2 Aquatic Invertebrates

PES: A/B Class

The Molenaars River has a SASS4 score = 175 and ASPT score = 7.9, the highest diversity index of all sites (*H'* = 4.37) and a relatively gradual rank-abundance curve. The community includes five baetid species, two of which contribute a significant proportion to community dominance patterns. *D. capensis* is an indicator of fast flowing, turbulent conditions. Notonemeuridae, a taxon sensitive to changes in water quality flow conditions was recorded.

The catchment is relatively pristine with little development and undisturbed mountain fynbos as the upper reaches are too steep for farming or development.

The A/B Class is not data driven as according to the data the river should be in an A Class. It is known however that conditions cannot be completely natural as the trout farming upstream has an impact on the water quality.

CAUSES	ORIGINS	NON-/FLOW RELATED
Impact on invertebrate habitat quality.	Slight enrichment in nutrients from trout farm outlets.	Non-flow related

Trajectory of change: None

Dallas (1998) obtained a SASS4 score = 161 and ASPT score = 9.47 for a site near to the present site, suggesting relatively stable conditions.

7.2.3 Riparian Vegetation

PES: B/C Class

The vegetation at the site is in a better condition than that in much of the rest of the catchment. Parts of the riparian vegetation in the reach represented by the site have been recently cleared of alien invasives, e.g., opposite "Suzman's Cottage", and although the vegetation is recovering, its condition is somewhat poorer than that evident at the IFR site. In most instances, the aquatic and Wetbank Zones are in excellent condition, with only minor invasion of the Wetbank and Lower Dynamic Zones. However, the N1 highway impacts on the Back Dynamic and Dry Bank Zones in places.

CAUSES	ORIGINS	NON-/FLOW RELATED
Alien trees.	Introduction of trees.	Non-flow related
Annual weeds.	Enrichment from trout farms.	Non-flow related
N1	N1	Non-flow related

Trajectory of change: Positive (Short term: B/C Class - Long term: B Class)

The positive trajectory predicted above is dependent on continued alien clearing and/or control in the catchment – see below.

If the alien clearing halted the results would be as follows:
5 years: Class C.
20 years: Class D/E.

7.2.4 Geomorphology

PES: B Class

The channel is largely natural, however, the N1 highway does impact slightly in places.

CAUSES	ORIGINS	NON-/FLOW RELATED
Increased sediment yield.	Farming, trout farming (bulldozing inlets and outlets) and increased fires.	Non-flow related.
Impingement of the macro-channel in places.	N1 highway, picnic spots.	Non-flow related.

Trajectory of change: None

7.2.5 Water Quality

PES: A/B Class

Relatively little development in catchment above the site that has affected water quality. As with the aquatic invertebrates, trout farming activities in the upper catchment have had an impact on the water quality (Brown, 1998). However this impact has been at microgram level, and is not detected by routine DWAF monitoring. A pulse effect is, however, caused when trout dams are being cleaned out.

Trajectory of Change: None

Developments in the catchment have not modified general water quality in such a way that trends can be detected. Nonetheless, there was a consistent increase in NO_2+NO_3-N concentrations between about 1985 to 1991 (about 0.011 mg l^{-1} per year) after which the increases in concentrations appear to have stabilised, even though there are inter annual differences. The PO_4 concentrations show a consistent slight increasing trend from the mid-1980s to 1994 (about 0.002 mg l^{-1} per year) after which the increase appeared to level off.

7.2.6 Hydrology

PES: A/B Class

Only minimal abstraction occurs during the summer months, and no major dams, weirs or irrigation areas located either upstream of or within the reach.

7.2.7 Ecostatus

The causes and origins are summarised as follows:

Non-flow related
Presence of alien fish and vegetation species.
Presence of the N1.
Trout farming.
Increased fire frequency.

The information on PES for the different components are summarised in Figure 7.1 below. The top row of graphs illustrates the classes allocated to the different components. The bottom graph illustrates the component PES values integrated into an overall value.

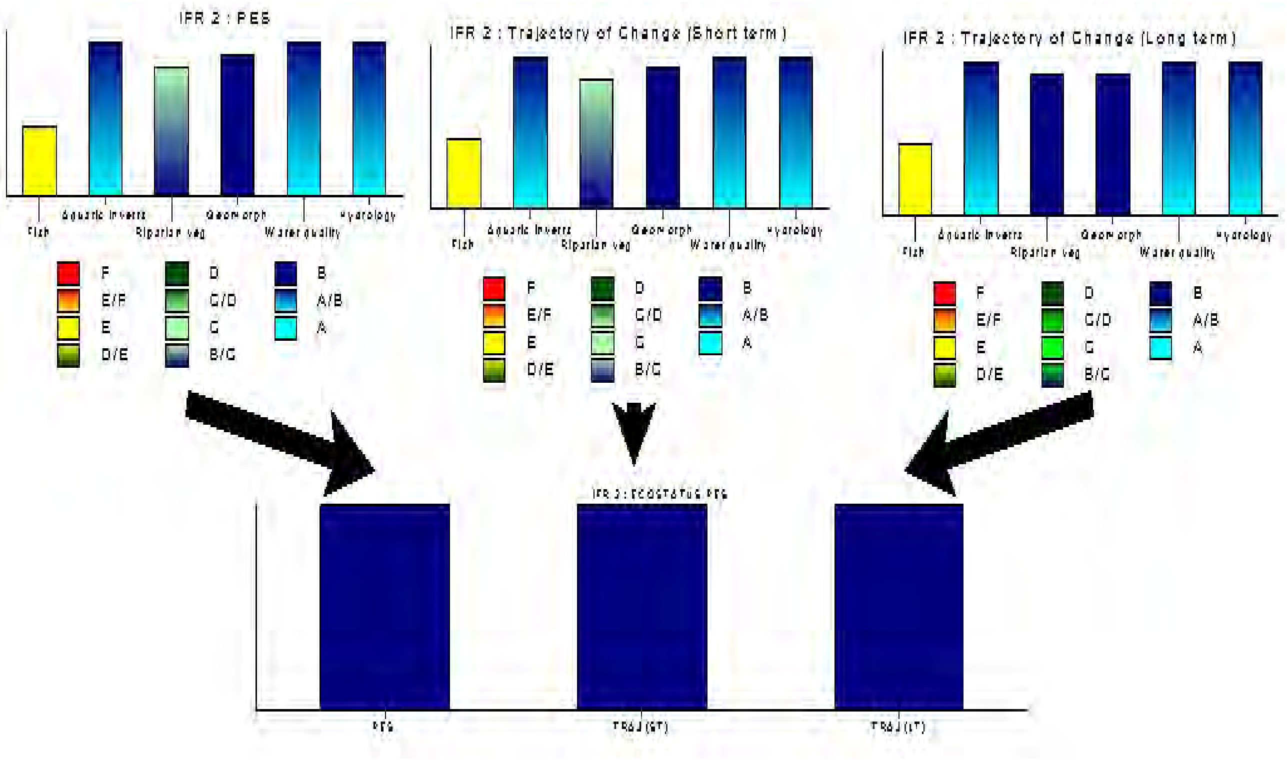

Figure 7.1 : Present Ecological Status (PES)

The one outlier in the above distribution of PES classes is the E Class for fish, which is low because of the presence of alien fish. This is a non-flow related impact and does not detract from the overall integrity of the river *habitat* (instream). Thus this low value was ignored when attaching an overall PES for the river. Three of the other evaluations are in an A/B Class (aquatic invertebrates, hydrology and water quality), the riparian vegetation in a B/C Class and the geomorphology in a B Class. The impacts on the geomorphology as a result of the upgrading and partial rerouting of the N1 (upgraded *c.* 6 years ago) may still be affecting the biota, even though on a coarse scale the geomorphology is perceived to be stable. Thus the geomorphology was the most significant driver in establishing the overall PES class at a B Class.

7.3 ECOLOGICAL AND SOCIAL IMPORTANCE

The results are attached as Appendix A.

Note that the social evaluation is a guesstimate on the part of ecologists with some local experience of the area and as such must be accorded a LOW confidence rating.

EIS rating	:	Very High.
Confidence		High.
Determinants	:	Presence of rare and endangered species. Presence of intolerant biota (water quality). Species/taxon richness. Presence of diversity of habitat types, refugia, and habitats sensitive to quality changes. Conservation and natural areas.

Social rating : High.
Confidence : Very low.
Determinants : Special features and beauty spots. General aesthetic value. Sense of place. Present recreation and potential for recreation.

AIM:

The EIS is very high, the social importance is high and the PES is high (B Class). Normally the aim would be to maintain PES and minimise the risk of degradation unless there are overriding reasons to improve conditions. Depending on the degree of difficulty it may be possible to improve individual components.

7.4 ATTAINABLE ECOTATUS CLASS (EC)

7.4.1 Fish

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Alien fish (decrease of indigenous species).	Non-flow related	Removal of alien fish.	Difficult
PES E - EC E This objective will be difficult to achieve. As an E Class represents an unacceptable objective, management objectives must be set at minimum as a D Class. Manipulation of flow will not achieve this.			

7.4.2 Aquatic Invertebrates and Water Quality

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Trout farms (nutrient enrichment).	Non-flow related	Better management and/or change from commercial to angling activities.	Reasonable
PES A/B - EC A/B To improve conditions, i.e., A Class, would virtually require a return to completely natural conditions and is an unrealistic goal. Improving the effluent quality the trout farms however would reduce the risk of the A/B Class not being maintained.			

7.4.3 Riparian Vegetation

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Alien trees.	Non-flow related	Continued clearing.	Is ongoing
Annual weeds (nutrients).	Non-flow related	Better management of trout farms and catchment management.	Reasonable
N1	Non-flow related	No further mitigation possible.	
PES B/C - EC B With continued clearing of aliens, the class will improve without any additional measures to be undertaken.			

7.4.4 Geomorphology

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Trout farming (bulldozing).	Non-flow related	See aquatic invertebrates.	Reasonable
N1, picnic spots.	Non-flow related	No further mitigation possible.	
Fires.	Non-flow related	Linked to the N1.	Difficult
PES B - EC B Due to the presence of the N1, the geomorphology can only be maintained in its present class.			

7.4.5 Summary of Attainability and Ecostatus EC

The river is presently in an excellent state and (aside from controlling effluent quality) it would be difficult to improve the current condition, the attainable ecological class could be to maintain PES with minimal to no risk of moving to a lower class.

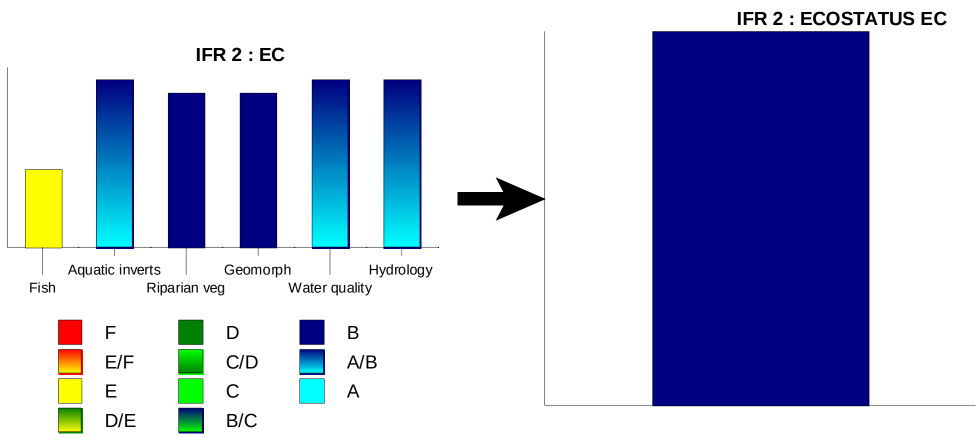

Figure 7.2 : Ecological Class (EC)

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	A/B	0	A/B	A/B	VERY HIGH	
Water quality	A/B	0	A/B	A/B		A/B
Geomorphology	B	0	B	B		B
Riparian veg	B/C	+	B/C	B		B
Fish	E	0	E	E		E
Aquatic inverts	A/B	0	A/B	A/B		A/B
Ecostatus	B	0	B	B		B
					Long term EC	B

Figure 7.3 : Summary of the PES and EC classes

7.5 OBJECTIVES

7.5.1 Fish

EC: E
General flow objectives: Maintain low flows during summer.
Overall fish objectives: To maintain and enhance hypothetical/possible future populations of the remaining indigenous fish.
Objectives for target/indicator species: Maintain spawning habitat and conditions, flow of aerated water at head of pools for survival of eggs and larvae of *Barbus andrewi*. This species is a serial spawner, breeding continuously throughout summer and therefore needs these flows throughout.

General flow objectives: Maintain winter floods, high flows.
Overall fish objectives: To facilitate dispersal of indigenous species especially out of overpopulated reaches.
Maintain water quality and therefore the health of resident fish species. Good water quality enhances the health and survival of eggs and larvae. Reduced parasite loads and increased juvenile survival improve recruitment to the adult population.
Objectives for target/indicator species: Indigenous species most notably the larger *B. andrewi* use floods and high flows for dispersal and may recolonise areas left vacant by alien species some of which are washed downstream.

General flow objectives: To maintain summer floods, freshettes
Overall fish objectives: Emigration of catadromous species
Objectives for target/indicator species: High flows cue and facilitate the migration of catadromous eel species

7.5.2 Aquatic Invertebrates

EC: A/B
General flow objectives:

OBJECTIVES	MOTIVATION
Maintain higher low flows in winter than in summer.	Summer species are adapted to lower flows than winter species.
Maintain a major flood at the beginning of the wet season, i.e., May/June and several more during the wet season.	The first major flood resets the river to winter conditions, flushing away fine sediments and summer species such as oligochaetes. Subsequent floods sort and rework sediments maintaining physical heterogeneity.
Maintain small freshes during spring and early summer.	Enhance downstream drift of animals and flush out areas of poor quality water accumulated during summer low flow.
Mimic natural pattern of average monthly flows, i.e., July/August highest, January/February lowest.	Different species are adapted to react to different flow cues for life history stages. Precautionary approach is to maintain the natural flow cues.
Maintain natural flow variability at monthly levels.	See above.
Maintain natural flow variability at daily levels.	We believe this level of variability to be important but do not have supporting data.
Maintain natural shape and duration of the flood hydrographs.	Successful laying and hatching of eggs and other life cycle activities could be linked to the duration of inundation of marginal areas, secondary channels and floodplains.

General objectives for invertebrate component

- SASS4 score = >140 and ASPT score >8.
- Community to include a large proportion of sensitive taxa including three or more baetid species, Notonemeuridae, Leptophlebiidae, Elmidae, Dryopidae, Helodidae and Limnichidae with lower relative abundances of Chironimidae and Oligochaeta.
- Community diversity = *H'* >4 i.e.. An even distribution of individuals amongst species, reflected low gradient rank-abundance curve.

Identification of and objectives for target species: The community rather than individual species will be used (see above). If essential to use target species, then the aim should be to maintaining reasonable populations of: *Demoreptus capensis* (riffles) and *Cloeodes* sp. (slow flow over sand).

7.5.3 Riparian Vegetation

EC: B

Back Dynamic Zone

General flow objectives: To maintain a clearing through the zone (1:20-1:50 year floods).

Overall vegetation objectives: Zone recovering from disturbance by roads on both banks and needs to reset.

Objectives for target/indicator species: To ensure survival of older and large *Brabejum stellatifolium* and *Podocarpus elongatus* individuals.

Tree-Shrub zone

General flow objectives: To maintain existing plants by depositing silt and debris (1:5 to 1:20 year floods). To promote seedling and juvenile establishment and maintenance (1:2 year and Class IV floods).

Overall vegetation objectives: To prevent stress on indigenous plants to restrict alien species invasions.

Objectives for target/indicator species: To expand distribution of the zone where it has been damaged by road construction or alien invasion, i.e., to restore density of stands of woody species (e.g., *Brabejum stellatifolium*, *Maytenus oleoides, Podocarpus elongatus* and *Rapanea melanophloeos*) coupled with continued alien woody eradication campaign. Threatened plants in this reach zone include *Cryptocarya angustifolia*.

Lower Dynamic Zone

General flow objectives: To maintain the zone in near natural state to prevent the channel shape change (steepening and narrowing of banks) that accompanies changes in vegetation (e.g., alien encroachment; 1:2 year and Classes III and IV floods).

Overall vegetation objectives: To discourage the establishment of annual and woody alien species. To allow deposition or erosion to take place on an annual basis.

Objectives for target/indicator species: Indigenous annual herbs should occur in the zone, and limited downward movement of tree and shrub species (see species listed for Tree Shrub zone) is expected.

Upper Wetbank Zone

General flow objectives: To maintain this zone to prevent excessive channel shape change (steepening and narrowing of banks) that accompanies vegetation changes (Class II - III floods and 5% winter baseflow).

Overall vegetation objectives:

- To prevent the establishment of annual and woody aliens.
- To allow deposition or erosion to take place on an annual basis.

Objectives for target/indicator species: Salix mucronata, Morella serrata, Metrosideros angustifolia and *Prionium serratum* seedlings and juveniles should be present in small local sand patches.

Lower Wetbank Zone

General flow objectives: To maintain zone vegetation (Class I flood; 5-90% winter baseflow and 5-90% summer baseflow levels).

Overall vegetation objectives: To ensure zone is wet regularly for fairly long periods in winter (with fluctuations in levels) to allow plants to grow in clear water even while submerged. This will also ensure that banks will be wetted through capillary action even when exposed.

Objectives for target/indicator species: *Metrosideros angustifolius, Prionium serratum* and *Juncus lomatophyllus.* Seedlings or juveniles should be present in small local open patches. To prevent invasion of riffle by *Juncus lomatophyllus* and closing of channel.

Aquatic Zone

General flow objectives: Maintain a clear channel, i.e., not clogged with aquatic plants (90-99% winter baseflow and 50% summer baseflow).

Overall vegetation objectives: To ensure that *Prionium serratum* does not invade aquatic zone and that the rooted aquatic plants survive, i.e. no increase OR decrease in numbers. To keep the water clear so that mosses and perennial herbs and seedlings in lower Wetbank can continue growing even when inundated during winter.

Objectives for target/indicator species: To have sufficient flow variation to allow *Isolepis digitata* to grow and to reproduce through flowering and vegetative reproduction.

7.5.4 Geomorphology

EC: B

The river is in good condition without serious non-flow related threats. Requirement: That existing flood patterns be maintained.

7.5.5 Water Quality

EC: A/B

TDS	:	Maintain TDS at <45 mg l^{-1}. No flow related pattern.
pH	:	Maintain the natural cycle (summer between current 5 and 95%tile, i.e., 5.6 – 7.6, medians 6.4 – 6.8, winter between current 5 and 95%tile, i.e., 5.0 – 6.8, median between 6.1 – 6.4). Note – first runoff mobilizes humic substances, which reduces pH.
Dissolved oxygen	:	Maintain between 80-120% of saturation. (Class A, RDM manual)
Water temperature	:	Maintain within 2 degrees Celcius of reference pattern. This site is a reference site.
TSS	:	Maintain within <10% from reference site. This site is a reference site.
Nutrients	:	Median PO_4 concentration 0.01-0.05 mg l^{-1} (RDM B Class). Maintain below 0.04 mg l^{-1} for 95% of the time. % PO_4:TP ratio <20%.
TN:TP ratio	:	This mountain stream without any water quality problems. Median NH_3-N<0.015. Maintain winter NO_2NO_3-N concentrations at <0.1 mg l^{-1} for 95% of the time (reduced with flow due to dilution effect) and summer concentrations < 0.22 mg l^{-1} for 95% of the time.
Toxic substances	:	Maintain toxic substances at TWQR for 90% of the time, ≤ CEV for 99% of the time and ≤ AEV for100% of the time as specified in the SAWQG for Aquatic Ecosystems. (RDM Manual) (Class A).

Flow related objectives: Maintain wash-off event in May so that pH drops due to mobilisation of humics.

Non-flow related objectives : Reduce nutrient input from trout farm if current summer base flows are reduced. Increased nutrients may cause biofilm formation (and NO2NO3-N to a C Class).

7.6 MAINTENANCE FLOW ASSURANCE

The assurance of maintenance low flows during winter is set as a flow that occurs 70% of the time. The assurance of maintenance low flows during summer is set as a flow that will occur 60% of time.

7.7 SEASONAL DISTRIBUTION

July was selected as the highest flow month and February was selected as the lowest flow month.

7.8 IFR RESULTS

7.8.1 Motivations : Low Flows

Each flow is motivated by the specialists and documented by them. The motivations for these flows are provided below.

MAINTENANCE LOW (DRY SEASON, FEBRUARY) 0.61 m^3s^{-1}

Descriptions of flow required:
Velocity range of 0.1 - 0.4 m s^{-1} and depth range between 0.2 and 0.25 m at IFR 2B. 0.89 m flow depth at IFR 2A.

Primary motivation:
Aquatic invertebrates: Available hydraulic conditions for *Afronurus* sp. Not limited. No major loss of wetted perimeter at this point and habitat for slow-flow taxa (*Cloeodes* sp. < 0.1 m/s) maintained.
Source: Invertebrate samples for this study, photos, profile, SVD histograms, available literature.
Riparian vegetation: Maintenance of Wetbank vegetation. To allow *Isolepis digitata* to reproduce and to keep pools relatively free of algae. Lower flow will result in stressed Wetbank vegetation and pools will become full of algae.
Source: Own data, reports and students studies.

Secondary motivation:
Fish: Maintenance of riffle/run connection between reaches, passage of 10 cm depth at least for juvenile fish, aeration of pool water. Lower flows will result in fish being confined to pools, the foraging area to decrease and overpopulation of pools.
Source: Breede River study.

Water quality consequences of low flows

February Maintenance:
There is almost no relationship between TDS and flow in the Molenaars River and TDS concentrations will probably remain in a high A Class with infrequent excursions into a B Class (estimated to be 26 mg l^{-1}). The objective is to keep winter nitrate concentrations below 0.1 mg l^{-1} for 95% of the time and in summer, below 0.22 mg l^{-1} for 95% of the time. It is estimated that winter nitrates would be about 0.11 mg l^{-1} and summer nitrates to be about 0.14 mg l^{-1}. The objectives for pH and N:P ratio will be met.

MAINTENANCE LOW (WET SEASON, JULY) 2.5 $m^3 s^{-1}$

Descriptions of flow required:
Velocities: 0.6 - 1.2 m s^{-1}, depth up to 0.25 m at IFR 2B. For vegetation a depth of 1 m is required at IFR 2 A.

Primary motivation:
Vegetation: Maintenance by capillary action of Lower and Upper Wetbank plants. To allow *Prionium* and *Metrosideros* to survive and to keep pools free of algae. To keep seedlings alive. Lower flows will result in the Wetbank plants being heavily stressed in their flowering and some seedlings will be lost.
Source: Own data, reports, students' studies.
Aquatic invertebrates: Maintenance of hydraulic conditions within the channel for winter community species *Demoreptus capensis,* conditions of highest occurrence. Sufficient inundation of marginal areas for refuge, and some movement of the marginal vegetation will occur to compensate for the reduction in flow. Flows lower than the recommended flows will result in a loss of suitable hydraulic conditions for *D. capensis* and other key winter community taxa, and a loss of areas of inundation providing refuge and connectivity between habitats.
Source: Invertebrate samples for BRBS, photos, profile.

Secondary Motivation:
Fish: (Require 2 m^3s^{-1}). Requires access to an inundated marginal cobble-bed side channel as a refuge. Lower flows will result in the loss of large proportion of winter refuge and foraging area.
Source: Study, literature.

Water quality consequences of low flows

July Maintenance:
There is almost no correlation between TDS and flow in the Molenaars River. Under the recommended flow conditions, TDS concentrations will probably remain in a high A Class with infrequent excursions into a B Class (estimated to be 26 mg l^{-1}). The objective is to keep winter nitrate concentrations below 0.1 mg l^{-1} for 95% of the time. It is estimated that winter nitrates would be about 0.11 mg l^{-1} as a result of trout farm impacts upstream of the IFR site. The objectives for pH and the N:P ratio will be met.

DROUGHT LOW (DRY SEASON, FEBRUARY) 0.3 m^3 s^{-1}

Descriptions of flow required:
Slow and shallow with increased loss of wetted perimeter. Habitat velocity range between 0.1 and 0.4 m s^{-1}, depth range between 0.2 and 0.25 m. Vegetation requires a depth of at least 0.83 m at IFR 2A.

Primary motivations:
Aquatic invertebrates: Some habitat remains as refuge for the remaining individuals. Flows lower than the recommended flow would result in a considerable reduction in wetted perimeter, loss of available habitat and connectivity between habitat patches. Species such as *Afronurus* sp. would be expected to become rare.
Source: Invertebrate samples for this study, photos, profile.
Riparian vegetation: Maintenance of Lower Wetbank plants by capillary action. *Isolepas digitata* will survive and provided the water levels fluctuate will reproduce sexually and vegetatively. The pools SHOULD remain relatively free of algae, provided the water remains oligotrophic. Flows lower than these could result in increased presence of algae, stressed LWB plants and a severe reduction in *I. digitata*.
Source: Own data, reports and student's studies.
Secondary motivation:
Fish: Maintenance of a trickle into the pool and drift food source. Flows lower than these would result in food limitation in pools, cannibalism, deterioration in water quality and increase in parasite loads of fish.

Water quality consequences of low flows

Drought flows
Some of the time the objective will not be met as the medians will increase from about 0.07 to 0.14 but according to the stress index, the stress will be less than 1 and the proportion of the medians increasing to a B Class will be minimal. The objectives for pH will be met.

DROUGHT LOW (WET SEASON, JULY) 0.8 m^3 s^{-1}

Descriptions of flow required:
To just reach the bottom of the LWB in Cross-section 1. This will allow survival of the plants there. In the other areas, survival will be less certain as it will be dependent on the capillary action of the plants.

> 0.1 m depth in the riffle/run habitat (fish), 0.4 m^3 s^{-1} - invertebrates, 0.91 m flow depth at IFR 2, Cross Section 1.

Primary motivation:
Riparian vegetation: To allow Lower and Upper Wetbank plants to replace parts of plants, e.g. leaves, lost during summer and to keep seedlings alive. To facilitate the survival of adult and some seedling *Salix*, *Prionium* and *Metrosideros*. Flow lower than these will result in all Wetbank plants being heavily stressed and in the demise of their seedlings.
Source: Own data, reports, students' studies.

Secondary motivations:
Aquatic invertebrates: Some reduction in wetted habitat for *Demoreptus capensis*, without loss of floodplain inundation. Lower flows will result in further reduction in wetted habitat with reduced survival of winter high-flow community.
Source: BRBS data, students' studies
Fish: Maintenance of a trickle into the pool and drift food source. Lower flows will result in food limitation in pools, cannibalism, deterioration in water quality and increase in parasite loads of fish.

Water quality consequences of drought flows:
Some of the time the objective won't be met as the medians will increase from about 0.07 to 0.14 but according to the stress index, the stress will be less than 1 and the proportion of the increasing to a B Class will be minimal. The objectives for pH will be met.

7.8.2 Motivations: High Flows

Fish:
Class I:
Used for migration, dispersal and recruitment of adults and juveniles. Class I summer floods also alleviate the potential for water quality problems. In general adult indigenous fish species are tolerant of reduced water quality, but if severe, will either curtail or reduce their reproductive output. Parasite loads increase with poor water quality, contributing to a decline in individual and population health. Juvenile fish are more tolerant than adults purely because all their resources are put into growth and don't have to apportion resources between reproduction and maintaining a large body size – as is the case with the adults. Eggs and larvae are susceptible to poor water quality and usually die. Some introduced species continue to reproduce, overpopulating waters with stunted individuals. These species are usually flushed downstream or out of the system with floods.

Class III and IV:
Similar effects to Class I and II floods. Also important for facultative catadromous species and estuarine associated species to migrate in and out of the system.

Aquatic invertebrates:
Class I:
Affects water quality in the river during the dry summer months. Loss of events in the summer would result in a reduction in water quality, which would impact on the more sensitive species.

Class II and III:
Used for dispersal of larvae and/or eggs through downstream drift. These floods also mobilise flood and organic matter into the water column, and prevent localised build-up of organic material or mud on rock surfaces, which would favour different taxa, e.g., oligochaetes.

Class IV and larger:
Required for habitat maintenance, e.g., flushing of interstitial spaces and resetting/ordering of substrata.

Riparian vegetation:

Class I:

Maintains the Lower Wetbank (LWB). Fewer floods (Class I and II – see water quality) would have a negative effect on growth performance because fewer nutrients will be mobilised from the catchments. A delay in these floods may also negatively affect growth by shortening the period when plants can benefit from these floods.

Class II, III, IV:

- To maintain the Lower Dynamic Zone.
- These floods will prevent infilling of the channels. This will result in exotics becoming dense along the margins of the Upper Wetbank (UWB) and heat from subsequent fires and shading will destroy both UWB and Tree-Shrub Zone (TSZ) plants.

1:2 and 1:5 floods:

- Flood level reached important for the maintenance of the Lower Dynamic Zone (LDZ).
- Sufficiently large to move sediments (remove seedlings from the LDZ).
- Partial (1/2) tree shrub zone maintain seedlings and juvenile and parents.
- Maintains the Lower Dynamic Zone and the Wetbank. The Tree-Shrub Zone will invade the Lower Dynamic Zone if large winter within-year floods are reduced. In mountain stream and foothill zones, these floods (and to a lesser extent Class III floods) also flush annuals and sediments from the system, thereby maintaining a balanced community (see geomorphology). If they were reduced in number (or magnitude) bare areas alongside the river would become colonised, and the channel would begin to reduce in width.

Geomorphology

The sediment transporting capacities of the different within-year flood classes at IFR Site 2 are provided below.

	CLASS I	CLASS II	CLASS III	CLASS IV
Section 1	Deposition	Deposition	Fine sediment passing	Fine sediment, gravel and small cobbles passing.
Section 2	-	-	Fine sediment passing	Fine sediment, gravel and small cobbles passing. Flushing.
Section 3	-	-	Fine sediment passing. Flushing.	Fine sediment, gravel and small cobbles passing. Flushing.

Water quality consequences:

Dry season and early wet season small floods, generally increase the concentrations of compounds that are mobilized from the catchment, i.e., nutrients, salts, organics, humic compounds, etc. Towards the middle and end of the wet season, most of the material has been mobilised resulting in a decrease in concentrations. Larger within-year floods result in decreased concentrations of compounds mobilized from the catchment. The recommended flood regime should facilitate the maintenance of the water quality in a Class A, provided the point and non-point sources of nutrients and other constituents do not increase significantly.

TABLE 7.1 : FLOOD REQUIREMENTS FOR IFR 2

FLOOD CLASS	MONTHLY DISTRIBUTION	SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NUMBER OF EVENTS			DISTR	C CLASS
			NATURAL	PRESENT DAY	MIN DEG: B CLASS		
I	10 - 4	5	8	8	3	10-4	
II	5-6	16	3	3	3	5-9	
III	8-10	31	4	4	3	8-10	
IV	6-9	61	3	3	1	6-9	
1 : 2	98						
1 : 5	153						
1 : 10	189						
1 : 20	196						

7.8.3 IFR Table

The results as motivated above are presented in the IFR table below.

TABLE 7.2 : IFR TABLE: IFR 2 - B CLASS

IFR 2: MOLENAARS RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) MAR (VIRGIN): 157.9 MAR (PRESENT): 131										
MONTHS	**MAINTENANCE LOW FLOWS**			**HIGH FLOWS**				**DROUGHT LOW FLOWS**		
	DEPTH[4]	**FLOW**	**VOLUME**	**DEPTH[4]**	**FLOW**	**DURATION**	**VOLUME[1]**	**DEPTH[4]**	**FLOW**	**VOLUME**
	(m)	($m^3 s^{-1}$)	($10^6 m^3$)	(m)	$m^3 s^{-1}$ Daily average	(days)	($10^6 m^3$)	(m)	($m^3 s^{-1}$)	($10^6 m^3$)
Oct	0.99	1.7	4.6	1.16	5	3	0.51	0.88	0.6	1.61
Nov	0.94	1.1	2.8					0.85	0.42	1.09
Dec	0.92	0.93	2.49					0.85	0.38	1.02
Jan[2]	0.9	0.73	1.96					0.83	0.3	0.8
Feb	0.88	0.61	1.48	1.16	5	3	0.68	0.83	0.3	0.73
Mar	0.88	0.6	1.61					0.83	0.28	0.75
Apr	0.89	0.63	1.63	1.16	5	3	0.68	0.83	0.3	0.78
May	0.94	1.16	3.11	1.43	16	4	2.69	0.86	0.44	1.18
Jun	1	1.9	4.93	1.43	16	4	2.56	0.89	0.65	1.69
Jul[3]	1.04	2.5	6.7	1.94	61	5	11.98	0.91	0.8	2.14
Aug	1.05	2.7	7.2	1.65	31	4	5.14	0.91	0.86	2.3
Sep	1.05	2.6	6.74	1.65	31 + 16	3 + 4	5.15	0.91	0.84	2.18
TOTAL			45.27				35.43			**16.26**
% OF MAR (VIRGIN)			28.7				22.44			**10.3**
Long term % OF MAR (VIRGIN): 49.73 (78.54 MCM)										
1	The volume represents the daily average less the low flows									
2	January was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.									
3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Depths taken from cross-section 3.									

7.8.4 IFR Rule Table

For an explanation of the rule table, refer to 6.8.4.

The IFR rule table for IFR 2 is provided in Table 7.3.

TABLE 7.3 : IFR RULE TABLE - B CLASS

Data are given in $m^3 s^{-1}$ mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.241	2.241	2.226	2.194	2.124	1.988	1.745	1.371	0.920	0.629
Nov	1.314	1.314	1.306	1.288	1.250	1.175	1.041	0.835	0.586	0.426
Dec	1.111	1.111	1.103	1.082	1.036	0.949	0.807	0.627	0.461	0.385
Jan	0.872	0.872	0.866	0.850	0.814	0.745	0.635	0.493	0.364	0.304
Feb	1.038	1.038	0.847	0.749	0.736	0.691	0.666	0.568	0.407	0.333
Mar	0.717	0.717	0.713	0.705	0.686	0.649	0.584	0.483	0.361	0.283
Apr	1.040	1.040	1.034	1.019	0.989	0.929	0.822	0.571	0.459	0.331
May	2.483	2.483	2.465	2.426	2.343	2.180	1.889	1.441	0.901	0.552
Jun	3.349	3.349	3.332	3.297	3.227	3.089	2.826	2.347	1.566	0.765
Jul	10.944	10.112	9.364	8.693	8.053	6.815	6.187	5.049	3.192	1.034
Aug	6.636	6.280	5.949	5.643	5.330	4.723	4.310	3.559	2.334	1.077
Sep	11.499	10.409	7.299	6.856	6.663	6.269	5.409	3.041	2.410	1.311
Natural Duration curves										
Oct	6.239	5.533	3.420	3.014	2.731	2.403	2.342	2.056	1.565	1.325
Nov	6.281	2.000	1.901	1.861	1.495	1.402	1.269	1.195	0.998	0.815
Dec	5.488	2.593	1.748	1.441	1.172	1.114	1.007	0.902	0.850	0.766
Jan	3.012	1.128	0.935	0.897	0.883	0.870	0.793	0.749	0.701	0.559
Feb	1.794	1.219	0.847	0.749	0.736	0.691	0.666	0.645	0.574	0.355
Mar	3.816	1.501	1.014	0.912	0.799	0.699	0.649	0.571	0.529	0.442
Apr	3.673	3.353	2.419	2.377	1.736	1.003	0.862	0.571	0.516	0.376
May	20.165	12.825	7.329	7.217	6.377	6.011	5.612	1.710	1.422	0.769
Jun	23.102	18.364	13.202	11.181	9.637	8.738	6.806	5.058	2.662	0.968
Jul	22.155	18.511	13.713	13.441	12.511	11.044	10.682	5.634	4.659	1.034
Aug	22.043	13.997	12.015	9.864	8.875	8.206	6.355	5.907	5.600	5.115
Sep	13.970	10.972	7.299	6.856	6.663	6.269	5.409	3.041	2.627	2.315

7.8.5 IFR Time Series

For an explanation of the time series, see 6.8.4 and 5.8.

TABLE 7.4 : FINAL RESULTS FOR A TIME SERIES 1969 - 1990 (10^6m^3) - B CLASS

Total Runoff : REGION VI IFR 2
IFR Modified Flow Data Management Class B

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1969	6.001	3.240	1.679	1.109	1.597	1.293	1.189	6.554	8.660	21.576	16.553	17.090	86.541
1970	5.690	3.241	2.899	2.179	1.373	1.739	1.810	3.860	4.059	18.515	15.114	7.881	68.359
1971	1.878	1.206	1.030	1.522	1.808	0.809	1.480	5.059	6.083	5.016	6.251	14.020	46.164
1972	2.464	1.103	2.159	0.848	0.844	1.887	0.939	1.480	1.983	29.313	12.258	13.070	68.350
1973	5.963	2.416	2.977	0.813	0.805	0.757	0.857	2.412	8.662	8.549	17.775	17.770	69.755
1974	6.001	3.407	2.776	2.319	1.610	0.967	2.688	6.649	7.273	24.037	14.076	3.397	75.200
1975	5.992	3.340	2.585	0.974	1.136	1.108	1.343	1.711	8.681	21.569	2.885	8.310	59.634
1976	4.144	3.407	2.977	2.337	2.511	1.911	2.695	6.649	8.681	28.336	17.775	15.640	97.063
1977	5.921	2.488	2.954	1.882	1.813	1.674	2.642	4.884	2.622	2.770	15.935	17.350	62.936
1978	5.875	3.364	2.163	2.105	2.049	1.916	2.048	5.933	8.547	15.045	12.651	17.270	78.966
1979	6.001	3.386	1.408	2.299	1.650	1.563	2.679	6.404	6.702	10.936	3.922	7.290	54.241
1980	5.569	3.407	2.977	2.337	2.511	1.921	2.563	3.036	5.031	23.283	14.734	29.806	97.174
1981	4.674	3.397	2.846	2.275	1.671	1.420	2.602	5.839	8.038	13.524	7.826	4.103	58.215
1982	5.845	3.407	2.967	2.333	2.511	1.921	2.305	6.645	8.681	26.703	11.476	20.990	95.785
1983	4.373	2.698	2.396	1.321	1.561	1.900	2.496	6.649	8.007	16.572	9.533	29.806	87.311
1984	6.001	2.918	2.977	2.337	2.442	1.921	2.695	4.425	8.440	25.912	15.463	16.250	91.780
1985	3.673	2.164	1.893	1.700	0.985	1.917	2.695	6.277	8.637	25.080	17.356	18.150	90.525
1986	2.985	3.046	1.235	2.337	1.780	1.803	2.407	6.649	8.593	18.253	16.819	18.920	84.828
1987	5.324	1.797	2.971	2.198	1.684	1.478	2.695	6.603	7.324	16.059	16.305	21.640	86.077
1988	5.085	1.519	1.235	1.488	1.878	1.921	2.662	5.839	7.765	17.657	11.543	26.981	85.573
1989	5.983	3.399	2.541	1.996	2.511	1.837	2.695	6.499	8.365	27.084	14.276	6.246	83.433
1990	1.686	3.242	2.928	2.329	2.150	1.854	2.130	6.628	8.681	29.313	10.536	28.553	100.030
Mean	4.870	2.800	2.390	1.865	1.767	1.614	2.196	5.304	7.251	19.323	12.776	16.388	78.543

The IFR time series illustrated for the above 10 years and compared to natural and present flows are as follows:

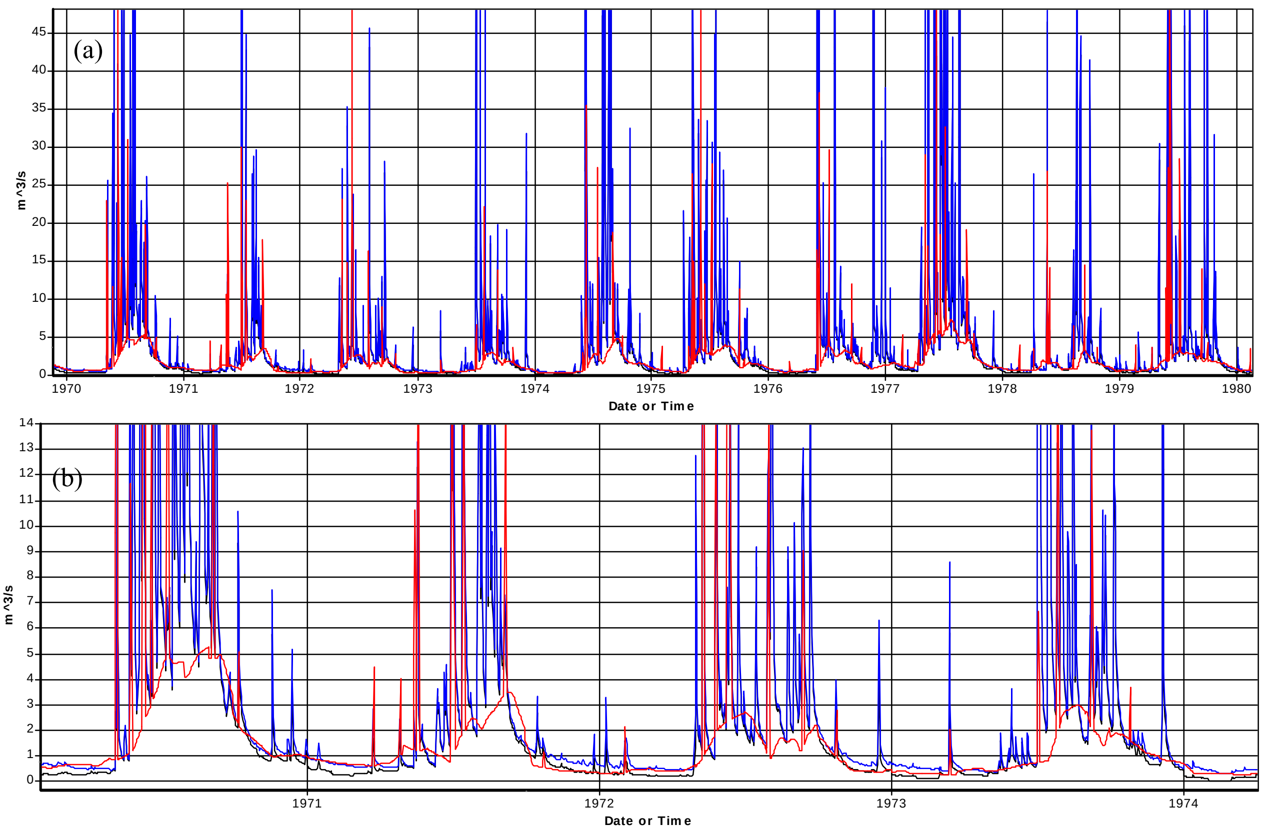

Figure 7.4 : IFR time series between (a) 1970 – 1980 and (b) 1970 - 1974 (red line = IFR, blue line = Virgin, black line = Present Day).

7.9 SCENARIO RESULTS

The Class C conditions are scaled according to the % of MAR for low flows proportionately according to the difference in the Desktop results between a C and a B Class. The seasonal distribution used for the specialist meeting results was also used for the extrapolations.

TABLE 7.5 : SUMMARY OF INFORMATION USED FOR EXTRAPOLATION.

DESKTOP % OF MAINTENANCE LOW FLOWS	IFR % OF MAINTENANCE LOW FLOWS	SEASONAL DISTRIBUTION
15 C Class	16.6	Maintenance: 0.95
26 B Class	28.7*	Drought:0.51

* % set at IFR specialist meeting.

High flows as provided through the Drift method for the different classes were used.

7.9.1 C Class Results

TABLE 7.6 : IFR TABLE - C CLASS

.	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLIFR												
($m^3 s^{-1}$)	1.000	0.600	0.500	0.400	0.350	0.300	0.400	0.700	1.100	1.500	1.600	1.500
(MCM)	2.678	1.555	1.339	1.071	0.847	0.804	1.037	1.875	2.851	4.018	4.285	3.888
(%MAR)	1.70	0.98	0.85	0.68	0.54	0.51	0.66	1.19	1.81	2.54	2.71	2.46
DLIFR												
($m^3 s^{-1}$)	0.600	0.420	0.380	0.300	0.300	0.280	0.300	0.440	0.650	0.800	0.860	0.840
(MCM)	1.607	1.089	1.018	0.804	0.726	0.750	0.778	1.178	1.685	2.143	2.303	2.177
(%MAR)	1.02	0.69	0.64	0.51	0.46	0.47	0.49	0.75	1.07	1.36	1.46	1.38
MHIFR												
($m^3 s^{-1}$)	4.000	0.000	0.000	0.000	0.000	0.000	4.620	15.300	14.800	59.500	29.300	29.400
(MCM)	0.622	0.000	0.000	0.000	0.000	0.000	0.719	2.776	2.685	12.184	5.316	5.334
(%MAR)	0.39	0.00	0.00	0.00	0.00	0.00	0.45	1.76	1.70	7.71	3.37	3.38
(Days)	3	0	0	0	0	0	3	4	4	5	4	4

Annual Totals

	MLIFR	DLIFR	MHIFR	DHIFR	Maint.	Drought
MCM	26.248	16.257	29.636	0.000	55.884	16.257
% Nat. MAR	16.62	10.29	18.77	0.00	35.39	10.29

TABLE 7.7 : IFR RULE TABLE - C CLASS

Data are given in $m^3\ s^{-1}$ mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.672	1.672	1.663	1.642	1.597	1.509	1.351	1.110	0.818	0.630
Nov	0.837	0.837	0.834	0.825	0.807	0.772	0.710	0.614	0.497	0.423
Dec	0.678	0.678	0.675	0.666	0.648	0.612	0.554	0.481	0.413	0.382
Jan	0.542	0.542	0.540	0.533	0.518	0.489	0.442	0.382	0.327	0.302
Feb	0.475	0.475	0.473	0.468	0.457	0.436	0.402	0.359	0.319	0.301
Mar	0.419	0.419	0.418	0.415	0.409	0.397	0.377	0.345	0.306	0.281
Apr	0.889	0.889	0.884	0.873	0.849	0.802	0.717	0.571	0.432	0.331
May	2.213	2.213	2.198	2.165	2.094	1.953	1.703	1.318	0.853	0.554
Jun	2.851	2.851	2.837	2.809	2.752	2.641	2.428	2.043	1.413	0.767
Jul	10.261	9.414	8.659	7.988	7.360	6.146	5.595	4.595	2.963	1.034
Aug	5.843	5.473	5.138	4.834	4.537	3.962	3.635	3.041	2.072	1.079
Sep	6.089	5.570	5.119	4.721	4.333	3.657	3.193	2.480	1.620	1.065

7.10 CONFIDENCE EVALUATION

IFR Site 2 is the most studied of the IFR sites used in the BRBS and as such the confidence of the assessments done here are relatively high. In addition, the site has a DWAF gauging weir immediately upstream that provided good, long term observed hydrological data on which to base the assessments:

Overall Confidence: High

8. IFR SITE 3 : BREEDE RIVER AT LE CHASSEUR

TARGET REACH : MOORDKUIL TO UPSTREAM OF THE CONFLUENCE WITH THE KOGMANS RIVER

8.1 REFERENCE CONDITIONS

8.1.1 Fish

Three indigenous freshwater species, namely the witvis *Barbus andrewi*, Burchell's redfin *Pseudobarbus burchelli* and Cape kurper, *Sandelia capensis*, are likely to have occurred at IFR Site 3. Other indigenous species likely to have occurred here include three obligate catadromous eels, these being the longfin eel *Anguilla mossambica*, the Madagascan mottled eel, *A. marmorata*, and the African mottled eel *A. bengalensis labiata*. In addition, the estuarine round-herring, *Gilchristella aestuaria,* which can live and breed in freshwater, probably occurred as high up in the system as IFR Site 3.

Reference indigenous species list (7 of 7):
Barbus andrewi
Pseudobarbus burchelli
Sandelia capensis
Anguilla mossambica
Anguilla marmorata.
A. bengalensis labiata.
Gilchristella aestuaria.

8.1.2 Aquatic Invertebrates

Reference conditions for Transitional and Lowland Floodplain rivers are based on data accumulated for the present study including, community composition, diversity indices, rank-abundance curves as well as SASS4 scores. Natural, unmodified conditions are expected to have a SASS4 score = >110 and ASPT score >7. The community is expected to include a large proportion of sensitive taxa including three or more baetid species, Leptophlebiidae, Tricorythidae and Limnichidae with a lower relative abundance of Chironimidae and Oligochaeta. Community diversity is expected to be high (*H'* >3) with an even distribution of individuals amongst species, reflected by a low gradient rank-abundance curve.

8.1.3 Riparian Vegetation

There should be a clear distinction between the different zones in the riparian vegetation as detailed in Boucher (1998), and Boucher and Tlale (2000). There should be a distinct Floodplain. In summary, these zones should be as follows:

Aquatic vegetation: The density of instream aquatic vegetation should be less than 10% cover. Backwaters along rapids with gravel beds can support denser stands of aquatics.

Wetbank vegetation: Sandy deposits should only be colonised by herbaceous species, i.e., no shrubs or trees. In this reach, the Upper Wetbank Zone should characteristically support a dense 3.5—4.0 m short tree or tall shrub stratum of *Morella serrata* behind fringing *Salix mucronata* with 1.5 m tall *Prionium serratum* beneath. There should be no bank collapse.

Lower Dynamic Zone: There should be no bank collapse and no invasion by woody exotic species.

Tree/shrub zone: The dry bank should be dominated by indigenous woody perennials. There should be no invasive alien species. Post-fire recruitment should be dominated by woody indigenous perennials.

Floodplain: Should be 100% intact and have no invasion by woody exotic species.

8.1.4 Geomorphology

River type: Foothill cobble-bed river.

Active channel well defined, with stable well-vegetated banks. Cobbles not embedded. No bulldozing or artificial manipulation of the bed, banks or floodplain, and no channelisation.

8.1.5 Water Quality

System variable:

TDS	:	< 45 mg l^{-1}
pH	:	7.0 – 8.0
DO	:	80 - 120% saturation
TSS	:	< 5 mg l^{-1}
Temperature	:	unmodified
Nutrients	:	PO_4/TP ratio: 0 – 10% Median $P0_4$: < 0.01 mg l^{-1} TN:TP ratio:> 20:1
Toxic substances	:	Meets the target water quality range for toxic substances as stated in the South African Water Quality Guidelines for Aquatic Ecosystems for 90% of the time, 99% of time less than or equal to chronic effect value, 100% of time less than the acute effect value.

8.1.6 Hydrology

No change to natural distribution flow regime.

8.2 PES, CAUSES AND ORIGINS, TRAJECTORY OF CHANGE

8.2.1 Fish

PES: D Class

The PES for this site is the result of the presence of bass and carp, and the presence of only 2 of the 7 indigenous freshwater species expected to occur there.

CAUSES	ORIGINS	NON-/FLOW RELATED
Presence of carp and bass.	Introduction.	Non-flow related
Reduction in habitat.	Increased turbidity from releases from Brandvlei Dam.	Flow-related
	Carp disturb the river bed and re-suspend sediments.	Non-flow related

Trajectory of change: Negative ***Short term: D/E Class*** ***Long term: E Class***

A major point of concern is the high silt load of the summer releases and the consequences for larval *B. andrewi*. Hatchery reared larval *B. andrewi* experienced 100 % mortality after being covered with a layer of fine silt (Bok and Immelman 1989). This suggests that the breeding success of the witvis is being compromised by the turbid irrigation releases from Brandvlei Dam - with long-term implications for the survival of the species in this stretch of river.

8.2.2 Aquatic Invertebrates

PES: D Class

Le Chasseur has a SASS4 score = 91 and ASPT score = 7, the lowest diversity index of all sites (*H'* = 2.78) and a steep rank-abundance curve with the community dominated by Simuliidae and Chironimidae. The low diversity index and community dominance patterns suggest there is a significant impact to community structure and function.

CAUSES	ORIGINS	NON-/FLOW RELATED
Reduced water quality.	Agricultural runoff from surrounding farmland.	Non-flow related
Increased summer low flows and lack of variability.	Agriculture - releases from Brandvlei Dam.	Flow related
Increase in suspended sediments.	Releases from Brandvlei Dam and catchment activities (see geomorphology).	Flow and non-flow related

Trajectory of change: None

A comparison between the results obtained in this study and those of an earlier sampling effort at the same site ((SASS4 score = 89, ASPT score = 5.56; Dallas 1998) suggests that conditions have not changed markedly in the intervening period (3 years) and, hence that they are stable and moderately modified.

8.2.3 Riparian Vegetation

PES: C Class

Aquatic vegetation: Water hyacinth has been recorded in the reach in recent years.

Wetbank vegetation: The Wetbank Zone is present and in good condition a in short section but is heavily invaded by *Sesbania punicea* in places. In places, the channel, including the Wetbank, has been bulldozed, and a trapezoidal canal system created, which bears little or no resemblance to the natural condition.

Lower Dynamic Zone: Moderately invaded by *Acacia saligna*.

Tree/shrub zone: *A. saligna* is a consistent exotic woody invasive of the tree/shrub zone that forms dense stands in disturbed areas.

Back Dynamic Zone: This zone is impacted along much of the reach. This is variously because of agricultural terraces, roads, irrigation canals or the presence of holiday homes. In the drier parts of the reach this area is heavily infested with the poisonous shrub, *Nerium oleander*, which is known to invade rivers in arid environments.

Floodplain: Destroyed through farming activities.

CAUSES	ORIGINS	NON-/FLOW RELATED
Invasion by alien species.	Introduction of, lack of management, agricultural activities.	Non-flow related
Changes to the back dynamic zone.	Presence of roads, canals and terraces.	Non-flow related
Changes to instream macrophytes (increase).	Releases from Brandvlei.	Flow-related

Trajectory of change: Negative (Short term: C Class - Long term: D Class)

The Wetbank vegetation zone is continuously being narrowed through stable unnaturally high flow of muddy water in summer months.

8.2.4 Geomorphology

PES: C Class

CAUSES	ORIGINS	NON-/FLOW RELATED
Some embeddedness of cobbles due to increased sediment yield.	Farming activities and Brandvlei Dam.	Non-flow related
Some manipulation (loss and destruction in places) of floodplain and river banks.	Agriculture.	Non-flow related
Instream manipulation.	Sand mining.	Non-flow related

Trajectory of change: None

A negative trajectory may still be present at a localised scale, i.e., at the IFR site, as a result of the ongoing influence of an old weir.

8.2.5 Water Quality

PES: B Class

Note : Water quality only assessed in measured parameters.

Water quality data measured at Le Chasseur (TDS, pH and nutrients), indicate a Class B. However, based on observed high suspended sediment loads (as a result of releases from Brandvlei Dam to control TDS levels), algal blooms observed in some sections of this river reach, as well as the low SASS scores observed at Le Chasseur, it was argued that the water quality was probably in a poorer class (C) than is indicated by the available water quality data.

Irrigation return flows and minor point sources in the catchment above the IFR site results in increased salinity. However, during the high irrigation months, salinity in this reach of the river is managed through releases of good quality water from Brandvlei Dam. This maintains the river in a Class B (in terms of TDS, pH and nutrients). Without these releases, water quality would be poor during the low flow summer months. Brandvlei Dam releases carry high suspended-sediment loads when releases are made to control elevated TDS concentrations in the middle Breede River.

No data are available for suspended sediments, which are perceived to be much higher than natural background concentrations.

CAUSES	ORIGINS	NON-/FLOW RELATED
High TDS.	Irrigation return flows in tributaries and main stem between Brandvlei Dam and IFR Site 3.	Non-flow (IFR) related
High TSS loads.	Releases from Brandvlei to alleviate high TDS.	Non-flow (IFR) related

Trajectory of change: None

TDS concentrations in the middle Breede River are managed through the release of low TDS water from Brandvlei Dam. There is a moderate increase in NO_3+NO_2-N (about 0.08 mg l^{-1} per year) and a slight increase in PO_4-P concentrations (about 0.002 mg l^{-1} per year) since 1992. This is probably the result of intensive agriculture in the catchment and treated sewage discharge from Worcester municipality.

8.2.6 Hydrology

PES: C/D Class

Approximately 70% of the natural MAR still flows past this reach in a year, however, the distribution of this water is somewhat altered from natural by the presence of Brandvlei Dam. Although full seasonal reversal does not occur, there is a tendency towards such, resulting from the high summer irrigation releases made into the Breede River from Brandvlei Dam. These releases also dampen the variability in the low season flows. Virtually NO contribution is received from the tributaries in this section of the river in the summer.

8.2.7 Combined PES

The most significant causes and origins are summarised as follows:

Non-flow related Presence of alien fish and vegetation species. Manipulation of the Floodplain. Return flows from agriculture. *Flow-related* Turbid releases from Brandvlei Dam. Unseasonal releases from Brandvlei Dam.

The condition of the fish and aquatic invertebrates (relative to the reference condition) is worse than that of the other components. This is partly a result of non-flow related impacts, such as the presence of alien fish species and physical manipulation of the channel. It is, however, also likely that the high TSS releases from Brandvlei Dam have contributed to the overall condition of the fish and invertebrate communities in this reach. TSS concentration is not measured at DWAF gauging weirs and thus the possibility of unnaturally high [TSS] is not reflected in the water quality PES. However, in setting the combined PES, the possibility that the water quality class is an overestimation was considered and the combined PES has been set midway between the class assigned for the geomorphology and water quality drivers (C Class) and that set for the fish and aquatic invertebrates (D Class), i.e., a C/D Class.

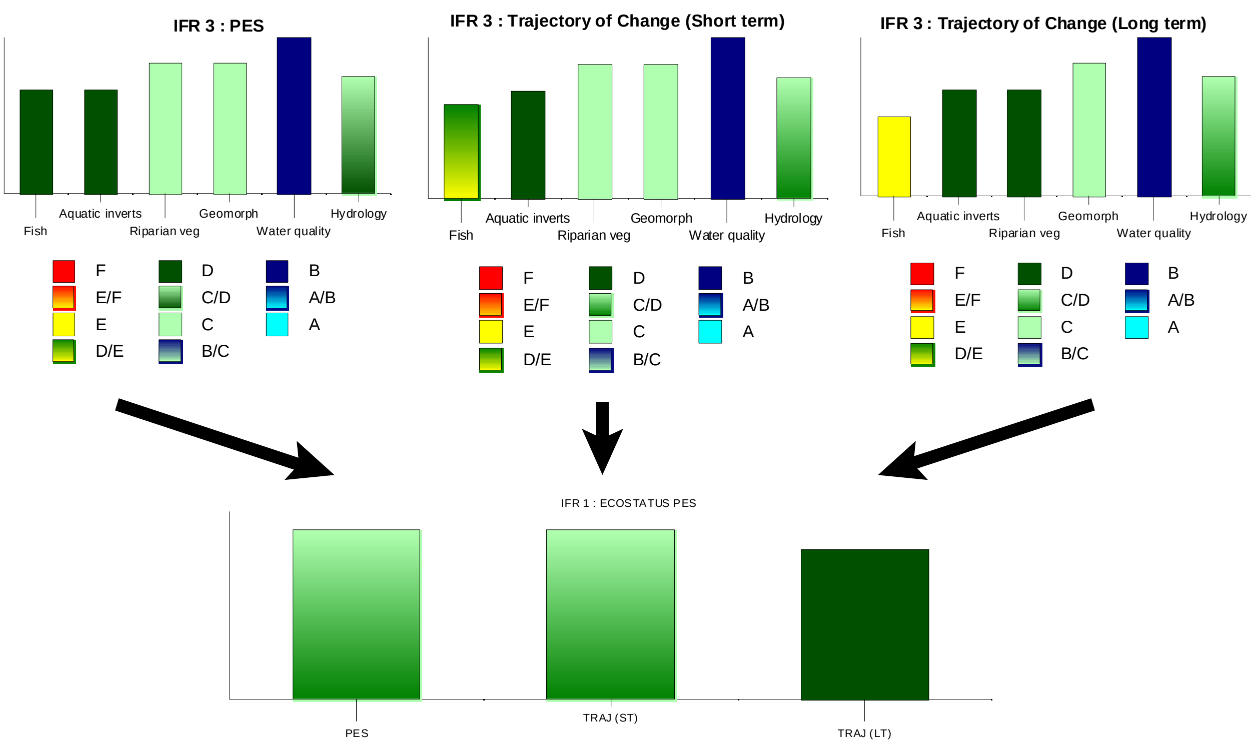

Figure 8.1 : Present Ecological Status (PES)

8.3 ECOLOGICAL AND SOCIAL IMPORTANCE (EIS and SI)

EIS rating: Moderate
Confidence: High
Determinants: Presence of rare, endangered and unique species. Presence of refugia. Important for migration.

Social rating: Moderate
Confidence: Very low
Determinants: Recreation and ecotourism, as well as the potential for recreation.

AIM:
The EIS is moderate, the social importance is moderate and the PES is moderate to low (C/D Class). The overall trajectory of change is negative and results in a D Class. No motivation is therefore provided to improve the PES and the target is for it to be maintained.

8.4 ATTAINABLE EC

8.4.1 Fish

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Alien fish.	Non-flow related	Remove fish.	Very difficult
Turbidity (Brandvlei releases).	Flow related	Mitigate colloidal particles.	Difficult
Carp - resuspends sediment.	Non-flow related	Remove fish.	Difficult
PES D - EC D The turbidity is perceived to be the major problem and, if one addresses the TSS in Brandvlei Dam releases, it is possible that with the carp present and the condition of the tributaries feeding this section of river the background TSS will remain elevated.			

8.4.2 Aquatic Invertebrates

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Agriculture (elevated summer flows).	Flow related	Implement the Reserve.	Reasonable
Brandvlei releases (turbidity).	Flow related	Mitigate colloidal particles.	Difficult
Agriculture (runoff).	Non-flow related	Irrigation and pesticide management - establish vegetation buffer zones.	Reasonable
PES D - EC D Turbidity and the increased summer flows are perceived to be the major problem and if one addresses this, the class should be maintained in a D Class.			

8.4.3 Riparian Vvegetation

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Presence of roads.	Non-flow related	Re-align tracks outside the riparian zone.	Difficult
Introduction of alien vegetation.	Non-flow related	Management and clearing (Working for Water).	Reasonable
Agriculture (increased summer flows).	Flow related	Implement the Reserve.	Reasonable
PES C - EC C Improvement is required to halt/slow down the trajectory of change, which is caused by the unnatural summer base flows. Addressing this should ensure the maintenance of the PES.			

8.4.4 Geomorphology

There is no negative trajectory of change, and thus no specific impacts that need to be addressed to maintain the geomorphology PES of a C Class.

8.4.5 Water Quality

The general water quality assessment (excl. [TSS]) of a C Class for the PES should be maintained.

The recorded water quality data resulted in a higher PES than is suggested from the SASS (invertebrate data), where potential water quality problems associated with the unnaturally high TSS loads appear to have eliminated some of the more sensitive invertebrate taxa. TSS concentrations are not routinely measured by DWAF, and no data are available for this site. Thus, it should be noted that the PES assessment for water quality EXCLUDES considerations of TSS.

8.4.6 Summary of Attainability and Ecostatus EC

The major issue in this section is the increased summer base flows, lack of flow variability and the associated turbid water from Brandvlei Dam. If this problem can be addressed, the maintenance of the PES of a C/D Class should be possible.

If an increased proportion of irrigation water could be conveyed by canal, this would reduce high summer flows, possibly increase summer variability and reduce turbidity in the river.

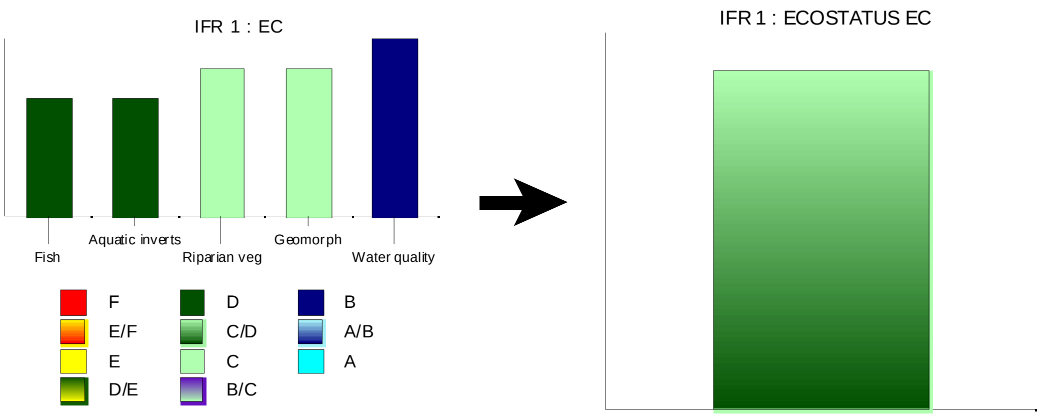

Figure 8.2 : Ecological Class (EC)

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	C/D	0	C/D	C/D	MODERATE	
Water quality	B (flagged)	0	B	B		B
Geomorphology	C	0	C	C		C
Riparian veg	C	-	C	D		C
Fish	D	-	D/E	E		D
Aquatic inverts	D	0	D	D		D
Ecostatus	C/D	-	C/D	D		C/D
					Long term EC	C/D

(Flag symbol) Concern based on landuse information or inconsistency between the bio-assessment and the water chemistry

Figure 8.3 : Summary of the PES and EC classes

8.5 OBJECTIVES

8.5.1 Fish

EC: D
General flow objectives: Maintain low flows during summer.
Overall fish objectives: To maintain and enhance populations of the remaining indigenous fish.
Objectives for target/indicator species: Maintain spawning habitat and conditions, flow of aerated water at head of pools, for survival of eggs and larvae of *Barbus andrewi*. This species is a serial spawner and can breed continuously throughout summer and therefore needs these flows throughout.

General flow objectives: Maintain winter floods.
Overall fish objectives: To facilitate dispersal of indigenous species especially out of overpopulated reaches and to maintain spawning substrate of indigenous species.
Objectives for target/indicator species: Indigenous species, most notably the larger *B. andrewi*, use floods and high flows for dispersal and may recolonise areas left vacant by alien species, which are washed downstream during high flows. Floods also flush sand and sediments from interstitial spaces amongst cobble and gravel at the heads of pools.

General flow objectives: Maintain summer floods and freshettes.
Overall fish objectives : Ensure no adverse effects results from incorrect timing of summer releases.
Objectives for target/indicator species: High flows facilitate the migration of catadromous species, however silt-laden releases may destroy eggs and larvae of *B. andrewi,* particularly if they coincide with peak spawning times.

8.5.2 Aquatic Invertebrates

EC: D
General flow objectives: Maintenance of present flow regime should maintain the long-term objective of a D Class (invertebrates) river. However, decreasing the abnormally high summer low flows to a more natural level could achieve the long-term objective with less water in the river. The reduction in present day summer low flows would reinstate the natural difference between summer and winter low flows. In order for the reach as a whole to be maintained as a D Class, the IFR site needs to be maintained at a higher class (SASS 4: 90 - 70) as its condition is slightly better than that of the reach as a whole.
Overall invertebrate objectives:

- Maintain at least a SASS 4 score = 90 and ASPT score = 7.
- Maintain diversity index at a minimum of *H'* = 2.78.
- Maintain a community that includes Leptophlebiidae, Tricorythidae and Limnichidae.

Objective for target/indicator species: See above community characteristics.

8.5.3 Riparian Vegetation

General

The Back Dynamic deposits from the river on the right bank are slightly saline (as a result of runoff from the surrounding catchment) and dry, hence the presence of *Acacia karroo*. The sand on the left bank is, however, low in salinity and sustains a community of Sand Plain Fynbos. Hence the vegetation at IFR Site 3 represents an unusual combination of fynbos and arid communities. Sand washed from the flat portions of the catchment, has the salt leached from it by the oligotrophic acidic water flowing from the mountains. This sand is then deposited on the inside of bends of the Breede River (as is the case with the left bank at IFR Site 3). Should flow conditions in the river prevent this erosion of sand, and subsequent leaching and deposition, the Sand Plain Fynbos community that it supports, which only has a limited distribution, would disappear.

The riffle zone is showing signs of terrestrialisation on the right side. A reduction in fresh(er) water would probably result in *Paspalum dioicum* invading the channel. This, in turn, would result in increased deposition of sediments in the resultant grass mat, which result in channel shape change. Thereafter, *Eucalyptus camaldulensis* and *E. cladocalyx* and *Sesbania punicea* would become established, as is already occurring in other places in the reach.

EC: C

Back Dynamic Zone

General flow objectives: Maintain the zone and to mobilise debris, to move/deposit sediments (1:20 to 1:50 year floods). An additional non-flow related objective would be to control development in the floodplain. This includes buildings, windmills and roads.

Overall riparian objectives: This zone has been destroyed in part by agriculture. Remnants are required.

Objective for target/indicator species: Acacia karroo should be maintained in a healthy condition, i.e., no die-back.

Tree Shrub Zone

General flow objectives: Maintenance of the deposition of silt, debris and seeds, which supported the tree shrub zone (1:5 to 1:20 year floods, and Class IV floods). In particular the sand deposits on the left bank.

Overall riparian objectives: Reduce stress on plants and restrict alien species invasion.

Objective for target/indicator species: Expand distribution of species representative of the zone, i.e., to restore density of stands of woody species (e.g., *Acacia karroo, Morella serrata*). This should be coupled with a campaign to eradicate alien woody species (*Acacia cyclops, A. saligna, Nerium oleander*) in the lower section of the reach, particularly in the vicinity of Robertson and Bonnievale.

Lower Dynamic Zone

General flow objectives: Maintain zone in near natural state to prevent channel shape change (steepening and narrowing of banks), which follows a change in the vegetation (1:2 year and Class III and IV floods).

Overall riparian objectives: Prevent the establishment of alien annuals or woody species, through the provision of flushing flows. Maintain the sand deposits on the left bank, and in so doing protect the Sand Plain Fynbos community.

Objective for target/indicator species: Indigenous annual herbs should occur in the zone, and limited downward movement of tree and shrub species (see species listed for Tree Shrub zone) is expected.

Wetbank Zone

General flow objectives: Maintain zone in near natural state to prevent channel shape change (steepening and narrowing of banks), which follows a change in the vegetation (Class II - III floods and 5% winter base flow).

Overall riparian objectives: Community objectives are to prevent alien annuals and then alien woody establishment. To allow for deposition or erosion to take place on an annual winter basis. To keep salinities down. To reinstate summer low flows.

Objective for target/indicator species: Target/indicator species objectives are to keep *Cyperus textilis*, *Prionium serratum*, *Phragmites australis*, *Morella serrata, Salix mucronata* and *Metrosideros angustifolia* individuals healthy. To restrict increase in *Phragmites* that would result through increased salinities from farming.

Aquatic Zone

General flow objectives: Maintain aquatic zone (5 - 99% winter baseflow and summer flows). Also to reinstate fluctuation in flow, clear water and to keep salinities down.

Overall riparian objectives: To inundated plants for most of winter (with fluctuations in levels) to allow plants to grow in clear water even while submerged.

Objective for target/indicator species: Allow *Potamogeton* beds to increase in summer and decrease in winter.

8.5.4 Geomorphology

EC: C

Large and lesser floods to transport incoming sediments past the site and to prevent embedded deposits.

8.5.5 Water Quality

EC: B

TDS	:	Maintain TDS at <300 mg l^{-1} for 95% of the time. Note - as long as the TDS is managed to meet the requirements for irrigation users at Zanddrift (carry on current practise if freshettes to maintain TDS), TDS will be maintained in a Class B.

pH	:	Maintain pH between 7 - 8 for 95% of the time.
Dissolved oxygen	:	Maintain between 80-100% of saturation.
Water temperature	:	Maintain within 3 ^{o}C of seasonal range at the middle Breede River reference site.
Total suspended solids	:	Maintain within 15% of seasonal range at the reference site. Note - releases will maintain the TDS irrigation targets in the middle Breede River which will mean that TSS targets will not be met because water in Brandvlei Dam is very turbid due to high colloidal clay content.
Nutrients	:	Median PO_4 concentration < 0.05 % PO_4:TP ratio <20% TN:TP ratio>10:1 Median NH_3-N<0.015 Maintain winter NO_2NO_3-N concentrations at <0.8 mg l^{-1} for 95% of the time and summer concentrations < 0.5 mg l^{-1} for 95% of the time
Toxic substances	:	Maintain toxic substances ≤ CEV for 95% of the time and ≤ AEV for 99% of the time, as specified in the SAWQG for aquatic ecosystems.
Flow related water quality objectives	:	Prevent biofilm formation by maintaining the flows at greater flows required to slightly move fines and clays (0.93 m s^{-1}) and gravel (1.98 m s^{-1}).
Non-flow related water quality objectives	:	Pesticides are a concern as a result of intensive agriculture upstream of the site. See objectives for toxic substances.

8.6 MAINTENANCE FLOW ASSURANCE

The assurance of maintenance low flows during winter is set at 70%. The assurance of maintenance low flows during summer is set at 60%.

8.7 SEASONAL DISTRIBUTION

December was selected as the key highest flow month and July was selected as the key lowest flow month.

8.8 IFR RESULTS

8.8.1 Motivations: Low Flows

Each flow is motivated and documented by the specialists. The motivations for these flows are provided below.

MAINTENANCE LOW (DRY SEASON, DECEMBER) $4\ m^3 s^{-1}$

Descriptions of flow required:

Maintenance of pool depth at >1.8 m. Velocity of at least 2 m s^{-1} where the run enters the downstream pool. Water level high enough to inundate marginal vegetation. Maintenance in summer of 0.48 m flow depth at IFR Site 3C. Average depths of 0.5 m over the rapid for riffle community must be maintained.

Primary motivations:

Riparian vegetation: *Potamogeton* beds should be maintained. If these flows are not provided, loss of *Potamogeton* into seed form will occur. It is, however, possible that presence of the rooted aquatics has resulted in a build up of gravel on the right bank and that the target flow is elevated as a result. *Prionium serratum* to root and establish in new bare areas. *Prionium* will not reproduce vegetatively during the year.

Source: Breede study, own data, reports, student studies.

Aquatic invertebrates: Hydropsychidae are dominant components of the riffle community and most frequently found at depths of 0.4 – 0.6 m. If this flow does not occur, it will result in reduced abundances of individuals in the riffle community, including Hydropsychidae and Baetidae.

Source: Invertebrate samples for BRBS, photos, profile, SVD histograms, available literature.

Fish: Maintain pool depths of at least 1.8 m for eel habitat. Aerated water is required for the survival of *B. andrewi* eggs and larvae. Inundation of marginal vegetation as refuge for juveniles is also required. If this flow is not provided, eels will disappear from this reach, and there will be a loss of *B. andrewi* as a result of a decline in spawning and recruitment success.

Source: Breede study, literature.

Water quality consequences:

Water is released from Brandvlei Dam to meet irrigation demands and to maintain TDS concentrations at Zandvliet within irrigation targets. If flows from Brandvlei Dam are reduced to meet the IFR requirement, TDS concentrations in the river will increase, perhaps to a C Class, as a result of irrigation return flows during the summer months. Nutrients will not be affected by the change in summer flows. Crops are generally not irrigated during winter months.

MAINTENANCE LOW (WET SEASON, JULY) $16\ m^3 s^{-1}$

Descriptions of flow required:

- 2.5 m depth in the pool (Cross-section A).
- 8 m s^{-1} or 0.72 m depth in the riffle (Cross-section B and C).

Primary motivation:

Riparian vegetation: Top of lower Wetbank maintenance. Maintain trees through capillary action and washes algae from the backwaters and pools. Does not influence *Potamogeton* growth and would prevent the invasion of the channel by *Phragmites* and *Prionium*.

Source: Own data reports and student studies.

Secondary motivation:

Aquatic invertebrates: Rapid/riffle habitat maintained for persistence and life history requirements of flow-sensitive taxa.

Source: Invertebrate samples for BRBS, photos, profile.

Water quality consequences:

The TDS related to the IFR flow is well within a B Class and will probably stay within a B Class.

DROUGHT LOW (DRY SEASON, DECEMBER) $2.2\ m^3 s^{-1}$

Descriptions of flow required:

Maintenance of pool depth at 1.8 m and ensure a trickle of aerated water into the head of the pool. $0.25\ m\,s^{-1}$, 0.18 m depth, 3.8 m width at the riffle.

Primary motivation:

Fish: Maintenance of pool habitat for *B. andrewi* and eels. Lower or more frequent droughts could lead to possible dying off of pool population of *B. andrewi* and eels, prevention of this would be dependent on drought duration. Drought would be accompanied by a decline in water quality, which will be an added stress to the indigenous fish.

Source: Breede study, literature.

Aquatic invertebrates: Maintain flow conditions sufficient to ensure survival of flow-sensitive taxa (e.g., Hydropsychidae).

Source: Invertebrate samples for BRBS, photos, profile.

Water quality consequences:

Under very low summer flows, TDS concentrations will increase and will probably increase to a C Class, as a result of irrigation return flows during the summer months not being diluted with better quality water. The effect will be exacerbated if droughts happen in series.

DROUGHT LOW (WET SEASON, JULY) $4\ m^3 s^{-1}$

Descriptions of flow required:

Maintenance of pool depth at 1.8 m. Moderate velocity with some deep pools = $0.3\ m\,s^{-1}$ in pool.

Primary motivation:

Fish: Maintenance of pool habitat for *B. andrewi* and eels. Inundation of marginal vegetation as refuge for juveniles born the previous summer. Possible maintenance of connectivity between reaches. Lower or more frequent droughts could lead to possible dying off of pool population of *B. andrewi* and eels, prevention of this would be dependent on drought duration. Drought would be accompanied by a decline in water quality, which will be an added stress to the indigenous fish.

Source: Study, literature.

Aquatic invertebrates: Maintenance of wetted habitat in riffle, further loss would result in rapid drop-off of wetted habitat area.

Source: Invertebrate samples for BRBS, photos, profile.

Secondary motivation:

Riparian vegetation: Survival of Wetbank species. Note: If current conditions prevail it is likely that invasive aquatic plants would become prevalent during the drought conditions described above.

Sources: Own data reports and students' studies.

Water quality consequences:

Under very low winter flows, TDS concentrations will increase and may increase to a C Class. Crops are generally not irrigated during winter months. Nitrates will not be washed off the catchment during droughts due to few wash-off events.

8.8.2 Motivations : High Flows

Approach: The drift flood data for IFR 1, 2 and 4 were used to generate a :"minimum degradation" flood regime, i.e., maintenance of the target EC. Once the minimum degradation flood regime had been determined for the three sites, there was a distinct pattern in numbers of within year floods at the sites. This pattern was extrapolated to the other sites on the system (*viz.* IFR Site 3, 5 and 6) and used as a starting point for the determination of a flood regime at those sites. These were adjusted according to the specialist's requirements of each site.

In general, the following numbers of within year floods were required for minimum degradation in the Breede River:

TABLE 8.1 : FLOOD REQUIREMENTS FOR MINIMUM DEGRADATION

WITHIN-YEAR FLOODS	MINIMUM DEGRADATION NUMBER PER ANNUM
Class I	3-4
Class II	2
Class III	1-2
Class IV	1-2

TABLE 8.2 : FLOOD REQUIREMENTS FOR IFR SITE 3

FLOOD CLASS	MONTHLY DISTRIBUTION	SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NUMBER OF EVENTS			DISTRIBUTION
			NATURAL	PRESENT DAY	MIN DEG: C/D	
I	10 - 4	31.5	7	9	3	11 - 3
II	5 - 9	87.95	3	3	2	9-11 4-5
III	5 - 9	176.58	3	3	2	5 - 8
IV	5 - 9	370.06	1.7	1	1	5 - 9
1 : 2	533					
1 : 5	714					
1 : 10	882					
1 : 20	882					

Fish:

Class I:

Species Motivation:

Pseudobarbus burchelli is a rare south-western Cape endemic confined to the Breede River and adjacent systems. It is excluded from the mainstream and many tributaries by alien predators. It is an omnivore actively selecting different prey types depending on season and locality thereby having a role in structuring invertebrate communities. It may breed twice during summer relying on steady periods of summer rain 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. This is a short-lived species (3 years) so one missed opportunity could significantly (adversely) affect reproductive success.

General Motivation:

- Floods are more disruptive to alien than to 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.
- From macro-invertebrate report: 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.
- 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

Class II, III and IV:

Species Motivation:

Barbus andrewi: Critically endangered species confined in distribution to the Berg and Breede systems. The largest benthic feeder in the mainstream preying on crabs *Potamonautes sidneyi*, *Burnupia* spp. and other benthic invertebrates. Probably the only indigenous species that turns over significant amounts of sediment when feeding. Historically, would have been a large component of otter diets. Low flows confine them to deep pools for long periods. Excessive low flows lead to the loss of aerated water at the head of pools essential for the survival of eggs and larvae. Silt deposits inundate spawning beds and larval habitat. Silt turned over or suspended by the introduced *C. carpio* suffocates eggs and larvae. Unseasonal, summer, silt laden releases from dams may lead to 100 % larval mortality.

Anguillidae: Two southern African endemics and one Indo-Pacific in origin all catadromous with similar life-history characteristics. The largest piscivorous predators in the Breede 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.

General Motivations:
See above

<u>Aquatic invertebrates:</u>
Class I:

- Mobilisation and delivery of organic material: Flows move particles along the river supplying filter and benthic feeders. Some are trapped in fast flowing areas and some re-settle in slow areas. An increase in organic material favours filter feeders and could impact on pool dwellers. A decrease results in a decrease in filter feeders and benthic shredders/gatherers depending on particle size.
- Drift: Many species move or are dislodged into the water column and drift downstream. Some use it as a means for relocating in more favourable areas. Whilst in the water column they provide food for fish. Drifting invertebrates recolonise downstream areas thereby enhancing recovery of the ecosystem from natural and anthropogenic disturbances.
- Inundation of secondary channels: The inundation of secondary channels will create Floodplain refugia. Floodplain refugia are important for macro-invertebrates that are unable to survive in high flows characteristic of flood conditions.
- Scouring of biofilms

Class II and III:

- Class I motivations above plus the following.
- Mobilisation and sorting of sediments: All but the lowest flows do some work moving sediments. The higher the velocities, the larger the particles moved. High flushing flows flush fines from interstitial spaces in the river bed. Flows that move gravel, cobbles and boulders, sort these into areas of similar particle size. Well-sorted substrates provide a highly heterogenous physical habitat, which enhances species diversity, abundance and general resilience. When fines are flushed from cobble beds, hyporheic refugia become available.

Class IV:

- Class I, II and III motivations as well as the scour of pools. If these floods do not occur, infilling of pools will occur, reduction of flushing of interstitial spaces; reduction in scouring of biofilms, reduction in sorting of different size substrata, reduction in diversity of invertebrate species.

<u>Riparian vegetation:</u>
Class I, II, III, IV:

- To maintain the Lower Dynamic Zone, i.e., to mobilise sediments and to clear channel of floating ecostis and of reed and palmiet encroachment.

- These floods will prevent infilling of the channels. This will result in exotics becoming dense along the margins of the Wetbank and heat from subsequent fires and shading will destroy both Wetbank and tree-shrub zone plants. Sand to maintain the fynbos along the river will decrease and result in loss of Inland Sand Plain Fynbos (Willdenowia veld), i.e., some Proteaceae that are already on endangered list will become more endangered.

1:2 and 1:5 floods:

- Flood level reached important for the maintenance of the Low Dynamic Zone.
- Sufficiently large to move sediments (remove seedlings from the Lower Dynamic Zone).
- Partial (1/2) tree shrub zone maintain seedlings and juvenile and parents.
- Additional maintenance of the Sand Plain Fynbos - depositing washed sand required for further growth. Grows in Tree Shrub Zone and partially in top of Lower Dynamic Zone. These sandy areas that act as distribution points for the SPF to move into terrestrial areas.
- If these flows do not occur then the invasion of the Lower Dynamic Zone by alien vegetation will increase, leading to an increased flooding risk. Terrestrialisation of the Tree Shrub Zone will occur.

Water quality consequences:
If the Class I floods occur during the summer, TDS will be diluted, and probably remain in a B Class. Class II and higher floods will result in dilution and will maintain TDS in a B Class.

Geomorphology:
In order to establish whether the reduced flows would lead to accumulation of fine sediments along the river upstream of the site, the estimated sediment yield from the catchment has been compared with the sediment carrying capacity of the reduced flood flows. The unit sediment yield was taken as 300 ton km^{-2} per annum and the effective catchment size is 3254 km^2. Therefore, the average suspended sediment load is 976200 tons. Assuming an average sediment concentration of 1% by mass, the required volume of annual flood discharges would by 97.6 MCM. The calculated total annual flood discharges for the flood regime provided would be *c.* 329 MCM, thus there should not be general accumulation of sediment upstream of this site, as the flood flows should be able to transport concentrations of 1%. Conversely the average sediment accumulation will be (976 200/327 000 000) x 100 % = 0.3 %, i.e., quite low.

8.8.3 IFR Table

The results as motivation above are presented in the IFR table below.

TABLE 8.3 : IFR TABLE: IFR SITE 3 – C/D CLASS

IFR 3: BREEDE RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) MAR (VIRGIN): 1210 MAR (PRESENT): 763										
MONTHS	**MAINTENANCE LOW FLOWS**			**HIGH FLOWS**				**DROUGHT LOW FLOWS**		
	DEPTH[4]	**FLOW**	**VOLUME**	**DEPTH[4]**	**FLOW**	**DURATION**	**VOLUME[1]**	**DEPTH[4]**	**FLOW**	**VOLUME**
		($m^3 s^{-1}$)	**($10^6 m^3$)**		**$m^3 s^{-1}$ Daily average**		**($10^6 m^3$)**		**($m^3 s^{-1}$)**	**($10^6 m^3$)**
Oct	0.61	7.6	20.4	1	31.5	4	4.3	0.42	2.7	7.2
Nov	0.55	5.8	15					0.41	2.5	6.5
Dec2	0.48	4	10.7					0.39	2.2	5.9
Jan	0.56	6	16					0.40	2.4	6.4
Feb	0.45	3.3	8					0.39	2.2	5.3
Mar	0.49	4.1	11					0.39	2.2	6
Apr	0.51	4.6	12	1	31.5	4	4.9	0.39	2.3	6
May	0.57	6.4	17.1	1.35	88	6	18.7	0.41	2.5	6.7
Jun	0.67	10	26	1.6	177	6	38.2	0.44	3.2	8.3
Jul3	0.79	16	43	2	370	7	89.3	0.48	4	11
Aug	0.76	14.5	39	1.6	177	6	37.3	0.47	3.8	10.2
Sep	0.71	12	31	1.35 & 1	88 & 31.5	6 & 4	22	0.46	3.5	9
TOTAL			**249.2**				**214.7**			**88.5**
% OF MAR (VIRGIN)			**20.57**				**17.75**			**7.3**
Long term % OF MAR (VIRGIN): 44.6 (539.5 MCM)										
1	The volume represents the daily average less the low flows									
2	Dec was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.									
3	July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Depths taken at cross section 3									

Note :
The š1:2 floods are also included in the requirement although not included in the Table above.

8.8.4 IFR Rule Table

Before the monthly distributions of IFRs can be considered useful for water resource planning and management, it is necessary to determine a basis for deciding when the maintenance (or above) components of the recommended flow should apply and when lower flows (i.e down to and including the drought recommendations) should apply. During 1997 and 1998, these decisions were made during a number of specialist meetings on the basis of the IFR model which allows a set of rules to be applied and the results visualised by the various specialists through representative time series of IFR modified flows. A similar system has been incorporated into the desktop based on a monthly data and these are referred to as 'Assurance Rules'. They are essentially curves relating to the percentage of time that certain flows will be equalled or exceed in the modified flow regime and can be used in conjunction with the natural time series and associated flow duration curves to generate representative time series of flows required to satisfy the Reserve requirements.

The IFR rule table for IFR Site 3 is provided below (Table 8.4).

TABLE 8.4 : IFR RULE TABLE - C/D CLASS

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

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	14.619	14.619	14.515	14.279	13.777	12.787	11.025	8.316	5.045	2.937
Nov	9.531	9.531	9.468	9.327	9.027	7.205	6.777	5.762	3.806	2.545
Dec	6.258	6.258	6.211	6.096	5.842	4.909	4.572	3.569	2.651	2.227
Jan	9.381	8.866	4.398	3.054	3.029	2.458	2.181	2.113	1.857	1.690
Feb	5.165	4.445	4.407	3.795	2.445	1.596	1.572	1.513	1.462	1.016
Mar	6.740	6.740	6.700	5.224	5.180	2.094	1.856	1.806	1.711	1.618
Apr	10.043	10.043	9.976	9.824	9.501	7.196	6.793	5.993	3.227	2.537
May	19.709	19.709	19.563	19.231	18.526	17.136	14.662	10.857	6.263	3.303
Jun	37.769	37.769	37.552	37.107	36.216	34.460	31.103	25.015	15.079	4.885
Jul	87.387	81.178	75.546	70.439	65.457	55.812	50.349	40.440	24.267	7.675
Aug	50.128	47.541	45.119	42.836	40.448	35.815	32.364	26.104	15.887	5.405
Sep	36.211	34.068	32.109	30.245	28.171	24.448	20.880	15.394	8.769	4.500
Natural Duration curves										
Oct	56.082	29.510	17.901	16.871	15.889	13.780	12.668	11.255	10.685	8.602
Nov	47.915	19.892	14.194	10.252	9.806	7.205	6.777	6.483	6.353	5.829
Dec	20.665	10.424	7.358	7.219	7.038	4.909	4.903	3.788	3.535	2.864
Jan	89.305	8.866	4.398	3.054	3.029	2.458	2.181	2.113	1.857	1.690
Feb	10.330	4.445	4.407	3.795	2.445	1.596	1.572	1.513	1.462	1.016
Mar	27.098	24.207	13.787	5.224	5.180	2.094	1.856	1.806	1.711	1.618
Apr	42.808	31.277	16.590	16.467	14.965	7.196	6.793	6.374	3.227	2.991
May	187.426	83.687	67.965	46.553	34.052	25.914	25.206	23.905	22.284	7.148
Jun	137.164	103.228	99.939	98.108	85.904	52.280	52.243	43.872	41.953	16.150
Jul	250.330	167.960	144.286	136.014	99.166	88.828	72.126	68.924	45.197	40.268
Aug	163.117	120.256	113.849	98.963	95.374	57.311	53.103	51.523	41.490	39.927
Sep	137.729	133.929	105.295	81.488	73.405	49.120	46.908	38.914	16.535	11.416

8.8.5 IFR Time Series

The final result of the application of the Desktop model is a representative time series of monthly flow volumes (the same length as that used to represent the natural flow regime) recommended for the quantity component of the Ecological Reserve for the selected ecological class.

The representative time series for the IFR sites are provided below.

TABLE 8.5 : FINAL RESULTS FOR A TIME SERIES 1980 - 1990 ($10^6 m^3$) - C/D CLASS

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1980	29.530	24.704	16.761	25.126	12.495	13.874	18.651	10.810	20.799	149.486	108.336	85.347	515.918
1981	38.577	24.369	12.246	8.113	3.661	4.838	26.031	29.079	39.084	34.244	23.122	14.406	257.770
1982	39.026	19.636	15.647	5.841	10.753	13.992	7.445	52.788	97.897	226.764	86.684	54.121	630.593
1983	13.512	9.864	9.560	4.526	2.457	18.052	17.608	52.788	64.839	175.320	42.551	93.859	504.936
1984	39.155	24.704	16.761	23.748	10.661	18.052	24.589	16.774	97.627	194.426	123.566	39.900	629.963
1985	34.391	23.398	16.492	8.180	3.803	12.007	24.628	39.270	90.433	157.018	134.263	65.938	609.821
1986	22.274	18.675	7.102	11.779	3.860	4.582	15.534	52.606	93.872	108.313	131.224	63.369	533.190
1987	36.899	14.935	16.705	5.660	3.538	4.333	25.671	45.898	80.620	64.997	99.010	73.020	471.285
1988	34.249	17.566	6.212	4.975	5.916	18.002	25.950	49.620	89.320	134.855	117.347	91.396	595.408
1989	39.155	24.629	14.450	7.223	9.181	5.609	26.031	51.976	96.777	208.616	95.927	22.729	602.303
1990	9.265	7.407	13.148	6.583	4.640	4.971	8.365	46.068	97.897	234.058	69.916	80.482	582.799
Mean	30.548	19.081	13.189	10.159	6.451	10.756	20.046	40.698	79.015	153.463	93.813	62.233	539.453

The IFR time series illustrated for the above 10 years and compared to natural and present flows are as follows:

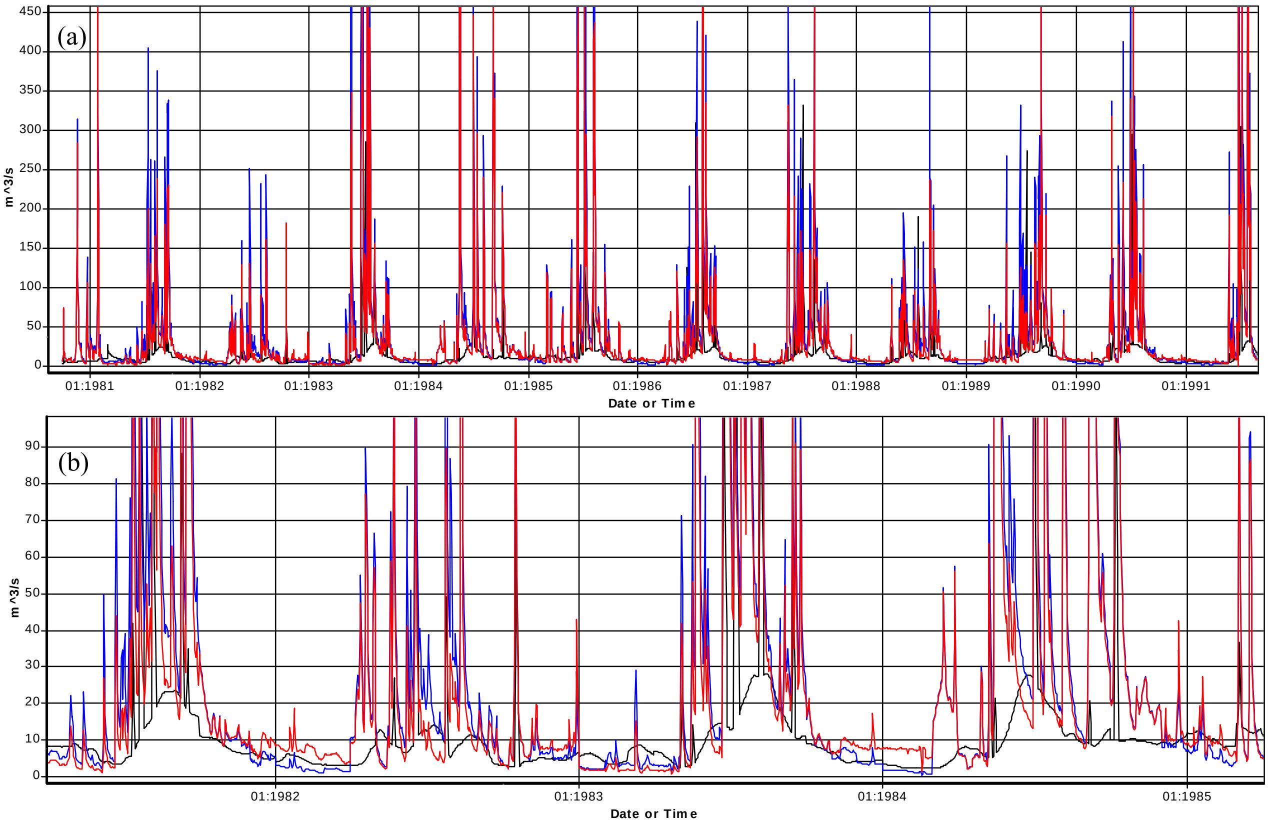

Figure 8.4 : IFR time series between (a) 1981-1991 and (b) 1981-1985 (red line = IFR, blue line = Virgin, black line = Present Day)

8.9 SCENARIO RESULTS

Results for a C and a D Class are provided as additional Reserve scenario results. The proportional difference between the C, the C/D and the D Class for maintenance low flows as provided by the Desktop Model was used to extrapolate a C and D scenario from the C/D Class as provided in 8.8 above (see Table 8.5). The same seasonal distribution for maintenance low flows as determined from the C/D Class was used in the extrapolated C and D Class.

TABLE 8.6 : SUMMARY OF INFORMATION USED FOR EXTRAPOLATION

DESKTOP % OF MAINTENANCE LOW FLOWS	IFR % OF MAINTENANCE LOW FLOWS	SEASONAL DISTRIBUTION
6.21 D Class	13.5	Drought : 0.09
9.45 C /D Class	20.57*	Maintenance: 0.4
12.46 C Class	27.1	

* % set at IFR specialist meeting

Drought flows are the same for all classes. High flows as provided through the Drift method for the different classes were used.

8.9.1 C Class Results

TABLE 8.7 : IFR TABLE - C CLASS

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLIFR												
$(m^3\ s^{-1})$	9.486	7.300	5.000	7.400	4.100	5.100	5.700	8.000	12.500	20.000	18.000	22.000
(MCM)	25.406	18.922	13.392	19.820	9.919	13.660	14.774	21.427	32.400	53.568	48.211	57.024
(%MAR)	2.10	1.56	1.11	1.64	0.82	1.13	1.22	1.77	2.68	4.42	3.98	4.71
DLIFR												
$(m^3\ s^{-1})$	2.700	2.500	2.200	2.400	2.200	2.200	2.300	2.500	3.200	4.000	3.800	3.500
(MCM)	7.232	6.480	5.892	6.428	5.322	5.892	5.962	6.696	8.294	10.714	10.178	9.072
(%MAR)	0.60	0.54	0.49	0.53	0.44	0.49	0.49	0.55	0.69	0.88	0.84	0.75
MHIFR												
$(m^3\ s^{-1})$	22.000	0.000	0.000	0.000	0.000	0.000	25.800	80.000	164.500	359.000	159.000	97.500
(MCM)	3.992	0.000	0.000	0.000	0.000	0.000	4.681	18.317	37.664	90.571	36.405	19.965
(%MAR)	0.33	0.00	0.00	0.00	0.00	0.00	0.39	1.51	3.11	7.48	3.01	1.65
(Days)	4	0	0	0	0	0	4	6	6	7	6	5

Annual Totals

	MLIFR	DLIFR	MHIFR	DHIFR	Maint.	Drought
MCM	328.523	88.163	211.594	0.000	540.118	88.163
% Nat. MAR	27.14	7.28	17.48	0.00	44.61	7.28

TABLE 8.8 : IFR RULE TABLE - C CLASS

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	14.992	14.992	14.884	14.640	14.122	13.100	11.280	8.481	5.102	2.925
Nov	10.172	10.172	10.104	9.950	9.622	7.205	6.777	6.058	3.924	2.548
Dec	6.771	6.771	6.719	6.589	6.303	4.909	4.872	3.742	2.707	2.229
Jan	10.016	8.866	4.398	3.054	3.029	2.458	2.181	2.113	1.857	1.690
Feb	5.555	4.445	4.407	3.795	2.445	1.596	1.572	1.513	1.462	1.016
Mar	7.109	7.109	7.066	5.224	5.180	2.094	1.856	1.806	1.711	1.618
Apr	10.099	10.099	10.032	9.879	9.553	7.196	6.793	6.014	3.227	2.528
May	19.305	19.305	19.162	18.838	18.150	16.793	14.377	10.661	6.175	3.285
Jun	35.730	35.730	35.526	35.109	34.271	32.622	29.470	23.752	14.421	4.848
Jul	89.014	82.721	77.009	71.826	66.763	56.960	51.373	41.237	24.696	7.726
Aug	50.146	47.616	45.240	42.994	40.631	36.044	32.564	26.250	15.945	5.374
Sep	45.589	43.646	41.760	39.820	37.410	32.987	27.889	20.049	10.583	4.483

8.9.2 D Class Results

TABLE 8.9 : IFR TABLE - D CLASS

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLIFR												
($m^3 s^{-1}$)	7.600	5.800	4.000	6.000	3.300	4.100	4.600	6.400	10.000	16.000	14.500	12.000
(MCM)	20.356	15.034	10.714	16.070	7.983	10.981	11.923	17.142	25.920	42.854	38.837	31.104
(%MAR)	1.68	1.24	0.89	1.33	0.66	0.91	0.99	1.42	2.14	3.54	3.21	2.57
DLIFR												
($m^3 s^{-1}$)	2.700	2.500	2.200	2.400	2.200	2.200	2.300	2.500	3.200	4.000	3.800	3.500
(MCM)	7.232	6.480	5.892	6.428	5.322	5.892	5.962	6.696	8.294	10.714	10.178	9.072
(%MAR)	0.60	0.54	0.49	0.53	0.44	0.49	0.49	0.55	0.69	0.89	0.84	0.75
MHIFR												
($m^3 s^{-1}$)	23.900	0.000	0.000	0.000	0.000	0.000	26.900	81.600	167.000	354.000	162.500	107.500
(MCM)	4.336	0.000	0.000	0.000	0.000	0.000	4.881	18.683	38.236	89.310	37.206	22.013
(%MAR)	0.36	0.00	0.00	0.00	0.00	0.00	0.40	1.54	3.16	7.38	3.07	1.82
(Days)	4	0	0	0	0	0	4	6	6	7	6	5

Annual Totals

	MLIFR	DLIFR	MHIFR	DHIFR	Maint.	Drought
MCM	248.918	88.163	214.665	0.000	463.583	88.163
% Nat. MAR	20.57	7.29	17.74	0.00	38.31	7.29

TABLE 8.10 : IFR RULE TABLE - D CLASS

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	12.367	12.367	12.284	12.097	11.699	10.914	9.516	7.366	4.771	3.098
Nov	6.082	6.082	6.051	5.979	5.826	5.524	4.987	4.162	3.165	2.522
Dec	3.914	3.914	3.895	3.846	3.738	3.533	3.202	2.778	2.390	2.211
Jan	4.227	4.227	4.207	3.054	3.029	2.458	2.181	2.113	1.857	1.690
Feb	3.290	3.290	3.278	3.247	2.445	1.596	1.572	1.513	1.462	1.016
Mar	4.277	4.277	4.259	4.217	4.128	2.094	1.856	1.806	1.711	1.618
Apr	9.574	9.574	9.513	9.374	9.079	7.196	6.793	5.869	3.227	2.708
May	18.736	18.736	18.601	18.293	17.639	16.350	14.055	10.526	6.265	3.519
Jun	35.843	35.843	35.641	35.228	34.398	32.764	29.640	23.974	14.726	5.239
Jul	94.111	86.100	78.947	72.592	66.635	55.118	49.842	40.272	24.654	8.630
Aug	15.765	15.765	15.686	15.526	15.203	14.568	13.355	11.153	7.561	3.875
Sep	18.058	18.058	17.929	17.637	17.015	15.790	13.608	10.253	6.201	3.591

8.10 CONFIDENCE EVALUATION

The reach of the Breede River represented by IFR Site 3 has received irrigation releases from Brandvlei Dam since the early 1970s, resulting in unnaturally elevated summer baseflows in the system. It is possible/likely that the system has adjusted somewhat to these elevated baseflows, and thus the site information used by the specialists to recommend flows has been set in response to the elevated irrigation flows, rather than to the natural hydrology. The upshot of this is that the recommended summer lowflows may be slightly higher than would have been recommended under natural conditions.

Overall confidence: Moderate.

9. IFR SITE 4: LOWER BREEDE

TARGET REACH: THE BUFFELJAGS CONFLUENCE TO THE ESTUARY

9.1 REFERENCE CONDITIONS

9.1.1 Fish

The open water and lees of the bedrock sills and islands are ideal for the shoaling estuarine species namely *Myxus capensis*, *Mugil cephalus* and *Gilchristella aestuaria*. The deep pools with rocky overhangs, boulders and fringed with palmiet are predictable habitats of the *Anguilla* species. *Phragmites* beds, and pockets of shallow submerged vegetation provide refugia for juvenile fish. Deep pools with a mixture of large and small cobbles are also habitat for *B. andrewi*, *S. capensis* and *P. burchelli* and were historically recorded in the Swellendam area.

Reference indigenous species list (10 of 10):
Barbus andrewi
Pseudobarbus burchelli
Sandelia capensis
Anguilla mossambica
Anguilla marmorata.
Anguilla bengalensis labiata
Myxus capensis
Mugil cephalus
Gilchristella aestuaria
Monodactylus falciformis.

9.1.2 Aquatic Invertebrates

Reference conditions for Transitional and Lowland Floodplain rivers are based on data accumulated for the present study including, community composition, diversity indices, rank-abundance curves as well as SASS4 scores. Natural, unmodified conditions are expected to have a SASS4 score = >110 and ASPT score >7. The community is expected to include a large proportion of sensitive taxa including three or more baetid species, Leptophlebiidae, Trichorythidae and Limnichidae with lower relative abundances of Chironimidae and Oligochaeta. Community diversity is expected to be high (*H'* >3) with an even distribution of individuals amongst species, reflected by low gradient rank-abundance curve.

9.1.3 Riparian Vegetation

Aquatic vegetation: The density of instream aquatic vegetation should be less than 5% cover. Cover of floating aquatic species should be negligible.
Wetbank vegetation: New sandy deposits should only be colonised by indigenous herbaceous species, such as *Cyperus textilis* and *Isolepis prolifer*, mature shrubs or trees of present fringing water throughout. There should be no bank collapse.

Lower Dynamic Zone: There should be no bank collapse and no invasion by herbaceous or woody exotic species.
Tree/shrub zone: The dry bank should be dominated by indigenous woody perennials. An indigenous grass cover should be present in the herbaceous stratum. There should be no invasive alien species. Post-fire recruitment should be dominated by woody indigenous perennials.
Floodplain: Should be 100% intact and have no invasion by woody exotic species.

9.1.4 Geomorphology

River type: Foothill gravel-bed river.

Active channel well defined, with stable well-vegetated banks. Cobbles not embedded. Flood channels well-defined and clear of obstacles. No bulldozing or artificial manipulation of the bed, banks, floodplain and no channelisation.

9.1.5 Water Quality

System variables:

TDS	:	< 45 mg l^{-1}
PH	:	7.0 – 8.0
DO	:	80 - 120% saturation
TSS	:	< 5 mg l^{-1}
Temperature	:	unmodified
Nutrients	:	PO_4/TP ratio : 0 – 10%
Median $P0_4$	:	< 0.01 mg l^{-1}
TN:TP ratio	:	> 20:1
Toxic substances	:	Meets the target water quality range for toxic substances as stated in the South African Water Quality Guidelines for Aquatic Ecosystems for 90% of the time, 99% of time less than or equal to chronic effect value, 100% of time less than the acute effect value.

9.1.6 Hydrology

No change to natural distribution flow regime.

9.2 PES, CAUSES AND ORIGIN, TRAJECTORY OF CHANGE

9.2.1 Fish

PES: C Class

The C Class ranking for this site was the result of the presence of two of the three expected eels species, as well as the estuarine vagrants at the site. Although bass and carp were present, they did not appear dominant.

CAUSES	ORIGINS	NON-/FLOW RELATED
Presence of carp and bass.	Introduction of alien species.	Non-flow related

Trajectory of Change: None

9.2.2 Aquatic Invertebrates

PES: C Class

The Lower Breede River has a SASS4 score = 87 and ASPT score = 6.9, an average diversity index of all sites (H' = 3.4) and a steep rank-abundance curve with the community dominated by Hydropsychidae. This dominance pattern has been attributed to the high flow conditions in the rapid, a relatively low disturbance regime and a high concentration of suspended organic matter. Two baetid species were recorded and the presence of sensitive taxa such as Leptophlebiidae suggests that this site is only moderately impacted.

CAUSES	ORIGINS	NON-/FLOW RELATED
Spill of fertilizer.	Point source accidental spillage.	Non-flow related
Reduction in habitat quality - algae growth on rocks (sediment and nutrients).	Abstraction - particularly of summer flows.	Flow related
	Farming runoff - increased sediment yield as a result of farming practices.	Non-flow related

Trajectory of change: None

Comparison of the results obtained during this study with an assessment conducted by Dallas (1998) at a site nearby suggests that conditions are stable (SASS4 score = 91, ASPT score = 5.53) and moderately modified.

9.2.3 Riparian Vegetation

PES: C Class

Aquatic vegetation: *Eichhornia crassipes* (water hyacinth) has been recorded in the reach in recent years.

Wetbank vegetation: The exotic woody invasive, *Sesbania punicea*, is the dominant shrub in places.

Lower Dynamic Zone: The Lower Dynamic Zone like the Back Dynamic Zone, particularly along the right (west) bank are dominated by vegetation subjected to grazing pressures, thus grasses, such as *Cynodon dactylon, Ehrharta calycina, Eragrostis curvula, Hyparrhenia hirta, Lolium multiflorum*, and herbaceous weeds, such as, *Anagallis arvensis*, *Chenopodium ambrosoides, Hypochoeris radicata, Rumex crispus, Solanum nigrum,* etc. are prevalent in the Lower Dynamic Zone and in the Tree/shrub zone.

Tree/shrub zone: Scattered *A. mearnsii* and tall invasive *Eucalyptus camaldulensis* trees line both banks in the Tree/shrub zone.

Back Dynamic Zone: The Back Dynamic Zone is more heavily invaded by *Acacia saligna* than the Tree/shrub zone, along both banks. Grazing also impacts on the vegetation in the zone.

CAUSES	ORIGINS	NON-/FLOW RELATED
Invasion by alien species (*Eucalyptus* and *Sesbania*) and annual weeds (in Wetbank Zone). This abets the narrowing of the channel.	Introduction and lack of management of alien species.	Non-flow related
	Agriculture.	Flow related
Presence of hyacinth, algae, instream macrophytes (increase). Low flows in summer combined with increased nutrients as a result of irrigation return flows.	Agriculture (abstraction).	Non-flow related
		Flow related
Increase in aliens in tree/shrub and Wetbank Zone due to late onset of winter flows. Puts stress on indigenous vegetation.	Dams retarding winter flows.	Flow related
Overgrazing.	Agriculture (sheep and cattle).	Non-flow related

Trajectory of change: Negative (Short term C Class - Long term C/D Class)
If the spread of alien plants in this reach is not addressed, the situation will worsen. Furthermore, over-grazing will exacerbate the spread of alien vegetation in the area.

9.2.4 Geomorphology

PES: B Class
There are clear impacts on the macro-channel in places, e.g., roads or tracks, camping sites, pump stations, however, these are not serious. The suspended sediment load will continue to increase (farming). In general the channel appears to be at or near equilibrium.

Trajectory of change: Negative (Short term B Class - Long term B/C Class)
Current (and further) attenuation of large floods will result in the channel becoming progressively narrower and the pools progressively shallower.

9.2.5 Water Quality

PES: C Class
The lower Breede River was assigned a C Class rating for two reasons. Irrigation return flows in the middle Breede River and its tributaries have increased salinity substantially in the middle Breede River. The inflow of the Riviersonderend River then dilutes the water in the Breede River resulting in an improvement in salinity downstream of the confluence. The Buffeljags River results in a further improvement in salinity in the Breede River. There are some point sources (e.g., Swellendam sewage works) that discharge into the Breede River upstream of the IFR Site 4.

Data were only available for the Breede River upstream of Buffeljags River and for the Buffeljags River at the Buffeljags Dam. Thus water quality conditions for IFR Site 4 were inferred from other disciplines.

Note - water quality between the IFR 3 and 4 reaches would be a low class, perhaps as low at a Class E.

Trajectory of change: Negative (Short term: C Class - Long term: C Class)
Small increasing trend (about 7.3 mg l^{-1} TDS per year) due to irrigation returns flows in the Middle Breede River.

9.2.6 Hydrology

PES: C Class
Approximately 58% of the natural MAR still flows down this reach each year. Also, despite the presence of one large dam (Theewaterskloof) and several smaller dams (e.g., Buffeljags, Satynskloof and Koekedouw) many of the floods and larger freshes still do occur. Summer low flows have been decreased by about 50%. No major instream dam on lower and middle main stem.

9.2.7 Ecostatus

The causes and origins are summarised as follows:

Non-flow related Presence of alien fish and vegetation species Return flows from agriculture (sediments and nutrients)

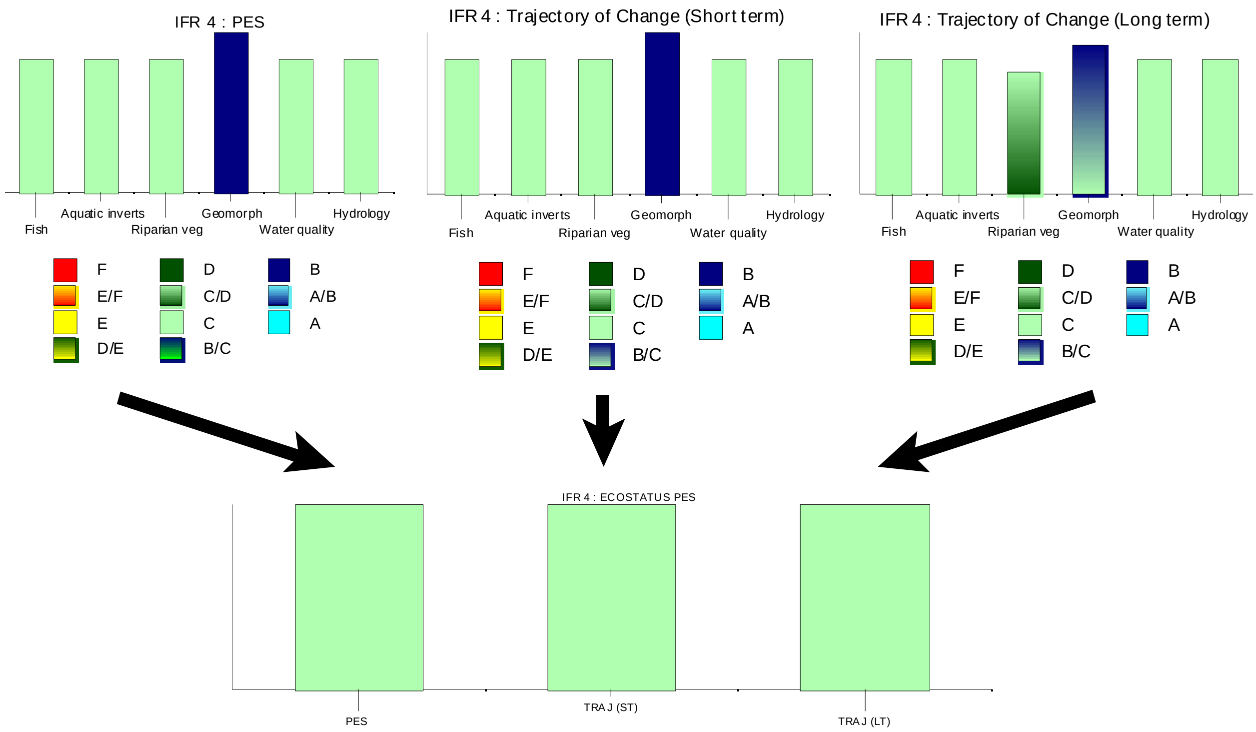

Figure 9.1 : Present Ecological Status (PES)

Geomorphology was in a B Class but the other components were all a C Class. Also, the geomorphology is predicted to have a negative trajectory. Thus, the overall ecostatus EC was set at a C Class.

9.3 ECOLOGICAL AND SOCIAL IMPORTANCE

EIS rating: High.
Confidence: High.
Determinants: Important for migration route. Conservation and natural areas.

Social rating: Moderate.
Confidence: Low.
Determinants: Recreation dependant on a healthy functioning ecosystem, as well as the aesthetic value.
AIM:
The EIS is high, the social importance is moderate. The PES is moderate (C Class) and the overall trajectory of change is stable. The high EIS provides motivation to improve the state if this is attainable.

9.4 ATTAINABLE EC

9.4.1 Fish

ORIGINS	FLOW RELATED ?	ACTION	DIFFICULTY
Alien fish.	Non-flow related	Remove fish.	Very difficult
PES C - EC C As the mitigation would be very difficult to implement successfully, the attainable EC for fish is to maintain the PES.			

9.4.2 Aquatic Invertebrates

ORIGINS	FLOW RELATED?	ACTION	DIFFICULTY
Agriculture (abstraction).	Flow related	Implementing the Reserve.	Reasonable
Agriculture (sediment and nutrients - run-off).	Non-flow related	Catchment management (e.g., buffer zones).	Difficult
PES C - EC B/C If catchment management and good agricultural practices were implemented, the invertebrate communities would be maintained in a C Class and possibly improve to a B/C Class. It is also possible that the effects of a fertiliser spill, which occurred 3-5 years ago, may be contributing to the Class C rating assigned to the invertebrates.			

9.4.3 Riparian Vegetation

ORIGINS	FLOW RELATED?	ACTION	DIFFICULTY
Agriculture (abstraction).	Flow related	Implement the Reserve.	Reasonable
Theewaterskloof (attenuation of winter flows).	Flow related	Implement the Reserve.	Reasonable
Agriculture (overgrazing).	Non-flow related	Catchment management.	Difficult
Introduction of alien vegetation.	Non-flow related	Management and clearing (Working for Water).	Reasonable/Difficult
Presence of hyacinth, algae, instream macrophytes.	Non-flow related	Reinstate buffer zones.	Reasonable/Difficult
	Flow related	Implement the Reserve.	Reasonable
PES C - EC C The riparian and instream vegetation in this reach is on a negative trajectory. Thus it is recommended that the attainable EC for vegetation would be to maintain the PES**.**			

9.4.4 Geomorphology

ORIGINS	FLOW RELATED?	ACTION	DIFFICULTY
Catchment activities (farming and tourism).	Non-flow related	Catchment management.	Difficult
PES B - EC B The channel geomorphology, which is in a better condition than the other components needs only to be maintained to achieve an overall improved ecostatus. There is however a negative trajectory of change and some non-flow related activities will have to be addressed to slow/halt the trajectory.			

9.4.5 Water Quality

ORIGINS	FLOW RELATED?	ACTION	DEGREE OF DIFFICULTY
Agriculture (salinities).	Non-flow related	Better agriculture practices. Buffer zones.	Reasonable/ Difficult
PES C - EC B The salinity issue is the major problem and if this is addressed, a higher class could be achieved.			

9.4.6 Summary of Attainability and Ecostatus EC

Non-flow related impacts, such as irrigation return flows and overgrazing are the major reasons for the decline in condition of the river reach represented by IFR Site 4. If measures to mitigate these, such as the creation of buffer riparian zones and overall improved catchment management, were implemented then the negative trajectory for vegetation and geomorphology could be halted. Indeed, if the non-flow related impacts were reduced, and provided other factors did not worsen, there could be an improvement from the overall ecostatus Class C to a C/B Class.

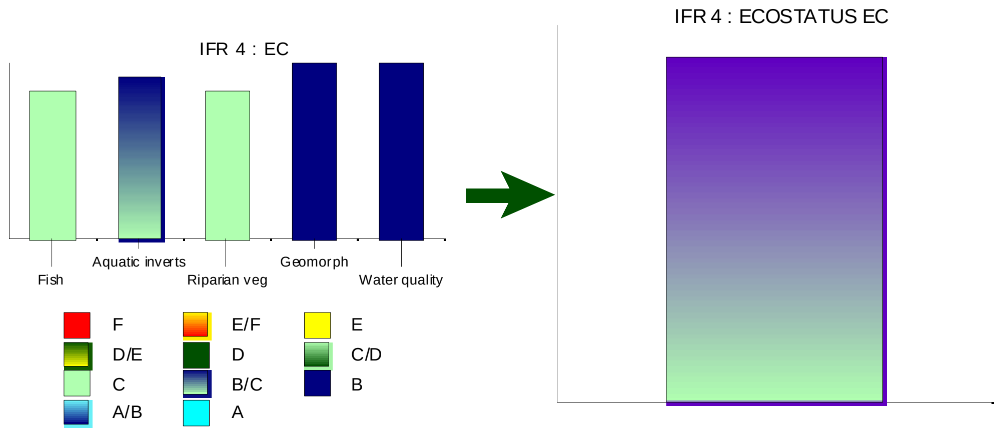

Figure 9.2 : Ecological Class (EC)

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	C	0	C	C	VERY HIGH	
Water quality	C	-	C	C		B
Geomorphology	B	-	B	B/C		B
Riparian veg	C	-	C	C/D		C
Fish	C	0	C	C		C
Aquatic inverts	C	0	C	C		B/C
Ecostatus	C	0	C	C		B/C
					Long term EC	B/C

Figure 9.3 : Summary of PES and EC

9.5 OBJECTIVES

9.5.1 Fish

EC: C
General flow objectives: Maintain low flows during summer.
Overall fish objectives: To maintain and enhance populations of the remaining indigenous fish.
Objectives for target/indicator species: Pools must be maintained at > 1.8 m depth to provide eel habitat. Maintain the connection between the estuary and the river for facultative catadromous species and estuarine vagrants.

General flow objectives: Maintain summer floods, freshettes
Overall fish objectives: Emigration and recruitment of catadromous species
Objectives for target/indicator species: High flows facilitate the migration and recruitment of catadromous species.

9.5.2 Aquatic Invertebrates

EC: B/C
General flow objectives: Maintain summer low flows.
General objectives for the invertebrate component:

- Maintain a SASS4 score ≥ 87 and ASPT score ≥ 6.9.
- Maintain diversity index at a minimum of *H*' = 3.4.
- Maintain a community including Hydropsychidae, Leptophlebiidae, Ecnomidae, Philopotamidae, Cyrenidae and Baetidae (riffles).

Identification of and objectives for target species: It is preferable to aim at maintenance of the above community characteristics rather than focussing on target species.

9.5.3 Riparian Vegetation

EC: C Class
Note that the river deposits in the Back Dynamic and Tree-shrub zone on both banks are slightly saline and nutrient rich, possibly because of low rainfall and rainfall introducing salts from surrounding Bokkeveld Shales. That may explain why the river reach supports an arid zone river *Acacia karroo* community.

The right bank at this site has exposed shale bedrock in the Tree-shrub to Back Dynamic Zone which has attenuated and disrupted identification of change-over points between these zones.

The riffle zone is already showing signs of terrestrialisation on the left side. The next stage from an absence of fresher water would be an invasion by *Paspalum dioicum* and the addition of river deposits in the grass mat that would speed up terrestrialisation and channel shape change dramatically. *Eucalyptus camaldulensis*, *E. cladocalyx* and *Sesbania punicea* are already establishing on the banks in this reach as this process continues.

Back Dynamic Zone

General flow objectives: To maintain the zone (1:20-1:50 year flood).

General objectives for the riparian component: Required to form channels, to mobilize debris, to move/deposit sediments.

Objectives for target/indicator species: Acacia karroo.

Tree-Shrub zone

General flow objectives: To maintain existing plants by depositing silt and debris (1:5 to 1:20 year floods). To promote seedling and juvenile establishment and maintenance (1:2 year and Class IV floods).

General objectives for the riparian component: To reduce stress on indigenous plants to restrict alien species invasions.

Objectives for target/indicator species: To expand distribution of the zone as it has been damaged, i.e., to restore density of stands of woody species (e.g., *Acacia karroo, Morella serrata*) coupled with alien woody (*Acacia cyclops, A. mearnsii, A. saligna, Eucalyptus sp.*).

Lower Dynamic Zone

General flow objectives: To maintain zone in near natural state to prevent channel shape change (steepening and narrowing of banks) caused by change to vegetation (1:2 year and Classes III and IV floods).

General objectives for the riparian component:

- To prevent alien annuals and then alien woody establishment through flushing flows.
- To allow deposition or erosion to take place on an annual winter basis.

Objectives for target/indicator species: Indigenous annual herbs should occur in the zone, and limited downward movement of tree and shrub species (see species listed for Tree Shrub zone) is expected.

Wetbank Zone

General flow objectives: To maintain this zone to prevent excessive channel shape change (steepening and narrowing of banks) that accompanies vegetation changes (Class II - III floods and 5% winter baseflow).

General objectives for the riparian component:

- To prevent the establishment of annual and woody aliens.
- To allow deposition or erosion to take place on an annual basis.
- To keep salinities down.
- To reinstate freshets lost from Theewaterskloof-Holsloot-Koekedouw-Buffeljags Dams and farm dams, particularly during autumn and at the beginning of winter.

Objectives for target/indicator species: Maintain *Cyperus textilis*, *Prionium serratum*, *Phragmites australis*, *Morella serrata*, *Salix mucronata* and *Metrosideros angustifolia*. To restrict increase in *Phragmites* that would result through increased salinities anticipated and probably already present (see water quality).

Aquatic Zone

General flow objectives: To maintain this zone to prevent channel shape change (steepening and narrowing of banks) caused by changed vegetation (50-99% winter baseflow and summer flows).

General objectives for the riparian component:

- To ensure zone plants are inundated during most of winter.
- To ensure that the soil will be wetted through capillary action when exposed.
- To ensure the zone is wet regularly for fairly long periods in winter (with fluctuations in levels).

Objectives for target/indicator species: Target/indicator species objectives are to allow *Potamogeton* beds to increase in summer and decrease in winter and to ensure *Prionium* remains healthy and does not deteriorate if salinities increase.

9.5.4 Geomorphology

To maintain current conditions, lesser and major floods should be retained in future.

9.5.5 Water Quality

EC: B

TDS	:	Maintain TDS during summer months (Oct – April) < 800 mg l^{-1} (C Class) for 95% of the time, TDS during winter months (Jun-Sept) at < 300 mg l^{-1} (B Class) for 95% of the time.
pH	:	Maintain within current range of 7.2 – 8.2 for 95% of the time.
Dissolved oxygen	:	Maintain between 80-100% of saturation. (B Class).
Water temperature	:	Maintain within 4 deg C of the seasonal range observed at a lower Breede River reference site.
Total suspended solids	:	Velocities should be high enough to prevent sedimentation and biofilm formation in riffles. Maintain within 20% of the seasonal range of a lower Breede River reference site.
Nutrients	:	Median PO_4 concentration < 0.05. PO_4:TP ratio: < 40%. TN:TP ratio > 5:1. Median NH_3-N : 0.3 mg l^{-1}. Maintain winter NO_2NO_3-N concentrations at <1 mg l^{-1} and summer concentrations < 0.3 mg l^{-1}.
Toxic substances	:	Maintain toxic substances at ≤ CEV for 75% of the time and ≤ AEV for 90% of the time as specified in the SAWQG for aquatic ecosystems.
Other comments	:	IFR Site 4 is situated downstream of the DWAF salinity management point at Zanddrift canal.

The IFR Site 4 is situated downstream of the Buffeljags River that probably improves water quality in the stream.

9.6 MAINTENANCE FLOW ASSURANCE

The assurance of maintenance low flows during winter is set as a flow that occurs 70% of the time. The assurance of maintenance low flows during summer is set as a flow that will occur 60% of time.

9.7 SEASONAL DISTRIBUTION

February was selected as the highest flow month and August was selected as the lowest flow month.

9.8 IFR RESULTS

9.8.1 Low Flow Motivations

Each flow is motivated by the specialists and documented by them. The motivations for these flows are provided below.

MAINTENANCE LOW (DRY SEASON, FEBRUARY) $3.0\ m^3\ s^{-1}$

Descriptions of flow required:
0.14 - 0.18 m depth in pool habitat around bedrock islands and sills (fish). Maintenance in summer = 4 $m^3\ s^{-1}$ or 4.24 m flow depth at IFR4A.

Primary motivation:
Aquatic invertebrate: Maintenance of riffle habitat for flow-sensitive taxa, maintenance of wetted perimeter. (Note : Hydraulic data low confidence, especially low velocities. Relied on wetted perimeter data from transects. Lower flows will lead to major loss of wetted perimeter, reduced habitat availability and connectivity).
Source: Invertebrate samples for this study, photos, profile, SVD histograms, available literature.
Riparian vegetation: *Potamogeton* beds to be maintained. *Prionium serratum* to root and establish in new bare areas. To keep water fresh. To provide water through capillary action to Wet Bank plants. Lower flows will result in loss of *Potamogeton* into seed form. *Prionium* will not reproduce vegetatively. Wetbank vegetation will be stressed during dry period. Algae will increase.
Source: Own data, site visits, students' studies.

Secondary motivation:
Fish: Maintenance of eel habitat. At lower flows eels will move to another part of the river, causing knock on high stress to the species resident there.
Source: This study.

Water quality consequences:
The objective is to maintain a C Class, i.e., TDS < 800 (Oct - Apr) and <300 mg 1^{-1} (Jun-Sept). The high TDS in summer is the result of irrigation return flows. The recommended flow will

probably keep the TDS in a C Class (estimated to be about 680 mg l^{-1}) because the Buffeljags River will have an increased dilution effect from what is observed at H7H006Q01 (Breede River at Swellendam). During summer, nitrates are not a problem because they are only mobilised during runoff events. The flow will be sufficient to move moderate amounts of clay/silt/sand and gravel which will probably prevent the formation of biofilm on rocks.

MAINTENANCE LOW (WET SEASON, AUGUST) $31\ m^3\ s^{-1}$

Descriptions of flow required:
31 $m^3\ s^{-1}$ or 4.7 m flow depth at IFR4A.

Primary motivation:
Aquatic invertebrates: Inundation of secondary channels and flood plain areas, increasing available wetted perimeter and habitat for riffle communities. Lower flows will lead to loss of habitat areas in secondary channels and flood plain areas, reduced abundances for riffle taxa.
Source: Invertebrate samples for this study, photos, profile.
Riparian vegetation: Maintenance *of Potamogeton* beds and *Prionium serratum* and other Wet Bank plants to recover from dry period. To keep water fresh. To reduce algae. To keep *Eichhornia* populations down. Lower flows will result in an increase in *Potamogeton* beds and floating *Eichhornia* mats. *Prionium* and Wetbank vegetation will not recover from dry season and vegetation zone will become increasingly invaded by woody exotic plants while deaths will occur during subsequent dry period. Algae will be prevalent in water even during winter.
Source: Own data, site visits, students' studies.

Secondary motivation:
Fish: Maintain sufficient depth for eel habitat in pool and around bedrock sills and islands.

Water quality motivation:
The objective is to maintain the lower Breede River in a B Class during winter (<300 mg l^{-1} TDS). The high TDS observed during the summer months is diluted with good quality runoff during the winter months, specifically from the Riviersonderend. The recommended flow will probably keep the TDS in a high B Class with occasional excursions into a C Class (estimated to be 320 mg l^{-1}). The Buffeljags River will further improve quality at the IFR site relative to that recorded at H7H006Q01 (Breede River at Swellendam). Elevated nitrogen concentrations will probably remain within the target of 1 mg l^{-1} because [NO_3] is a function of wash-off from the catchment. The flow will be sufficient to move moderate amounts of clay/silt/sand, gravel and embedded sand and silt, which will probably prevent the formation of biofilm on rocks.

DROUGHT LOW (DRY SEASON, FEBRUARY) $1.6\ m^3\ s^{-1}$

Descriptions of flow required:
Maintenance in summer = 1.4 $m^3\ s^{-1}$ or 4 m flow depth at IFR4A.

Primary motivation:
Riparian vegetation: *Potamogeton* beds to survive. *Prionium serratum* and Wetbank plants to survive. Lower flows will result in loss of *Potamogeton* into seed form. *Prionium* and Wetbank vegetation will be stressed and deaths will occur during dry period. Algae will dominate water.

Secondary motivation:
Fish: Maintain connections between pools, allows along-stream movement for all species in the fish community. Lower flows will lead to food limitation in pool, deterioration in water quality, increase in parasite loads of fish, loss of much marginal habitat in pool.
Source: This study, literature.
Aquatic invertebrate: Some remaining velocities for remnant flow-sensitive taxa. Lower flow will lead to loss of wetted perimeter and decrease in average velocities leading to loss of riffle communities.

Water quality consequences:
During droughts, irrigation return flows will probably continue but river flow (in Riviersonderend and Buffeljags) to dilute the return flows will probably be reduced. The recommended flow will probably result in higher TDS concentrations during the summer months and will probably deteriorate to a low D Class (estimated to be about 840 mg l^{-1}). The flow will be sufficient to move moderate amounts of clay/silt/sand and gravel which will probably prevent the formation of biofilm on rocks.

DROUGHT LOW (WET SEASON, AUGUST) 18 $m^3 s^{-1}$

Descriptions of flow required:
Flow depth of 4.5 m depth at IFR Site 4 A.

Primary motivation:
Riparian vegetation: Restrict *Potamogeton* beds and for survival of *Prionium serratum* and other Wetbank plants. To keep water fresh. To keep algae and *Eichhornia* populations down. Lower flows will result in the following: *Potamogeton* beds will increase considerably. *Prionium* and Wetbank vegetation will not recover from dry season and vegetation zone will become increasingly invaded by woody exotic plants while extensive deaths will occur during subsequent dry period. Algae will be very prevalent in water even during winter. Very extensive *Eichhornia* mats will cover large parts of river.
Source: Own data, site visits, students' studies.

Secondary motivation:
Fish: Maintenance of eel habitat. Lower flows will result in eels moving to other areas causing high stress to resident species.
Aquatic invertebrates: Maintain perenniality, *viz.* 95 percentile on the August flow duration curve.

Water quality consequence:

During the winter, very little irrigation takes place and return flows are much lower. TDS concentrations during the drought wet season flows will probably remain in a high B Class and infrequent excursions into a C Class (estimated to be 450 mg l^{-1}). Nitrate concentrations will probably improve because less will be washed off the catchment during a drought.

9.8.2 Motivations : High Flows

TABLE 9.1 : FLOOD REQUIREMENTS FOR IFR SITE 4 (adjusted at scenario meeting*)

FLOOD CLASS	MONTHLY DISTRIBUTION	PEAK SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NUMBER OF EVENTS				
			NATURAL	PRESENT DAY	B/C	B	C
I	10 and 4	26	3	4	4	4	2
II	5-6	59	4	4	1	1	2
III	8-10	119	4	3	3	3	2
IV	6-9	233	3	2	1	1	1
1 : 2	714						
1 : 5	878						
1 : 10	1576						
1 : 20	2 335						

** at the scenario meeting, the specialists agreed that in order to ensure that IFR Site 4 was maintained in a B or B/C class the frequency of within year flood events needed to approximate that of present day conditions.*

9.8.3 IFR Table

The results as motivated above are presented in the Table 9.2.

TABLE 9.2 : IFR TABLE: IFR SITE 4 - B/C CLASS

IFR 4: BREEDE RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) MAR (VIRGIN): 1719.56 $10^6 m^3$ MAR (PRESENT): 1059.31 $10^6 m^3$										
MONTHS	MAINTENANCE LOW FLOWS			HIGH FLOWS				DROUGHT LOW FLOWS		
	DEPTH	FLOW ($m^3 s^{-1}$)	VOLUME ($10^6 m^3$)	DEPTH[4]	FLOW ($m^3 s^{-1}$) Daily average	DURATION	VOLUME[1] ($10^6 m^3$)	DEPTH	FLOW ($m^3 s^{-1}$)	VOLUME ($10^6 m^3$)
Oct	1.30	17.2	46.1	*c.* 8.3	26.04	4	4.7	1.10	9.2	24.6
Nov	1.18	12.6	32.6	*c.* 8.3	26.04	4	4.7	0.90	7.0	18.2
Dec	0.82	5.7	15.7					0.63	3.8	10.3
Jan	0.76	5.1	13.7					0.57	3.5	9.4
Feb	0.82	6.1	14.8	*c.* 8.3	26.04	4	4.7	0.63	4.1	9.9
Mar2	0.64	3.9	10.5					0.45	2.9	7.8
Apr	0.85	6.3	16.3	*c.* 8.3	26.04	4	4.7	0.64	4.1	10.6
May	0.90	7.3	19.6	1.5		5		0.69	4.5	12.1
Jun	1.26	13.8	35.8		59.55 & 119.5	4 & 5	54.9	1.00	7.6	19.8
Jul	1.32	17.9	48.0		119	5	24.5	1.10	9.5	25.5
Aug3	1.5	24.6	65.8		232	6	53.2	1.27	12.7	33.9
Sep	1.42	22.3	57.8		119.5	5	24.5	1.26	11.6	30.2
TOTAL			376.55				176			212.4
% OF MAR (VIRGIN)			**21.90**				**10.24**			**12.35**
Long term % of MAR (VIRGIN): 33.8 (581.8 MCM)										
1	The volume represents the daily average less the low flows									
2	February was the month identified by the specialists to determine the dry season flows.									
3	August was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Cross-section 2 was used to calculate the depths provided.									
5	Distributions: Drought = 2. Main. = 3.87									

9.8.4 IFR Rule Table

For information regarding the IFR rule table, see 6.8.4.

The IFR rule table for IFR Site 4 is provided in Table 9.3.

TABLE 9.3 : IFR RULE TABLE – B/C CLASS

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

MAR	=	1719.565
S.Dev.	=	697.912
CV	=	0.406
Q75	=	28.420
Q75/MMF	=	0.198
BFI Index	=	0.411
CV(JJA+JFM) Index	=	2.179

IFR Management Class = B/C

Total IFR	=	552.550 (32.13 %MAR)
Maint. Lowflow	=	376.545 (21.90 %MAR)
Drought Lowflow	=	212.383 (12.35 %MAR)
Maint. Highflow	=	176.005 (10.24 %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	123.103	74.288	0.603	46.066	24.632	4.725	50.791
Nov	87.228	68.014	0.780	32.550	18.252	4.725	37.275
Dec	42.493	27.806	0.654	15.696	10.295	0.000	15.696
Jan	30.617	60.698	1.982	13.721	9.362	0.000	13.721
Feb	29.743	41.983	1.412	14.814	9.878	4.725	19.539
Mar	31.170	23.933	0.768	10.451	7.819	0.000	10.451
Apr	73.516	85.057	1.157	16.305	10.582	4.725	21.030
May	175.952	178.711	1.016	19.574	12.125	0.000	19.574
Jun	261.688	215.830	0.825	35.837	19.803	54.934	90.770
Jul	307.711	205.673	0.668	47.991	25.541	24.470	72.461
Aug	350.745	309.211	0.882	65.759	33.929	53.233	118.992
Sep	205.598	114.636	0.558	57.781	30.163	24.470	82.251

9.8.5 IFR Time Series

For an explanation, refer to 6.8.5

The representative time series for the IFR sites is given in Table 9.4.

TABLE 9.4 : FINAL RESULTS FOR A TIME SERIES 1927 - 1990 ($10^6 m^3$) - B/C CLASS

Total Runoff : R Site 4 BIFR S
IFR Modified Flow Data Management Class B/C

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1927	25.676	41.857	11.465	14.712	9.200	13.031	19.800	7.930	106.318	64.445	98.395	95.537	508.366
1928	35.239	45.721	19.386	13.915	8.480	12.867	25.338	22.479	91.559	96.110	149.900	52.861	573.854
1929	32.074	19.499	19.359	16.927	23.578	13.031	19.384	12.202	21.550	28.342	119.636	115.524	441.106
1930	60.258	41.444	13.081	16.776	14.800	12.689	25.605	24.218	56.156	78.119	167.861	105.917	616.925
1931	62.661	45.334	19.405	16.966	23.578	12.832	11.900	23.680	98.575	82.270	62.084	119.488	578.774
1932	62.507	37.205	13.901	10.577	11.650	9.313	8.040	19.146	106.717	101.940	149.046	69.066	599.107
1933	42.575	40.117	15.620	16.507	23.000	12.607	11.680	20.640	82.811	53.461	118.046	104.537	541.601
1934	62.661	45.832	19.242	12.759	15.700	11.444	25.191	24.248	99.316	78.652	111.034	82.868	588.946
1935	36.024	44.522	17.354	16.778	12.160	9.734	8.150	21.048	46.390	76.888	141.797	99.246	530.092
1936	46.604	45.832	19.405	16.966	13.060	13.031	24.711	23.505	106.691	100.935	65.107	45.177	521.023
1937	36.574	33.233	19.301	16.966	10.890	12.640	25.500	24.127	78.495	53.932	102.723	99.747	514.127
1938	46.747	43.890	18.306	13.437	23.578	13.031	24.586	24.035	53.254	36.247	158.311	90.151	545.573
1939	31.065	20.098	10.810	9.589	23.578	13.018	25.605	21.444	103.728	62.770	39.855	43.714	405.273
1940	30.002	45.763	19.042	16.966	12.820	8.130	25.605	24.390	106.717	94.756	154.707	119.488	658.385
1941	62.661	45.334	18.471	16.966	14.680	8.590	9.190	24.373	106.717	67.966	125.861	33.009	533.818
1942	45.730	30.925	19.405	16.966	23.578	12.985	24.562	15.871	96.122	88.103	161.769	110.052	646.068
1943	61.574	45.832	19.405	14.422	8.310	11.997	18.150	24.312	106.717	78.923	152.794	108.516	650.953
1944	62.327	42.727	16.234	10.206	7.870	5.710	17.602	24.390	106.717	103.792	171.091	78.012	646.678
1945	62.661	45.777	14.792	10.598	8.950	13.031	24.689	14.790	33.531	33.712	71.267	116.073	449.871
1946	59.970	20.462	10.352	8.710	6.950	13.031	24.476	17.900	50.888	99.238	116.100	55.257	483.334
1947	54.181	38.771	11.306	13.252	9.400	13.011	23.947	23.617	84.217	86.670	48.985	117.564	524.920
1948	62.661	45.832	11.515	10.876	7.820	4.990	24.602	16.177	68.074	70.180	121.945	96.043	540.716
1949	61.620	45.832	19.405	11.927	7.750	5.150	25.605	12.897	29.682	101.794	43.911	107.717	473.290
1950	59.442	45.832	19.405	16.966	23.578	11.419	25.563	16.260	106.717	86.933	85.423	105.999	603.538
1951	60.488	45.423	13.368	11.048	12.990	9.212	12.740	24.237	91.160	86.904	173.413	119.488	660.472
1952	62.050	45.832	19.405	16.266	10.750	6.920	25.605	24.390	82.149	96.771	134.964	41.263	566.364
1953	54.145	45.120	18.168	12.204	9.180	10.237	25.477	24.390	106.325	103.792	177.272	104.716	691.026
1954	58.948	37.545	17.534	16.783	23.578	13.031	18.533	12.747	101.479	100.828	177.272	93.031	671.310
1955	62.661	45.358	16.742	15.308	10.990	11.932	14.961	23.875	106.461	91.236	152.543	62.150	614.215
1956	56.809	31.298	18.839	16.186	23.578	12.954	21.313	24.390	106.717	103.792	173.461	105.193	694.529
1957	62.661	45.592	14.364	9.994	19.970	12.901	21.182	24.390	103.944	29.199	145.394	54.483	544.074
1958	51.180	36.213	10.699	16.816	23.510	12.496	25.605	24.390	90.317	70.753	157.397	78.703	598.078
1959	62.661	43.749	12.109	15.583	9.390	11.859	17.803	23.511	105.781	46.013	39.855	33.009	421.323
1960	25.340	18.894	14.754	16.966	14.930	10.404	21.157	21.064	96.637	62.709	135.579	115.284	553.717
1961	60.427	32.271	10.560	15.837	19.790	12.936	25.382	14.175	106.717	90.464	177.272	116.752	682.584
1962	62.661	45.832	19.405	16.799	12.100	13.031	23.337	19.980	75.336	87.473	172.927	70.978	619.861
1963	42.223	41.845	19.115	16.879	23.578	13.006	22.828	16.133	106.717	84.298	160.668	84.017	631.307
1964	59.586	45.832	19.311	16.308	22.040	13.031	25.405	24.281	89.504	60.865	107.229	35.698	519.090
1965	62.391	45.633	19.361	16.955	12.960	13.010	23.296	14.401	100.886	92.716	153.528	100.155	655.292
1966	37.634	18.894	10.352	9.410	11.330	12.224	25.605	24.339	106.717	73.183	83.366	64.811	477.864
1967	61.996	44.059	16.156	14.900	8.320	6.630	24.128	24.390	106.071	94.874	150.023	52.058	603.604
1968	62.661	45.047	18.020	16.664	14.410	9.411	25.303	14.786	71.873	45.777	69.499	98.665	492.117
1969	62.510	25.919	10.495	11.277	22.240	10.552	8.570	21.816	105.089	87.601	162.083	96.685	624.839
1970	54.743	28.742	18.078	11.631	23.480	12.936	25.545	17.814	62.620	95.587	165.687	66.559	583.422
1971	25.340	44.458	13.843	12.149	20.590	11.021	19.445	24.035	94.074	38.339	99.818	76.827	479.938
1972	27.008	34.242	12.784	9.584	8.650	12.113	22.537	12.658	24.720	97.404	122.401	76.437	460.538
1973	40.566	23.848	19.163	16.663	23.578	12.219	15.249	22.284	105.231	63.766	177.272	117.456	637.294
1974	62.458	45.381	18.558	16.607	13.430	10.803	24.579	24.390	102.896	91.019	148.662	77.842	636.625
1975	55.060	40.233	18.524	14.775	17.060	12.881	21.710	17.907	106.717	98.288	108.343	47.254	558.749
1976	62.328	45.832	19.405	16.966	23.578	12.939	25.605	24.390	106.717	103.792	177.272	101.658	720.481
1977	59.302	44.745	19.405	16.966	14.040	11.509	25.183	20.330	34.891	28.342	143.464	94.286	512.463
1978	61.972	41.608	19.187	16.157	23.578	12.985	15.540	23.341	105.155	74.960	125.888	102.447	622.819
1979	62.661	43.749	12.405	16.931	14.440	9.518	24.272	23.371	95.648	55.199	86.101	44.428	488.723
1980	50.113	45.832	19.405	16.966	23.578	13.031	25.605	22.623	71.980	94.467	168.075	119.488	671.165
1981	60.482	38.231	19.355	16.913	17.020	12.933	25.605	24.288	100.564	73.656	78.570	86.372	553.989
1982	55.425	29.753	18.772	13.951	20.310	12.685	15.498	24.390	106.717	103.792	122.811	112.791	636.896
1983	61.701	40.042	17.379	15.275	21.440	13.031	23.610	24.390	99.949	94.994	96.120	119.488	627.419
1984	62.661	45.641	19.405	16.966	23.577	13.031	25.463	21.804	106.182	102.658	165.499	83.609	686.496
1985	62.527	45.832	19.405	16.966	15.090	12.658	25.476	23.369	104.438	92.519	177.272	113.061	708.613
1986	61.179	44.601	16.365	16.515	9.250	10.132	25.545	24.390	105.654	82.158	167.365	102.638	665.792
1987	58.410	21.799	19.270	9.566	10.220	12.355	25.605	23.588	103.048	73.390	137.981	109.935	605.167
1988	54.246	27.002	16.705	13.807	13.960	13.031	25.605	24.165	103.626	86.697	156.224	119.488	654.555
1989	62.661	45.832	19.181	16.045	23.530	12.659	25.605	24.358	106.088	101.769	127.254	35.837	600.818
1990	42.525	23.754	18.542	16.899	23.457	11.438	16.183	23.706	106.687	103.792	125.114	113.317	625.414
Mean	53.373	39.050	16.717	14.706	16.163	11.547	21.675	21.202	90.018	79.563	129.978	87.811	581.803

The IFR time series illustrated for the above 60 years and compared to natural and present flows are as follows (Note: Due to the rate in rise, the summer spates are not picked up clearly by the model):

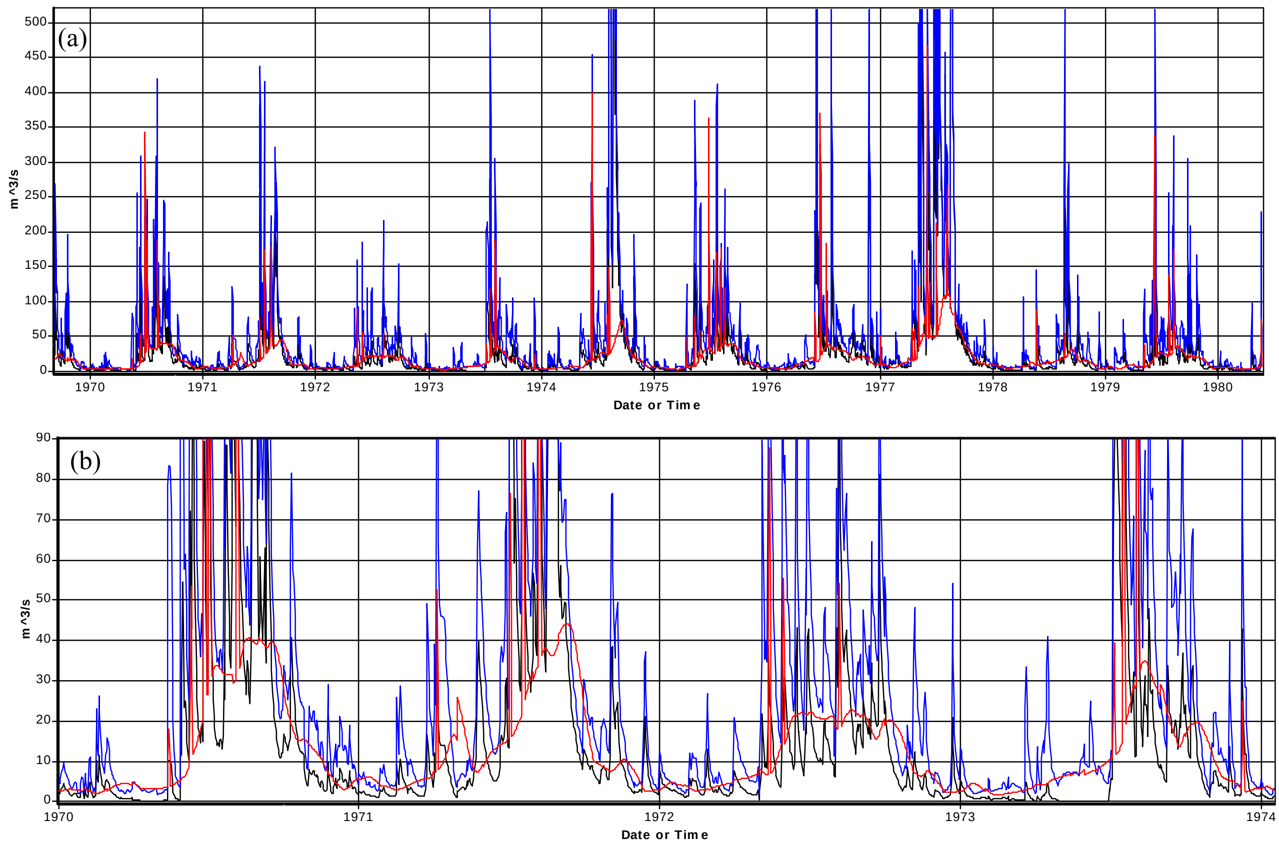

Figure 9.4 : IFR time series between (a) 1970 – 1980 and (b) 1970 – 1974 (red line = IFR; blue line = Virgin, black line = Present Day)

9.9 SCENARIO RESULTS

The scenario results were extrapolated from the B/C Class results generated during the specialist meetings. The desktop % of MAR for estimated reserves for the relevant classes were used and then proportionately scaled using the specialist meeting B/C Class result. The desktop results for the B and C Class was then changed to suit the seasonal distribution established by the specialist meeting, and then the overall volumes were changed to equal the required percentage.

TABLE 9.5 : SUMMARY OF INFORMATION USED FOR EXTRAPOLATION.

DESKTOP % OF MAINTENANCE LOW FLOWS	IFR % OF MAINTENANCE LOW FLOWS (SPECIALIST MEETING AND EXTRAPOLATED)	SEASONAL DISTRIBUTION FACTOR (ACCORDING TO DESKTOP)
21.7 B Class	29.76	Drought: 4.61
17.5 B/C Class	21.87	Maintenance: 2.68
12.7 C Class	17.42	

* Results as specified in the specialist meeting

9.9.1 B Class Results

TABLE 9.6 : IFR TABLE - B CLASS

IFR Table for Breede IFR4HB
Latitude 0.00, Longitude 0.00
Natural MAR = 1719.565

Note : MLIFR -> Maintenance Low Flows
: DLIFR -> Drought Low Flows
: MHIFR -> Maintenance High Flows
: DHIFR -> Drought High Flows
: MHDur -> Event Duration for MHIFR
: DHDur -> Event Duration for DHIFR
: High flows (MHIFR & DHIFR) represent peaks less low flows.
: Where there are two or more high flow events, they are lumped together

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLIFR												
(m^3/s)	25.260	17.200	5.903	4.644	5.913	2.560	6.501	8.375	19.365	26.487	37.812	33.818
(MCM)	67.657	44.583	15.811	12.439	14.306	6.857	16.850	22.430	50.194	70.944	101.276	87.657
(%MAR)	3.93	2.59	0.92	0.72	0.83	0.40	0.98	1.30	2.92	4.13	5.89	5.10
DLIFR												
(m^3/s)	10.780	7.172	2.153	1.592	2.106	0.663	2.404	3.255	8.137	11.327	16.374	14.578
(MCM)	28.873	18.590	5.767	4.264	5.096	1.777	6.230	8.717	21.090	30.338	43.856	37.786
(%MAR)	1.68	1.08	0.34	0.25	0.30	0.10	0.36	0.51	1.23	1.76	2.55	2.20
MHIFR												
(m^3/s)	26.000	26.000	0.000	0.000	26.000	0.000	26.000	179.000	119.500	232.500	119.500	0.000
(MCM)	4.717	4.717	0.000	0.000	4.717	0.000	4.717	54.903	24.470	53.233	24.470	0.000
(%MAR)	0.27	0.27	0.00	0.00	0.27	0.00	0.27	3.19	1.42	3.10	1.42	0.00
(Days)	4	4	0	0	4	0	4	9	5	6	5	0
DHIFR												
(m^3/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(MCM)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(%MAR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(Days)	0	0	0	0	0	0	0	0	0	0	0	0

Annual Totals

	MLIFR	DLIFR	MHIFR	DHIFR	Maint.	Drought
MCM	511.005	212.383	175.945	0.000	686.950	212.383
% Nat. MAR	29.72	12.35	10.23	0.00	39.95	12.35

TABLE 9.7 : IFR RULE TABLE - B CLASS

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

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	32.116	32.116	31.929	31.504	30.600	28.819	25.648	20.771	14.883	11.088
Nov	22.547	22.547	22.412	22.107	21.458	20.179	17.902	14.401	10.173	7.449
Dec	7.053	7.053	6.997	6.857	6.550	5.963	5.017	3.806	2.697	2.184
Jan	5.548	5.548	5.503	5.390	5.142	4.668	3.904	2.926	2.031	1.617
Feb	9.197	9.197	9.118	8.180	6.118	5.551	4.816	3.886	3.067	2.345
Mar	3.057	3.057	3.036	2.988	2.886	2.684	2.325	1.774	1.108	0.678
Apr	9.758	9.758	9.694	9.550	9.244	8.640	7.565	5.912	3.916	2.630
May	32.427	32.427	32.186	31.642	30.483	28.200	24.136	17.885	10.337	5.474
Jun	33.469	33.469	33.309	32.982	32.325	31.030	28.557	24.070	16.746	9.233
Jul	67.022	63.323	59.928	56.805	53.675	47.610	43.745	36.734	25.291	13.553
Aug	61.450	59.749	58.061	56.364	54.400	50.579	46.827	40.021	28.914	17.519
Sep	40.419	40.419	40.190	39.671	38.568	36.393	32.520	26.564	19.373	14.740
Natural Duration curves										
Oct	87.033	61.593	47.764	40.842	37.578	34.046	30.615	26.714	21.263	18.963
Nov	72.330	45.926	34.410	28.684	23.920	21.725	18.248	16.381	14.776	11.520
Dec	33.953	20.859	15.722	14.147	12.433	10.805	10.290	9.476	8.658	6.153
Jan	16.405	10.659	9.278	8.065	6.549	5.731	5.604	5.485	4.831	4.055
Feb	34.131	16.179	9.507	8.180	6.118	5.551	4.816	3.886	3.505	3.204
Mar	24.369	20.322	13.788	10.768	9.382	7.180	5.447	4.768	3.207	1.923
Apr	78.102	39.363	29.078	21.404	16.744	12.998	10.015	7.967	4.915	3.144
May	185.144	96.024	67.107	53.476	41.066	37.101	27.300	21.330	15.252	7.348
Jun	262.361	155.529	132.859	95.571	76.142	57.840	44.522	34.691	20.243	9.537
Jul	241.301	162.642	137.675	111.992	101.699	82.012	65.703	53.024	38.004	24.194
Aug	283.434	160.506	134.170	119.411	99.167	84.181	73.839	60.611	54.514	32.796
Sep	149.622	114.294	92.882	75.652	68.951	56.613	48.495	43.688	36.420	30.502

9.9.2 C Class Results

TABLE 9.8 : IFR TABLE - C CLASS

Note : MLIFR -> Maintenance Low Flows
: DLIFR -> Drought Low Flows
: MHIFR -> Maintenance High Flows
: DHIFR -> Drought High Flows

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MLIFR												
(m^3/s)	14.930	10.096	3.336	2.582	3.321	1.334	3.688	4.817	11.393	15.665	22.448	20.050
(MCM)	39.990	26.170	8.936	6.917	8.035	3.574	9.559	12.901	29.530	41.958	60.126	51.969
(%MAR)	2.33	1.52	0.52	0.40	0.47	0.21	0.56	0.75	1.72	2.44	3.50	3.02
DLIFR												
(m^3/s)	10.780	7.172	2.153	1.592	2.106	0.663	2.404	3.255	8.137	11.327	16.374	14.578
(MCM)	28.873	18.590	5.767	4.264	5.096	1.777	6.230	8.717	21.090	30.338	43.856	37.786
(%MAR)	1.68	1.08	0.34	0.25	0.30	0.10	0.36	0.51	1.23	1.76	2.55	2.20
MHIFR												
(m^3/s)	26.000	0.000	0.000	0.000	26.000	0.000	59.000	119.000	119.000	233.000	119.000	0.000
(MCM)	4.717	0.000	0.000	0.000	4.717	0.000	10.705	24.367	24.367	53.348	24.367	0.000
(%MAR)	0.27	0.00	0.00	0.00	0.27	0.00	0.62	1.42	1.42	3.10	1.42	0.00
(Days)	4	0	0	0	4	0	4	5	5	6	5	0
DHIFR												
(m^3/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(MCM)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(%MAR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(Days)	0	0	0	0	0	0	0	0	0	0	0	0

Annual Totals

	MLIFR	DLIFR	MHIFR	DHIFR	Maint.	Drought	
MCM	299.665	212.383	146.590	0.000	446.254	212.383	
% Nat. MAR	17.43	12.35	8.52	0.00	25.95	12.35	4HC

TABLE 9.9 : IFR RULE TABLE - C CLASS

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

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	61.444	61.444	61.160	60.515	59.144	56.443	51.632	44.234	35.301	29.545
Nov	36.525	36.525	36.366	36.006	35.240	33.730	31.042	26.909	21.918	18.702
Dec	12.113	12.113	12.041	11.860	11.463	10.702	9.476	7.907	6.471	5.806
Jan	9.375	9.375	9.316	9.171	8.851	8.238	7.251	5.988	4.831	4.296
Feb	16.425	16.425	16.301	15.992	14.800	13.430	11.650	9.230	6.773	5.636
Mar	4.983	4.983	4.955	4.890	4.753	4.483	4.003	3.264	2.372	1.797
Apr	26.110	26.110	25.943	25.565	24.762	23.179	20.360	16.025	10.791	7.418
May	47.076	47.076	46.758	46.036	44.502	41.479	36.095	27.816	17.820	11.378
Jun	72.362	72.362	72.041	71.386	70.070	67.479	62.525	53.540	38.877	23.833
Jul	155.575	145.647	136.693	128.635	120.887	105.894	97.980	83.625	60.196	36.161
Aug	130.270	125.735	121.454	117.381	113.055	104.657	98.079	86.148	66.675	46.698
Sep	72.537	72.537	72.229	71.531	70.047	67.122	61.914	53.905	44.235	38.004
Natural Duration curves										
Oct	233.110	164.970	127.930	109.390	100.650	91.190	82.000	71.550	56.950	50.790
Nov	187.480	119.040	89.190	74.350	62.000	56.310	47.300	42.460	38.300	29.860
Dec	90.940	55.870	42.110	37.890	33.300	28.940	27.560	25.380	23.190	16.480
Jan	43.940	28.550	24.850	21.600	17.540	15.350	15.010	14.690	12.940	10.860
Feb	82.570	39.140	23.000	19.790	14.800	13.430	11.650	9.400	8.480	7.750
Mar	65.270	54.430	36.930	28.840	25.130	19.230	14.590	12.770	8.590	5.150
Apr	202.440	102.030	75.370	55.480	43.400	33.690	25.960	20.650	12.740	8.150
May	495.890	257.190	179.740	143.230	109.990	99.370	73.120	57.130	40.850	19.680
Jun	680.040	403.130	344.370	247.720	197.360	149.920	115.400	89.920	52.470	24.720
Jul	646.300	435.620	368.750	299.960	272.390	219.660	175.980	142.020	101.790	64.800
Aug	759.150	429.900	359.360	319.830	265.610	225.470	197.770	162.340	146.010	87.840
Sep	387.820	296.250	240.750	196.090	178.720	146.740	125.700	113.240	94.400	79.060

9.10 CONFIDENCE EVALUATION

IFR Site 4 was a difficult site to assess. There were no observed hydrological data for this reach of the river, and flow in the river during field visits was often too high to allow for discharge readings to be taken. Consequently, calibration of the hydraulic cross-sections was difficult. In addition, the site represents a large lower river, a type of river that is often difficult to assess in terms of its flow requirements.

Overall confidence: Moderate.

10. IFR SITE 5: RIVIERSONDEREND AT GREYTON

TARGET REACH: RIVIERSONDEREND RIVER FROM THE CONFLUENCE OF THE BAVIAANS RIVER TO THE TOWN OF RIVIERSONDEREND

10.1 REFERENCE CONDITIONS

10.1.1 Fish

Four indigenous freshwater species, namely the witvis, *Barbus andrewi*, Burchell's redfin, *Pseudobarbus burchelli*, Cape kurper, *Sandelia capensis,* and Cape galaxias, *Galaxias zebratus* are likely to have been abundant at IFR Site 5. Other indigenous species likely to have occurred here include three obligate catadromous eels, these being the longfin eel, *Anguilla mossambica*, the Madagascan mottled eel, *A. marmorata,* and, possibly, the African mottled eel, *A. bengalensis labiata*.

Reference indigenous species list (6 of 7):
Barbus andrewi
Pseudobarbus burchelli
Sandelia capensis
Galaxias zebratus
Anguilla mossambica
Anguilla marmorata
Anguilla bengalensis labiata (possible).

10.1.2 Aquatic Invertebrates

Reference conditions for Transitional and Lowland Floodplain rivers are based on data accumulated for the present study including, community composition, diversity indices, rank-abundance curves as well as SASS4 scores. Natural, unmodified conditions are expected to have a SASS4 score = >110 and ASPT score >7. The community is expected to include a large proportion of sensitive taxa including three or more baetid species, Leptophlebiidae, Trichorythidae and Limnichidae with a lower relative abundance of Chironimidae and Oligochaeta. Community diversity is expected to be high (*H'* >3) with an even distribution of individuals amongst species, reflected by a low gradient rank-abundance curve.

10.1.3 Riparian Vegetation

There should be a clear distinction between the different zones in the riparian vegetation as detailed in Boucher (1998), and Boucher and Tlale (2000). There should be a distinct floodplain. In summary, these zones should be as follows:
Aquatic vegetation: The density of instream aquatic vegetation should be less than 10% cover. Pools and backwaters should support rooted indigenous aquatics.
Wetbank vegetation: Sandy deposits should be colonised by indigenous herbaceous species such as grasses and sedges, and stream fringing shrubs such as *Prionium serratum* and *Salix*

mucronata should occur in clumps or patches and no invasion by woody exotic species should be present. There should be no bank collapse.
Lower Dynamic zone: There should be no bank collapse and no invasion by herbaceous or woody exotic species.
Tree/shrub zone: Indigenous woody perennials should dominate the Dry bank. There should be no invasive alien invasive species. Indigenous herbs or woody perennials should dominate post-fire recruitment.
Floodplain: Should be 100% intact and have no invasion by woody exotic species.

10.1.4 Geomorphology

River type: Foothill gravel-bed river.

Active channel well defined, with stable well-vegetated banks. Flood channels well-defined and clear of obstacles. Cobbles not embedded. No bulldozing or artificial manipulation of the bed, banks, flood channels, floodplain and no channelisation.

10.1.5 Water Quality

System variables

TDS	:	< 45 mg l^{-1}
pH	:	6.5 – 7.5
DO	:	80 - 120% saturation
TSS	:	< 5 mg l^{-1}
Temperature	:	unmodified
Nutrients	:	PO_4/TP ratio: 0 – 10% Median $P0_4$: < 0.01 mg l^{-1} TN:TP ratio: > 20:1.
Toxic substances	:	Meets the target water quality range for toxic substances as stated in the South African Water Quality Guidelines for Aquatic Ecosystems for 90% of the time, 99% of time less than or equal to chronic effect value, 100% of time less than the acute effect value.

10.1.6 Hydrology

No change to natural distribution flow regime.

10.2 PES, CAUSES AND ORIGIN, TRAJECTORY OF CHANGE

10.2.1 Fish

PES: E Class
IFR Site 5 is in better condition that much of the rest of the river reach it represents. This is because within a severely impacted reach the sites that display the most natural features are often selected as IFR sites.

The detailed PES evaluations presented below are based on the IFR site, which was assigned a D Class. The overall reach PES was estimated at being closer to an E/F Class.

The PES details for IFR Site 5 are as follows:
The fish community at the site is dominated by large mouth, *Micropterus salmoides*, and small mouth, *Micropterus dolomieu*, bass. Bluegill, *Lepomis macrochirus* and tench, *Tinca tinca* also occur at this site. The eel, *A. mossambica*, and the Cape kurper, *Sandelia capensis* still occur at the site but in much reduced numbers. *Pseudobarbus burchelli* and *B. andrewi* are known to still occur in isolated populations at various localities along the Riviersonderend but none were caught at this site and the habitat in much of the reach does not appear suitable. Much of the habitat that would have attracted these indigenous species has been removed through infilling of the channel, which took place after the closure of Theewaterskloof Dam.

CAUSES	ORIGINS	NON-/FLOW RELATED
Drastic reduction in habitat quality and quantity (loss of floods, reduction in side channels, down cutting in main channel).	Management of Theewaterskloof Dam.	Flow related
Reduction of the floodplain and side channels (loss of fish habitat).	Agriculture - Mechanical infilling.	Non-flow related
Reduction of indigenous fish species.	Introduction of alien fish.	Non-flow related

Trajectory of change: Negative (Short term: E Class - Long term: F Class)
The habitat available at the site is in fact limited throughout the reach, and alien species have a firm foothold. After 20 years a complete loss of indigenous species will occur.

10.2.2 Aquatic Invertebrates

PES: C/D Class
Most of the reach has good water quality and poor habitat quality (see water quality (Class B) and geomorphology (Class E)). IFR Site 5 itself scored a B Class for invertebrates on the basis of its SASS score. This is because, unlike most of the reach, macroinvertebrate habitat quality at the site is good.

IFR Site 5 has a SASS4 score = 95 and ASPT score = 6.8, the highest diversity index of all sites (H' = 4.1) and a gradually sloping rank-abundance curve with the community dominated by Caenidae and Chironimidae. The presence of sensitive taxa including three baetid species, Leptophlebiidae, Ephemerellidae and Tricorythidae suggests that this site is largely natural. The dominance of Caenidae in the macroinvertebrate community suggests that large areas are dominated by depositional environment.

CAUSES	ORIGINS	NON-/FLOW RELATED
Depositional environment.	Regulated flow, failure of flows to eliminate accumulated sediment (Theewaterskloof Dam).	Flow related

Trajectory of change: Negative (Short term D Class - Long term E Class)

Comparison between the results obtained in this study and those obtained by Dallas (1998; SASS4 score = 135, ASPT score = 6.67) at a nearby site suggest that conditions are deteriorating. The negative geomorphology trajectory supports this contention. Thus, the long-term trajectory at this site is expected to be negative.

10.2.3 Riparian Vegetation

PES: E Class

Aquatic vegetation: The *Paspalum* and *Potomageton* beds invade the stream during low flows and, conversely, are reduced during high flows and particularly during floods. In the Riviersonderend, floods no longer occur regularly and thus the aquatic vegetation has increased significantly. Cover c. 70% in places.

Wetbank vegetation: The vegetation in the Wetbank Zone is not well developed here. This might be a result of lower flows with less fluctuation in water level since the Theewaterskloof Dam was built. Typical species in this zone are clumps of 3.0 m tall *Salix mucronata* shrubs and *Pennisetum macrourum* with scattered *Paspalum dilatatum* and remnant *P. distichum* between.

Lower Dynamic Zone: The vegetation in the Lower Dynamic Zone is sparse and mainly containing exotic grasses and herbaceous weeds such as *Anagallis arvensis, Aster squamatus, Briza maxima, B. minor, Hypochoeris radicata, Lolium multiflorum, Paspalum urvillei* and *Poa annua,* as well as the indigenous grasses *Cynodon dactylon* and *Eragrostis curvula.* Remnant scattered plants of 0.5—1.2 m tall *Cliffortia strobilifera* are still present and represent the *Cliffortia strobilifera* Wetbank Fringing Shrubland community at the transition to the Tree-shrub Zone.

Tree/shrub Zone: The Tree/shrub and Back Dynamic Zones are all but totally dominated by tall shrubs and trees of the exotic invasive species *Acacia longifolia, A. mearnsii* and *A. saligna.* In places these have been cleared by Working for Water but virtually no indigenous vegetation remains.

Back Dynamic Zone: As above.

CAUSES	ORIGINS	NON-/FLOW RELATED
Lack of tree/shrub zone and back dynamic zone.	Lack of floods - Theewaterskloof.	Flow related
Invasion by alien species, especially black wattle and *Eucalyptus camaldulensis*	Lack of floods.	Flow related
	Introduction and lack of management of alien species.	Non-flow related
Disturbance of banks.	Bulldozing of floodplain to create agricultural lands - farming along banks.	Non-flow related

Trajectory of change: Negative (Short term: E Class Long term: E/F Class)

The full extent of the negative impacts of Theewaterskloof Dam on the riparian vegetation has not yet been reached.

10.2.4 Geomorphology

PES:* *E Class

Extensive bulldozing of floodplain, often with berms constructed along the macrochannel to prevent sideways flooding. Active channel incised in places. Infilling evident throughout.

CAUSES	ORIGINS	NON-/FLOW RELATED
Decrease of floodplain and active channel.	Decrease of floods leading to increase of alien and other (more terrestrial) vegetation.	Flow related
Decrease of floodplain and active channel.	Infilling (bulldozing - creation of agricultural fields).	Partially flow related
Loss of flow - sediments and organics accumulating in pools.	Theewaterskloof.	Flow related.
Loss of floods - bank encroachment and build up of bed due to vegetation trapping sediments.	Theewaterskloof.	Flow related
In places, flows concentrated in narrower channels - incising during floods.	Theewaterskloof.	Flow related

Trajectory of change: Negative (Short term: E Class - Long term: E/F Class)

The full extent of the negative effects of Theewaterskloof on the channel shape and condition has not yet been reached. The general nature of the changes that are occurring are associated with the absence of regular flooding - the river channel is becoming narrower and deeper. In addition, floodplains are being infilled and terrestrialised, further reducing the carrying capacity of the river channel. However, the really big floods, such as the 1:20 or 1:50 year floods, will not be stopped by Theewaterskloof Dam, with the result that such a flood will result in catastrophic impacts to the existing (modified channel) and flood damages are likely to exceed those that would have occurred in the absence of the dam.

10.2.5 Water Quality

PES:* *B Class

The presence of Theewaterskloof Dam has slightly reduced the water quality in the downstream river. In addition, agricultural developments (mainly dairy and wheat farming) between the dam and the IFR Site 5 at Greyton result in a slight increase in salinity and nutrients.

CAUSES	ORIGINS	NON-/FLOW RELATED
Increase in salinity and nutrients.	Agriculture (dairy and wheat farming).	Non-flow related
	The presence of Theewaterskloof Dam.	Flow related

Trajectory of change: Negative (Short term: B Class - Long term: B/C Class)
At Theewaterskloof Dam, no trend detected. In the lower reaches, however, there is a steady increase in TDS concentrations each year of 5.1 mg l^{-1}. This is most likely a result of agricultural return flows in the middle and lower reaches of the Riviersonderend River.

10.2.6 Hydrology

PES: E Class
No IFR releases from Theewaterskloof Dam. Only *c*. 25 % of the MAR still flows down the river. All small winter freshes and within-year floods have been lost, and the 1:2 year flood is greatly reduced. Summer freshes have been lost. Seasonal reversal occurs. In places, this naturally perennial river stops flowing during the summer. This is due to Theewaterskloof Dam (primarily abstraction for use in Cape Town and surrounds) and abstraction for agriculture.

10.2.7 Combined PES

The causes and origins are summarised as follows:

Non-flow related
Presence of alien fish and vegetation species.
Mechanical disturbance to the channel.
Flow related - DOMINANT
Lack of floods and environmental releases from Theewaterskloof compounded by abstraction for irrigation.

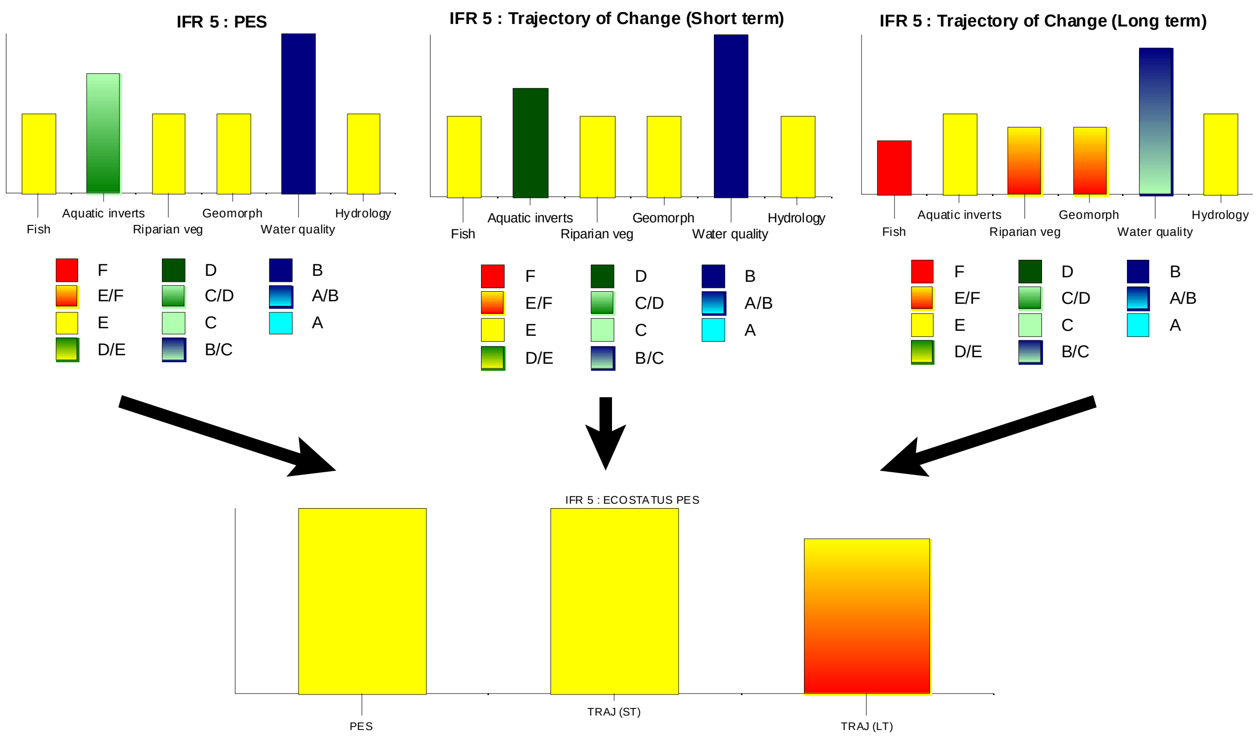

Figure 10.1 : Present Ecological Status (PES)

Water quality is in a good state and the aquatic invertebrate state reflects this at IFR Site 5. However, the physical drivers, hydrology and geomorphology, reflect severe changes to the river (E Class) and the combined PES assigned to this reach is therefore in an E Class.

10.3 ECOLOGICAL AND SOCIAL IMPORTANCE

EIS rating: High
Confidence: High
Determinants: Rare and endangered species, species and taxon richness, diversity of habitat types and refugia, sensitivity to flow related water quality changes, migration routes.
Social rating: Low.
Confidence: Low.
Determinants: Water supplies, recreation dependent on a natural functioning river and potential for recreation.

AIM:
The EIS is high, the social importance is low and the PES is very low (E Class). The overall trajectory of change is negative and will result in an E/F Class. In terms of the RDM documentation (DWAF 1999) it is recommended that the future PES be targeted at a D Class.

10.4 ATTAINABLE EC

10.4.1 Fish

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Theewaterskloof Dam (improve habitat).	Flow related	Implement the Reserve.	Difficult
Catchment degradation and alien vegetation.	Non-flow related	Improve habitats mechanically and remove alien vegetation.	Difficult
Alien fish.	Non-flow related	Remove the aliens.	Difficult
PES E - EC E/D÷D The fish habitats available at IFR Site 5, and particularly in the rest of the reach, are extremely poor and the condition of the river is on a negative trajectory. To improve conditions to a D Class, the flow regime would require some restoration but this would need to be combined with an overall improvement in catchment management.			

10.4.2 Aquatic Invertebrates

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Theewaterskloof.	Flow related	Implement the Reserve.	Difficult
PES C/D - EC C/D The invertebrates at IFR Site 5 are presently in a C/D Class. However, conditions elsewhere in the reach are poor and a negative trajectory of change is predicted. Thus, some of the flow related impacts would need to be addressed in order to maintain a C/D EC at the site. The additional improvements required for the fish above could potentially result in a C Class for the invertebrates.			

10.4.3 Riparian Vegetation

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Theewaterskloof Dam (no IFR)	Flow related	Implement the Reserve.	Reasonable
Agriculture (alien species).	Non-flow related	Catchment management - Working for Water.	Difficult
	Flow related	Implement the Reserve - less stress on indigenous vegetation.	Reasonable
Agriculture (bulldozing etc).	Non-flow related	Catchment management.	Difficult
PES E - EC E/D÷D Reinstating some flows and removing alien vegetation would result in an improvement to a Class D in the long term.			

10.4.4 Geomorphology

ORIGINS	NON-/FLOW RELATED	ACTION	DEGREE OF DIFFICULTY
Theewaterskloof Dam.	Flow related	Implement the Reserve.	Reasonable
	Non-flow related	Mechanically manipulate the channel to reshape banks and recreate lost habitat.	Reasonable
Bulldozing and alien vegetation (loss of flood plain).	Non-flow related	Catchment management.	Difficult
PES E - EC E ÷D Smaller floods are required to remove mud and organic material. This could halt the negative trajectory in the short term. Large floods, which will remove alien vegetation, will open up the channel in the long term.			

10.4.5 Water Quality

PES B - EC B

It is likely that, should the water quality deteriorate it would result in a further decline in the condition of other components of the river, e.g., vegetation (algae), fish and invertebrates. For instance, invertebrates are in a better than expected state mainly due to the colonisation of the few areas of remaining good quality habitat and the general good quality of the water in the river. Thus it is recommended that the target EC for water quality be a B Class.

10.4.6 Summary of Attainability and Ecostatus EC

Flow related impacts due to the present operation of Theewaterskloof Dam (especially the lack of a flooding regime) are the main reason for the decline in condition. Associated with these issues is the presence of alien vegetation and fish as well as the physical manipulation of the channel. If these activities are addressed the situation could be improved in the long term to a D Class. Due to the significant changes presently in the system, this will be very difficult.

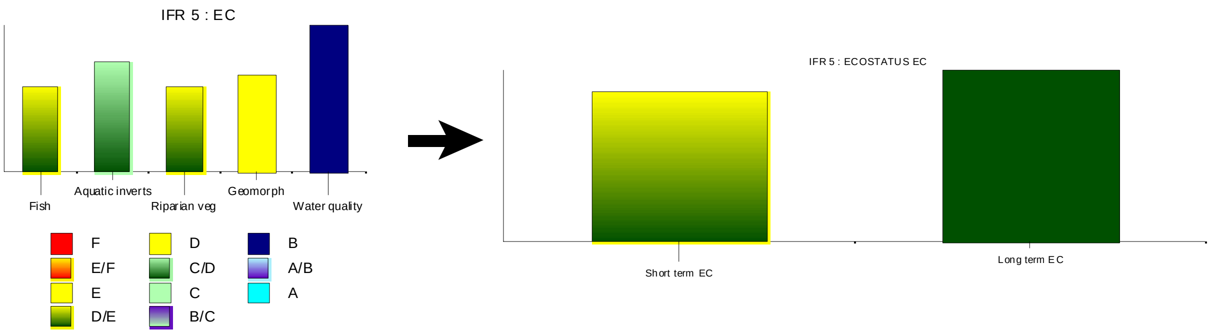

Figure 10.2 : Ecological Class (EC)

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	E	0	E	E		
Water quality	B (flag)	-	B	B/C	H	B
Geomorphology	E	-	E	E/F	I	E → D
Riparian veg	E	-	E	E/F	G	E/D → D
Fish	E	-	E	F	H	E/D → D
Aquatic inverts	C/D	-	D	E		C/D
Ecostatus	E	-	E	E/F		D/E
					Long term EC	D

(flag) Concern based on landuse information or inconsistency between the bio-assessment and the water chemistry (i.e. biota in a lower class than chemistry)

Figure 10.3 : Summary of the PES and EC classes

10.5 OBJECTIVES

10.5.1 Fish

EC: ED/÷D
General flow objectives: Maintain low flows during summer.
Overall fish objectives: Maintenance of refugia for indigenous fish within the reach.

Objectives for target/indicator species: Maintain inundation of (*Potamogeton*) (for *Galaxia* species) habitat by maintaining a flow of above 2.2 m s^{-1}. Inundation of other shallow vegetation would provide refugia for *Sandelia* and *Pseudobarb*us.

General flow objectives: Maintain summer floods, high flows.
Overall fish objectives: To facilitate migration of catadromous species.
Objectives for target/indicator species: Catadromous eels use high flows and summer floods as cues and a passage to migrate back to the sea. Juveniles use the summer high flows to recruit and move upstream.

General flow objectives: Maintain summer floods, freshettes.
Overall fish objectives: Population control, removal of alien species
Objectives for target/indicator species: Well-timed floods during spring will aid in the destruction and flushing of nests, eggs and larvae of alien species (*L. macrochirus* and *Micropterus* spp.), which start breeding earlier in spring than do the indigenous species.

10.5.2 Aquatic Invertebrates

EC: C/D
General flow objectives: Maintenance of present flow regime should maintain the long term objective of a D Class (invertebrates) river. However, decreasing the abnormally high summer low flows to a more natural level should also maintain this long term objective with less water in the river. The reduction in present day summer low flows would reinstate the natural difference between summer and winter low flows, which the invertebrates have evolved to respond to. In order for the reach as a whole to be maintained as a D Class, the IFR site needs to be maintained at a higher class (SASS4 = 90 – 70).
General invertebrate objectives:

- Maintain a SASS4 score = 90 and ASPT score = 7, at least.
- Maintain diversity index at a minimum of *H*' = 2.78.
- Maintain a community that includes Leptophlebiidae, Trichorythidae and Limnichidae.

Identification of and objectives for target species: The maintenance of above community characteristics rather than focusing on target species is preferred.

10.5.3 Riparian Vegetation

EC: E/D÷D
Back Dynamic Zone
General flow objectives: Largely lost through farming. (A secondary objective would be to control farmers and holiday home invasion of floodplain with buildings (fixed structures).

Tree-Shrub zone
General flow objectives: Maintenance of existing plants in this zone through the deposition of silt and debris (1:5 to 1:20 year floods). Restore the community through seedling and juvenile establishment (1:2 year and Class IV floods).
General riparian vegetation objectives: Reduce stress on indigenous plants and restrict alien species invasions.

Identification of and objectives for target species: Expand the distribution of species associated with this zone, i.e., to restore density of stands of woody species (e.g., *Cliffortia heterophylla* along edges, *Brachylaena neriifolia, Metrosideros angustifolia, Morella serrata, Rapanea melanophloeos*) coupled with reduction of alien woody (e.g. *Acacia longifolia, A. mearnsii, A. saligna).*

Lower Dynamic Zone

General flow objectives: To maintain the sand deposits on the left bank (1:2 year and Class IV floods) and scour woody seedlings from the Lower Dynamic Zone.

To promote a more natural deposition or erosion regime.

General riparian vegetation objectives: Restrict alien annuals and prevent alien woody establishment.

Identification of and objectives for target species: Indigenous annual herbs should occur in the zone, and limited downward movement of tree and shrub species (see species listed for Tree Shrub zone) is expected.

Upper Wetbank Zone

General flow objectives: Maintain this zone to reduce channel shape change (steepening and narrowing of banks) caused by changed vegetation (Class II to Class III floods and 5% winter base flow).

General riparian vegetation objectives: Prevent the establishment of annual and woody alien plants.

Identification of and objectives for target species: *Morella serrata, Salix mucronata* and *Cliffortia heterophylla, Prionium serratum and Salix mucronata* to be maintained in a healthy condition.

Lower Wetbank Zone

General flow objectives: To push Wetbank vegetation back from the Aquatic Zone (Class I floods, and 5-90% winter base flow and 5-95% summer base flow levels level).

General riparian vegetation objectives: To ensure zone is wet regularly for fairly long periods in winter (with fluctuations in levels) to allow plants to grow in clear water even while submerged.

Identification of and objectives for target species: To promote the expansion of *Cyperus textilis, Prionium serratum* and *Phragmites australis* and to prevent invasion of riffle by *Paspalum distichum.*

Aquatic Zone

General flow objectives: Maintain the plants in the Aquatic Zone (90-99% winter base flow and 50% summer base flow). It is important to reinstate fluctuations in flow, particularly with regard to summer, autumn and early winter base flow levels. Prevent a build up of aquatic plants (Class I and II, and larger, floods).

General riparian vegetation objectives:

- Ensure zone plants are inundated during most of the year.

Identification of and objectives for target species: To allow natural expansion and contraction of *Potamogeton* beds and to restrict expansion of *Potamogeton* and *Ludwigia* beds.

10.5.4 Geomorphology

EC: E÷D

The river channel has been seriously impacted. Decreased flood flows have led to:

- Build-up within pool of organic materials as well as sediments;
- Invasion of flood plains by alien trees;
- Build-up of control section through extended growth of plants, which trap fine sediments.

The following is required to halt/reverse this process:

- Increased flood flows to flush out deposited sediments as well as in stream vegetation;
- Removal of alien trees from the floodplain.

10.5.5 Water Quality

EC: B

TDS	:	Summer low flows: <100 mg l^{-1} for 95% of the time; winter low flows: < 150 mg l^{-1}. Floods: < 150 mg l^{-1}. (Note: There is no clear relationship between flow and TDS because of Theewaterskloof Dam upstream of the site).
pH	:	Maintain between current 5 and 95 percentiles (i.e., 6.6 - 7.4). (Note - no flow related pattern. >50 data points in 1995 to present data set).
Dissolved oxygen	:	Maintain between 80-100% of saturation. (No data - used RDM document).
Water temperature	:	Maintain within 3° C of seasonal range at middle Breede River reference site (No data - used RDM document).
Nutrients	:	Median PO_4 concentration: < 0.05. % PO_4:TP ratio : <20% TN:TP ratio : >10:1 Median NH_3-N : <0.015 NO_2NO_3-N : Maintain winter concentrations at <0.25 mg l^{-1} for 95% of the time and summer concentrations < 0.2 mg l^{-1} for 95% of the time. Floods - relationship between high flow and concentration.
Toxic substances	:	Maintain toxic substances ≤ CEV for 95% of the time and ≤ AEV for 99% of the time as specified in the SAWQG for aquatic ecosystems.

10.6 MAINTENANCE FLOW ASSURANCE

The assurance of maintenance low flows during winter is set as a flow that occurs 70% of the time. The assurance of maintenance low flows during summer is set as a flow that will occur 60% of time.

10.7 SEASONAL DISTRIBUTION

Flows were set for the highest (Feb/March) and lowest (Aug/Sep) flow months.

10.8 IFR RESULTS

10.8.1 Motivations: Low Flows

The specialists' motivations for each flow are provided below.

MAINTENANCE LOW (DRY SEASON, FEB/MAR) $0.4\ m^3\ s^{-1}$

Descriptions of flow required:
Equates to 0.26 m depth at riffle. Some flow over riffle where the velocity is at least 0.47 m s^{-1} is expected. Maintenance of pool depth at 1.8 m.

Primary motivations:
Riparian vegetation: Aquatic Zone and top of Lower Wetbank maintenance. Provides stimulus for growth responses by trees and shrub juveniles. Keeps river clean of algae. Would keep invasion of river by *Prionium* under control. Would be needed to manage *Potamogeton* and *Ludwigia* densities – to keep under control and to prevent closing of channel. Lower flows will encourage encroachment of the vegetation into the channel. The shape of the channel could change to a donga.
Sources: Own data reports and students' studies.
Fish: Maintenance of riffle/run channels to ensure inundation of macrophytes within which *Galaxias* forage and find refuge. Mean velocity at time of sampling was 0.47 m s^{-1} as opposed to a mean focal (i.e., where fish were recorded) velocity of 0.01 m s^{-1}. Maintenance of pool depth for eels. Lower flows will result in the disappearance of macrophyte refuge, foraging area and *Galaxias* from this reach.

Secondary motivation:
Aquatic invertebrates: Maintain hydraulic conditions favourable for riffle taxa *Pseudapannota maculosum* (vel: 0.4 – 0.6 m s^{-1}; depth: 0.5 – 0.6 m), Hydropsychidae (vel: 0.7 - >1.0 m s^{-1}; depth: 0.5 – 0.7 m). This provides inundation of 0.1 - 0.2 metres depth on the small floodplain around the bridge. Lower flows will result in similar diversity indices, but lower abundances overall. Diversity will, however, decline if the floodplain dries out (loss of wetted habitat for slow-flow and marginal vegetation taxa). Medium confidence.
Sources: Invertebrate samples for BRBS, photos, profile, SVD histograms, available literature.

MAINTENANCE LOW (WET SEASON, JULY) $3.5\ m^3\ s^{-1}$

Descriptions of flow required:
Equates to c. 0.5 m depth at riffle. It is expected that there will be areas on cross-sections 2 and 3 where the velocity reaches at least 2 m s^{-1}. (Note: This is *c.* = to average for cross-section 3). Periodic inundation of the side portions or the riffle are allowed for in spates

Primary motivation:
Riparian vegetation: Top of Lower Wetbank maintenance. Would keep invasion of river by *Paspalum* under control. Also needed to manage *Prionium* densities – to prevent further closing of channel. Lower flows will encourage the increase in exotics.
Sources: Own data reports and students studies.

Secondary motivation:
Aquatic invertebrates: Maintenance of hydraulic conditions within the channel for winter community species, e.g., Leptophlebiidae. Inundation of floodplain. Weak motivation because no samples were taken in July. Low confidence.
Sources: Invertebrate samples for BRBS, photos, profile.

DROUGHT LOW (DRY SEASON, JANUARY) 0.35 $m^3 s^{-1}$

Descriptions of flow required:
Some flow over riffle is required. Maintenance of the pool depth at >1.8 m. Periodic inundation of the side portions or the riffle is allowed for in spates.

Primary motivation:
Riparian vegetation: Aquatic Zone and top of Lower Wetbank maintenance. Would be needed to sustain *Potamogeton* and *Ludwigia*. Lower flows will result in the deterioration of instream rooted aquatics community at this section.
Fish: This is the minimum flow at which the riffle/run side channels inundate *Galaxias* macrophyte habitat (see dry season maintenance flow).
Sources: This study.

Secondary motivations:
Aquatic invertebrates: Sufficient water to maintain the small deeper channel adjacent to the left bank. This could act as a refuge when the floodplain has dried out. Gradual shrinkage of wetted habitat in the wetted channel will result in a decline in overall abundance followed by a reduction in diversity of taxa. Medium confidence.
Sources: Invertebrate samples for BRBS, photos, profile.

DROUGHT LOW (WET SEASON, JULY) 0.96 $m^3 s^{-1}$

Descriptions of flow required:
0.35 m depth in riffle area (cross-section 2) and maintenance of pool depth at > 1.8 m. Also allows for some (very minor) fluctuation between summer and winter.

Primary motivation:
Fish: Need to maintain a depth of water in the riffle/run habitats of at least 30 cm to inundate macrophytes as this is where *Galaxias* forage and take refuge. Mean velocity at time of sampling was 0.47 $m s^{-1}$, as opposed to a mean focal (i.e., where fish were recorded) velocity of 0.01 $m s^{-1}$. A pool depth (maximum) of 1.8 m is required to provide habitat for eels.

Secondary motivations:
Aquatic invertebrates: Sufficient water to maintain the small deeper channel adjacent the left bank. Some reduction in wetted habitat without loss of floodplain inundation. This motivation is weakened by the fact that no samples were collected in July during this study, i.e., low confidence.
Sources: Photos, profile.

10.8.2 Motivations: High Flows

TABLE 10.1 : FLOOD REQUIREMENTS FOR IFR SITE 5

FLOOD CLASS	MONTHLY DISTRIBUTION	PEAK SIZE ($M^3 S^{-1}$) DAILY AVERAGE	NATURAL	PRESENT DAY	E - D	MONTHLY DISTRIB.
< I	10 - 4	4	Included in class I	Included in class I	3	12 - 2
I	10 - 4	7	6	0.5	1	11 - 12
II	5 - 9	20.7	4	0	1	5 - 6
III	5 - 9	41.4	3	0	2	5 - 6
IV	5 - 9	85.8	1.7	0.2	1	6 - 9
1:2	129					
1:5	209					
1:10	416					
1:20	467					

Aquatic vegetation:
Class III and IV:
For the Class III/IV flood, scouring flows are needed early in the winter to reset the river to winter conditions, this will flush out summer species (Oligochaeta, *Burnupia* sp., *Ephydridae*), scour biofilms, flush fines in interstitial spaces and provide habitat required by winter species. If these floods do not occur, winter species will appear in a sporadic and uncoordinated way and some species my not establish themselves.
Source: BRBS, geomorphology, King (1982) and King (pers. obs.).

Riparian vegetation:
Class I and II:
Required to clear alien seedlings or juveniles that are becoming established in the marginal vegetation. Maintains bank vegetation and promotes *Prionium* growth. Keeps soil moist so that fire temperatures are kept low and are therefore less destructive to soil seed banks and plants.

Class III:
Top of Lower Wetbank and Tree-shrub maintenance. Keeps *Prionium* healthy and trees and their juveniles in tree-shrub zone growing by capilliary action. Keeps river clean of algae. Would keep invasion of river by *Prionium* under control but also maintain the species. Would be needed to manage *Potamogeton* and *Ludwigia* densities - to keep them and *Paspalum* under control to prevent channel narrowing. To keep alien establishment out of control. These flows will prevent encroachment of vegetation into the channel.

1:5, 1:10 and 1:20 year floods:
To allow tree shrub zone to be reinstated following RDP bank clearing of aliens. To support seedlings, to wash out seed, to remove materials deposited under dense aliens i.e. bank re-shaping. To develop buffer strip. Aliens re-infest the banks continuously without natural vegetation restoring which is aim of RDP program. Farming will continue to encroach.

Geomorphology:

In order to establish whether the reduced flows would lead to accumulation of fine sediments along the river upstream of the site the estimated sediment yield from the catchment has been compared with the sediment carrying capacity of the reduced flood flows.

The sediment yield was taken as 300 t/km^2/annum and the effective catchment size is 1289 km^2. Therefore the average suspended sediment load is 386 700 tonnes. Assuming an average sediment concentration of 1% by mass, the required volume of annual flood discharges would be 38.7 MCM. With the calculated total annual flood discharges of 51 and 73 MCM respectively for scenarios D and C there should not be general long term accumulation of fine sediments upstream of the site, the flood flows should be able to transport sediment concentrations in excess of 1% by mass. However, given that only the largest floods (with return periods greater than 20 years) will be able to lower the pool bed to existing levels, there will be build-up of the pool bed inbetween extreme floods and the 1:2 and 1:5 year flood will be very important for the maintenance of pool depth albeit at a reduced value.

Fish:

Class I:

Species Motivation:

Pseudobarbus burchelli is a rare southwestern Cape endemic confined to the Breede and adjacent systems. It is excluded from the mainstream and many tributaries by alien predators. It is an omnivore actively selecting different prey types depending on season and locality thereby having a role in structuring invertebrate communities. It may breed twice during summer relying on steady periods of summer rain 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. This is a short-lived species (3 years) so one missed opportunity could result in total reproductive failure.

Sandelia capensis is a vulnerable southwestern Cape endemic confined to small tributaries by alien predators. 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 would have once been a large component of the diet of piscivorous birds and eels in the Breede mainstream. *S. capensis* 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 behavior. 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.

Galaxi zebratus: Vulnerable southwestern Cape endemic confined to small tributaries and shallow isolated parts of large tributaries by alien predators. Actively select preferred prey and therefore one of the deciding factors in invertebrate community structure. Preyed on by the Gomphidae, *Sandelia capensis* 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 that are likely to require well aerated flowing or well mixed water for survival. Low flow in the larger tributaries would result in the loss of much of the fast flow, macrophyte habitat that it currently utilises.

General Motivation:

- Floods are more disruptive to alien than indigenous fish species, the latter having adapted to these events within their particular habitat.
- Indigenous fish 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.
- From macroinvertebrate report: 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.
- Parasite loads increase with poor water quality, contributing to a decline in individual and population health.
- Some introduced fish species continue to reproduce, overpopulating waters with stunted individuals. These species are usually flushed downstream or out of the system with floods.

Class II, III and IV:

Species Motivation:

Barbus andrewi: Critically endangered species confined in distribution to the Berg and Breede systems. The largest benthic feeder in the mainstream preying on crabs *Potamonautes sidneyi*, *Burnupia* spp. and other benthic invertebrates. Probably the only indigenous species that turns over significant amounts of sediment when feeding. Historically, would have been a large component of otter diets. Low flows confine them to deep pools for long periods. Too low flows lead to the loss of aerated water at the head of pools essential for the survival of eggs and larvae. Silt deposits inundate spawning beds and larval habitat. Silt turned over or suspended by the introduced *C. carpio* suffocates eggs and larvae. Unseasonal summer, silt laden releases from dams may lead to 100 % larval mortality.

Anguillidae: Two southern African endemics and one Indo-Pacific in origin all catadromous with similar life-history characteristics. They are the largest piscivorous predators in the Breede System and probably the most dominant before the advent of the aliens. Also a major predator on crabs and frogs. Summer floods needed 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.

Sandelia capensis : See Class I
Pseudobarbus burchelli: See Class I
Galaxi zebratus : See Class I

General Motivations:
See above.
Rehabilitation of the reach will entail removal of *Potamogeton* and other macrophytes from the shallow areas. These are currently the only refugia maintaining *Galaxias, Pseudobarbus* and *Sandelia* within the system. Therefore any rehabilitation plan will have to take account of and maintain these refugia until such time as rehabilitation is completed and new refugia have become established.

Water quality consequences
If the floods are partially restored to the Riviersonderend, they will have to be released from Theewaterskloof Dam. Moderately elevated TDS concentrations (about 120-140 mg l^{-1}) during the winter months will be reduced to approximate TDS concentrations in the dam (about 40-60 mg l^{-1}) during flood releases.

Nitrates are washed into the river from the dryland farming and a 'first-flush effect' in May is evident in the river nitrate data. The re-establishment of buffer zones will mitigate the effect of elevated nitrate concentrations during winter. Buffer zones along the main stem river will probably be restored by the recommended flood regime. The effect of temperature and dissolved oxygen of the released water (depending on whether the release is a surface or bottom water release) will probably be localised and mitigated to a large degree by the time the water reaches IFR Site 5.

10.8.3 IFR Table

The results as motivation above are presented in the Table 10.2.

TABLE 10.2 : IFR TABLE: IFR SITE 5 - C/D CLASS

IFR SITE 5: RIVIERSONDEREND RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) MAR (VIRGIN): 347.41 MAR (PRESENT): 93.50											
MONTH	**MAINTENANCE LOW FLOWS**			**HIGH FLOWS**				**DROUGHT LOW FLOWS**			
	DEPTH[4]	**FLOW ($m^3 s^{-1}$)**	**VOLUME ($10^6 m^3$)**	**DEPTH[4]**	**FLOW ($m^3 s^{-1}$) Daily average**	**DURATION**	**VOLUME[1] ($10^6 m^3$)**	**DEPTH[4]**	**FLOW ($m^3 s^{-1}$)**	**VOLUME ($10^6 m^3$)**
Oct	0.47	2.7	7.23					0.34	0.93	2.5
Nov	0.46	2.5	6.48	0.65	7.5	2	0.61	0.33	0.85	2.2
Dec	0.31	0.7	1.88	0.53	4	2	0.40	0.24	0.35	0.94
Jan 2	0.29	0.6	1.61	0.53	4	2	0.41	0.24	0.35	0.94
Feb	0.28	0.5	1.21	0.53	4	2	0.423	0.24	0.35	0.85
Mar	0.26	0.4	1.07					0.23	0.3	0.80
Apr	0.41	1.8	4.67					0.24	0.4	1.04
May	0.43	2.0	5.36	0.90	20.6	3	2.89	0.32	0.8	2.1
Jun	0.49	3.0	7.78	1.10	21	3	2.80	0.33	0.9	2.3
Jul3	0.51	3.5	9.37	1.15	44.5	4	7.44	0.34	0.96	2.6
Aug	0.53	3.8	10.18	1.40	84.9	6	18.57	0.34	0.99	2.7
Sep	0.53	4.0	10.37	1.16	45	4	7.44	0.34	1	2.6
TOTAL			**67.19**				**40.98**			**21.55**
% OF MAR (VIRGIN)			**19.34**				**11.80**			**6.20**
Long term % OF MAR (VIRGIN)				**38.65 (134.27 $10^6 m^3$)**						

1 The volume represents the daily average less the low flows

2 December was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.

3 July was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.

4 As per cross-section 2.

10.8.4 IFR Rule Table

For an explanation of the rule table, refer to 6.8.4.

Note : Tables 10.3 and 10.4 were generated by the Desktop model using B Class rules. The reason for this is that in the Desktop Model the D Class rules are set at a higher percentage above maintenance than the other classes. However, for IFR Site 5, the D Class results from the workshop were *c*. 36% of the MAR and it was decided that D Class rules were not required to compensate for a low percentage of MAR.

TABLE 10.3 : IFR RULE TABLE - C/D CLASS

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

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.433	4.433	4.402	4.332	4.182	3.887	3.362	2.555	1.580	0.952
Nov	4.412	4.412	4.381	4.309	4.158	3.464	3.001	2.368	1.530	0.896
Dec	1.285	1.285	1.274	1.248	1.190	1.080	0.903	0.675	0.467	0.371
Jan	1.134	1.134	1.126	1.047	0.945	0.806	0.759	0.625	0.451	0.370
Feb	1.006	1.006	0.999	0.921	0.819	0.774	0.659	0.583	0.438	0.371
Mar	0.658	0.658	0.655	0.647	0.632	0.602	0.548	0.466	0.366	0.302
Apr	2.954	2.954	2.931	2.880	2.771	2.556	2.109	1.120	0.810	0.343
May	4.707	4.707	4.673	4.597	4.435	4.115	3.546	2.670	1.613	0.932
Jun	6.734	6.734	6.697	6.620	6.466	6.162	5.581	4.527	2.808	1.044
Jul	11.070	10.553	10.063	9.595	9.095	8.124	7.348	5.940	3.643	1.286
Aug	18.988	17.698	16.523	15.453	14.400	12.360	11.157	8.974	5.412	1.758
Sep	12.139	11.415	10.753	10.121	9.417	8.152	6.933	5.059	2.796	1.338
Natural Duration curves										
Oct	16.452	13.738	10.960	9.681	8.717	7.504	7.229	6.078	4.677	2.886
Nov	12.370	10.243	6.583	5.542	4.595	3.464	3.001	2.368	2.152	1.454
Dec	4.833	3.049	2.501	1.943	1.648	1.453	1.331	1.285	1.083	0.835
Jan	2.674	1.924	1.262	1.047	0.945	0.806	0.759	0.686	0.595	0.516
Feb	2.834	1.515	1.126	0.921	0.819	0.774	0.659	0.590	0.555	0.374
Mar	4.272	1.965	1.334	1.057	0.818	0.735	0.646	0.574	0.478	0.392
Apr	14.299	12.015	7.907	5.628	3.593	3.236	2.109	1.120	0.810	0.343
May	28.361	22.782	15.156	13.872	12.527	9.860	7.257	6.305	3.444	1.120
Jun	62.834	39.467	27.212	22.446	19.550	18.095	16.486	9.010	8.501	1.866
Jul	47.786	35.105	33.652	27.964	23.394	20.089	16.134	14.002	8.204	5.324
Aug	51.100	26.823	25.039	21.263	20.840	17.631	15.730	14.446	12.553	8.100
Sep	32.125	23.409	15.748	15.042	14.492	11.525	10.611	9.871	8.940	7.510

10.8.5 IFR Time Series

For an explanation of the time series, see 6.8.3.

TABLE 10.4 : FINAL RESULTS FOR A TIME SERIES 1964 - 1993 (10^6m^3) - C/D CLASS

Total Runoff : REGION VI VOND
IFR Modified Flow Data Management Class C/D

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1964	9.895	11.399	3.343	2.836	2.433	1.762	7.535	12.313	13.097	12.710	30.493	9.772	117.588
1965	11.201	11.398	3.441	3.039	1.928	1.762	7.008	4.296	15.971	25.700	45.566	24.409	155.718
1966	2.966	2.963	1.049	2.103	0.931	0.981	7.657	11.878	17.426	17.792	13.152	15.402	94.300
1967	11.584	10.778	2.893	2.611	1.729	0.883	5.466	12.607	17.308	21.760	41.332	11.341	140.293
1968	11.873	10.562	2.953	3.015	2.425	1.719	7.230	2.948	9.417	8.258	19.074	26.234	105.708
1969	11.873	2.729	0.993	0.991	2.098	1.096	0.889	9.760	16.892	22.151	42.599	27.871	139.942
1970	9.258	5.171	3.153	2.019	1.474	1.612	3.612	7.152	11.735	26.953	49.343	21.129	142.611
1971	5.356	11.354	2.636	2.803	2.416	1.248	2.904	12.517	13.782	3.443	26.953	13.112	98.525
1972	2.550	6.138	1.468	1.389	1.435	1.560	1.906	2.496	2.706	25.490	38.568	19.546	105.249
1973	5.842	2.322	3.382	1.862	2.219	1.416	1.372	9.171	16.701	9.757	50.859	29.588	134.490
1974	11.790	11.170	1.808	2.346	1.872	1.469	7.200	12.607	15.073	24.361	44.256	16.968	150.921
1975	8.754	8.770	2.198	1.039	0.899	1.623	2.099	4.320	17.455	27.887	29.882	7.247	112.173
1976	11.711	11.436	3.441	3.039	2.433	1.753	7.657	12.607	17.455	29.649	50.859	22.084	174.123
1977	6.843	8.462	3.436	3.028	1.799	1.693	6.261	9.497	4.114	5.388	37.135	27.736	115.391
1978	11.835	11.315	3.428	3.029	2.433	1.762	2.465	10.462	16.573	15.592	33.105	25.105	137.103
1979	11.873	10.926	1.251	2.998	2.404	1.119	7.012	11.222	6.907	18.289	4.708	4.817	83.525
1980	7.862	11.436	3.441	3.039	2.433	1.762	7.465	6.101	7.278	28.264	49.010	31.464	159.554
1981	11.258	9.399	3.441	3.039	1.197	1.724	7.657	11.647	14.466	15.910	14.496	26.075	120.308
1982	10.916	3.966	3.380	2.160	2.433	1.758	2.914	12.607	17.455	29.042	22.944	29.763	139.338
1983	11.602	6.331	2.078	1.647	1.594	1.745	6.625	12.607	10.694	27.504	27.093	31.464	140.984
1984	11.873	11.029	3.441	3.039	2.433	1.762	7.566	8.257	17.358	28.715	46.584	17.970	160.026
1985	11.701	11.436	3.441	3.039	1.975	1.760	7.598	12.095	17.409	25.420	50.859	29.441	176.173
1986	9.005	11.267	1.757	2.539	1.410	1.352	7.182	12.607	17.262	19.681	47.403	26.942	158.407
1987	10.464	5.065	3.413	1.207	1.006	1.648	7.641	12.182	15.438	19.727	31.962	28.588	138.342
1988	10.411	8.979	1.087	1.120	1.306	1.762	7.657	12.421	16.759	22.141	43.958	31.464	159.065
1989	11.873	11.436	3.214	2.243	2.433	1.734	7.657	12.566	17.159	26.239	33.556	4.404	134.513
1990	3.523	7.778	2.417	2.033	2.227	1.471	2.664	12.567	17.455	29.649	41.389	30.633	153.806
1991	11.848	11.436	2.711	2.131	2.275	1.744	7.629	11.022	17.455	26.749	24.036	23.425	142.460
1992	11.873	11.436	3.188	1.673	1.982	0.852	7.657	12.489	17.029	29.649	39.270	3.468	140.566
1993	4.232	7.300	3.232	2.531	1.060	0.810	5.974	5.539	17.455	21.023	7.722	19.970	96.848
Mean	9.455	8.840	2.704	2.320	1.890	1.511	5.739	10.019	14.443	21.496	34.606	21.248	134.268

The IFR time series for the above years relative to the natural and present flows is illustrated in Figure 10.4.

10.9 OTHER SCENARIOS

Scenarios lower than a Class D should not be considered (DWAF 1999), and given the difficulties associated with provided IFR releases for the Riviersonderend (i.e., the presence of Theewaterskloof Dam – main water supply for Cape Town), it was deemed unrealistic to provide scenarios for conditions better that D Class, as these would undoubtedly require more water than that recommended for a D Class river.

10.10 CONFIDENCE EVALUATION

The data:

For IFR Site 5, the hydrological data were generated using the gauging weir (G06H009) downstream of the town of Riviersonderend, near to the confluence with the Breede River.

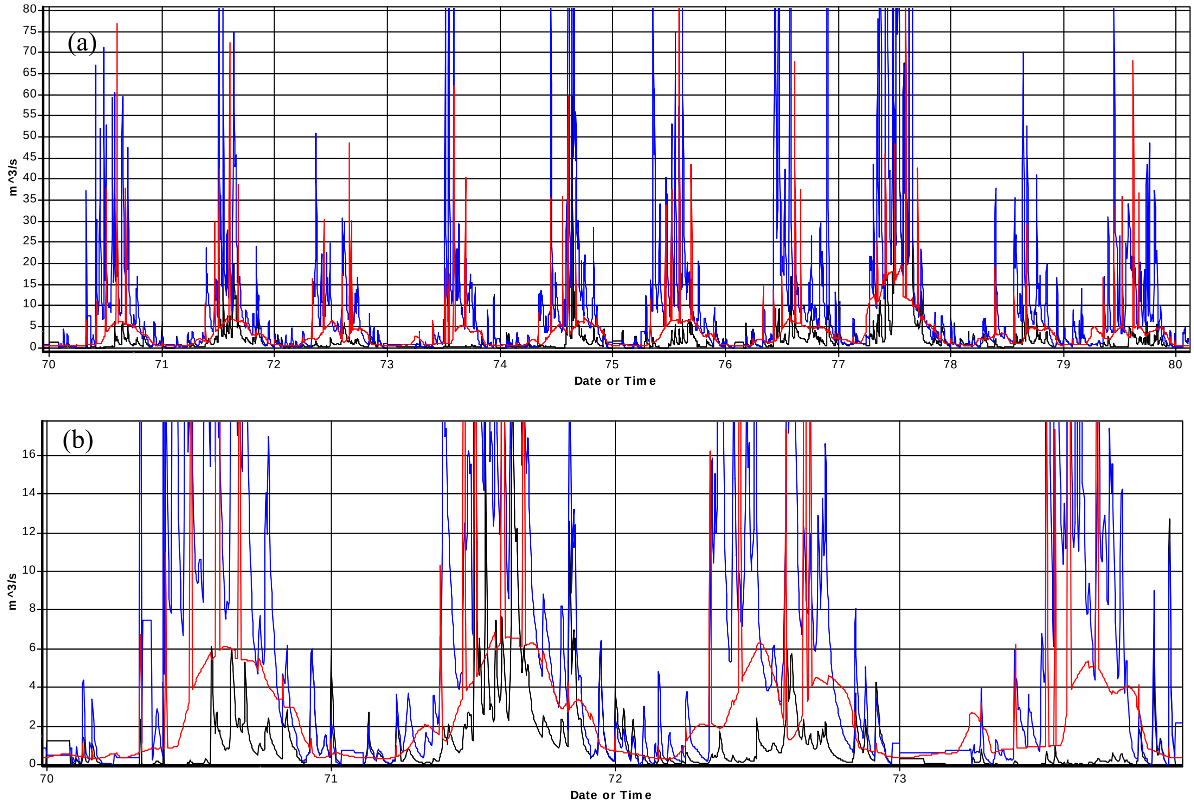

Figure 10.4 : IFR time series between (a) 1970 – 1980, (b) 1970- 1974 (red line = IFR; blue line = Virgin; black line = Present Day)

The problem:

The biological information at the site suggested that the required flows for summer and winter maintenance flows were in the region of 1.2 and 8 $m^3 s^{-1}$ respectively. According to the hydrology generated for this site (as above), these flows occurred only 14% (1.2) and 61% (8) of the time in January and July, respectively. Thus, according to the hydrology that had been provided for the site, the recommended maintenance base flows (for a Class D river) in summer were higher than those that occurred naturally in the system. Similarly, the wet season lowflows would have represented a high percentile on the natural lowflow hydrology.

The actions:

The biological, hydraulic and hydrology specialists rechecked their data and a discussion ensued as to the possible reasons for the apparent mismatch.

The explanation:

There are several possible explanations for the apparent mismatch:

- In order to adjust the data from the gauging weir (G06H009) to that of the site, the hydrologist had to account for present-day abstraction from the river, including Theewaterskloof Dam, Riviersonderend town, and the downstream farmers. These abstractions are not well documented, and thus, open to inaccuracies. The hydrologist decided to use the naturalised data for inflow to Theewaterskloof Dam, and to add the contributions of the incremental catchments, downstream of this point. This led to a 0.25% increase in the discharges at IFR Site 5, relative to the data generated from G06H009.

- Theewaterskloof Dam was constructed in the early 1970's. Since then the downstream river has received irrigation releases and releases for Ruensveld East and West from the dam in summer, resulting in unnaturally elevated base flows in the system. It is possible/likely that the system has adjusted somewhat to these elevated base flows, and thus the site information used by the specialists to recommend flows has been set in response to the elevated irrigation flows, rather than to the natural hydrology.
- The recommendations from the specialists are based on expert opinion, with the aid of limited original data collection. Their confidence in their recommendations ranges from low (invertebrates and fish) to moderate (vegetation and water quality), i.e., some of the mismatch may be accounted for by inaccuracies in the biological information used to make the recommendations.

Geomorphology is not a major motivator for low flows.

The hydraulic specialists were confident that they had excellent agreement between their observed and modelled data, and that it was unlikely that the hydraulics were a major contributor to the apparent mismatch.

The way forward:
In consultation with the specialists, it was decided to:

- revisit the specialist recommendations and revise where appropriate;
- record the specialists recommendations, with their motivations;
- revisit the hydrology, in particular the current day hydrology, and recheck the values provided for IFR Site 5.

11. IFR 6 : BAVIAANS RIVER UPSTREAM OF THE DWAF GAUGING WEIR

TARGET REACH: FROM 1 KM UPSTREAM OF THE DWAF GAUGING WEIR TO THE TOWN OF GENADENDAL

11.1 REFERENCE CONDITIONS

11.1.1 Fish

Pseudobarbus burchelli and *Sandelia capensis* are likely to have been abundant amongst the cobbles and in the emergent vegetation at the end of the pool. *Galaxias zebratus* are likely to have been present but in lower numbers along the undercut bank and amongst the emergent vegetation.

Reference indigenous species list (3 of 3):
Pseudobarbus burchelli
Sandelia capensis
Galaxias zebratus

11.1.2 Aquatic Invertebrates

Reference conditions for Mountain Stream and Foothill rivers are based on data accumulated for the present study including, community composition, diversity indices, rank-abundance curves as well as SASS4 scores. Natural, unmodified conditions are expected to have a SASS4 score = >140 and ASPT score >8. The community is expected to include a large proportion of sensitive taxa including three or more baetid species, Notonemeuridae, Leptophlebiidae, Elmidae, Dryopidae, Helodidae and Limnichidae with lower relative abundances of Chironimidae and Oligochaeta. Community diversity is expected to be high (*H'* >4) with an even distribution of individuals amongst species, reflected by a low gradient rank-abundance curve.

11.1.3 Riparian Vegetation

There should be a clear distinction between the different zones in the riparian vegetation as detailed in Boucher (1998), and Boucher and Tlale (2000). There should be a distinct floodplain. In summary, these zones should be as follows:

Aquatic Zone: The density of instream aquatic vegetation should be less than 1% cover. Some minor (< 5% cover) intrusion of rooted Wetbank Zone herbs into the channel can take place during the dry season.
Wetbank Zone: Few new sandy deposits should be present and they should only be colonised by herbaceous species such as sedges, i.e., no mature shrubs or trees. The Wetbank Zone vegetation cover should be virtually continuous and dominated by tall shrubs. There should be no bank collapse.
Lower Dynamic Zone: There should be no bank collapse and no invasion by woody exotic species. The zone should be very narrow where present.

Tree/shrub zone: Indigenous woody perennials should dominate the Drybank. There should be no invasive alien species. Post-fire environment should be dominated by sprouting indigenous perennials.

11.1.4 Geomorphology

River type: Foothill cobble-bed river.

Active channel well defined, with stable well-vegetated banks. Cobbles not embedded. No bulldozing or artificial manipulation of the bed, banks, floodplain and no channelisation.

11.1.5 Water Quality

TDS	:	< 45 mg/l
pH	:	6.5 – 7.5
DO	:	80 - 120% saturation
TSS	:	< 5 mg/l
Temperature	:	unmodified
Nutrients	:	PO_4/TP ratio : 0 – 10%
Median $P0_4$	:	< 0.01 mg/l
TN:TP ratio	:	> 20:1
Toxic substances	:	Meets the target water quality range for toxic substances as stated in the South African Water Quality Guidelines for Aquatic Ecosystems for 90% of the time, 99% of time less than or equal to chronic effect value, 100% of time less than the acute effect value.

11.1.6 Hydrology

No change to natural distribution flow regime.

11.2 PES, CAUSES AND ORIGIN, TRAJECTORY OF CHANGE

11.2.1 Fish

PES: A/B Class

Despite the presence of the upstream dam, the fish community at IFR Site 6 is largely natural. All species expected to occur here historically, were recorded during this study. Given the data available for this river, it is impossible to tell if the numbers of these species have declined. It is suspected that some changes would have occurred following the construction of the dam upstream, therefore an A class is not allocated.

CAUSES	ORIGINS	NON-/FLOW RELATED
Change in flow regime.	Upstream weir.	Flow related
Grazing.	Agriculture.	Non-flow related

Trajectory of change: None

As the weir has been place for a number of years, it is assumed that the fish species would have adjusted to any changes that may have occurred.

11.2.2 Aquatic Invertebrates

PES: A/B Class

Baviaanskloof has a SASS4 score = 109 and ASPT score = 8.38, a moderate diversity index (*H'*= 3.58) and a gradually sloping rank-abundance curve with the community dominated by Chironimidae. The low SASS4 score for this site suggests a D class, however the large numbers of sensitive taxa including Notonemeuridae and Ephemerellidae suggest that this site should be higher. Furthermore an assessment conducted by Dallas (1998) at a site nearby suggests that it is an A class site (SASS4 score = 150, ASPT score = 8.82). Thus the possibility exists that the conditions at the time of sampling for this study (rain) may have contributed to a relatively low score. Invertebrates tend to take refuge when flows are high. Judging from the condition of the habitat at this site, and baring any major once-off impacts, it is unlikely that the PES would have dropped from an A to a D in three years. Habitat condition suggests that the PES should be in the region of A/B.

CAUSES	ORIGINS	NON-/FLOW RELATED
Reduced habitat.	Minor infilling of banks, invasion by alien plants.	Non-flow related
Some flow impacts (quality and quantity).	Reduced summer low flows - dam (town supply).	Flow related
Grazing (habitat).	Agriculture.	Non-flow related

Trajectory of change: None

11.2.3 Riparian Vegetation

PES: C Class

Aquatic Zone: No true Aquatic Zone is present. Plants rooted in the Lower Wetbank Zone such as the sedges, *Isolepis prolifer* and particularly *Juncus lomatophyllus* extend into the stream forming fringing mats in summer that would be washed away during high flows in winter.

Wetbank Zone: The Upper Wetbank Zone (Group I in Table 6.1) typically supports a 3.0 — 5.0 m tall shrub vegetation, dominated by *Erica caffra, Metrosideros angustifolia* and *Psoralea pinnata*. Tussock-forming sedges, such as *Carpha glomerata*, and restio’s, e.g., *Calopsis paniculata,* dominate the 1.0 m high middle stratum with dense straggly low bushes of the shrubs, *Hippia montana* and *Oftia africana* between. Exotic invasive woody *Acacia longifolia* was previously fairly common here, judging from felled remains.

Lower Dynamic Zone: The Lower Dynamic Zone is not obvious here as it is largely overgrown. Some slumping on the left (north) bank indicates its presence. The 1.0 m tall shrubs, *Athanasia trifurcata* and *Stoebe plumosa*, and the grasses and sedges, *Ehrharta ramosa, Ficinia nigrescens* and *F. trichodes* are dominant here.

Tree/shrub zone: The Tree/shrub zone is dominated by the 1.5 — 2.0 m tall shrubs *Halleria elliptica* and *Rhus angustifolia* with extensive stands of 1.0 m tall bracken fern, *Pteridium aquilinum,* underneath.
Back Dynamic Zone: The Back Dynamic Zone is largely in disturbed terraced areas. Here 1.0 — 1.5 m tall shrubs, *Athanasia trifurcata* and *Rhus angustifolia*, are dominant.

CAUSES	ORIGINS	Non-/Flow related
Blocked floodplain and reduced flows.	Past dense alien vegetation.	Non-flow related
Grazing.	Agriculture.	Non-flow related
Encroachment of vegetation at bed level.	Genadendal (abstraction of summer flows).	Flow related

Trajectory of change: Positive (Short term: B/C Class Long term: B Class).
Positive, provided the alien clearing and follow-up activities continue to take place, otherwise negative. The river has stabilised at a lower level after upstream impoundment.

If follow-up operations halted:
5 years: Class C.
20 years: Class D.

11.2.4 Geomorphology

PES: B Class
Some minor impacts on the edges of the macrochannel, i.e., a road and terracing.

CAUSES	ORIGINS	NON-/FLOW RELATED
Slight channel narrowing and infilling between cobbles.	Genadendal : Upstream abstraction.	Flow related

Trajectory of change: Stable

11.2.5 Water Quality

PES: A/B Class
Water quality slightly modified by the weir situated upstream of the IFR site.

CAUSES	ORIGINS	NON-/FLOW RELATED
Increased nutrients and TDS.	Upstream weir.	Flow related

Trajectory of change: Negative (Short-term A/B Class/Long-term B Class).
Very slight increasing trend of 0.2 mg/l TDS per year.

11.2.6 Hydrology

PES: B Class

Although there is an abstraction weir upstream of the reach, the indications are that flow is only slightly impacted. Hydrology data are not available to make the assessment.

11.2.7 Overall PES

The causes and origins are summarised as follows:

Flow related Abstraction in summer for purposes of Genadendal and environment. *Non-flow related* Grazing.

The hydrology and water geomorphology drivers are in a B class. As the hydrology is the key factor that would have indicated change, it is felt that this should be considered for the overall PES. An Overall PES class of B was therefore selected.

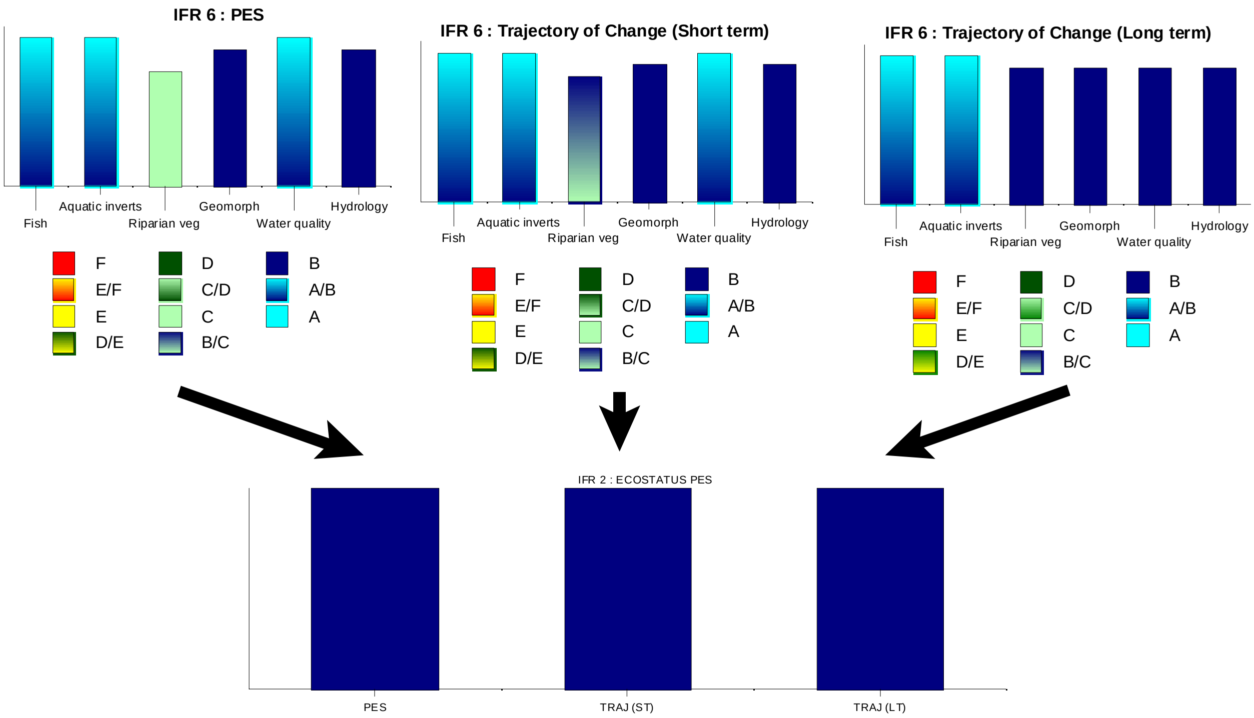

Figure 11.1 : Present Ecological Status (PES)

11.3 ECOLOGICAL AND SOCIAL IMPORTANCE

EIS rating: Very high.
Confidence: High.
Determinants: Presence of rare, endangered and unique species as well as intolerant biota. Important refugia and habitats that are sensitive to flow and flow related water quality changes.

Social rating: Moderate
Determinants: The town of Genadendal is an historic missionary station. There is also a historic mill.

AIM:
The *EIS is very high, the social importance is moderate and the PES is high (class B).* The overall trajectory of change is stable. Normally the aim would be to maintain PES and minimise the risk of degradation unless there are overriding reasons to improve conditions. Depending on the degree of difficulty it may be possible to improve individual components.

11.4 ATTAINABLE EC

As there is no negative trajectory of change, no action is required to maintain the river in its present state.

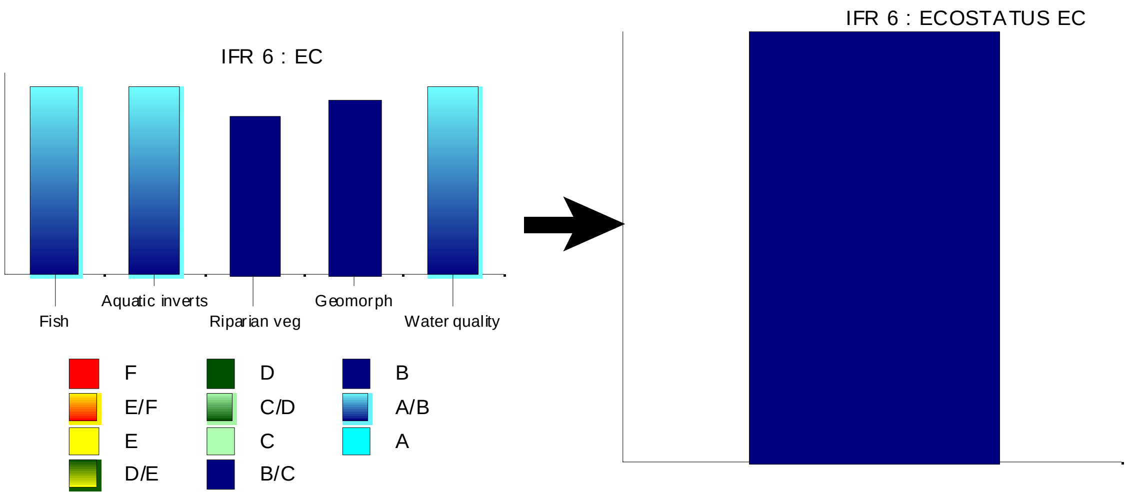

Figure 11.2 : Ecological Class (EC)

COMPONENTS	PES	TRAJ	SHORT TERM (5y)	LONG TERM (20y)	EIS	EC
Hydrology	B	0	B	B		
Water quality	A/B	-	A/B	A/B	HIGH	A/B
Geomorphology	B	0	B	B		B
Riparian veg	C	+	B/C	B		B
Fish	A/B	0	A/B	A/B		A/B
Aquatic inverts	A/B	0	A/B	A/B		A/B
Ecostatus	B	0	B	B		B
					Long term EC	B

Figure 11.3 : Summary of the PES and EC

11.5 OBJECTIVES

11.5.1 Fish

EC: A/B

General flow objectives: Maintain low flows during summer.

Overall fish objectives: Maintain a food source and the feeding behaviour of the fish.

Objectives for target/indicator species: Maintain upstream source of invertebrates which *Galaxias*, *Pseudobarbus* and *Sandelia* prey upon as they drift downstream.

General flow objectives: Maintain summer floods, freshes.

Overall fish objectives: Maintain spawning cues.

Objectives for target/indicator species: *Pseudobarbus burchelli* requires a prolonged period of high flows/freshes in the summer months as a cue for spawning. Spawns twice during summer at three-month intervals therefore two or more freshes should promote spawning success.

11.5.2 Aquatic Invertebrates

EC: A/B

General flow objectives: Maintenance of the full range of flows presently in the river.

Objectives for target/indicator species:

- Maintain higher low flows in winter than in summer. Summer species are adapted to lower flows than winter species.

- Maintain a major flood at the beginning of the wet season, i.e., May/June and several more during the wet season. The first major flood resets the river to winter conditions, flushing away fine sediment and summer species such as Oligochaetes. Subsequent floods sort and rework sediments maintaining physical heterogeneity.
- Maintain small freshes during spring and early summer. Enhance downstream drift of animals and flush out areas of poor quality water accumulated during summer low flows.
- Mimic natural pattern of average monthly flows, i.e., July/August highest January/February lowest. Different species are adapted to react to different flow cues for life history stages. Precautionary approach is to maintain the natural flow cues, because we do not know at present what these cues are.
- Maintain natural flow variability at monthly levels. Motivation as above.
- Maintain natural flow variability at daily levels. This level of variability is important but no supporting data is available.
- Maintain natural shape and duration of the flood hydrographs. Successful laying and hatching of eggs and other life cycle activities could be linked to the duration of inundation of marginal areas, secondary channels and floodplains.

General objectives for the invertebrates:

- Maintain at least SASS 4 score = 109 and ASPT score = 8.3.
- Maintain diversity index at a minimum of *H'*=3.58.
- Maintain a gradually sloping rank-abundance curve.
- Maintain a community that includes sensitive taxa, i.e., three or more baetid species, Notonemeuridae, Leptophlebiidae, Elmidae, Dryopidae, Helodidae and Limnichidae with lower relative abundance of Chironimidae and Oligochaeta.

Identification of and objectives for target species: No specific target species.

11.5.3 Riparian Vegetation

EC: B

Back Dynamic Zone

General flow objectives: To maintain a clear dynamic zone (1:20-1:50 year floods).

Overall vegetation objectives: No specific objectives stated as zone is currently recovering from fire and post-alien vegetation clearing.

Identification of and objectives for target species: No specific target species.

Tree-Shrub zone

General flow objectives: Maintain the Tree-shrub zone through the ongoing deposition of silt and debris (1:5 to 1:20 year floods) and to promote seedling and juvenile establishment and maintenance (1:2 year and Class IV floods).

Overall vegetation objectives: To reduce stress on plants and thereby restrict the invasion by alien species.

Identification of and objectives for target species: Target/indicator species objectives are to expand distribution of the zone as it has been damaged i.e. to restore density of stands of woody species (e.g., *Brabejum stellatifolium*, *Maytenus oleoides Rapanea melanophloeos*) coupled with continued alien woody eradication campaign).

Lower Dynamic Zone

General flow objectives: Maintain the Lower Dynamic Zone in near natural state to prevent channel shape change (steepening and narrowing of banks) caused by change to vegetation (1:2 year and Class IV floods).

Overall vegetation objectives: To prevent establishment of annual or woody alien species. However, some downward movement of tree and shrub species in response to flow reduction is expected and acceptable.

Identification of and objectives for target species: No specific target/indicator species.

Upper Wetbank Zone

General flow objectives: Maintain the Upper Wetbank Zone to prevent channel shape change (steepening and narrowing of banks) caused by changed vegetation (Class II to Class III floods and 5% exceedence winter low flows).

Overall vegetation objectives : To prevent establishment of annual or woody alien species.

Identification of and objectives for target species: Maintain *Salix mucronata* and *Metrosideros angustifolia*.

Lower Wetbank Zone

General flow objectives: Maintain Class I flood; present day 5-90% winter low flows and 5-90% summer low flows.

Overall vegetation objectives: Community objective is to ensure zone is wet regularly for fairly long periods in winter (with fluctuations in levels) to allow plants to grow in clear water even while submerged. To ensure that banks will be wetted through capillary action when exposed.

Identification of and objectives for target species: Maintain *Metrosideros angustifolius, Juncus lomatophyllus*. Also prevent invasion of riffle by *Juncus lomatophyllus.*

Aquatic Zone

General flow objectives Maintain present day 90-99% winter base flow and 50% summer base flow so that the banks will be wetted through capillary action even when exposed.

Overall vegetation objectives: No specific community objectives.

Identification of and objectives for target species: Prevent algae increases.

11.5.4 Geomorphology

This river is geomorphologically in a good condition and will remain so unless flood flow patterns are impacted upon and/or alien vegetation re-infests the river banks.

11.5.5 Water Quality

EC: A/B

TDS	:	Maintain TDS at < 55mg/l for 95% of the time. Note - no change in TDS with flow.
pH	:	Maintain inter-quartile range between current 25 and 75 percentiles (i.e. 4.5 - 6.5).
Dissolved oxygen	:	Maintain between 80-120% of saturation.
Water temperature	:	Maintain within 2 degree C of reference site. This site is regarded as a reference site (RDM manual specifications).
Total suspended solids	:	Maintain at <10% from reference site. This site is regarded as a reference site (RDM Manual specifications).
Nutrients	:	Median PO_4 concentration < 0.04 for 95% % PO_4:TP ratio <15%. TN:TP ratio>10:1. Median NH_3-N<0.007. NO_2NO_3-N <0.15 mg/l.
Toxic substances	:	Maintain toxic substances at TWQR for 90% of the time and <=CEV for 99% of the time and <= AEV for 100% of the time as specified in the SAWQG for aquatic ecosystems.

11.6 MAINTENANCE FLOW ASSURANCE

The assurance of maintenance low flows during winter is set as a flow that occurs at least 70% of the time. The assurance of maintenance low flows during summer is set as a flow that will occur 60% of time.

11.7 SEASONAL DISTRIBUTION

September was selected as the highest flow month and March was selected as the lowest flow month.

11.8 IFR RESULTS

IFR Site 6 – Baviaans River. Problems with the hydrological information emerged at the IFR Workshop. We had considerable difficulties with IFR Site 6, Baviaans River, as the biophysical information suggested that the hydrological data from the DWAF gauging weir was underestimating flow in the river. Subsequent discussions between Ninham Shand, DWAF and Prof Albert Rooseboom seemed to confirm this. Thus, in an effort to keep the process going forward, the specialists determined the IFR without reference to the hydrological data. This means that the standard back-checking for consistency has NOT been undertaken.

Furthermore, it must be noted that the depths and velocities provided in the motivations for each of the biophysical components of the study are related to field measurements NOT the hydraulic information prepared for the workshop, except where stated otherwise. The hydraulic information prepared for the workshop, which was modelled but not calibrated, was however used to provide the related depths in the IFR table. Thus, should inconsistencies emerge between the hydrology and the recommended IFR, the first step should be to recheck the hydraulics.

11.8.1 Motivations

MAINTENANCE LOW (DRY SEASON, JANUARY) **0.16 m^3s^{-1}**

Descriptions of flow required:
Fish: 0.4-0.6 m depth, 0.2 m s^{-1} (cross-section 3 - velocity from modelled hydraulic data).
Aquatic invertebrates: 0.1 – 0.2 m (cross-section 1), 0.22 - 0.5 m s^{-1} (velocity from modelled hydraulic data).
Riparian vegetation: 0.09 – 0.15 m or 252.32 amsl (cross-section 2)
Geomorphology: None.

Primary motivation:
Fish: *Pseudobarbus*, *Sandelia* and *Galaxias* forage and maintain position at 0.11-0.2 m s^{-1} and they prey mostly on baetids drifting downstream from the riffle into the pool at mean velocities of 0.2-0.5 m s^{-1}. Assuming that drift food supply disappears at 0.2 m s^{-1} this would be the required velocity. Bulk of all three species found at 20-40 cm depth in 40-60 cm deep water. Lower depths and velocities would result in changing foraging behaviour and loss of 80 % of current food source for the three species.
Source: This study, de Moor (1991).
Aquatic invertebrates: Summer invertebrates not sampled at this site. Community at Molenaars and descriptions from King (1981) used to infer probable community members: Heptageniidae, *Baetis harrisoni* which would be catered for by the above conditions.
Source: Invertebrate samples for BRBS, photos, SVD histograms, King (1981).
NB The logic trail followed was to identify two representative riffle species for the summer and the winter either from this study or from research on the Molenaars and Eerste Rivers. The range of depths and velocities at which these species most frequently occurred were identified and are listed as the required hydraulic conditions for this site. These required conditions were checked with the frequency plots of depths and velocities recorded by the habitat-mapping specialist. For both seasons, the required conditions matched those actually recorded. As a second check these depths agree with those that the botanists identified as being appropriate for the various zones that are inundated in summer and winter
Riparian vegetation: Aquatic maintenance. Keeps river relatively clean of algae. Will find *Juncus lomatophyllus* takes over the streambed.
Source: Own data reports and students' studies.

MAINTENANCE LOW (WET SEASON, JULY) 0.21 m^{3}s^{-1})

Descriptions of flow required:
Fish: 0.4-0.6 m depth, 0.2 m s^{-1}.
Aquatic invertebrates: 0.2 - 1.2 m s^{-1} and depths between 0.1 – 0.7 m in riffle areas (HH1).
Riparian vegetation: *C.* 0.5 m depth or 252.73 amsl (Cross-section 2).
Geomorphology: None.

Primary motivation:
Fish: Winter refuge of *Pseudobarbus* in *Isolepis* within backwater of cascade. Similarly to summer situation, *Pseudobarbus*, *Sandelia* and *Galaxias* forage and maintain position at 0.11-0.2 m s^{-1}. Prey mostly on Baetids drifting downstream from the riffle into the pool at mean velocities of 0.2-0.5 m s^{-1}. Assuming that drift food supply disappears at 0.2 m s^{-1}, this would be the required velocity. Change in foraging behaviour and loss of 80 % of current food source for the three species**.**
Source: This study, literature.
Aquatic invertebrates: Maintenance of hydraulic conditions within the channel for winter community species, e.g., *Lestagella* sp.
Source: This study, samples, photos, profile.
Riparian vegetation: Required to maintain the top of the Lower Wetbank.
Source: Own data reports, observations, students' studies.

DROUGHT LOW (DRY SEASON, JANUARY) 0.017 m^3 s^{-1}

Descriptions of flow required:
Fish: 0.1 – 0.2 m depth (cross-section 2).
Aquatic invertebrates: Mean column velocities of 0.2 – 0.3 m s^{-1}, depth 0.1 m in riffles (HH1).
Riparian vegetation: *c.* 0.10 m depth or 252.32 m amsl alt altitude (cross-section 2).
Geomorphology: None.

Primary motivation:
Fish: *Juncus* is the main refuge for *Sandelia*, *Pseudobarbus* and *Galaxias*. Dies out at approx. 8 cm. Minimum depth of all fish found in *Juncus* was 10 cm. Loss of refuge will increase the loss of all fish species through predation.
Aquatic invertebrates: To continue to provide the lower end of the depth and velocity ranges in which the target species (named in summer maintenance section) have been recorded.
Source: Invertebrate samples for BRBS (this study), photos, profile.
Riparian vegetation: To keep Wetbank vegetation alive. Wetbank vegetation will degenerate significantly if it receives no water.
Source: Own data reports, observations, students' studies.

DROUGHT LOW (WET SEASON, JULY) $0.019\ m^3s^{-1}$

Descriptions of flow required:
Fish: 0.1-0.2 m depth (cross-section 2).
Aquatic invertebrates: Mean column velocities of 0.2 – 0.6 m s^{-1}, depths ranging between 0.1 and 0.4 m in riffles (HH1).
Riparian vegetation: *c.* 0.10 m depth or 252.32 m amsl alt altitude (cross-section 2).
Geomorphology: None.

Primary motivation:
Fish: As for summer lowflows, *Juncus* is the main refuge for *Sandelia*, *Pseudobarbus* and *Galaxias*. Dies out at approx. 8 cm. Minimum depth of all fish found in *Juncus* was 10 cm. Loss of refuge leads to a loss of fish through predation.
Aquatic invertebrates: To continue to provide at least the lowest depth and velocity ranges in which the target species (named in winter maintenance section) have been recorded.
Source: Invertebrate samples for BRBS (this study), photos, profiles.
Riparian vegetation: To maintain the bottom of the Lower Wetbank vegetation.

Water quality consequences:
No relationship was found between water quality and lowflow. This means that there is a high probability that water quality will not change from present day concentration ranges when there is a change in lowflow. Mean present day concentrations represent a high B class water quality. Note - Water quality deterioration in the Riviersonderend is probably mitigated by good water quality in the streams flowing from the Riviersonderend mountains. A change in flow or deterioration of water quality in these streams will have a cumulative impact on water quality in the Riviersonderend River.

FLOOD REGIME

Fish:
CLASS I: At least two, three months apart, Oct-Nov, Feb-Mar. *Pseudobarbus burchelli* requires a prolonged period of high flows/freshettes in the summer months as a cue for spawning. Spawns twice during summer at three-month intervals therefore two or more freshettes should promote spawning success.
Aquatic invertebrates:
CLASS I and II – require at least two floods to maintain current. Used for dispersal of larvae and/or eggs through downstream drift. These floods also mobilise flood and organic matter into the water column, and prevent localised build-up of organic material or mud on rock surfaces, which would favour different taxa, e.g., oligochaetes.

Riparian vegetation:

CLASS II and III: (up to 0.7 m depth at cross-section 2). Maintains the upper Wetbank. These floods also affect plant growth and performance. A delay in these floods may also negatively affect growth by shortening the period when plants can benefit from these floods.

CLASS IV and 1:2 yrs: (Up to 1.4 m depth at Cross-section 2) maintains the Lower Dynamic Zone and the Wetbank. The tree-shrub zone will invade the Lower Dynamic Zone if large winter within-year floods are reduced. In Mountain Stream and Foothill zones, these floods (and to a lesser extent Class III floods) also flush annuals and sediments from the system, thereby maintaining a balanced community.

The above requirements are summarised in Table 11.1:

TABLE 11.1 : SUMMARY OF DEPTH AND VELOCITY REQUIREMENTS AT IFR SITE 6

MAINTENANCE FLOWS				
MONTH	**FLOW RATE ($m^3 s^{-1}$)**	**BOTANY**	**INVERT.**	**FISH**
Jan	0.16	0.09-0.15 m @ X-section 2	0.22 - 0.5 m s^{-1} in HH1. 0.1 - 0.2 m @ X-sect 1	Primary: 0.2 - 0.4 m in HH3. Also 0.21 m s^{-1} @ X-sect 2.
Jul	0.21	Primary: 0.5 m @ X-sect 2, to maintain Lower Wetbank - measured recordings (22 April field visit). 0.43 m on calibrated cross-section	Primary:0.1 - 0.7m @ HH1. 0.2 - 1.2 m s^{-1} in HH1	Secondary: 0.2 - 0.4m in HH3. Also 0.21 m s^{-1} @ X-sect 2.
Drought flows				
Jan	0.017	Secondary: 0.1 m @ X-sect 2	Primary: 0.2 and 0.3 m s^{-1} in HH1. 0.1m @ X-sect 1.	Primary 0.1m in HH3
Jul	0.019	Secondary : 0.15 m @ X-sect 2	Primary: 0.1 to 0.4 m at HH1. 0.2 - 0.6 m s^{-1} in HH1	Primary 0.1 - 0.1 m in HH3

The flood recommendations for IFR Site 6, to maintain a B Class river are provided in Table 11.2.

TABLE 11.2 : FLOOD REQUIREMENTS FOR IFR SITE 6

WITHIN YEAR FLOODS					
CLASS FLOODS	**ESTIMATED PEAK**	**CLASS B**	**CLASS C**	**CLASS D**	**MONTHLY DISTRIBUTION**
Class I	0.8 $m^3 s^{-1}$	3	2	2	10-11 and 3-4
Class II	1.6 $m^3 s^{-1}$	2	2	1	5 and 6
Class III	3 $m^3 s^{-1}$	2	2	1	6-7 and 8-10
Class IV	6 $m^3 s^{-1}$	1	1	1	6-9
OTHER FLOODS					
1:2	Not known	yes	yes	yes	
1:5	Not known	yes	yes	no	
1:10	Not known	yes	yes	yes	
1:20	Not known	yes	yes	yes	

11.8.2 IFR Table

The results as motivation above are presented in the Table 11.3.

TABLE 11.3 : IFR TABLE: IFR SITE 6 – B CLASS

IFR 6: BAVIAANS RIVER ASSURANCE OF MAINTENANCE LOW FLOWS: 60% (summer) and 70% (winter) MAR (VIRGIN): Not known MAR (PRESENT): Not known										
MONTHS	MAINTENANCE LOW FLOWS			HIGH FLOWS				DROUGHT LOW FLOWS		
	DEPTH	FLOW	VOLUME	DEPTH	FLOW	DURATION	VOLUME[1]	DEPTH	FLOW	VOLUME
		($m^3 s^{-1}$)	($10^6 m^3$)		$m^3 s^{-1}$ Daily average		($10^6 m^3$)		($m^3 s^{-1}$)	($10^6 m^3$)
Oct	0.46	0.4	1.07	0.53	0.8	2	0.048	0.33	0.03	0.08
Nov	0.43	0.34	0.88					0.43	0.027	0.07
Dec	0.4	0.15	0.4					0.33	0.016	0.04
Jan	0.4	0.16	0.43					0.33	0.017	0.05
Feb[2]	0.35	0.09	0.22	0.53	0.8	2	0.086	0.33	0.013	0.03
Mar	0.33	0.04	0.11					0.33	0.01	0.03
Apr	0.37	0.07	0.18	0.53	0.8	2	0.086	0.33	0.012	0.03
May	0.33	0.04	0.11	0.6	1.6	3	0.243	0.33	0.01	0.03
Jun	0.4	0.13	0.34	0.6	1.6	3	0.229	0.33	0.015	0.04
Jul	0.43	0.21	0.56	0.73	3	3	0.434	0.33	0.019	0.05
Aug[2]	0.43	0.27	0.72	0.88	6	4	1.04	0.33	0.023	0.06
Sep	0.43	0.35	0.91	0.73	3	3	0.412	0.35	0.028	0.07
TOTAL :			5.93				2.58			0.58
% OF MAR (VIRGIN)										
Long term % OF MAR (VIRGIN): Not known										
1	The volume represents the daily average less the low flows									
2	February was the month identified by the specialists to determine the dry season flows. Due to the unnatural high flows occurring presently in the system - the flow was set near natural.									
3	August was the month identified by the specialists to determine the wet season flows. The other months are extrapolated using hydrological regional parameters for the Western Cape.									
4	Cross-section 2 used to determine depths provided. Assuming uniform flow conditions.									

Note : The š1:2 floods are also included in the requirement although not included in the table above.

Without the correct hydrology it was not possible to provide the IFR rules and the IFR flow sequence for IFR Site 6. However, the flood requirements for a Class C and D river are provided (Table 11.2) and calculation of the scenarios according to the process describe in Section 6 would be a relatively simple task once the hydrology were available.

11.9 CONFIDENCE EVALUATION

See Section 11.8

Overall Confidence: Low.