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KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY

TECHNICAL COMPONENT

EWR SEEKOEI ESTUARY REPORT

Coastal & Environmental Services

**KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY
– TECHNICAL COMPONENT**

EWR RIVERS REPORT: FINAL

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Prepared by: Coastal & Environmental Services
PO Box 934
Grahamstown
6140

Prepared for: The Director
Directorate Resource Directed Measures
Department of Water Affairs and Forestry
Private Bag X313
Pretoria
0001

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Authors:

D Louw and S Koekemoer

IWR Source-to-Sea

PO Box 122

Persekor Park

Pretoria

0020

The following specialists contributed to the specialist meeting:

D Louw (EWR co-ordinator), A Birkhead (Hydraulician), M Uys (Aquatic invertebrates), A Bok (Fish), N Kemper (Riparian vegetation), D Hughes (Hydrology), K Rowntree (Geomorphologist), P Scherman (Water quality), C Thirion (Ecostatus and Flow Stressor - Response), S Koekemoer (Co-ordinator trainee), L Du Preez (Geomorphologist trainee), P Gola (Water quality trainee), S Bukhosini (Hydrology trainee).

**DEPARTMENT OF WATER AFFAIRS and FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES**

**KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY
– TECHNICAL COMPONENT
EWR REPORT: FINAL**

Approved for CES by:

.....
**Dr Patsy Scherman
Technical Team Leader**

Approved for the Project Management team by:

.....
**Erik van der Berg
Project Manager**

Approved for the Directorate Resource Directed Measures by:

.....
**Harrison Pienaar
Chief Director**

EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND

A Reserve Determination study for the Kromme and Seekoei Catchments in the Eastern Cape was commissioned during 2003. The Kromme / Seekoei River catchments were identified as requiring high confidence comprehensive Reserve assessments before licensing can proceed, due to the apparent highly stressed nature of the catchments, over-utilisation of water resources and water quality problems in the Kromme, Seekoei and Swart rivers. Other concerns included over-abstraction of well-fields by coastal towns in summer, and the impact of many illegal farm dams in the area. Detailed determinations of the requirements of the Ecological Reserve were therefore required in order to confirm current perceptions and aid future planning. However, the level at which a Reserve study can be conducted is dependent on the data available for the study. Due to hydrological, water quality and biotic data constraints, the Kromme River system was assessed using mainly Intermediate Ecological Reserve Methodology (IERM), while the Seekoei and Swart River sites were evaluated following the requirements of Rapid Ecological Reserve Methodology III (RERM). The additional study for the Diep River was also assessed using RERM III.

IWR Source-to-Sea (IWR S2S) undertook the Ecological Water Requirements (EWR): Rivers - *quantity* task 2 for the lead consultant, Coastal & Environmental Services (CES).

The study area has been defined as follows:

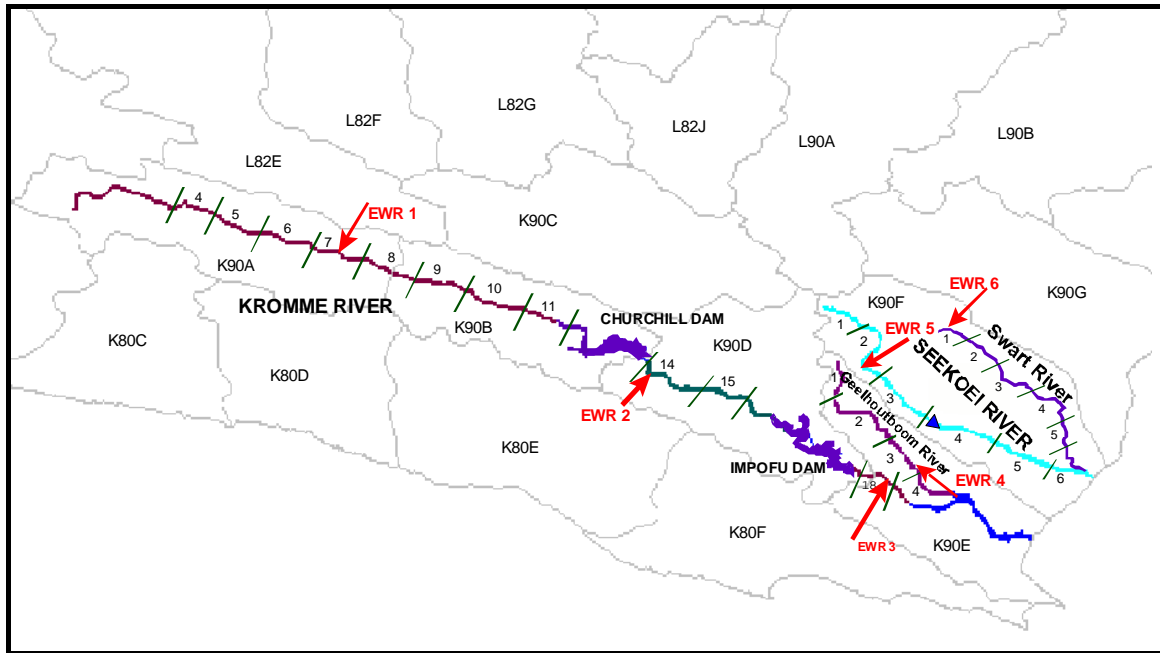
- The Kromme River from below the Palmiet Wetlands to the estuary, including the estuary.
- The Geelhoutboom River, a tributary of the Kromme River, below Churchill Dam.
- The Seekoei River, including the estuary.
- The Swart River, a tributary of the Seekoei River.

Six EWR sites were selected, as shown on the study area map:

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

EWR site	River	Latitude	Longitude	Quaternary	RU
EWR1	Kromme	E 24° 15.680	S 33° 55.905	K90A	A
EWR2	Kromme	E 24° 29.865	S 34° 00.822	K90D	B
EWR3	Kromme	E 24° 43.6	S 34° 06.3	K90E	C
EWR4	Geelhoutboom	E 24° 44.723	S 34° 05.411	K90E	E
EWR5	Seekoei	S 33° 59.968	E 24° 42.113	K90F	F
EWR6	Swart	S 34° 00.05	E 24° 50.83	K90F	H

A subsequent study also included a rapid study on the Diep River (tributary on the Kromme). All information pertaining to the Diep River is included in Appendix K.



This report serves to document a specialist meeting held from 20 to 23 September 2004; providing the Ecoclassification and the EWR flow scenarios for different ecological categories (ECs).

METHOD FOLLOWED

The Intermediate Ecological Reserve Methodology (IERM) was followed at EWR sites 1, 2 and 4. Data collection at EWR 5 and 6 were according to the Rapid Ecological Reserve Methodology (RERM) Level III, but the approach used to determine the scenarios followed the IERM.

ECOCLASSIFICATION

The approach used to determine the Ecoclassification is documented in a draft manual developed by DWAF and IWR Source-to-Sea (IWRS2S, 2004). The approach consists broadly of the following steps:

- Define the Present Ecological State (PES) for each component in terms of categories A to F.
- Integrate the component PES into an overall state called the Ecostatus.
- Determine the Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SI).
- Based on the above, as well as considering the PES, derive the Recommended EC (REC).
- Based on the REC, derive the realistic alternative ECs, to be addressed during scenario development.

The results are summarised as follows:

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

The Kromme River upstream of the dams (Churchill and Impofu) is in a C state with most of the problems centred around the presence of alien vegetation, alien fish and land use upstream. However, this is the best section of the Kromme River, and should not be allowed to degrade further. The section downstream of Churchill Dam is affected by decreased flows and an abnormal flow regime, as well as the presence of alien vegetation and fish. The same is true for the section downstream of Impofu Dam, although exacerbated by abstractions from the downstream pool. This section of river, although short, is very important as it forms the only freshwater link between the marine, estuarine and freshwater environments. During most of the year, no link is possible due to lack of releases and the abstraction of the pool.

The PES categories for both EWR 5 (Seekoei River) and 6 (Swart River) are representative of the upstream sections of the respective rivers. In both cases the downstream sections have been severely modified and in some cases, there is no river left as the farm dams form a continuum.

The confidence in data used to determine the Ecoclassification is mostly low. Ecoclassification assessments are therefore mostly of medium confidence because Ecoclassification is based on, and derived from, available data. The lack of data, and the resulting lack of understanding of the system, is primarily centred around the lack of confidence in the hydrology. The lack of understanding in most cases revolves around whether the system is perennial or seasonal, and whether the modelling is accurate. Reference conditions for biota are dependant on this understanding, and this factor, combined with the lack of historical data and the minimal present day surveys undertaken, results in a lack of confidence in reference conditions and therefore a lack of confidence in the degree of change under present conditions. The lack of water quality data further compounds the general uncertainty.

The comparative confidence in the evaluation of EWRs 1 and 4 are the lowest due to the uncertainty around the perenniality of the system. The confidence increases for EWR 5 and 6 as the sites are perennial due to their position upstream in the river system. No alternative ECs were addressed at Site 2 as the PES is already in a D state and it was not deemed practical to assess a higher category in this isolated stretch of river. At EWRs 4, 5 and 6 alternative ECs were not evaluated (other than one category down at EWR 6) as the river represents isolated sections in heavily modified stretches of river.

EWR FLOW SCENARIOS

The Habitat Flow Stressor Response method (HFSR) (IWRS2S, 2004) was used to set low flows, and a method adjusted from the standard Building Block Methodology (BBM; King and Louw,

1998) and Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach was followed to set high flows.

EWR assessments were not undertaken for EWR 3 as it was not possible to undertake a hydraulic assessment at this site. The importance of this site is highlighted as it is the only stretch (3km) of freshwater to link with the marine and estuarine environments. Flow requirements for this stretch of river should consist of at least two flood releases followed by at least 10 days of continuous base flow. The magnitude of the floods cannot be determined as no hydraulic rating at this site was possible. The magnitude is however not important as this flood must only serve as a trigger for fish migration.

The results of the other EWR sites are summarised in the following table as a percentage of the virgin mean annual runoff (MAR). It should be noted that these percentages must be used with caution due to the uncertainty around the naturalised hydrology. The hydrology for the study was based on simulated hydrology. Pitman calibrations were used to generate natural and present day flow sequences at specified riverine sites in the Kromme (AWRSA (1994) calibration) and the Seekoei / Swart (WRSM90 calibration) rivers.

EWR site	REC	Maintenance low flows (%)	Drought low flows (%)	High flows (%)	Long term mean of VMAR (%)
EWR 1	C	13.76	1.93	15.94	29.7
EWR 2	D	3.13	0.57	10.95	14.08
EWR 4	C/D	5.76	1.02	11.38	17.14
EWR 5	C	12.17	2.07	11.25	23.43
EWR 6	B	12.32	3.28	11.95	24.27

None of the results indicate any significantly different results from those expected as a percentage of the virgin MAR. The high maintenance flows required at EWR sites 5 and 6 are high when compared to the other sites, probably due to these sites being situated closer to the the sources of the rivers, i.e. in the upper half of the quaternary catchment. It has long been suspected that the smaller rivers usually situated on steep gradients or high in the system require a larger percentage of base flows than the larger downstream rivers. This could be due to the fact that a small decrease in flow can have a major impact on habitat in a small river, compared with a less noticeable impact in a larger river.

The confidence evaluation for low flows ranges from medium to medium - high. This is mostly due to the reasonable hydraulic confidence, as most hydraulic calibrations were obtained during low flow conditions.

For four out of the five EWR sites, high flow assessments were of low confidence. This is purely based on the lack of high flows experienced during the data collection phase and the resulting low confidence in the conversion of water levels to flow.

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TERMINOLOGY AND ACRONYMS

ASPT	Average Score Per Taxon
BBM	Building Block Methodology
BFI	Base Flow Index
DLF	Drought Low Flow
DO	Dissolved Oxygen
D: RDM	Directorate: Resource Directed Measures
DRIFT	Downstream Response to Imposed Flow Transformation
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FD	Fast and Deep
F-SR	Flow-Stressor Response
FRAI	Fish Response Assessment Index
FS	Fast and Shallow
GSM	Gravel Stones Mud
HFSR	Habitat Flow Stressor Response
HSI	Habitat Suitability Index
IERM	Intermediate Ecological Reserve Methodology
IFR	Instream Flow Requirement
IRAI	Invertebrate Response Assessment Index
MAR	Mean Annual Runoff
MCDA	Multi Criteria Decision Analysis
MLF	Maintenance Low Flow
MV	Marginal Vegetation
MVIC	Marginal Vegetation in Current
MVOC	Marginal Vegetation out of Current
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RERM	Rapid Ecological Reserve Methodology
RQS	Resource Quality Services
RU	Resource Unit
SASS5	South African Scoring System version 5
SD	Slow and Deep
SI	Socio-cultural Importance
SIC	Stones in Current
SOOC	Stones out of Current
SS	Slow and Shallow
VMAR	Virgin Mean Annual Runoff
VIC	Vegetation in Current
VOOC	Vegetation out of Current
WP	Wetted Perimeter
WQSU	Water Quality Sub-Unit

1 INTRODUCTION AND BACKGROUND

1.1 Background

This task forms part of the Kromme/Seekoei Catchments Reserve Determination Study. IWR Source-to-Sea was requested by Coastal & Environmental Services to undertake an Ecological Reserve study for the Quantity component of the Kromme/Seekoei Rivers systems. Due to hydrological and biota data as well as budget constraints, the Intermediate Ecological Reserve Methodology (IERM) was followed for most of the study area (as required by the Inception Report).

Figure 1-1 is a schematic representation of the 8-step Ecological Reserve process followed in this study. This report summarizes steps 3 and 4 of the Ecological Reserve process.

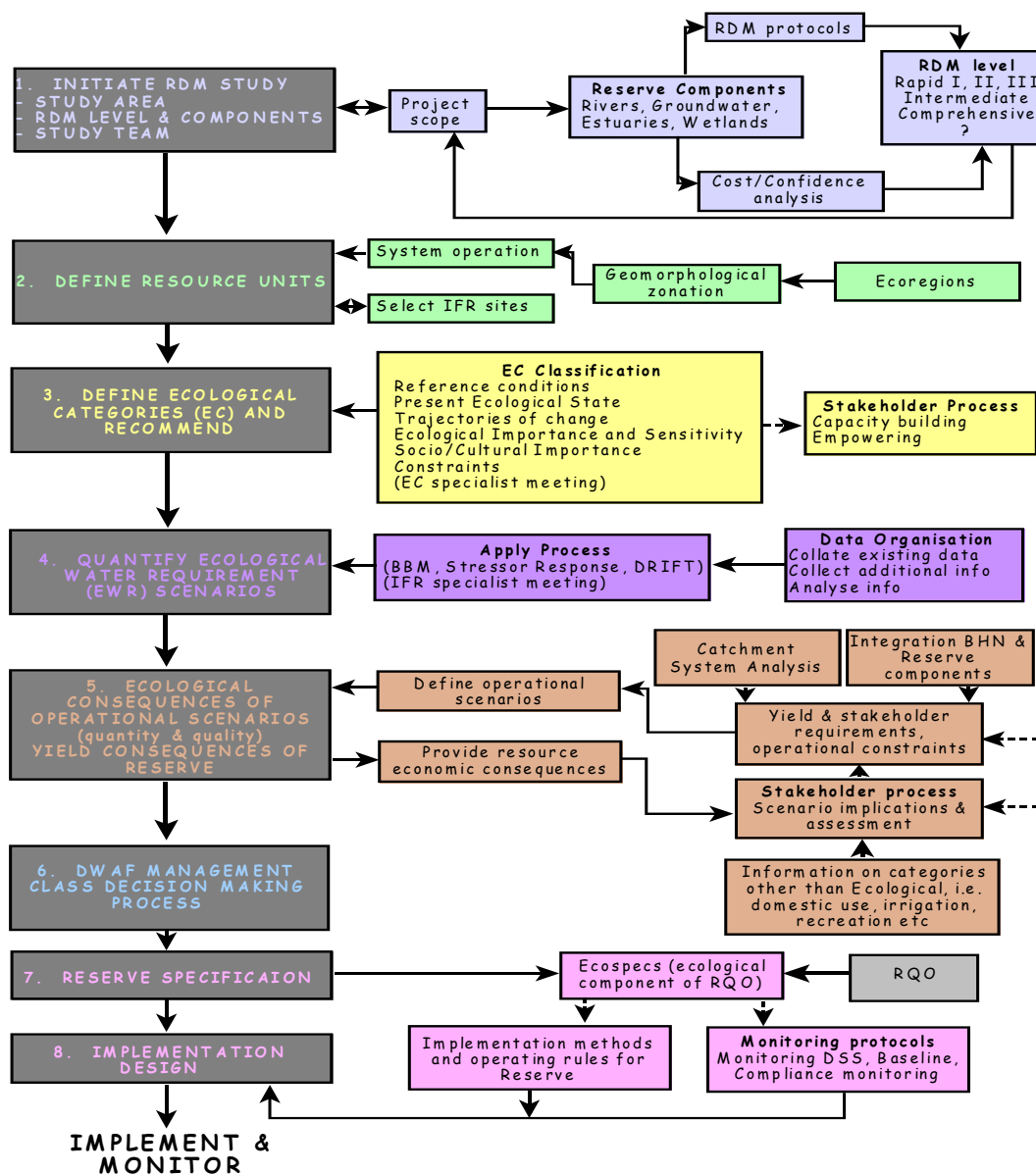


Figure 1-1 The 8-step Ecological Reserve procedure (DWAf, 2003)

1.2 Study area

The study area has been defined as follows:

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

Six EWR sites were selected, as shown on the study area map:

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

Figure 1-2 illustrates the sites on the map.

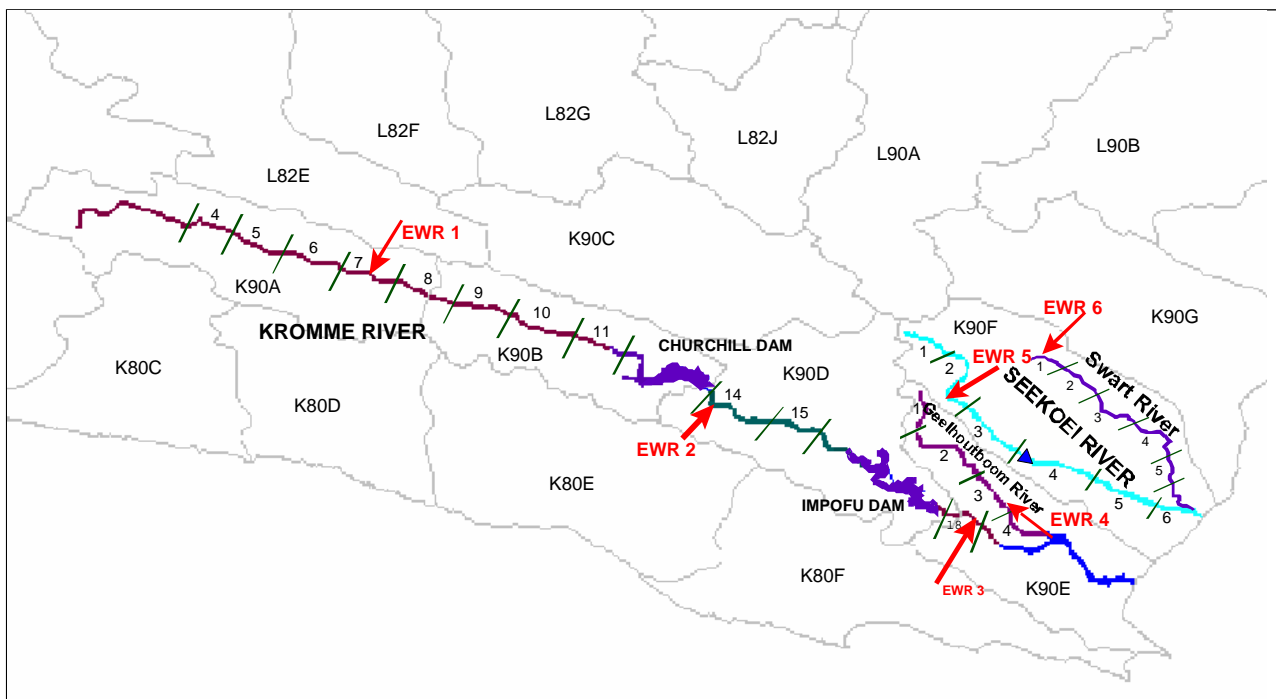


Figure 1-2 Study area, showing the location of the EWR sites

1.3 Purpose of this Report

This report serves to document the results of the specialist meeting held from 20 – 23 September 2004, and to recommend the Ecological Category (EC) and associated Ecological Water Requirements (EWRs) scenarios. The assessment of Ecological Water Requirements includes only the quantity component. Input from the quality specialist was provided to determine

Recommended Ecological Categories (REC). The quality component will be addressed in a separate study report.

The purpose of this report is to

- document the approach to determine the REC, the results and alternative ECs; and
- provide the EWR (quantity) results for each EWR site.

Chapters 2, 3 and 4 provide some background to the approach. The method and the interpretation of results are provided in chapters 5 to 20. The chapters explaining 'approaches' used have the same format and follows the same order in which the chapters containing the results are produced. The 'approaches' chapters are only a summarised guide for persons experienced in the determination of flow requirements and must not be seen as a detailed explanation. This report is a technical report and the main purpose is to provide results and a summarised rationale for the results.

1.4 Outline of the Report

The report is outlined as follows:

Chapter 1: Introduction and Background

This chapter

Chapter 2: Approach: Ecological classification

This chapter covers the general approach to the sequential steps followed in the Ecological Classification. The approach to defining the reference condition, PES, trend and Ecological Category for each biological component is provided.

Chapter 3: Approach: Determination of stress indices

This chapter provides an explanation of the approach followed during the determination of stress indices for all physical and biological components at the six EWR sites.

Chapter 4: Approach: Determination of EWR scenarios

This chapter provides the general approach to the determination of different EWR scenarios with respect to low and high flows. Aspects covered in this chapter are component and integrated/stress curves, generating stress requirements, general approach to high flows, final results and confidence in the final results.

Chapters 5 – 20: EWR Ecoclassification

The results as described in chapters 2 to 4 are provided for each EWR site.

Chapter 21: Conclusions and Recommendations

The results are summarised and recommendations are made.

Chapter 22: References

2 APPROACH TO THE ECOLOGICAL CLASSIFICATION

2.1 General approach

The objective of the Ecological Classification process is to create an understanding of the PES and ecological functioning of the river and estuary and, based on this, to set realistic ecological aims/objectives. This is necessary as a scenario-based approach requires the ecological aims, or ecological states, to be described. For each of these states, a flow scenario must be described.

Ecological Classification must not be confused with the Classification System used to determine Water Resource Management Classes. It forms a component of the Classification System which considers a much wider suite of components than only the ecological components.

The sequential steps followed in Ecological Classification are shown in Table 2-1. Questions and associated actions are itemised.

Table 2-1 Sequence of actions required, to provide technical information for Ecological Classification.

QUESTION	ACTION
1. What was the river like before human impact?	1. DETERMINE NATURAL REFERENCE CONDITIONS.
2. Compared to how the river used to look, what does it look like now?	2. DETERMINE PES (Category A – F).
3. Is the river changing, and if so, how severely and how fast?	3. DETERMINE TREND OF CHANGE IF THE STATUS QUO IS MAINTAINED.
4. What is the main cause for the change?	4. DETERMINE CRITICAL CAUSE FOR THE PES AND/OR THE TREND OF CHANGE.
5. What is the source of the causes?	5. DETERMINE THE SOURCE OF THE CAUSE.
6. How ecologically and socially important is the river?	6. DETERMINE ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORIES (low, moderate, high, very high), AS WELL AS SOCIO-CULTURAL IMPORTANCE.
7. What would the ecological aims be for the river?	7. CONSIDERING THE IMPORTANCE AND THE PRESENT ECOLOGICAL STATE, SHOULD THE PES BE IMPROVED (if so, by how much) OR MAINTAINED (Category A - D)? (NOTE: Maintaining the PES could still require restoration management depending on the trend of change).
8. Can the main cause realistically (and practically) be addressed to achieve the ecological aims?	8a. DETERMINE WHAT MEASURES/ACTIONS WOULD BE REQUIRED TO ADDRESS THE CAUSES. 8b. DETERMINE HOW DIFFICULT (easy, reasonable, difficult, very difficult) IT WOULD BE TO ADDRESS THE SOURCE. (i.e. RESTORATION/REVERSIBILITY POTENTIAL). PROVIDE REASONS.

QUESTION	ACTION
9. What should the Ecological Category be for the river?	9. CONSIDERING THE ECOLOGICAL OBJECTIVES FOR THE RIVER, AND ASSESSING THE DIFFICULTY OF ACHIEVING THESE, DETERMINE THE RECOMMENDED ECOLOGICAL CATEGORY (REC) AND THE RANGE OF ECs TO BE ADDRESSED DURING THE SCENARIO PROCESS.

The PES results of the process, and subsequent EC, are provided as different river categories ranging from A (near natural) to F (completely modified).

The range of ECs for which flow scenarios must be supplied is guided by the rules shown in Table 2-2. These must be seen as guidelines to determine a *realistic* range of ECs which can be addressed during the scenario process.

Table 2-2 Guidelines for the range of ECs to be addressed

PES	Range of ECs
A	A
A/B	A/B, B/C
B	B, C
B/C	B, B/C, C/D
C	B, C, D
C/D	B/C, C/D, D
D	C, D
D/E, E, E/F, F	D

The process is described in detail in the Ecoclassification and Habitat Flow Stressor Response (HFSR) manual (IWRS2S, 2004).

2.2 Reference conditions

Reference conditions refer to those conditions that occur under natural conditions prior to significant anthropogenic impact. Reference conditions are derived from river reaches in undisturbed conditions, aerial photographs, historical information, expert judgement etc. Descriptions are provided for each EWR site in the results chapters. Note that the water quality reference conditions are provided in a separate report (DWAF, in prep.).

2.3 Present Ecological State (PES)

Detailed information is available in Appendices A – E for all indices, with hydraulics information, Socio-Cultural Importance and Ecological Importance and Sensitivity results outlined in appendices F – H.

2.3.1 Habitat driver status

A rule-based model is used to provide a PES for the driver components (geomorphology, water quality and hydrology), and an integrated PES for the driver, as well as information regarding the source of the problem (catchment or river flow related, referred to as flow and non flow related).

The main drivers are rated as follows to provide the individual component categories:

- Rating: A rating is provided as a degree of change from reference conditions with 0 being no change and 5 being the maximum change.
- Weighting: A weighting procedure is then followed using a MCDA (Multi Criteria Decision Analysis) approach to determine how important or relevant the rating is for this specific type of river.

2.3.2 Biological responses PES

This step evaluates the present state of the biological components, which would respond to the driver status, and provides an integrated instream status.

2.3.2.1 Fish

The Fish Response Assessment Index (FRAI) has been developed by Dr CJ Kleynhans to determine the fish PES category. A similar rating and weighting process is followed as described for the drivers. The assessment addresses each of the following points and then integrates the results into a fish PES category.

- Flow depth preferences;
- Flow modification;
- Cover preferences;
- Health; and
- Introduced species.

More detail is provided in the HFSR Manual (IWRS2S, 2004).

2.3.2.2 Aquatic Invertebrates

The Invertebrate Response Assessment Index (IRAI) has been developed by Ms C Thirion to determine the invertebrate PES category. A similar rating and weighting process is followed as described for the drivers. The assessment addresses each of the following points and then integrates the results into an invertebrate PES category:

- Indicators of flow modification.
- Indicators of habitat modification.
- Indicators of water quality modification.

More detail is provided in the HFSR Manual (IWRS2S, 2004).

2.3.2.3 Riparian vegetation

A vegetation model is available (developed by Mr NP Kemper and Dr CJ Kleynhans) but has not been widely tested and is not documented in detail in any manual. The method used in this study follows a similar approach to the other response models and evaluates different vegetation zones, i.e. the marginal, upper and lower riparian zones. Each of the zones is described by the following criteria:

- Vegetation abundance.
- Vegetation cover.
- Vegetation species richness/diversity.
- Species composition.
- Species diversity.

Each of the zones are then evaluated according to their importance relative to each other for this specific type of river, and are then rated to determine a vegetation PES.

2.3.3 Trend

The trend provides an indication of whether at the time of the PES assessment, components such as geomorphology, and in some cases water quality, fish, aquatic invertebrates and vegetation, have already fully reacted to changes that HAVE taken place in the catchment.

The answers are provided in terms of stable or non-stable trends. Stable trends can be negative and/or positive. For non-stable trends; an indication of the degree of change is provided in terms of change in category and whether this will take place in the short (five years) term or long (twenty years) term.

2.3.4 PES Ecostatus

A rule-based model has been developed to derive the Ecostatus, which represents the overall condition/health of the river. Ecostatus (modified from Iversen *et al.*, 2000) is the ecological status of a river and is defined as the “totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna.” This ability relates directly to the capacity of the system to provide a variety of goods and services.

The Ecostatus model therefore integrates the driver and instream status (see Table 2-3), and is designed to provide an indication of whether the driver, or the response state, is the most representative of the overall state of the river. A MCDA weighting system is used again; by evaluating a list of questions (see extract of model below in Table 2-3).

Table 2-3 Summary of the Ecostatus for EWR 1

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality		3		
Fish: What is the general level of trophic specialisation		2		
What is the general level of habitat specialisation		3		
What is the general level of flow intolerance		4	3	0.53
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3		
How sensitive are hydraulic habitats to flow change?		3		
How sensitive is water quality to flow change?		2	2.67	0.47
Total			5.67	1
INSTREAM CATEGORY	PES	Category		
	63.47	C		
DRIVER CATEGORY	63.8	C		
ECOSTATUS	63.61	C		

(1) This rating is applicable to low flows
 (%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

The relationship between all the different components is illustrated in Figure 2-1.

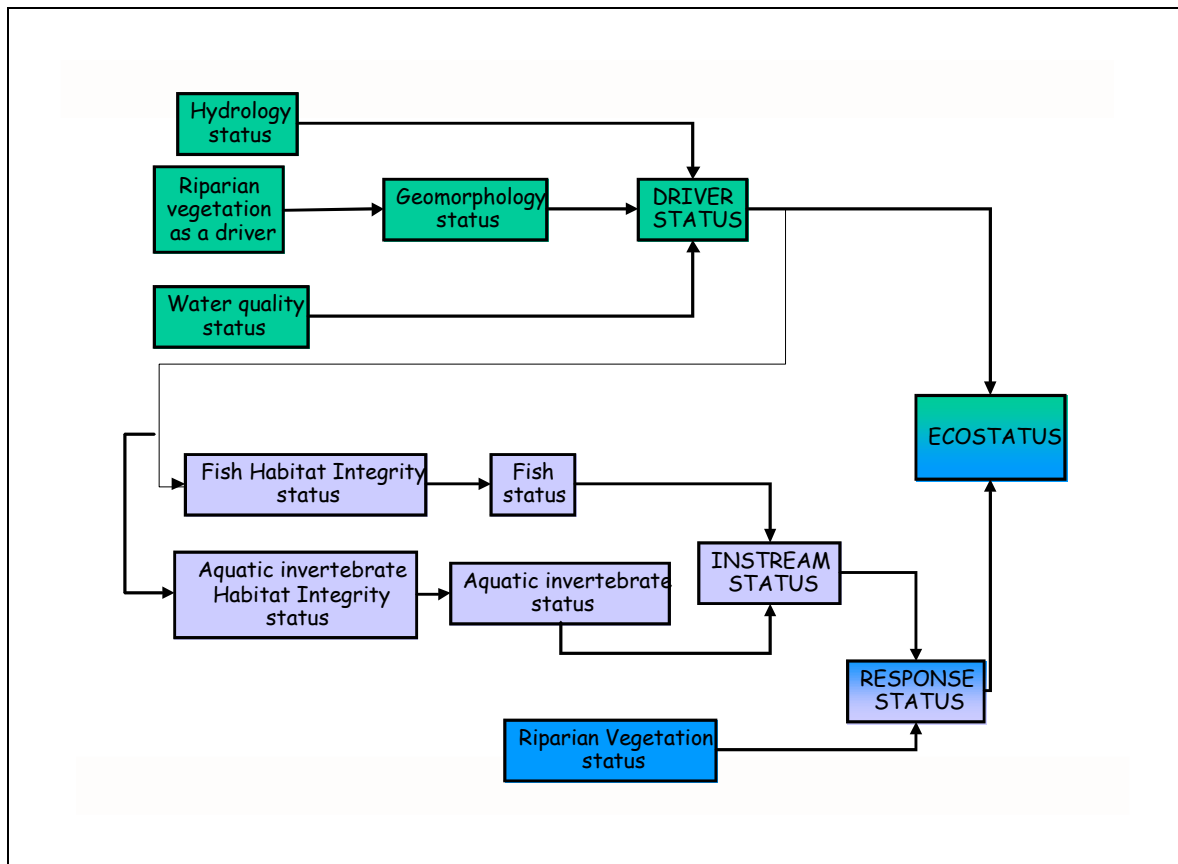


Figure 2-1 Illustration of the connections between the different component states, the integrated driver and instream status and the overall integrated state, referred to as the Ecostatus

The results of the PES of all the components and the Ecostatus are also illustrated in Figure 2-2.

2.3.5 Ecological Importance and Sensitivity (EIS)

The EIS model was developed by Dr CJ Kleynhans, DWAF Directorate, RQS. The EIS of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration for the natural as well as present day EIS in the assessment. Reference in the report is to the present day EIS as this would be the realistic assessment to consider.

The results of the EIS rule-based models are all attached as Appendix H. A summary of the results appears in the 'results' chapters. A figure illustrating the model is also provided in the appendix; as well as the explanations of each criterion.

2.4 Range of ECs

The REC is determined by assessing the EIS and the PES. If the EIS is high, or very high, the PES should be improved a full category unless the PES is a B category (stays a B category) or a B/C category (improves to a B category). If the EIS is moderate or low, the PES should be maintained unless the PES is below a D category (improves to a D category). Before the rule is applied, the PES and the reasons for the PES, are also assessed and considered to determine a realistic and attainable REC.

Pending the REC, the alternative ECs are derived according to the guidelines in Table 2-1. The specialists discuss the alternative EC and describe the conditions of the drivers. The rule-based models are then run in a predictive way to achieve the alternative EC and the resulting ECs are summarised in a table such as Figure 2-2.

Driver Components	Component REC	Driver REC	ECOSTATUS
HYDROLOGY	D	D	D
GEOMORPHOLOGY	D		
WATER QUALITY	B/C		
Response components	Component REC	Instream REC	
FISH	C	C/D (C)	
AQUATIC INVERTEBRATES	D	D	
RIPARIAN VEGETATION	D		

Figure 2-2 Ecological Category table

3 APPROACH: DETERMINATION OF STRESS INDICES

This chapter, as well as Chapter 4, provides a summarised explanation of the overall approach followed to produce the quantity component (Instream Flow Requirements (IFRs)) of the Ecological Water Requirements scenarios (EWRs) for the Kromme/Seekoei. The Habitat Flow Stressor Response method (HFSR; IWRS2S, 2004) was used to determine the low flows, and a method adjusted from the standard Building Block Methodology (BBM; King and Louw, 1998) and Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach was followed to set high flows. In-depth, scientific rationales for these methods are available in the referenced scientific journals. Only the step-by-step method followed to determine the final flow recommendations for each EWR site is documented in this chapter. The results for each site are then recorded on a chapter-by-chapter basis without accompanying explanations.

3.1 Introduction

A site-specific index of zero (no stress or optimum habitat) to 10 (maximum stress or no habitat) was designed for fish and aquatic invertebrates. The approach for the instream biota is to scale the habitats (type and abundance) according to a flow-depth scale (zero to 10). The biotic response and associated stress level for these habitat conditions are then calculated.

The following tools are used to determine the stress indices:

- Hydraulics.
- Photos and videos of various flow conditions.
- Habitat modelling.
- Geomorphological information.
- Fish survey results and historical information.
- Aquatic invertebrate survey results and historical information.

3.2 Fish (Authored by Dr CJ Kleynhans)

The interpretation is based on the following assumptions and principles:

- Flow is directly related to the geomorphological processes that provide the habitat required by fish during various stages of their life cycle (spawning, larvae, ova, sub-adults, and adults). Broad categories of flow are interpreted in terms of flow velocities and depth:
 - Slow (<0.3m/s), Deep (>0.5m) or SD
 - Slow (<0.3m/s), Shallow (<0.3m) or SS
 - Fast (>0.3m/s), Deep (>0.5m) or FD
 - Fast (>0.3m/s), Shallow (<0.3m) or FS
- Habitat also involves the cover that fish species require. Cover (shelter) is directly or indirectly related to flow and includes overhanging vegetation, undercut banks and root wads, substrate, water column and aquatic macrophytes.

Biological responses to flow-depth classes are illustrated in Table 3-1 and Table 3-2. The explanations for the tables are provided in the descriptive blocks surrounding the tables.

Table 3-1 Illustration of a completed Flow - Depth class table

	FAST-DEEP: DEPTH > 0.3m; VELOCITY >0.3 m/s	FAST-SHALLOW: DEPTH <0.3 m; VELOCITY >0.3 m/s	SLOW-DEEP: DEPTH >0.5 m; VELOCITY <0.3 m/s	SLOW-SHALLOW: DEPTH <0.5 m; VELOCITY <0.3m/s	
(1) Overhanging vegetation - thick vegetation overhanging water by approximately 0.3 m and not more than 0.1 m above the water surface (Wang et al. 1996).	RIVER: Black Kei	SITE: IFR 2	DATE: 19-08-03		
Undercut banks and root wads - banks overhanging water by approximately 0.3 m and not more than 0.1 m above the water surface (Wang et al. 1996).	RELATIVE FLOW-DEPTH				
	FLOW (m ³ /s)	FAST DEEP 1	FAST 1	SLOW DEEP 4	SLOW 3
	COVER TYPES ASSOCIATED WITH EACH FLOW-DEPTH CLASS				
	Overhanging	1	Overhanging 3	Overhanging 3	Overhanging 2
	Undercut banks	1	Undercut banks 2	Undercut banks 2	Undercut banks 2
	Substrate:	3	Substrate: 3	Substrate: 1	Substrate: 3
	Water Column:	0	Water Column: 0	Water Column: 2	Water Column: 0
	Aquatic macrophytes:	1	Aquatic macrophytes: 3	Aquatic macrophytes: 1	Aquatic macrophytes: 3
	Remarks:		Remarks:		Remarks:
	Approx Width classes:	3	Approx Width 3	Approx Width 5	Approx Width 3
	1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6		1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6
Stream substrate - the degree to which various substrate components (rocks, boulders, cobbles, gravel, sand, fine sediment and woody debris ("snags")) provide cover for fish are judged qualitatively. No detail assessment of the contribution of individual components are attempted.	17				
Related to the water depth and dependant on the species (and its size).					
Aquatic macrophytes - submerged and emergent plants were included and a qualitative estimate made of the cover value for fish.					
					0=Absent; 1=Rare (<5%); 2=Spars e (5-25%); 3=Moderate (25-75%); 4= Abundant (75-90%); 5=Very abundant (>90%) (modified from Rankin 1995)
					Depending on the size of the river, a site with a low percentage of a particular depth-flow class can still actually cover a substantial area at a site. A low rating would be unrealistic in such a situation. This is compensated for by judging the qualitative value of depth-flow classes for fish. Percentage of area covered was mainly used, therefore, as a guideline in this estimation.
					These features are considered to provide fish with the necessary cover (e.g. refuge from high flow velocity, predators, high temperatures, etc.) to utilise a particular flow and depth class.

Table 3-2 Habitat suitability and the derived fish stress

		EWR 2	19-08-03			
Species requiring fast flow during all phases of the life-cycle.		FISH SPECIES RESPONSES: HABITAT SUITABILITY FOR DIFFERENT LIFE-STAGE REQUIREMENTS				
Species requiring fast flow during certain phases of the life-cycle, i.e. to breed in particular habitats and to make nursery areas with suitable cover available. Generally, increased habitat suitability and availability resulting from increased flow, can be expected to benefit such species. Flow will stimulate breeding activities and stimulate migration.		Rheophilic spp =	Semi-rheophilic spp	B. aeneus	Non-rheophilic spp	B. anoplus
Fast flow will stimulate breeding activities in suitable substrate. Slower flowing patches within fast areas (also edges) important as nursery areas for larvae.		Breeding and early life-stages=	Breeding and early life-stages=	1	Breeding and early life-stages=	2
Fast flowing habitats with suitable cover (often substrate related) is required for survival and abundance. Connectivity between fast flowing habitats is also essential (e.g. sufficient depth, cover and velocity).		Survival /Abundance =	Survival /Abundance =	2	Survival /Abundance =	3
Cover is often related to abundance of suitable substrate in fast flowing habitat. Increased flows will generally enhance cover over suitable substrate.		Cover =	Cover =	2	Cover =	4
Increased flows can be expected to enhance feeding conditions and prevent high population concentrations which will have limited spreading of diseases and parasites. High base flows will generally be associated with lowered physiological stress conditions.		Health and condition=	Health and condition=	3	Health and condition=	4
Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Water quality=	Water quality=	4	Water quality=	4
Fast flow will stimulate breeding activities in suitable substrate. Slower flowing habitats (also patches and edges within fast flowing areas) important as nursery areas for larvae.		Habitat flow stress response with breeding requirements	Habitat flow stress response with breeding requirements	5.2	Habitat flow stress response with breeding requirements	3.2
Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Habitat flow stress response without breeding requirements	Habitat flow stress response without breeding requirements	4.5	Habitat flow stress response without breeding requirements	2.5
Fast flow will stimulate breeding activities in suitable substrate. Slower flowing habitats (also patches and edges within fast flowing areas) important as nursery areas for larvae.		Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Increased flows can be expected to enhance feeding conditions and prevent high population concentrations which will limited spreading of diseases and parasites. High base flows will generally be associated with lowered physiological stress conditions.		
Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Fast flowing and slow flowing habitats with suitable cover (often substrate or water column) is required for survival and abundance. Connectivity between fast flowing and slow flowing habitats may also be important (e.g. depending on the species, sufficient depth, cover and velocity).		
Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.		Depending on the species, cover is related to abundance of suitable substrate in fast flowing habitat or overhanging vegetation, undercut banks, water column and macrophytes in slow flowing habitat. Increased flows (and water levels) will generally enhance these cover types.		

The output of Table 3-1 is a rating of habitats and cover for a specific flow. The output of Table 3-2 is a suitability rating for different requirements and levels calculated. The stress is calculated using the following approach:

Habitat suitabilities for a particular species were rated on the basis of expert knowledge, based on a simplified Habitat Suitability Index (HSI) calculated as proposed by Stuber et al, 1982. This method makes use of the suitability of various habitat characteristics to fulfil the life-stage requirements of the “target” species. The suitability of the habitat (flow-depth class and cover) under various flow conditions were scored for each of the following: Breeding (B), Survival / abundance (S), Cover (C), Health (H), Water quality (only flow related aspects – temperature and oxygen concentration) (W).

Suitability scoring followed the following guidelines:

Very high = 5; High = 4; Moderate = 3; Low = 2; Poor = 1; None = 0

The Habitat Suitability Index for a particular flow was calculated as follows:

$$HSI = (B+S+C+H+W)/5$$

Where assessment needs to be done outside the breeding season (dry season), the HSI can be calculated by excluding suitability for breeding requirements:

$$HSI = (S+C+H+W)/4$$

The average HSI score is expressed as a proportion of 10 and is then transformed to relate a high score out of 10 to a low suitability, and vice versa, e.g. 0 would indicate completely suitable conditions while 10 would indicate completely unsuitable conditions.

The tables illustrated in Tables 3.1 and 3.2 are used in the following sequential way:

- During every site visit the above tables are completed. Note that the completion of these tables is only of any use if the flow is known during the site visit.
- This then provides a habitat rating and associated fish stress at one or more flows which provides a calibration for the rest of the information.
- During the specialist meeting, these tables are completed for other flows. The first priority would be to rate flows, which have been measured for hydraulic calibration purposes and for which photographs, are available.
- During the specialist meeting, the hydraulician verifies these flows and habitat scores. For example, the habitat abundances are estimated by the fish specialists according to what they visualise, and secondly by what they experience if they are undertaking a fish survey. The hydraulician has more quantitative means at his disposal and can therefore check the rating.
- To complete the rest of the table, input from the hydraulician is required (see section below). The hydraulics specialist provides flows which would result in the range of flow depth classes required to complete the 0 - 10 flow depth scale. An interactive process follows, and once agreement on the flow for a specific flow depth scale is reached, the above tables are completed for those flows and the associated stresses derived.

The final stress index is provided in Table 3-3.

Table 3-3 Fish stress index table

	FLOW (CUMEC)					
	1.50	1.000	0.500	0.130	0.028	0.010
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)						
FAST DEEP	4	3.0	2.0	0.0	0.0	0.0
Overhanging vegetation	4.0	3.0	1.0	0.0	0.0	0.0
Undercut banks & root wads:	4.0	4.0	2.0	0.0	0.0	0.0
Substrate	4.0	3.0	3.0	0.0	0.0	0.0
Aquatic macrophytes	2.0	1.0	0.0	0.0	0.0	0.0
Water column	2.0	2.0	1.0	0.0	0.0	0.0
Average velocity						
Max velocity						
Average depth						
Max depth						
Wetted perimeter						
Width						
FAST SHALLOW	5.0	5.0	3.0	3.0	1.0	1.0
Overhanging vegetation	5.0	4.0	3.0	2.0	1.0	0.0
Undercut banks & root wads:	5.0	5.0	4.0	3.0	1.0	0.0
Substrate	5.0	5.0	4.0	4.0	2.0	1.0
Aquatic macrophytes	3.0	2.0	1.0	0.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0	0.0
Average velocity						
Max velocity						
Average depth						
Max depth						
Wetted perimeter						
Width						
SLOW DEEP	5.0	5.0	5.0	4.0	4.0	4.0
Overhanging vegetation	5.0	5.0	4.0	3.0	2.0	1.0
Undercut banks & root wads:	5.0	5.0	4.0	4.0	3.0	3.0
Substrate	3.0	3.0	3.0	3.0	2.0	2.0
Aquatic macrophytes	3.0	2.0	1.0	1.0	0.0	0.0
Water column						
Average velocity						
Max velocity						
Average depth						
Max depth						
Wetted perimeter						
Width						
SLOW SHALLOW	3.0	4.0	4.0	5.0	5.0	3.0
Overhanging vegetation	5.0	4.0	3.0	2.0	1.0	1.0
Undercut banks & root wads:	5.0	4.0	3.0	1.0	1.0	1.0
Substrate	4.0	4.0	4.0	4.0	3.0	1.0
Aquatic macrophytes	4.0	4.0	3.0	2.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0	0.0
Average velocity						
Max velocity						
Average depth						
Max depth						
Wetted perimeter						
Width						
FLOW	1.50	1.00	0.50	0.13	0.03	0.01
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD						
SEMI-RHEOPHILIC	SPECIES					
	P. afer					
Breeding and early life-stages =	5.0	5.0	3.0	1.0	0.0	0.0
Survival /Abundance =	5.0	5.0	4.0	3.0	2.0	1.0

Summary of habitat stress of above table converted to habitat response out of ten.

	1.50	1.00	0.50	0.13	0.03	0.01	0.00	0.00
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH CLASSES OPTIMUM FOR SITE ; 9=NO FLOW)								
Fast deep	2.0	4.0	6.0	10.0	10.0	10.0	10.0	10.0
Fast shallow	0.0	0.0	4.0	4.0	8.0	8.0	10.0	10.0
Slow deep	0.0	0.0	0.0	2.0	2.0	2.0	10.0	10.0
Slow shallow	4.0	2.0	2.0	0.0	0.0	4.0	10.0	10.0
OVERALL HABITAT RESPONSE	1.5	1.5	3.0	4.0	5.0	6.0	10.0	10.0

SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT								
SEMI-RHEOPHILIC	SPECIES:							
Breeding and early life-stages=	5.0	5.0	4.0	3.0	2.0	2.0	0.0	0
Survival /Abundance =	5.0	5.0	4.0	3.0	3.0	2.0	1.0	0
Cover =	5.0	5.0	4.0	3.0	3.0	2.0	1.0	0
Health and condition=	5.0	5.0	4.0	3.0	3.0	2.0	1.0	0
Water quality=	5.0	5.0	4.0	3.0	3.0	2.0	0.0	0
Semi-rheophilic stress - (breeding requirements included)	0.0	0.0	2.0	4.0	4.4	6.0	8.8	10.0

Derived species response from habitat response out of 10.

3.3 Aquatic invertebrates (Authored by Ms C Thirion)

The basis of the process is to assess habitat abundance and suitability. The first step in the process is to, during the site visit, rate the flow in terms of habitat conditions and related stress. Table 3-4 was developed for use during the site visit to rate a specific condition (in this example a flow of 0.17m³/s).

Table 3-4 Illustration of a completed Flow-Habitat table

Flow-Habitat Response	Habitat abundance and suitability					Modifier	Flow (m ³ /s)	Habitat response
	SIC	SOOC	VIC	VOOC	GSM			
Observation	3	4	2	2	3			
3	2	3	2	1	3	Boulders embedded, filamentous algae, vegetation on stems only (out of current).	0.17	SIC habitat reduced by embeddedness. SOOC habitat reduced due to algal covering over cobbles and some boulders. MV only roots and base of stems. SIC average depth 0.13m. If flow reduced by depth of 5-20cm, will alter SIC to SOOC. Flow removed from the exposed surfaces of boulders will remove SIC altogether. For VIC: A reduction in depth of 15cm will expose stems (in the VIC area). For VOOC, only root zone submerged at present.

The habitat rating and associated invertebrate stress observed during field visits are copied to the *invertebrate stress rating* spreadsheet (Table 3-5). This provides a calibration for the rest of the information. Those flows for which photographs are available are then rated and verified by the hydraulician. For instance, the habitat abundances are estimated by the invertebrate specialist according to what they visualise, and secondly by what they experience if they are undertaking an invertebrate survey. The hydraulician has more quantitative means at his disposal and can therefore check the rating. To complete the rest of the table, input from the hydraulician is required (Section 3.4). The hydraulics specialist gives guidance on the flows which would result in the range of flow habitat classes required to complete the 0 - 10 flow habitat scale. The tables are completed for those flows and the stresses are derived.

The final stress index is provided in Table 3-5.

Table 3-5 Completed invertebrate stress rating table for vegetation dwelling invertebrates

Flow Habitat Response Index	Habitat abundance and suitability					Flow (m ³ /s)	Depth (m)	Velocity (m/s)	Habitat response (specific to site)	Biotic response	Species stress
	SIC	SOOC	VIC	VOOC	GSM					MV Invertebrates	
0	5	5	5	5	5	2	0.75	0.46	All habitats in excess, very high quality.		
1	5	5	4	4	4	1.5	0.7	0.39	All habitats plentiful, very high quality.	Abundant and diverse MVICs	1
2	4	4	4	3	3				SIC and VIC sufficient, quality slightly reduced.	Slight reduction in MVIC diversity: High abundance	
3	3	4	3	3	3	0.35	0.51	0.17	Reduced SIC and VIC, Reduced quality.	Reduction in MVIC species diversity: Moderate abundance	4
4	3	4	3	2	3				SIC and VIC limited, of moderate quality.		
5	2	3	2	2	3	0.17	0.44	0.12	SIC and VIC very reduced, of moderate quality.	Sensitive MVIC species absent: Low abundance	6
6	2	3	1	1	2				SIC and VIC residual and of low quality		
7	1	2	0	1	2				No VIC, Some VOOC, little SIC.	All MVIC species: Rare	
8	1	2	0	0	2	0.02	0.28	0.05	Flowing water present, little SIC, no VIC.	Only pool dwellers present	9
9	0	1	0	0	1	0	0.2	0.03	No surface flow.		
10	0	0	0	0	0	0			No surface water.	No MVIC species present	10

3.3.1 Hydraulics input (Authored by Dr A L Birkhead)

The application of holistic methods for ecological flow determination (refer to Tharme, 1996) require that water requirements be expressed as discharge rates (including its temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling of sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments to be the most useful: depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (refer to Rowlston et al (2000) and Birkhead (2002) for descriptions of procedures for deriving hydraulic information for use in EWR studies (or Reserves) in South Africa). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters (listed above) may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables.

The cross-sectional profile plots and look-up tables comprise the “standard hydraulic data” used in Reserve determinations in South Africa at the Rapid III, Intermediate and Comprehensive levels. Ecologists use these standard hydraulic data with the aid of site assessments, photographs and

video exposure, to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat e.g. hydraulic, substrate and cover attributes for fish). For this reason, a procedure has been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Jordanova *et al.* (in press) for a detailed explanation of the method). The method enables the assessment of abundance of different habitat types to be applied more consistently in Reserve determinations.

3.3.2 Procedure for assessing the habitat flow response of fish

The procedure applies the concept of hydraulic habitat types (or classes) in the determination of ecological flows for fish using the Flow-Stressor Response (F-SR) methodology. It differs from the original F-SR method of O’Keeffe *et al.* (2002); and O’Keeffe and Hughes (2004) in that the hydraulic habitat is interpreted in terms of biological habitat requirements (e.g. fish), and should preferably be referred to the Habitat-Flow Stressor-Response (HFSR) method. It is a working method, and will benefit from future development and refinement by applied research and future Reserve assessments. There has been a need to further develop the role of hydraulics in flow assessments for fish, which applies an integrated assessment of hydraulic habitat through the use of different habitat types. These types have been defined using two basic hydraulic parameters, i.e. depth (D) and depth-averaged velocity (V), as suggested by Kleynhans (1999). Water surface width or perimeter is also incorporated as a scaling factor. Together with substrate and vegetation cover information, these parameters are sufficient to broadly describe fish habitat. Kleynhans further suggests that velocity and depth need only be specified coarsely, and has proposed the following four velocity-depth classes (hydraulic habitat types), as adapted from Oswood and Barber (1982):

- Slow (<0.3 m/s) and shallow (<0.5 m), i.e. SS: This includes shallow pools and backwaters.
- Slow (<0.3 m/s) and deep (>0.5m), i.e. SD: This includes deep pools and backwaters.
- Fast (>0.3 m/s) and shallow (<0.3 m), i.e. FS: “Shallow” runs, rapids and riffles.
- Fast (>0.3 m/s) and deep (>0.3 m), i.e. FD: “Deep” runs, rapids and riffles.

A graphical representation of the velocity-depth domain and its division into four classes is provided in Figure 3-1. (SS=slow and shallow, SD=slow and deep, FS=fast and shallow, FD=fast and deep). The velocity and depth axes are truncated for plotting purposes at 0.8 and 1.0, respectively (Kleynhans, 1999)

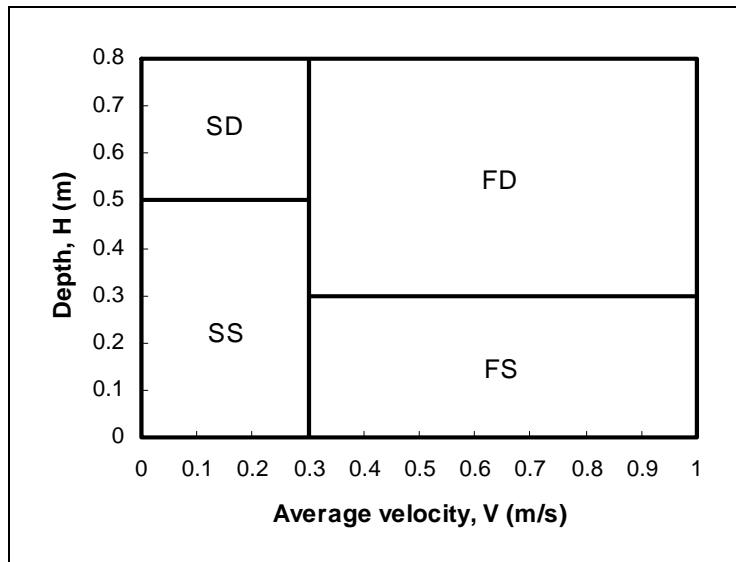


Figure 3-1 Hydraulic habitat descriptions for fish

Although the procedure (described below) has been developed within the context of the HFSR ecological flow assessment methodology, it is applicable for use in other holistic flow determination methods (e.g. DRIFT) that require a quantitative assessment of habitat suitability and abundance at different flows.

3.3.3 Rating observed habitat- type abundance

The first step in the method is the site scoring of the four habitat types defined for fish, taking cognisance of the substrate, cover and water column features provided at the site. The presence of these hydraulic habitat types is quantified using a relative abundance scale with associated proportional percentage occurrence. An example is shown in Table 3-6.

Table 3-6 Abundance scorings of habitat types for fish

Descriptor	Score	Occurrence (%)
None	0	0
Rare	1	0 – 10
Sparse	2	10 – 30
Moderate	3	30 – 60
Abundant	4	60 – 80
Very abundant	5	80 – 100

The on-site assessment is best undertaken; jointly by the hydraulician and fish ecologist, since it provides an opportunity for the specialists to develop an appreciation and understanding of relevant influences from the related disciplines. Secondly, the hydraulician is required to collect hydraulic data during the course of flow assessment studies, and it would be valuable to provide habitat type abundance scorings for each of these (since they are associated with a measured discharge rate). Although this assessment is subjective, it provides valuable information to complement the abundance scorings of hydraulic habitat type from more quantitative hydraulic modelling.

3.3.4 Modelling hydraulic habitat information

Riverine biota, including fish, macroinvertebrates and vegetation, display strong preferences for certain water depths, velocities and bed shear stresses, or combinations of these hydraulic variables (Lamouroux, 1998). Hydraulic descriptions used by ecologists differ from traditional hydraulic applications: riverine biota respond to sets of point hydraulic variables, whereas traditional hydraulic engineering has been concerned with larger spatial scales (e.g. flood analyses). Modelling point hydraulic variables in river reaches at low flows with large resistance elements using high resolution multi-dimensional hydraulic modelling, is imprecise and requires accurate topographical information (Lamouroux, 1998). An alternative method for providing this information is by modelling characteristic spatial-probability distributions of hydraulic parameters to describe typical variability in hydraulic habitats. The standard hydraulic information synthesized for a cross-section is used to represent average values for the morphological feature (e.g. rapid, riffle, pool, etc.), and can therefore be used to estimate typical depth and velocity distributions. Methods for predicting distributions of the two ecologically relevant hydraulic parameters of depth and velocity are described in the following sections.

3.3.5 Predicting frequency-depth distributions

The frequency-occurrence of flow depth may be computed using surveyed cross-sectional profiles and associated rating functions to provide measurement-based data. For a specified maximum depth (and related discharge), the actual depths along a cross-section are computed at equal distance increments. This is preferable to using actual surveyed ordinates across the riverbed, since these are usually measured at changes in slope and with a higher density of bed elevations in the low flow channel (i.e. not valid data for a statistical analysis). The range of depths (zero to maximum) along cross-sections are divided into equal depth class increments, and the frequency of occurrence of depths less than and greater than the threshold values determined (i.e. 0.3m and 0.5m used to distinguish between shallow and deep habitat for fast and slow velocities, respectively). If a three-dimensional spatial model has been set-up, frequency distributions of depth may be more accurately determined by calculating the proportion of inundated area that is shallow or deep.

3.3.6 Predicting probability-velocity distributions

Of the available velocity distribution models in the literature, the model of Lamouroux et al., (1995) appears to be the most robust and tested (Jordanova *et al.*, in press). A drawback, however, is that the model has been developed for pool-riffle sequences and not homogeneous geomorphological features. The velocity distribution model of Lamouroux et al., (1995), requires estimates of average depth, average velocity and dominant bed roughness. The first two parameters are available from standard hydraulic (cross-sectional) information. The dominant bed roughness is defined as the roughness element occupying the largest fraction of the bed, which may be determined from a visual assessment of the bed, or preferably from measured sediment size distributions (the size occupying the largest fraction of the bed is computed from the product of the projected sediment area and its frequency of occurrence).

3.3.7 Predicting habitat-type abundance as a function of discharge

An example of predicted frequency-depth and probability-velocity distributions for a riffle are given in Table 3-7 (and related tables 3-8 and 3-9). The maximum and average depth, average velocity, and perimeter are obtained from the standard hydraulic analysis. The analysis is undertaken for a range of discharges (in the low flow range), including measured values for which site assessments and/or photographs exist. Experience with measuring velocities in riffle and rapid morphologies has indicated that the maximum value is generally two to three times the average, and this information has been used by ecologists during previous flow assessments. The velocity distribution model of Lamouroux and colleagues (1995) supports this field-based experience, with maximum estimates approximately three times the average (refer to Table 3-7), and approximately 10% of the velocities are greater than twice the average value.

Using depth and velocity distributions (Table 3-10), the probability of occurrence for each habitat-type category (expressed as a percentage) may be assessed by assuming that depth and velocity are mutually exclusive parameters. Based on this assumption, the overall abundance of a habitat type is calculated by the product of the individual frequencies or probabilities. At low flows, the hydraulic habitat may be dominated by a particular habitat type (generally slow/shallow for riffles, e.g. in Table 3-10), but the corresponding river size may represent only a small proportion of the active channel size. To account for river scale, the habitat-type probabilities are proportioned using the relative perimeter, which is defined as the ratio of the perimeter to the value where the active channel bed becomes inundated. The active channel perimeter may be determined by an inflection on the perimeter-discharge plot. The abundance of hydraulic habitat type is converted from probability of occurrence to relative numeric values (or scores) in the range 0 to 5 using a scoring system such as that given in Table 3-10.

Table 3-8 provides an example of site abundance assessments for measured discharges as well as predictions based on the hydraulic modelling described above. It is necessary to reconcile the observed site assessments with values determined from modelling to provide a final assessment. Reasons for differences include the subjectivity inherent with site observations, the use of cross-sectional specific data to represent characteristic hydraulic habitat, and the use of a reach-based velocity distribution model. Agreement in the abundance scorings derived from the hydraulic predictions and site evaluations needs to take cognisance of the above considerations. Measured flows are generally accompanied by site photographs, which provide additional visual information to verify the modelled predictions as well as the extent and suitability of cover. Hydraulic modelling forms the basis for interpolating between assessments based on observation as well as extending the discharge range. The assessments should consider the range of morphologies and hydraulic conditions (i.e. both rapid/riffle and pool) to ensure that the habitat-types present are covered by the analysis.

The abundances may also be expressed in terms of the amount of channel perimeter contributed by each of the habitat-type classes (e.g. Table 3-8). This has been used in the DRIFT flow determination method to present hydraulic information. Plots of the contribution to overall perimeter of the different habitat types are useful for visualising changes in habitat with flow.

In the HFSR method, a simplified habitat suitability index for a particular “target” species or group of species is used to represent the habitat stress response index (refer to Jordanova et al., in

press). The suitability of the habitat (velocity-depth class, substrate and cover) under known (observed) and modelled flow conditions, is scored for each of the following components: breeding, survival and abundance, cover, health, and water quality.

Table 3-7 Example of modelled habitat-type frequency distributions for a riffle

Discharge (m ³ /s)	Depth, D (m)						Velocity, v (m/s)				Perimeter (m)	Habitat abundance (HA) (%)				Perimeter factored HA (%)			
	Max.	Ave.	%<0.5	%>0.5	%<0.3	%>0.3	Ave.	Max.	%<0.3	%>0.3		SS	SD	FS	FD	SS	SD	FS	FD
												V<0.3 D<0.5	V<0.3 D>0.5	V>0.3 D<0.3	V>0.3 D>0.3	V<0.3 D<0.5	V<0.3 D>0.5	V>0.3 D<0.3	V>0.3 D>0.3
0.05	0.36	0.16	100	0	94	6	0.02	<0.05	100	0	13.4	100	0	0	0	84	0	0	0
0.24	0.44	0.22	100	0	71	29	0.07	0.2	100	0	15.1	100	0	0	0	94	0	0	0
0.44	0.48	0.25	100	0	58	42	0.11	0.3	100	0	15.7	100	0	0	0	98	0	0	0
1.16	0.56	0.32	97	3	45	55	0.25	0.7	68	32	16.7	66	2	14	18	69	2	15	18
2.82	0.63	0.34	84	16	32	68	0.48	1.4	36	64	18.9	30	6	20	44	36	7	24	51
4.36	0.70	0.38	66	34	30	70	0.63	1.8	25	75	20.6	17	9	23	53	21	11	29	68

Table 3-8 Rated habitat-type abundances using the relative scale in Table 3-7

Discharge (m ³ /s)	Ecologists site assessment				Hydraulic prediction				Final assessment			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
	V<0.3 D<0.5	V<0.3 D>0.5	V>0.3 D<0.3	V>0.3 D>0.3	V<0.3 D<0.5	V<0.3 D>0.5	V>0.3 D<0.3	V>0.3 D>0.3	V<0.3 D<0.5	V<0.3 D>0.5	V>0.3 D<0.3	V>0.3 D>0.3
0.05					5	5	0	0	3	5	0	0
0.24	4	5	2	0	5	5	0	0	4	5	1	0
0.44	3	5	3	1	5	5	0	0	4	5	2	1
1.16	3	5	4	2	4	5	2	2	3	5	3	2
2.82	2	5	3	3	3	5	2	3	3	5	3	3
4.36	2	5	1	4	2	5	2	4	2	5	2	4

Table 3-9 Modelled habitat abundances

Discharge (m ³ /s)	Perimeter (m)			
	SS	SD	FS	FD
	V<0.3	V<0.3	V>0.3	V>0.3
	D<0.5	D>0.5	D<0.3	D>0.3
0.05	13.4	0.0	0.0	0.0
0.24	15.1	0.0	0.0	0.0
0.44	15.7	0.0	0.0	0.0
1.16	11.0	0.3	2.4	2.9
2.82	5.7	1.1	3.9	8.2
4.36	3.4	1.8	4.6	10.8

3.3.8 Providing velocity information for assessing the habitat flow response of aquatic invertebrates

The probability-velocity distribution model of Lamouroux et al. (1995) is also applied to provide velocity estimates for assessing habitat flow response of aquatic invertebrates. Three velocity classes were used: 0 - 0.1m/s (very slow), 0.1 - 0.3m/s (slow), 0.3 - 0.6m/s (fast) and >0.6m/s (very fast) (refer to Jordanova *et al.*, in press). Table 3-10 provides an example of the velocity class predictions for a riffle morphology (shaded rows represent measured flows).

Table 3-10 Probability velocity class predictions

Discharge (m ³ /s)	Velocity class (m/s)			
	0-0.1	0.1-0.3	0.3-0.6	0.6
0.01	100	0	0	0
0.04	85	15	0	0
0.2	65	35	0	0
0.5	47	44	9	0
1.0	35	37	25	3
2.0	26	29	35	10
5.0	14	18	31	37
11.8	6	10	19	65
22.8	3	5	12	80

3.4 Component Integrated / System stress

Once the stress indices (for low flows) have been identified for each component, the stress figures are tabled and the unidentified flow stresses are interpolated. At any one flow, the component with the highest stress point represents the integrated or system stress curve. Figure 3-2 illustrates the interpolated individual component stresses as well as the integrated curve. The black line represents the integrated curve and the other lines the stress flow relationships for the various components. The integrated curve in this case consists of the marginal aquatic invertebrates (purple line) for the stress range 10 to 2, and the riparian vegetation (yellow line) for the stress range 2 to 0.

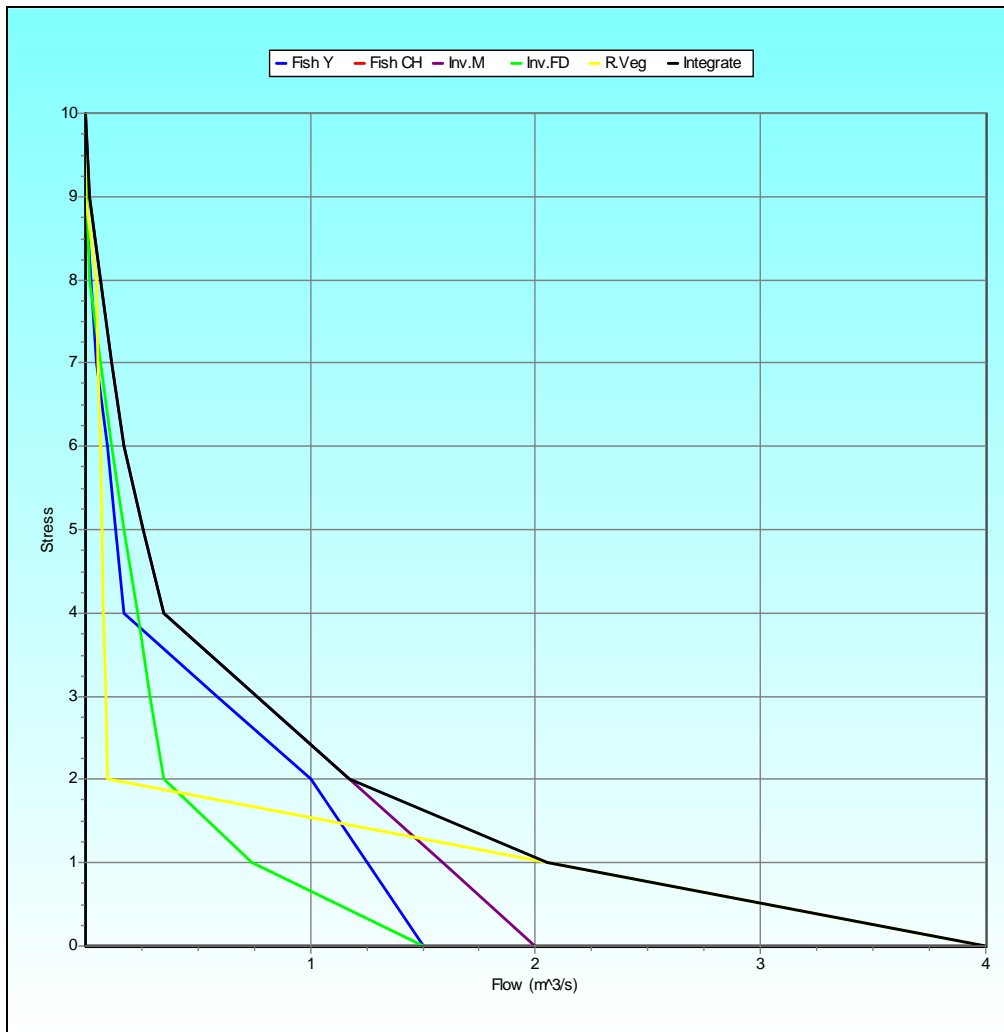


Figure 3-2 Component and integrated/stress curves

From this point on, all requirements are provided in terms of the integrated and not the component stresses. Specialists refer back to their component stress index in order to convert any one critical stress value to their corresponding component stress value. The critical stress and corresponding component stresses are tabled in the spreadsheets (Appendix I).

The generation of an integrated stress curve is necessary as the problem is that the component stress indices have different flow-stress relationships. For example, a fish stress of 2 implies a flow of 0.08 m³/s, whereas the marginal invertebrate stress of 2 equates to 1.2 m³/s. Component stresses are therefore standardised to flow-stress relationships common to all components. When the requirements are set, they are provided as certain stresses, occurring at a certain percentage of the time for the different components and plotted on a duration graph (axes consisting of stress and a % time) (Figure 3-3). The y-axis (stress) can only have one flow-stress relationship and the integrated stress-flow relationships are therefore used.

The conversion from component stress to the integrated stress is illustrated in Figure 3-3.

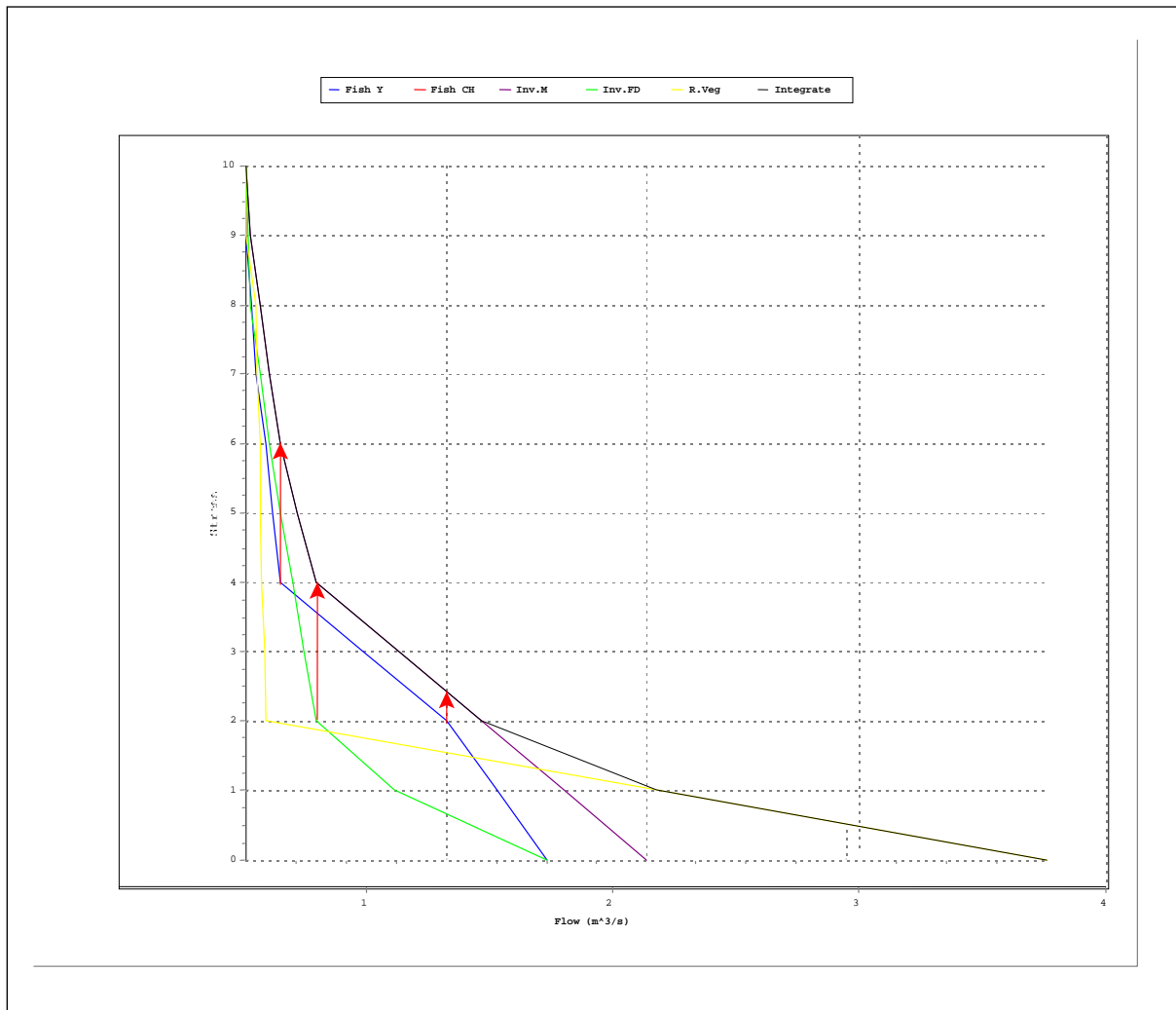


Figure 3-3 Conversion from component stress to integrated/stress

In Figure 3-3 the conversion is illustrated by the red arrows and described below from left to right:

- A fish stress of 4 equals a system stress of 6 (both implies a flow of 0.2m³/s). The explanation of this situation is that while the fish are not significantly stressed at 0.2m³/s, the aquatic invertebrates, which at that point represent the system stress, being the more sensitive component, are stressed (stress of 6).
- A flow dependant invertebrate stress of 2 equals a system stress of 4.
- A fish stress of 2 equals a system stress of 2.5.

4 APPROACH TO THE DETERMINATION OF EWR SCENARIOS

4.1 Low flow requirements

4.1.1 Generating stress requirements

The interpretation of stress durations is complex as the discharge values decrease up the y-axis, as opposed to the standard flow-duration graphs, in which discharge values increase up the y-axis. The relationship between flow-duration graphs (as used during the determination of flows in the application of the BBM process) and the stress duration graph, is illustrated in Figure 4-1.

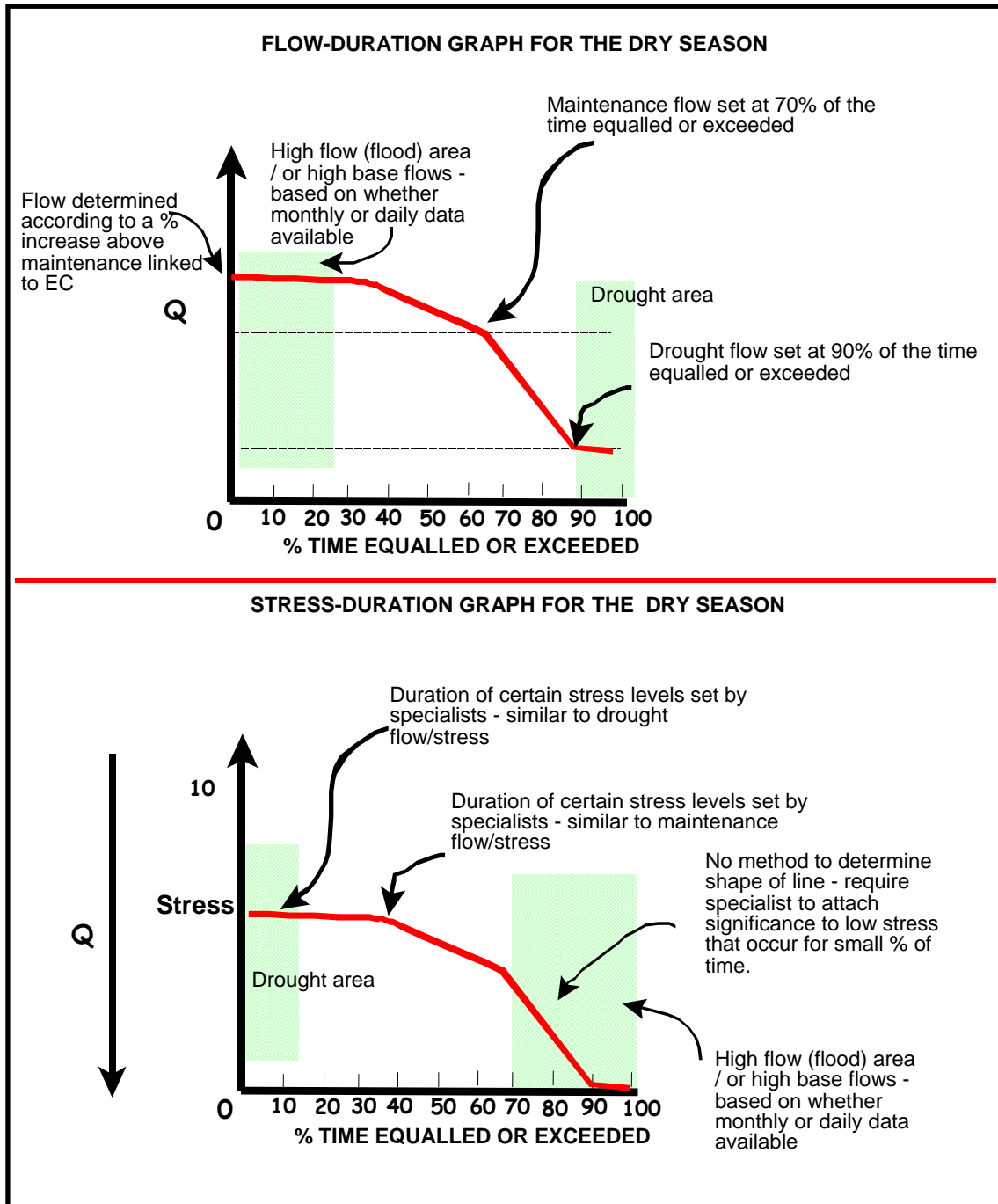


Figure 4-1 A comparison between flow-duration and stress duration graphs

The stepwise procedure for recommending the low flow EWR is discussed using the fish stress index for the illustration.

4.1.2 Generating stress requirements

The specialist must be able to interpret the stress-duration graph, as there must be no confusion with flow-duration graphs. The differences are illustrated in Figure 4-1.

The process and sequence of events are the same for fish and aquatic invertebrates. Fish are used below as an example.

- The fish specialist expresses the requirement as the percentage of time during which stress would be equalled or exceeded (i.e. higher stress, less flow) for each different season, i.e. stress-duration for a specific EC. This is in contrast to flow-duration, in which the requirement would be expressed as % time during which flow would be equalled or exceeded (i.e. more flow).
- The stress graph depicting natural and present flows is used to plot the fish stress requirements.
- The process followed to determine the requirements for the REC is set out in the block below and a case study/example is provided in Section 4.1.3.

DRY SEASON
<p>Note: The hydrologist provides a general description of the system, an explanation of how often droughts occur, and how to interpret the seasonal duration graphs.</p> <p>Determine the months that comprise the dry and wet season and/or select single months to use.</p> <p>Droughts</p> <p>Droughts normally occur about 5 to 10% of the time. Drought conditions are dependent on the type of hydrology. The stress requirement is relevant for drought conditions that occur over a reasonable period of time (i.e. at least a month in a season - not just an odd day or two).</p> <p>If drought conditions are set for the lowest that it should ever go, even for a day, a stress for 0 or 1% time equalled or exceeded should be provided.</p> <p>The questions that must then be answered are:</p> <ul style="list-style-type: none">• What are the identified, stress conditions associated with drought conditions?• Why is the stress specified critical? <p>Action: Plot the point/s you require (see example Figure 4-2). Document the requirement and reasoning as in the example (Section 4.1.3).</p> <p>REMEMBER, DROUGHTS ARE THE SAME FOR ALL ECOLOGICAL CATEGORIES.</p>

Maintenance flows for a specific EC

The % flows representing maintenance conditions, provided by the hydrologist, are representative of conditions occurring on average (based on the natural hydrology representing the natural variation and hydrological characteristics of the river).

In this case you therefore have a KNOWN percentage. The questions you then need to answer are:

- What are the habitat conditions you want to see on average for the species you are dealing with?
- What stress conditions does this habitat relate to?
- Why does it need this condition on average?

Action: Plot the point/s you require (see example Figure 4-2). Document the requirement and reasoning as in the example (Section 4.1.3).

Check

Connect the drought and maintenance points on the graph. Spot-check any stress, or duration, in between the two points and verify that this is the stress (habitat conditions) that is acceptable during dry periods between maintenance and drought for the specific duration (Figure 4-2). If the habitat conditions are not acceptable, then the drought and/or maintenance stresses must be re-evaluated.

Other durations for a specific EC

- Determine whether there are any other requirement for a habitat condition outside of the range between drought and the maintenance flow, i.e. lower stress/more flows (wet periods) than maintenance flows (Figure 4-2).
- What other significant habitat conditions and stress is required for a specific duration?
- Provide the duration and the motivation.

Action: Plot these points on the graph (see example Figure 4-2). Document the requirement and reasoning as in the example (Section 4.1.5).

WET SEASON

Repeat the procedure for the wet season.

NOTE: Due to the breeding and life cycle issues during the wet season, more points than just those for drought and maintenance conditions should be completed. However, do not provide points above approximately 60% as this is in the range of flood conditions.

⁽¹⁾ Note: The motivations/reasons as described above are relevant for all the EWR sites you are dealing with IF the indicator species/guilds are the same. In future these motivations will become generic for rivers in the same Level II Ecoregion and with the same indicator species/guilds

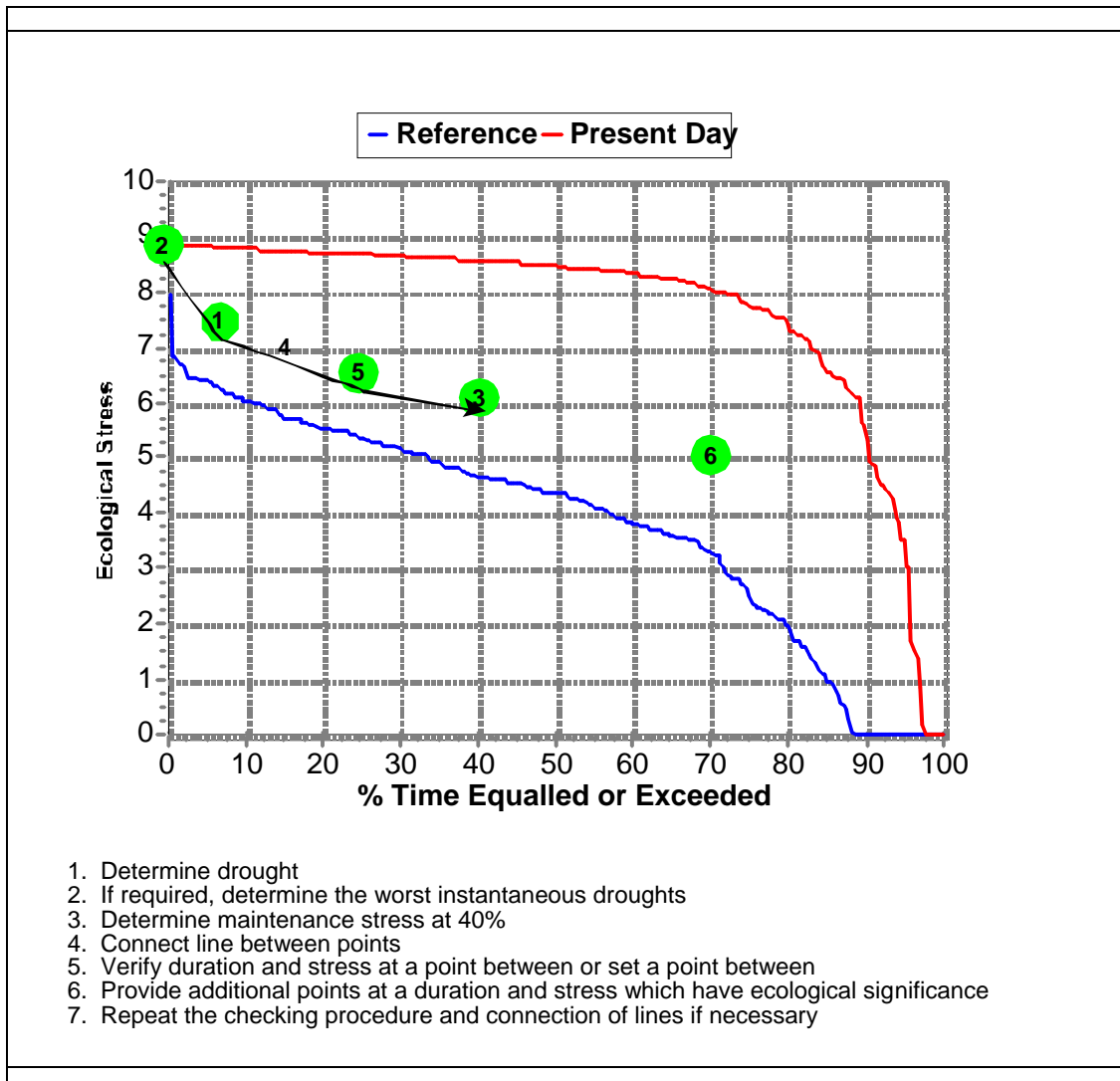


Figure 4-2 Sequence of steps followed during the determination of stress requirements (This graph is not related to any specific river and serves as an example only.)

4.1.3 Provision of motivations for determining stress requirements

An example is provided below using the Elands River site and the fish species that occur there. Note: It does not link to any of the graphic examples provided. The stresses provided are only examples.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: Fish: The indicators are rheophilic species dependant on the perennial flow.</p>
STRESS REQUIREMENTS FOR THE REC
DRY SEASON
<p>DROUGHT: i.e. ± 10% Survival conditions = Minimal fast shallow habitat in patches (minimum depth of 15 cm - approximate 1 - 2 abundance) provides cover and trophic requirements (stress of 7). 0% of the time: Still need flowing water (trickle), but if these conditions occur for more than 1% of the time, the species could be lost (stress of 8).</p>
<p>MAINTENANCE: 30% Require good habitat for the dry season. Minimum patches of fast deep and fast shallow habitats required, but need connectivity to ensure maintenance of population dynamics and abundances (stress of 4).</p>
WET SEASON
<p>DROUGHT: i.e. ± 10% Fish still spawn, but few situations with favourable habitat conditions exist. When favourable conditions occur, it will not necessarily be optimum conditions. (Therefore, start with maintenance which will describe the optimum conditions and then derive the 'less favourable conditions'). Relatively limited – stress of 5: FD, FS, available but limited and fragmented (patchy). 0 duration: Summer, temperature, oxygen and water quality play a role and survival conditions therefore different than dry season (stress of 7).</p>
<p>MAINTENANCE: 30% (Stress of 2) <i>Amphilius uranoscopus</i> Eggs: Margins of FS (>0.2 m, <0.2 m/s) gravel cobble substrate. October – January. >16°C. Duration 7 days of 3 - 30% exceedance. Larva: Feeding and Growth: Nursery areas (>0.20m deep <0.2m/s), margins of FS, SS and overhanging vegetation. Duration larval period: 2 months of 3 - 30% exceedance. Juvenile: Feeding and Growth: Mostly FD, FS (>0.20m deep >0.1m/s). Cover: Cobbles and rocks overhanging vegetation. Duration 3 - 6 months of 3 - 30% exceedance. Adult: SS, FS (>0.25m), gravel, cobble substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity), 3 - 30% exceedance.</p>
<p>Other: Population boost is required at 75% of the time. Close to natural conditions - limited risk. Stress of 1. (Note: Should as standard use “50% of the time”, i.e. stress of 2 (could also derive this by connecting the lines and checking.))</p>
STRESS REQUIREMENTS FOR THE ALTERNATIVE EC
<p>C conditions: Same diversity of habitat conditions, but occurring less often. Durations of stress will be longer. Increased risk as category below REC. Purely derived - more quantified methods will require modelling approaches that are outside the scope of these studies.</p>

The stress (integrated values) for the wet and dry season at specific percentage points are provided to the facilitator who plots them on a blank stress profile.

4.1.4 Low flow requirements

- The determined integrated stress index is used to identify required stress levels at specific durations for the wet and dry month or season. Drought flows are usually set at 95 to 100% assurance/duration/time equalled or exceeded. The equivalent stress assurance would be 5 to 0%. Based on the characteristics of the hydrological regime, maintenance flow assurance is determined and provided by the hydrologist. If for example the maintenance flow assurance is 70%, the equivalent stress assurance would be 30%.
- The points plotted for the components representing the lowest stress at any time guide the shape of the recommended low flow. Outliers are investigated and if confidence associated with these recommendations are very low; these points are not used to shape the curves.
- The curve is then drawn in by hand. This hand-drawn line represents a band of flow /stress requirements (Figure 4-3).

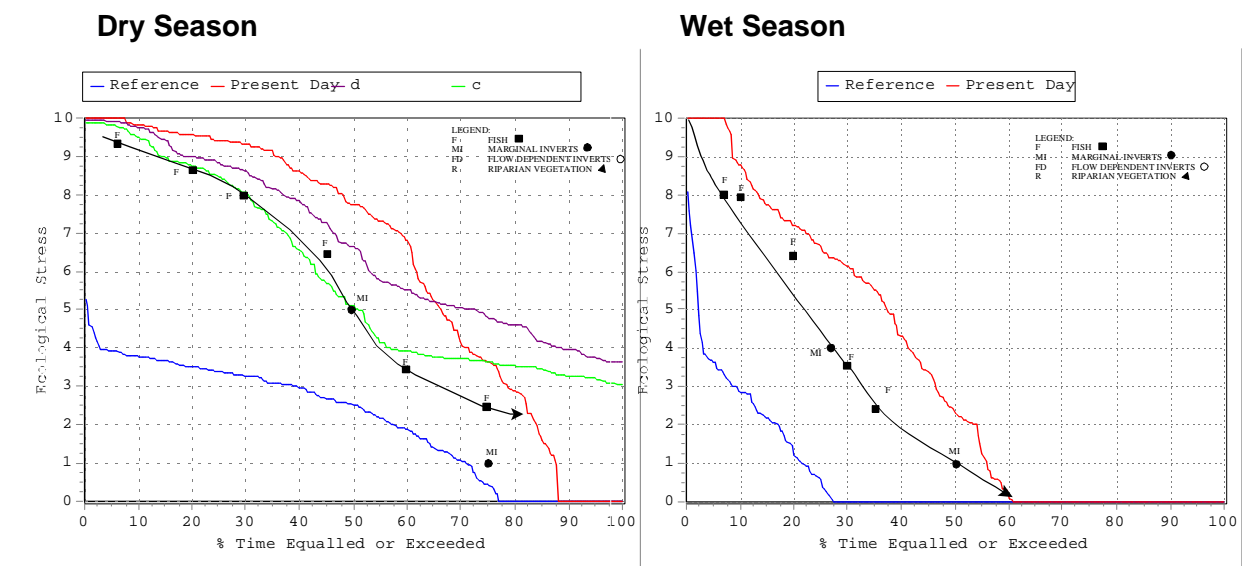


Figure 4-3 The hand-drawn line representing a band of flow/stress requirements from the individual specialists

- The hydrologist then investigates which Desktop Reserve Model-generated curve most closely represents the recommended curve and adjusts the hydrology to approximate the hand-drawn curve.
- This curve is presented to the specialists who indicate whether further manipulation is required, or whether the curve represents their requirements adequately.
- At this point the low flow recommendations for each Reserve scenario has been finalised and high flow recommendations are now required to enable the final flow scenarios to be provided (Figure 4-4. Note that c and d in the graph legend refers to EC).

Dry season

Wet season

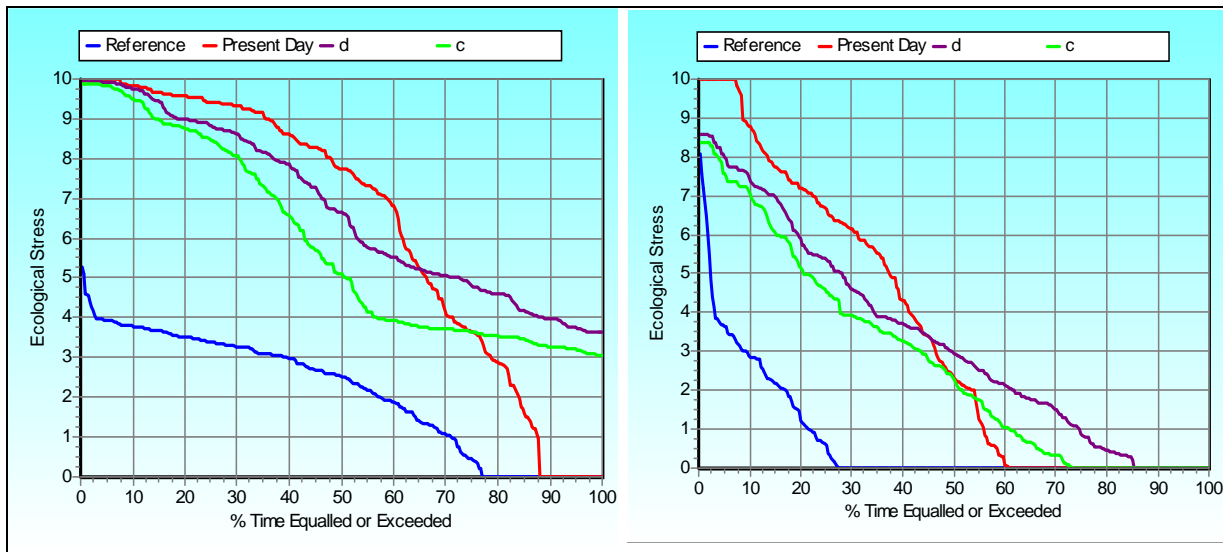


Figure 4-4 The final curve

4.2 Approach to high flows

The approach used for high flows in this study has elements of both the BBM and the DRIFT methodologies. Fish, invertebrate, riparian vegetation and geomorphologist specialists provide the functions of floods and identify the size of the events using the hydraulic cross-sections, photos and videos of known flows and specialist geomorphological knowledge.

The stepwise approach to determining the high flows is as follows:

- Each specialist identifies the range of high flows that will undertake similar functions. Class I high flows are the smallest events (the freshes / freshettes), and from Class II events the floods increase in size. The larger the classes, the larger the size of the events. The largest flood class will represent flows with a return period of 1:2 or more. An example is provided in Table 4-1 of the component requirements and final size of flood classes.
- Specialists provide their flood classes as the instantaneous peak which is required. The hydrologist converts this to a daily average as this is the requirement for the data to be captured into the Desktop Reserve Model.

Table 4-1 A summary of the flood class ranges and the recommended high flow events for each scenario

Component	Flood classes (m ³ /s)					
	I	II	III	IV	V	VI
Fish	1.25 - 3	3 - 6	> 6			
Invertebrates	1.5 – 3	3 - 5				
Vegetation		1.25 - 6	6 - 18	18 - 55	55 - 84	
Geomorphology		2 - 8		33 - 53	53 - 87	> 262
Integrated	1.5 – 3	3 - 8	6 - 18	33 - 55	55 - 87	> 262
Daily average	2	4	6	10	60	
Duration (days)	2	2	3	3	5	

- Specialists document the functions and describe the critical hydraulic parameters associated with each class of flood per component. This information is documented in the spreadsheets (Appendix I).
- The hydrologist checks the validity of these floods against naturalised daily hydrology, or in the absence of this, against any observed hydrological data or monthly volumes (the latter is used only as a last resort).
- Where possible, the hydrologist provides the number of events, which would occur under natural flow conditions for each of the flood classes. If daily hydrology is not available, an upstream reach of similar area is used to provide some indication.
- The specialists then identify which of that number of events should occur for each of the Reserve scenarios (ECs). The number of events should not exceed natural conditions and should only be similar to natural if the EC being considered is in a high category. The objectives and criteria set for the recommended and alternative ECs must be kept in mind when motivating the number of events per REC. Motivations linked to the number of events recommended are supplied in the spreadsheets. The results are provided in Table 4-2.
- The coordinator then assesses the number of events required. The integrated column is populated with the highest number of events required (Table 4-2). It is then assessed whether any of the flood requirements in certain flood classes will also cover requirements of specialists in other flood classes. The final number of events required is completed in the 'Final' column.
- An example would be the following. Four Class 1 floods are required for fish and two Class 1 floods for invertebrates. Normally the final requirement would be four Class 1 floods. However, if the invertebrates for example require two Class 2 floods and the fish no class 2 floods, the fish specialists would be consulted to determine whether two Class 1 and two Class 2 floods would suffice rather than 4 Class 1 floods. If one did not follow this approach, the fish would end up receiving 6 floods in total (four Class 1 and 2 Class 2) where they actually only require four events.

Table 4-2 Recommended high flow events for each scenario

Flood classes	NUMBER OF EVENTS: EC C					
	Invert	Fish	Veg	Geom	INTEG	FINAL
Class I	3	4	8	4	8	6 (May, June, July, Aug., Oct., Nov)
Class II	1	2			2	1 (Oct)
Class III			1	1	1	1 (Sept)

4.3 Final results

The low flows and high flows are incorporated into an integrated flow regime. The final output, i.e. the IFR rules (presented as duration tables), is provided from either the Desktop Reserve Model or the IFR Model. The IFR assurance rules are documented in the report. Results are also provided as IFR tables (the tab tables) and are presented in the report per EWR site.

4.4 Confidence evaluations of the results

Each specialist provides a confidence evaluation on a scale of 0 (no confidence) to 5 (high confidence) for their component, for various parameters, as well as the reasoning behind the evaluation. The information regarding each confidence evaluation parameter is provided below.

EWR site: The ability of the site to provide reasonable cues to set the EWR requirements is assessed.

Available data: The confidence in the available data, both historical and collected, and the relevant specialist’s ability to interpret the data accurately to recommend flows is assessed.

Ecological classification: The confidence in all contributions provided towards the PES and EC (reference conditions, PES, trajectory of change, EIS, EC) is assessed.

Output Low: The final output and the confidence that specialists have that the flow would achieve the specified component objectives specified, must be evaluated. If, for example, the requirements for a component were superseded by another component, the final flow represents more flows than recommended and the confidence should therefore be high. If however the flow regime was based on requirements, the confidence in the requirements set should be assessed.

Output High: Evaluate the final high flow regime that will provide size, frequency etc.

5 EWR 1 – MELKHOUTBOSKRAAL: ECOCLASSIFICATION

5.1 Reference Condition

5.1.1 Geomorphology

The reference condition for this reach consists of a cobble bed river with a high width-depth ratio and a propensity to braiding (main channel with secondary channels subject to channel switching). Due to the unstable nature of the valley floor, there is limited woody riparian vegetation. This condition is similar to that shown on the aerial photographs of 1942. A number of wetlands exist in the valley floor above this site.

5.1.2 Riparian vegetation

An intact and connected riparian zone from the upper zone through to the marginal zone defines the reference condition. The upper riparian zone comprises species more similar to that of valley bushveld than the surrounding false Karoo (Acocks, 1989). Low and Rebello (1996) describe this as south west coast Renosterveld. It comprises a closed thicket of shrubs and trees featuring *Podocarpus* (Yellow wood), *Carissa bispinosa*, *Scutia myrtina*, *Rhus lucida*, *Maytenus heterophylla*, *Ehretia rigida*, *Acacia karroo*, *Euclea undulata*, *Cassine aethiopica* and others. The lower riparian zone features *Diospyros lyciodes*, *Rhus dentata* and palmiet. Palmiet forms large clumps on the edges of pools. Palmiet also dominates the marginal zone, with smaller clumps of *Juncus* and other sedges and Restionaceae featuring in other open areas.

No exotic species are present under the reference condition and cultivation is absent in the upper riparian zone.

5.1.3 Water quality

There was no appropriate data that could be used for Reference Condition within this Water Quality Sub-Unit (WQSU) and the default benchmark boundary tables were used for the assessment. An additional monitoring site was instituted for the purposes of this study (WQ2 at Melkhoutboskraal) in the lower section of the WQSU and was used to assess the Present Ecological State. This data is of limited value as only four samples (February to May 2004) were collected.

5.1.4 Fish

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Kromme River at EWR 1.

- *Pseudobarbus afer*
- *Sandelia capensis*
- *Anguilla mossambica*
- *Anguilla marmorata*
- *Anguilla bicolor bicolor*

5.1.5 Aquatic invertebrates

This site would be expected to have had similar habitat diversity under reference conditions to that under the present conditions, but with more sustained inundation of marginal vegetation. There would have been greater shading from riparian vegetation, which would have led to higher leaf-fall, heterotrophic conditions, and the presence of a greater diversity of leaf-shredders such as stoneflies and mayflies. There would have been less mobile sediment in the stones habitats, no algal growth, water temperature might have been lower, but water quality conditions similar to the present state. These conditions favour a sensitive macroinvertebrate fauna with a greater number of mayfly families (Tricorythidae), the possibility of stoneflies, Caddisflies (Philopotamidae and Pisullidae) and an enhanced community of aquatic invertebrates with a preference for marginal vegetation e.g. Odonata (Lestidae), Coleoptera (Belostomatidae, Nepidae and Pleidae), some Corixidae (Naucoridae), and Gastropoda (Physidae and Lymnaeidae). Sponges (Porifera) would have been present on rock surfaces.

5.2 Present Ecological State (PES)

5.2.1 Habitat Driver PES

The hydrology PES (C category) and geomorphology PES (D category) information is available in Appendix A and Appendix B respectively. Water quality PES is a B/C category. The driver is a C category and the composition of the driver category is provided in Table 5-1.

The reasoning for the geomorphology category (D) is provided below.

PES	Causes	Sources	Flow/Non flow related
D	Channel incision.	Alien vegetation encroachment.	Non flow related.
	Bed armouring.	Channel incision leading to increase in stream power plus increase in floods.	Flow related.

Table 5-1 Habitat Driver Category for EWR 1

Components	Weighted driver score
GEOMORPHOLOGY	11.73 (D)
HYDROLOGY	33.67 (C)
WATER QUALITY	18.37 (B/C)
Weighted driver status (%)	63.78
HABITAT DRIVER CATEGORY	C

5.2.2 Biological response PES

5.2.2.1 Riparian vegetation (D/E)

The PES is poor due to the removal of indigenous vegetation and cultivation in the upper riparian zone. In addition, the infestation of the upper and middle riparian zones by Black Wattle is extensive. This has led to the stabilisation of the riparian zone and the subsequent incision of the

river and the marginal zone. The riparian zone has therefore become significantly disconnected leaving the upper zone isolated from the middle and lower parts. It is uncertain whether the remaining vegetation of the upper riparian zone, in its present location, is still dependent on the river for its supply of water.

PES	Causes	Sources	Flow/Non flow related
D/E	General degeneration of the riparian zone and isolation of upper riparian zone.	Invasion of exotic species and subsequent river incision.	Non flow related.
	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Cultivation in upper riparian zone and removal of vegetation.	Non flow related.
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Cattle grazing in riparian zone.	Non flow related.
	Changes in abundance of vegetation.	Cultivation in upper riparian zone and removal of vegetation.	Non flow related.
	Changes in vegetation cover.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.	
	Reduced impact of flooding as a consequence of exotic species invasion.	Flow related.	

5.2.2.2 Fish (C/D)

The presence at this site of large numbers of highly effective alien predatory largemouth bass, *Micropertus salmoides*, has resulted in the local extermination of the indigenous fish species *Pseudobarbus afer* and *Sandelia capensis* from the main channel of the Kromme River. These native species, which should be present in large numbers, do not have effective predator-avoidance behaviour and are very vulnerable to predation in clear, shallow streams.

The approach to assessing the PES for fish was to ignore the impact of alien fish and assess how the original (expected) endemic fish would have responded to habitat changes. This approach is followed at all the EWR site evaluations.

PES	Causes	Sources	Flow/Non flow related
D	Reduction in river flows, particularly low flows and increased periods of extremely low flows (or no flow).	<ul style="list-style-type: none"> • Destruction of Palmiet wetlands. • Direct abstraction and/or via farm dams for farming. • Increased evapotranspiration due to forestry and alien vegetation. 	<p>Non flow related.</p> <p>Flow related.</p> <p>Non flow related.</p>

PES	Causes	Sources	Flow/Non flow related
	Increased sediment load, silting up of pools, embedding rock substrate cover.	<ul style="list-style-type: none"> • Soil erosion due to bad farming practices. • Bank erosion and collapse due to alien trees (e.g. Black Wattles). 	<p>Non flow related.</p> <p>Non flow related.</p>
	Reduced water quality, including increased nutrients, increased temperatures, and reduced dissolved oxygen (DO) levels.	<ul style="list-style-type: none"> • Fertilizer input from farms. • Increased silt load and turbidity at high flows. • Reduced DO and increased temperature during low flows in summer. 	<p>Non flow related.</p> <p>Non flow related.</p> <p>Flow related.</p>
	Increased predation.	Presence of highly effective alien predator under favourable conditions for predation.	Non flow related.

5.2.2.3 Aquatic invertebrates (C)

Instream habitat at this site was plentiful and in relatively good condition. Stones were mobile, allowing for invertebrate colonisation on the upper side and lower surfaces, which typically relates to a healthy biodiversity of stone-dwelling fauna at a site. Only the root zones of the marginal vegetation were inundated. The lack of a robust vegetation zone limits the number of aquatic invertebrates with a preference for this biotope, and also results in a paucity of cover for juveniles in early summer. SASS5 scores were approximately 70% of assumed reference conditions, and the high Average Score per Taxon (ASPT) (>6) indicates that the fauna includes a healthy proportion of sensitive taxa.

PES	Causes	Sources	Flow/Non flow related
C	Loss of flow.	Abstraction.	Flow related
	Sedimentation of stones habitat.	Agricultural practices. Bank clearing.	Non flow related
	Loss of riparian and vegetation habitat.	Alien invasion.	Non flow related

5.2.3 Instream PES (C)

The Instream PES is summarised in Table 5-2.

Table 5-2 Instream PES for EWR 1

Criteria		Rating (0=low, 5=high)				
		Conf Rating	Ave	Weight	PES	Category
Availability of high confidence fish information		2				
1	Diversity of fish species with different flow requirements	2				
2	Diversity of fish species with a preference for different cover types	2				
3	Diversity of fish species with a preference for different flow depth classes	1				
4	Diversity of fish species with various tolerances to modified water quality	2.5	1.88	0.36	62.0	C
Availability of high confidence invertebrate information						
5	Diversity of invertebrate biotopes	3				
6	Diversity of invertebrate taxa with different velocity requirements	4				
7	Diversity of invertebrate taxa with different tolerances to modified water quality	3	3.33	0.64	64.3	C
			5.21	1	63.5	C

5.2.4 PES Ecostatus (C)

The Ecostatus is summarised in Table 5-3.

Table 5-3 Summary of the Ecostatus for EWR 1

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		3		
Fish: What is the general level of trophic specialisation?		2		
What is the general level of habitat specialisation?		3		
What is the general level of flow intolerance?		4	3	0.53
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3		
How sensitive are hydraulic habitats to flow change? ¹		3		
How sensitive is water quality to flow change?		2	2.67	0.47
Total			5.67	1
INSTREAM CATEGORY	PES	Category		
	63.47	C		
DRIVER CATEGORY	63.8	C		
ECOSTATUS	63.61	C		

⁽¹⁾ This rating is applicable to low flows

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

Note that the Ecostatus does not at this stage consider riparian vegetation. Riparian vegetation is a much lower category (D/E) due to the presence of alien vegetation. It was concluded that the Ecostatus should not be lowered due to the riparian vegetation condition. The C category is representative of the instream condition and the riparian vegetation condition is due to non flow related issues.

Table 5-4 is a summary of the PES categories for EWR 1. Trends of change are shown in Section 5.2.5.

Table 5-4 Summary of the PES categories for EWR 1

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C	C	C Instream
GEOMORPHOLOGY	D		
WATER QUALITY	B/C		
Response components	Component PES	Instream PES	
FISH	C/D (C)	C	
AQUATIC INVERTEBRATES	C		
RIPARIAN VEGETATION	D/E	D/E	

(1) The percentage was 60%; i.e. in a C-Category.

5.2.5 Trends

Geomorphology – Long term within category.

Vegetation – Negative.

Fish – Stable.

Aquatic Invertebrates – Stable.

5.3 Importance

5.3.1 Ecological Importance and Sensitivity (EIS)

The EIS was rated as moderate (present), as there are rare fish species (*P. afer*) and invertebrate families (Teloganodidae and Notonemouridae) present. There are a low number of invertebrate taxa present with a high preference for fast-flowing water all year round. Riparian and instream habitats include pools, riffles, undercut banks, instream vegetation and backwaters. The confidence is moderate.

5.3.2 Socio-cultural Importance (SI)

Land use for Resource Unit A (Segment 4 – 11, EWR 1: Segment 7) is almost exclusively agricultural with the small town of Kareedouw also dependent on this sector. Formal rural settlements have a limited dependence on the river with the exception of direct economic exploitation, such as commercial agriculture. However, commercial agriculture is not a factor that contributes to the determination of EIS.

The SI was rated as low and the confidence was moderate.

5.4 Range of Ecological Categories

5.4.1 Recommended Ecological Category (REC)

Due to the moderate EIS and low Socio-cultural Importance, the REC is to maintain the PES, apart from riparian vegetation, that is presently in a D/E category and must be improved to a D category. In reality any action taken to address the D/E category would probably significantly improve vegetation conditions (i.e. more than a D category). If alien vegetation is not cleared effectively a D category would result and a negative trend would prevail. If a C category is achieved and the condition of the riparian vegetation is improved, a positive trend that could result in a B category in the moderate to long term, would result.

Improvement of the riparian vegetation to a D category or better will only be possible if catchment, and specifically alien vegetation, problems are addressed in the long-term. Improvement in flow will then augment the improvement in the riparian vegetation.

The REC is therefore to maintain the C Ecostatus and all component categories, apart from riparian vegetation, which must improve from a D/E to at least a D category.

5.4.2 Alternative Ecological Categories

Only one alternative category, a D Ecostatus, was considered. A/B Ecostatus will not be considered, as it is highly unlikely that this can ever be achieved by improving flows. If non-flow related problems are addressed such as the rehabilitation of the wetland and addressing alien vegetation and fish, the river state will improve without improving flows.

The hypothetical D Ecostatus conditions represent a state where lower (than present) low flows occur and water quality would decrease half a category, i.e. from a B/C to a C/D category.

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios; the matrices that would be affected were changed. These spreadsheets, with the changes indicated as different colours are included in the specialist appendices.

The EC results for the components and the Ecostatus is provided in Table 5-5.

5.4.2.1 Fish

In the alternative EC for fish (D), the reduction in flows due to increased abstractions will mainly affect the low flows, i.e. longer periods of low flows experienced, including periods of critically low flows (possibly no flow periods). The fish stress will increase during these periods of reduced water flow and river levels, as this will result in the following:

- Result in fish, cover, such as undercut banks, root wads and marginal vegetation, not being available to fish further resulting in the crowding of fish in exposed areas and to increased predation.
- At low or NO flows the water quality will deteriorate (increased temperatures, lowered DO levels and growth of iron bacteria on substrate surfaces), resulting in poor fish health and increased mortalities due to disease.

The numbers of fish will drop and, although no species will be lost completely, they will become even more rare and isolated in small pockets.

5.4.2.2 Aquatic invertebrates

The reduction in flows and the change in habitat abundances associated with a D Ecstatus are likely to remove the most sensitive aquatic invertebrates in this community, e.g. Teloganonids and Sericostomatids. Some of the aquatic invertebrates that are moderately sensitive to flow and water quality changes may also be lost e.g. Helodid beetles and Heptageniid mayflies.

Table 5-5 Summary of the Alternative Ecological Category D for EWR 1

Driver Components	Component EC	Driver EC	ALTERNATIVE ECOSTATUS
HYDROLOGY	D	D	D
GEOMORPHOLOGY	D		
WATER QUALITY	C/D		
Response components	Component PES	Instream EC	
FISH	D	D	
AQUATIC INVERTEBRATES	D	D	
RIPARIAN VEGETATION	D	D	

The integrated rule-based model results are available in Appendix J for the alternative EC.

6 EWR 1 – MELKHOUTBOSKRAAL: STRESS INDICES

6.1 Stress Index: Fish

The indicator species is *Pseudobarbus afer*, which is a semi-rheophilic species. This species requires flowing water for spawning in riffle areas where it needs depths of over 10 - 15 cm and velocities of >0.3 m/s. This species is sensitive to water quality and requires flow especially during the wet season, but can tolerate short periods of no flows.

Availability of cover in the form of undercut banks and overhanging vegetation only become available to the fish at higher flows. The lack of cover at low flows leads to higher stress due to increased predation. Water quality is thought to deteriorate at low flows (higher temperatures, lower DO, algal growth and iron bacterial growth) as well as a drop in food abundance.

Fast-shallow riffle habitats are thus required for spawning in summer, while critical preferred habitats are slow deep and slow shallow with sufficient shelter from predation (substrate, undercut banks and overhanging vegetation). Habitat suitability, from which species stress is derived, is shown in Table 6-1.

6.2 Stress Index: Aquatic invertebrates

Hydropsychids and Simuliids are indicator groups for low stresses. These taxa occur in the Stones in Current (SIC) biotope (preference for velocities > 0.6m/s). Leptophlebiids are indicators for high stresses. This taxon will occur at low flows, but is likely to disappear at a stress of 9 when surface flow disappears. Elmids beetles have a preference for moderate flows (0.3 - 0.6 m/s) and were used as an indicator for middle-level stress of 3 - 4. In general the stresses were, however, set using the full community of aquatic invertebrates and their velocity and habitat preferences (IWR S2S, 2004). Due to the lack of Marginal Vegetation (MV), the community displayed a stronger preference for Stones in Current (SIC) and Stones out of Current (SOOC) biotopes. These are considered the indicator habitats. The stress table is shown as Table 6-2.

Table 6-1 Habitat suitability at EWR 1

	Flow (m ³ /s)					
	1.50	1.000	0.500	0.130	0.028	0.010
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE; 1=RARE; 2=SPARSE; 3=MODERATE; 4=ABUNDANT; 5=VERY ABUNDANT						
FAST DEEP	4.0	3.0	2.0	0.0	0.0	0.0
Overhanging vegetation	4.0	3.0	1.0	0.0	0.0	0.0
Undercut banks & root wads	4.0	4.0	2.0	0.0	0.0	0.0
Substrate	4.0	3.0	3.0	0.0	0.0	0.0
Aquatic macrophytes	2.0	1.0	0.0	0.0	0.0	0.0
Water column	2.0	2.0	1.0	0.0	0.0	0.0
FAST SHALLOW	5.0	5.0	3.0	3.0	1.0	1.0
Overhanging vegetation	5.0	4.0	3.0	2.0	1.0	0.0
Undercut banks & root wads	5.0	5.0	4.0	3.0	1.0	0.0
Substrate	5.0	5.0	4.0	4.0	2.0	1.0
Aquatic macrophytes	3.0	2.0	1.0	0.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0	0.0
SLOW DEEP	5.0	5.0	5.0	4.0	4.0	4.0
Overhanging vegetation	5.0	5.0	4.0	3.0	2.0	1.0
Undercut banks & root wads	5.0	5.0	4.0	4.0	3.0	3.0
Substrate	3.0	3.0	3.0	3.0	2.0	2.0
Aquatic macrophytes	3.0	2.0	1.0	1.0	0.0	0.0
SLOW SHALLOW	3.0	4.0	4.0	5.0	5.0	3.0
Overhanging vegetation	5.0	4.0	3.0	2.0	1.0	1.0
Undercut banks & root wads	5.0	4.0	3.0	1.0	1.0	1.0
Substrate	4.0	4.0	4.0	4.0	3.0	1.0
Aquatic macrophytes	4.0	4.0	3.0	2.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0	0.0
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD						
SEMI-RHEOPHILIC	<i>P. afer</i>					
Breeding and early life-stages	5.0	5.0	3.0	1.0	0.0	0.0
Survival /Abundance	5.0	5.0	4.0	3.0	2.0	1.0
Cover	5.0	5.0	4.0	3.0	2.0	1.0
Health and condition	5.0	5.0	5.0	4.0	3.0	2.0
Water quality	5.0	5.0	4.0	3.0	2.0	1.0
Rheophilic stress - (breeding requirements included)	0.0	0.0	2.0	4.4	6.4	8.0
Flow-depth converted to habitat response (10=All flow-depth classes absent (River	1.50	1.00	0.50	0.13	0.03	0.01

dry); 0=Flow-depth classes optimum for site; 9=No flow)						
Fast deep	2.0	4.0	6.0	10.0	10.0	10.0
Fast shallow	0.0	0.0	4.0	4.0	8.0	8.0
Slow deep	0.0	0.0	0.0	2.0	2.0	2.0
Slow shallow	4.0	2.0	2.0	0.0	0.0	4.0
OVERALL HABITAT RESPONSE	1.5	1.5	3.0	4.0	5.0	6.0

Table 6-2 Stress table – Flow dependant invertebrate at EWR 1

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE		
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow	Community stress
Rating (site at observed flow)	4	4	1	0	2	11		0.13					
0	5	5	4	3	4	21		1.43	All habitats in excess, very high quality: some very fast, most moderately fast, deep, very wide wetted perimeter.	Max depth 0.52 Av depth 0.31 Area 4.64 Width 15.10 WP 17.12 Av velocity 0.31	All very abundant. All healthy, all species persist.	1.08	0
1	5	5	2	3	3	18		1.08	All plentiful, high quality; fast and moderately fast, deep, very wide wetted perimeter.	Max depth 0.48 Av depth 0.27 Area 4.04 Width 14.8 WP	All abundant. All healthy, all species persist.		1

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress	
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present			
										16.8 Av velocity 0.27				
2	4	5	2	2	3	16		0.56	Critical habitats sufficient; quality slightly reduced: slow and moderately fast, deep, wide wetted perimeter slightly reduced.	Max depth 0.4 Av depth 0.21 Area 2.91 Width 13.72 WP 15.57 Av velocity 0.19		Slight reduction for sensitive rheophilic species. All healthy in some areas, all species persist.	2	
3	3	5	2	1	3	14		0.31	Reduced critical habitat, reduced critical quality; Moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced.	Max depth 0.34 Av depth 0.16 Area 2.11 Width 12.81 WP 14.51 Av velocity 0.15		0.56	Reduction for all rheophilic species, all healthy in limited areas, all species persist.	3

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
4	3	4	1	0	2	10		0.13	SIC limited, of reasonable quality, VIC virtually absent.	Max depth 0.26 Av depth 0.11 Area 1.17 Width 10.47 WP 11.8 Av velocity 0.1	Further reduction for all rheophilic species. All viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist.	0.31	4
5	2	4	1	0	2	9		0.07	Critical habitat very reduced, moderate/low quality, moderate/slow velocity, few deep areas, wetted perimeter moderately/very reduced.	Max depth 0.22 Av depth 0.09 Area 0.79 Width 8.64 WP 9.69 Av velocity 0.08	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species (Elmids) at risk or non-viable (disappear at <0.3m/s); most species persist.		5
6	1	4	1	0	2	8		0.028	Critical habitat (SIC and VIC) residual, low quality, slow	Max depth 0.18 Av depth	Sensitive rheophilic species rare, critical stages of sensitive	0.13	6

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress	
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present			
									velocity, limited deep areas, moderate wetted perimeter.	0.08 Area 0.48 Width 6.35 WP 7.1 Av velocity 0.07			rheophilic species (Elmids) non-viable, and at risk for some less sensitive species. Most species persist in the short-term.	
7	1	3	0	0	1	5		0.02	No critical habitat. Other habitats moderate quality; slow, shallow, narrow wetted perimeter.	Max depth 0.16 Av depth 0.07 Area 0.37 Width 5.00 WP 5.64 Av velocity 0.06			Most rheophilic species rare. All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear.	7
8	1	2	0	0	1	4		0.01	Flowing water habitats residual, low quality: slow trickle, moderate wetted perimeter.	Max depth 0.12 Av depth 0.05 Area 0.19			Remnant populations of some rheophilic species; most life stages of most rheophilic species at risk or non-viable,	8

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
										Width 3.96 WP 4.36 Av velocity 0.04	Leptophlebiids threatened.		
9	0	1	0	0	1	2		0	Standing water habitats only, very low quality, no flow.	Max depth 0.1 Av depth 0.04 Area 0.12 Width 3.16 WP 3.44 Av velocity 0.03	Mostly pool dwellers, most life stages of most rheophilic species non-viable; Leptophlebiids likely to disappear.	0	9
10	0	0	0	0	0	0		0	Only hyporheic refugia, no surface water.		Unlikely.	0	10

⁽¹⁾ SIC: Partially submerged hard substrate in current >0.1m/s.

⁽³⁾ VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1m/s.

⁽⁵⁾ GSM: Small particles submerged.

⁽²⁾ SOOC: Partially submerged hard substrate in current <0.1m/s.

⁽⁴⁾ VOOC: Submerged vegetation (at least 2-3cm submerged) in current <0.1m/s.

6.2.1 Integrated stress curve

The individual component stresses are illustrated as well as the integrated stress line (black line). Note that the invertebrate line (purple line) falls under the integrated stress line and cannot be seen.

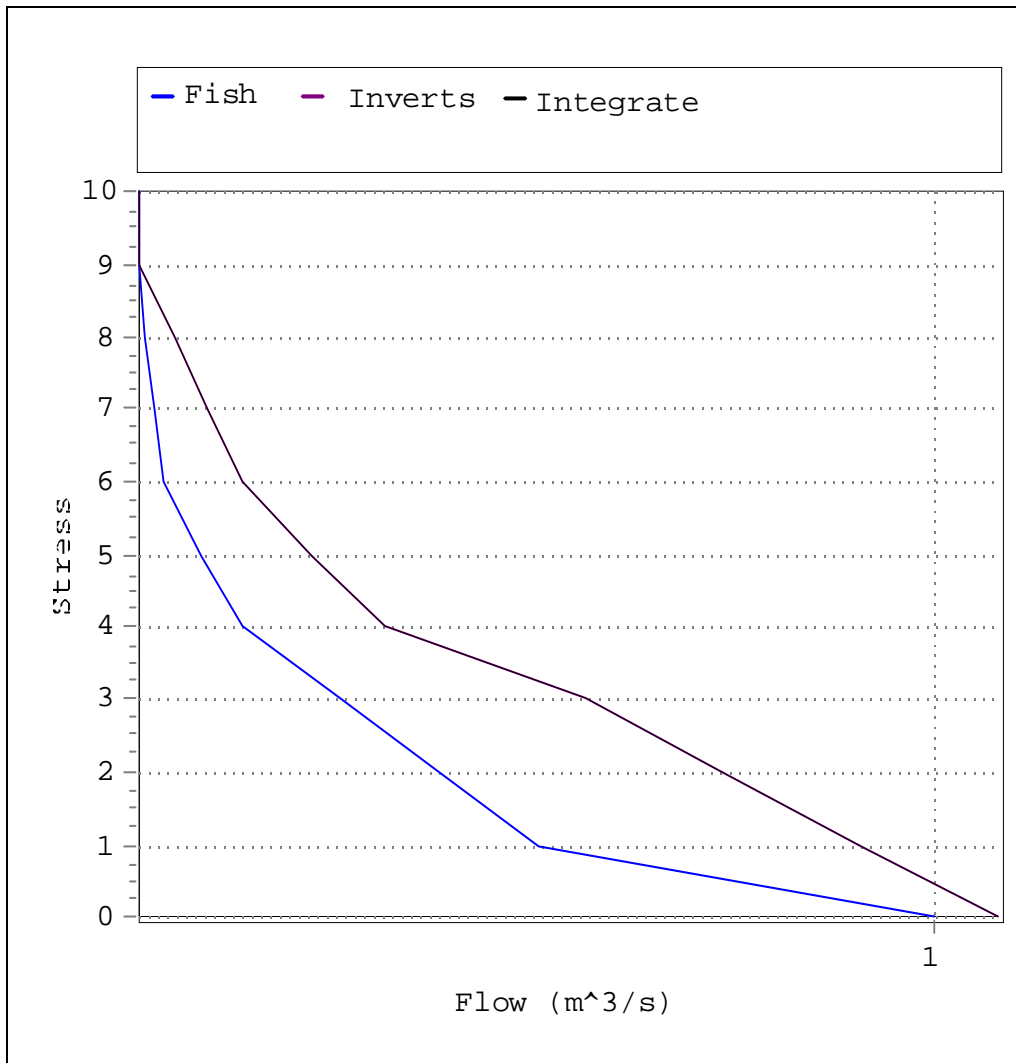


Figure 6-1 Component and integrated stress curve for EWR 1

7 EWR 1 – MELKKHOUTBOSKRAAL: DETERMINATION OF EWR SCENARIOS

7.1 Low flow requirements

The integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month/season. Drought flows were set as 95 to 100% assurance (i.e. stress durations of 5 to 0%) and, based on the hydrological characteristics, maintenance flows were set as 55% assurance (i.e. stress durations of 45%). Stress duration curves are shown in figures 7-1 and 7-2.

Dry season (January C category)

Wet season (August C Category)

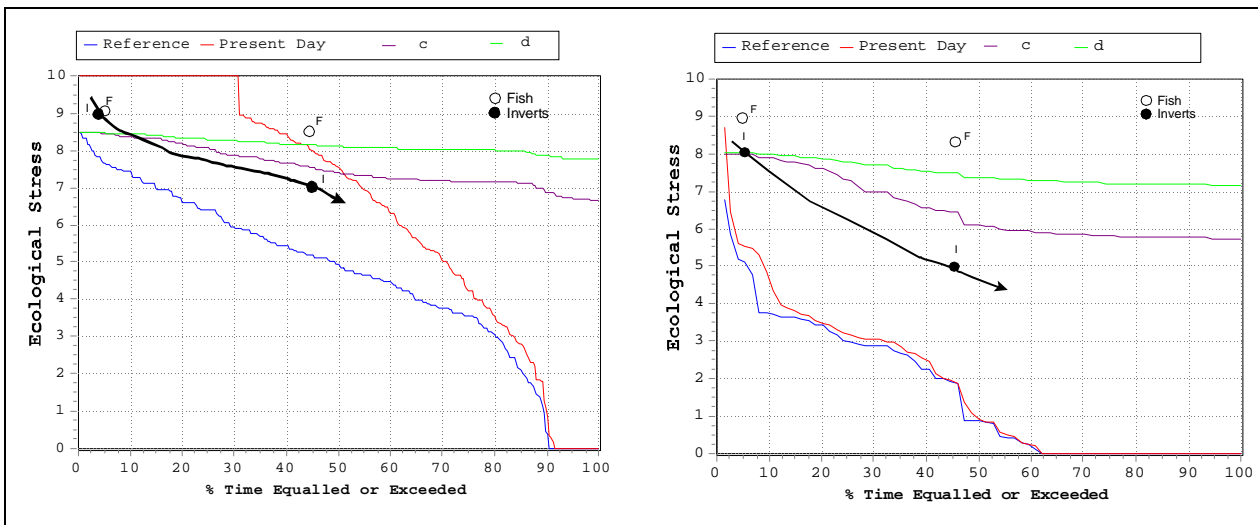


Figure 7-1 EWR 1 – Stress duration curve for a C REC

Dry season (January D category)

Wet season (August D category)

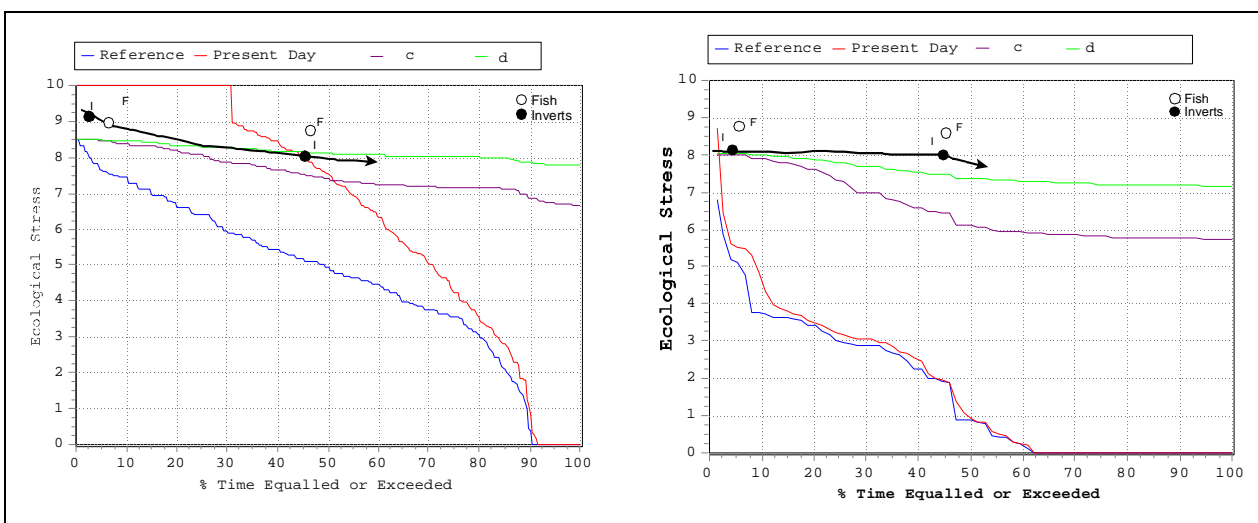


Figure 7-2 EWR 1 – Stress duration curve for an alternative scenario of a D EC

7.1.1 Stress duration motivations: Fish

Note – this motivation is similar for all EWR sites due to use of the same indicator species, *P. afer*.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: <i>Pseudobarbus afer</i> The indicator is a semi-rheophilic species that is dependant on the flow for breeding in riffles at suitable velocities and depths. Note peak spawning activities take place in Spring (September to December) and possibly some limited spawning in late summer, but main spawning requirements for species in terms of stress requirements are included in the wet season.</p>
FISH STRESS REQUIREMENTS
DRY SEASON (January)
<p>DROUGHT: 5% of the time at stress level of 9 Fish confined totally to pool with limited cover available, poor water quality and limited food available.</p>
<p>MAINTENANCE (C): 45% of the time at stress level of 8.5 Provides more cover and improved water quality and food.</p>
<p>MAINTENANCE (D): 45% of the time at stress level of 8.9 Reduced cover in form of overhanging and emergent vegetation results in significantly high predation and thus reduced population sizes, reduction in water quality during hot months (high temperatures and low dissolved oxygen levels) increases stress on fish</p>
WET SEASON (August)
<p>DROUGHT: 5% at stress level of 9 and higher There is very limited breeding capability as no shallow fast habitat remaining.</p>
<p>MAINTENANCE (C): 45% at stress at level 8.3 equalled or exceeded Providing some habitat for spawning and habitat slow shallow for larval growth. Sufficient cover and habitats, but limiting factor will be breeding habitat.</p>
<p>MAINTENANCE (C): 45% at stress at level 8.8 equalled or exceeded Suitable spawning habitat during breeding season reduced to critical levels, and reduced cover in form of overhanging and emergent vegetation results in increased predation</p>
<p>Indicator: <i>Pseudobarbus afer</i> Breeding thought to start in Spring (September – December). Clean riffles plus suitable depths and velocities are needed. <i>Juvenile:</i> Feeding and growth: Mostly slow shallow habitat. Cover: Overhanging vegetation and emergent vegetation. Duration 3 - 4 months. <i>Adult:</i> Cue: Increased temperature and flow.</p>

7.1.2 Stress duration motivations: Aquatic invertebrates

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: Invertebrate community</p> <p>Indicator taxa with a preference for moderate to fast flows are Hydropsychidae, Simuliidae and Sericostomatidae. The majority of the taxa (approximately 60%) can survive low flow conditions and some are capable of surviving zero flow conditions. Typically the more resilient taxa will relocate to SOOC and pool areas as flow decreases.</p>
INVERTEBRATE STRESS REQUIREMENTS
DRY SEASON (January)
<p>DROUGHT: Stress of 9 or less for 5% of the time</p> <p>At the higher stresses there will be no SIC habitat; however the majority of the community will endure for short periods in SOOC and pool habitats. The more flow-sensitive taxa (e.g. Elmids, Sericostomatids, Simuliids) will reduce in number and may disappear. As it is a summer month this could affect the age-structure of the population, with significant losses of critical life stages of Simuliids, for example. At a stress of 9, although there is zero flow, there is likely to be fair surface water connectivity at this site due to its relatively low gradient. This will ensure survival of the more resilient elements of the fauna (at least 50% of observed fauna).</p>
<p>MAINTENANCE (C): Stress of 7 or less for 45% of the time</p> <p>During high-stress periods there is likely to be a loss or reduction of taxa; which are sensitive to loss of flow or deterioration in water quality. For at least half the time, there is sufficient flow for sufficient periods to maintain the majority of the community, although the community structure and age distributions may alter significantly if flow ceases (Stress 9) for a continuous period of up to two weeks.</p>
<p>MAINTENANCE (D): Stress of 8 or less for 45% of the time</p> <p>The river has enough flow for sufficient duration to ensure a healthy community of aquatic invertebrates, although the indicator taxa with a preference for moderate and high flow conditions will disappear if the stress is consistently high (5 - 7) continuously for periods of greater than 2 - 3 weeks, or higher (8 - 10) for periods of a few days. As this is midsummer this could affect the structure (and particularly the age structure) of the invertebrate community.</p>
WET SEASON (August)
<p>DROUGHT: Stress of 8 or less for 5% of the time</p> <p>There is enough SOOC and pool habitat to maintain the majority of the late-winter invertebrate community (about 70%), during short periods of high stress. If flow reduction is followed by no-flow conditions that persist for longer than 2 - 3 days, the indicator taxa are likely to be eliminated or severely impacted. The effect of this will be a change in community structure and a reduction in the diversity of the breeding community in early summer, which relates to longer-term changes in the invertebrate biodiversity.</p>
<p>MAINTENANCE (C): Stress of 5 or less for 45% of the time</p> <p>The river has enough flow to ensure a healthy population of the more sensitive and flow-dependent components of the invertebrate community, and to ensure a viable breeding community. Availability and quality of summer breeding habitat is threatened if there is continuous higher stress (>6 - 7) for longer than 2 weeks. The low stresses (4 and less) equate to flows that will maintain those taxa with preferences for moderate flows.</p>
<p>MAINTENANCE (D): Stress of 8 or less for 45% of the time</p> <p>A stress of 6 equates to a flow of 0.03m³/s and an average velocity of 0.07m/s (max velocity approx. 0.15m/s). If there is a duration of greater than 2 - 3 days of this and greater stresses (which persist for 45% of the time during the wet season), sensitive flow-dependent species will be threatened and adult stages are likely to</p>

disappear. This will have consequences for the community structure in early summer, as a proportion of the breeding community will be absent. The more resilient taxa are likely to relocate to pools and SOOC habitats as flows decrease and at least 50% of the community should endure.

7.1.3 Stress duration motivations: Riparian vegetation

The two main vegetation components in the marginal zone are Palmiet and *Cyperus* spp. Their distributions are sparse in the riffle area and patchy on the periphery of the lower pool. Palmiet is relatively insensitive to reduced flows due to the fact that its roots are located in the lowest part of the channel. It is therefore unlikely that the Palmiet will be stressed even during drought conditions. The *Cyperus* is primarily located out of the main channel on the edges of the marginal zone. As its roots are located in the main channel, it requires low flows to inundate roots. Their maintenance also requires periodic elevated flows to saturate the rooting zone and provide sediment and nutrient requirements.

Wet season flows

Drought flows recommendation of $0.04\text{m}^3/\text{s}$ would be sufficient to wet the rooting zone of *Cyperus* to ensure its survival for short periods of time in the absence of elevated events. The duration of these drought flows should ideally not exceed 6 months. This period is likely to be reduced if these flows are accompanied with high air temperatures.

Recommended maintenance flows of $0.22\text{m}^3/\text{s}$ would be sufficient to maintain *Cyperus* given that elevated events will most likely accompany these discharges.

Dry season flows

Marginal vegetation is largely dormant during the dry season (winter) and is therefore capable of persisting drought conditions with flows of $0.001\text{m}^3/\text{s}$ for several months. Maintenance flows of $0.087\text{m}^3/\text{s}$ are also likely to ensure the maintenance of *Cyperus*. Plants will not be completely dormant at such flows. Growth would be evident and plants would be green.

7.2 Final low flow requirements

To produce the final results, the Desktop Reserve Model estimates for the specific category are used and are modified according to specialists' requirements. There are a range of options one can use to make these modifications, such as changing the total volume required for the year, changing specific monthly volumes, changing durations of either drought or maintenance flows, changing the seasonal distribution and changing the category rules and shape factors. These changes are documented to ensure that the results could be regenerated if required.

The following adjustments to the Desktop Reserve Model C and D requirements were made to fit the specialist requirements:

- Region 6 monthly Desktop Reserve Model distributions are not suitable for this catchment and the shape factor had to be changed to 6, while the drought duration was changed to 5% (lower parameter at 95%).
- C category:

- The Desktop Reserve Model provided 7.89 % of the virgin MAR for the Maintenance Low Flow (MLF).
- The Desktop Reserve Model provided 2.99% of the virgin MAR for the droughts.
- The requirements resulted in the January MLF to be increased by 70% and the August MLF by >70% which resulted in the MLF now being 13.8% of the virgin MAR (compared to 7.89% of the Desktop Reserve Model)
- The requirements resulted in droughts being reduced to zero, in January as well as being reduced in August, which resulted in the droughts now being 1.93% of the MAR compared to the 2.99% of the droughts.
- D category:
 - The Desktop Reserve model provided 3% of the virgin MAR for the MLF
 - The Desktop Reserve Model provided 2.99% of the virgin MAR for the droughts.
 - Similar changes were made to the C category resulting in MLF now being 6.1% of the virgin MAR and 2.99% of the droughts.

The final curves for EWR 1 are shown in Figure 7-3.

Dry season (January)

Wet season (August)

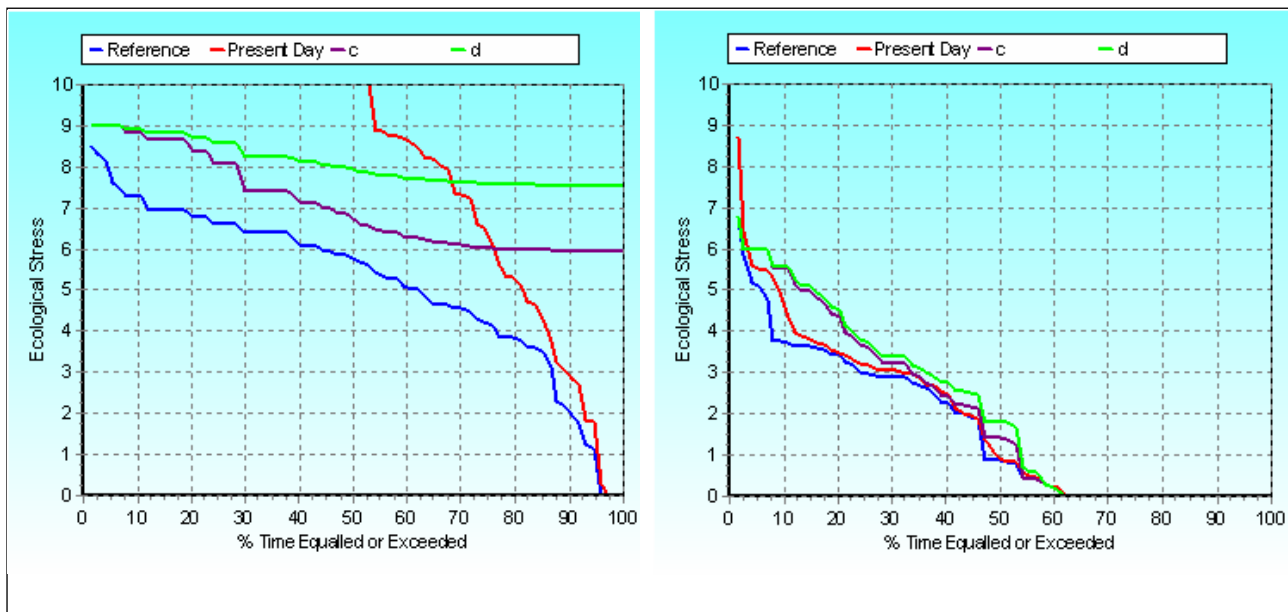


Figure 7-3 EWR 1 – Final curve

7.3 High flow requirements

The functions for each Flood Class are described in spreadsheets (see Appendix I). A summary of the flood class ranges and the recommended high flow events for EWR 1 is shown in Table 7-1.

Table 7-1 Flood class ranges, and the recommended high flow events for each scenario at EWR 1

Component	Flood classes (m ³ /s)					
	I	II	III	IV	V	VI
Fish	1.25 - 3	3 - 6	> 6			
Invertebrates	1.5 - 3	3 - 5				
Vegetation		1.25 - 6	6 - 18	18 - 55	55 - 84	
Geomorphology		2 - 8		33 - 53	53 - 87	> 262
Integrated	1.5 - 3	3 - 8	6 - 18	33 - 55	55 - 87	> 262
Daily average	2	4	6	10	60	
Duration (days)	2	2	3	3	5	

The number of high flow events required for each EC is provided in Table 7-2.

Table 7-2 The recommended number of high flow events required for each EC at EWR 1

Flood classes	NUMBER OF EVENTS: EC C						NUMBER OF EVENTS: EC D					
	Invert	Fish	Veg	Geom	INTEG ¹	FINAL	Invert	Fish	Veg	Geom	INTEG	FINAL
Class I	3	4			4		As the vegetation and geomorphology are only dealing with one category, the flood requirements for a C and a D category are the same.					
Class II	2	2	6	5	6	6						
Class III		1	1		1	1						
Class IV			1:3	1:3	1:3	1:3						
Class V			1:5	1:5	1:5	1:5						

(1) Integ = Integrated

These results were checked with the hydrology and were found to be acceptable.

7.4 Final results

Note: The model output refers to Instream Flow Requirements (IFRs), which reflect the flow component of EWR (the other being quality).

The results are summarised as follows, and provides a comparison with the Desktop Reserve Model.

	Desktop Reserve Model	2004 requirements
MLF (C)	7.89% of virgin MAR	13.8% of virgin MAR
High Flows (C)	11.3	15.9
Droughts (C)	2.99% of virgin MAR	1.93
Long Term mean (C)	18.5	27.5
MLF (D)	3	6.1
High Flows (D)	9.4	15.9
Droughts (D)	2.99	1.93
Long Term mean (D)	13.7	23.2

7.4.1 IFR table for REC: C

Please note: The IFR table is generated from the Desktop Reserve Model and the IFR assurance rule tables. The low flows in the table are therefore not specific values set, but are derived from the stress requirements. The high flows are according to those specified and not those normally associated with the Desktop Reserve Model IFR table where the high flows are presented as monthly averages.

Desktop Version 2, printed on 2004/09/22

Virgin MAR (MCM): 34.26

BFI index: 0.25

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows		
			Peak flow range (m ³ /s)	Average daily flows (m ³ /s)	Duration (days)
October	0.2	0.04	3-8	4	2
November	0.18	0.03	3-8	4	2
December	0.12	0.01			
January	0.1	0.001			
February	0.1	0.002			
March	0.11	0.003			
April	0.11	0.005			
May	0.12	0.01			
June	0.15	0.02	3-8	4	2
July	0.18	0.03	3-8	4	2
August	0.22	0.05	3-8 33-55	4; 10	2; 3
September	0.2	0.05	3-8 6-18	4; 6	2; 3

7.4.2 IFR assurance rules for REC: C

Desktop Version 2, Printed on 2004/09/22

Summary of IFR rule curves for: kromme_1 Natural Monthly Flows

Determination based on defined BBM Table with site-specific assurance rules.

Regional Type: S.Karoo REC = C

Data are given in m³/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.646	0.581	0.521	0.460	0.356	0.294	0.216	0.136	0.078	0.061
Nov	0.459	0.451	0.436	0.409	0.363	0.297	0.215	0.131	0.069	0.051
Dec	0.161	0.158	0.153	0.142	0.126	0.102	0.071	0.040	0.018	0.011
Jan	0.134	0.132	0.127	0.118	0.103	0.082	0.055	0.028	0.008	0.002
Feb	0.134	0.132	0.127	0.118	0.103	0.082	0.055	0.029	0.009	0.003
Mar	0.147	0.145	0.139	0.130	0.114	0.091	0.062	0.032	0.010	0.004
Apr	0.147	0.145	0.140	0.130	0.114	0.091	0.063	0.034	0.012	0.006
May	0.161	0.158	0.153	0.142	0.126	0.102	0.071	0.040	0.018	0.011
Jun	0.591	0.525	0.465	0.406	0.305	0.249	0.179	0.108	0.056	0.041
Jul	0.619	0.554	0.495	0.435	0.333	0.273	0.199	0.123	0.067	0.050
Aug	1.912	1.646	1.416	1.060	0.843	0.692	0.505	0.315	0.175	0.133
Sep	1.438	1.245	1.077	0.922	0.655	0.540	0.396	0.250	0.142	0.111

Reserve flows without High Flows

Oct	0.269	0.264	0.256	0.241	0.215	0.179	0.133	0.086	0.052	0.041
Nov	0.242	0.238	0.230	0.216	0.192	0.158	0.116	0.073	0.041	0.031
Dec	0.161	0.158	0.153	0.142	0.126	0.102	0.071	0.040	0.018	0.011
Jan	0.134	0.132	0.127	0.118	0.103	0.082	0.055	0.028	0.008	0.002
Feb	0.134	0.132	0.127	0.118	0.103	0.082	0.055	0.029	0.009	0.003
Mar	0.147	0.145	0.139	0.130	0.114	0.091	0.062	0.032	0.010	0.004
Apr	0.147	0.145	0.140	0.130	0.114	0.091	0.063	0.034	0.012	0.006
May	0.161	0.158	0.153	0.142	0.126	0.102	0.071	0.040	0.018	0.011
Jun	0.201	0.198	0.191	0.179	0.159	0.130	0.093	0.056	0.029	0.021
Jul	0.242	0.238	0.230	0.216	0.192	0.158	0.116	0.073	0.041	0.031
Aug	0.296	0.291	0.282	0.266	0.238	0.199	0.149	0.099	0.062	0.052
Sep	0.269	0.265	0.257	0.242	0.218	0.183	0.139	0.094	0.061	0.051

Natural Duration curves

Oct	4.047	2.046	1.307	1.090	0.963	0.836	0.687	0.493	0.358	0.149
Nov	3.889	1.420	0.980	0.718	0.640	0.517	0.463	0.401	0.270	0.069
Dec	1.180	0.732	0.523	0.426	0.321	0.269	0.231	0.209	0.157	0.052
Jan	0.777	0.366	0.269	0.217	0.157	0.127	0.112	0.097	0.075	0.030
Feb	1.744	0.422	0.306	0.198	0.174	0.141	0.091	0.083	0.066	0.041
Mar	1.501	0.612	0.381	0.284	0.239	0.209	0.172	0.112	0.067	0.045
Apr	1.188	0.725	0.486	0.378	0.278	0.255	0.170	0.131	0.108	0.062
May	4.891	1.441	0.650	0.463	0.336	0.254	0.224	0.202	0.119	0.052
Jun	2.230	1.150	0.895	0.687	0.594	0.386	0.301	0.216	0.154	0.108
Jul	2.322	1.389	1.187	0.896	0.739	0.620	0.538	0.336	0.239	0.097
Aug	7.490	2.300	1.508	1.060	0.933	0.732	0.582	0.493	0.381	0.142
Sep	4.182	1.844	1.443	1.204	0.949	0.787	0.640	0.502	0.409	0.201

7.4.3 IFR table for alternative EC: D

Desktop Version 2, printed on 2004/09/22

MAR (MCM): 34.26

BFI index: 0.25

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows		
			Peak flow range (m ³ /s)	Average daily (m ³ /s)	Duration (days)
October	0.1	0.04	3-8	4	2
November	0.09	0.03	3-8	4	2
December	0.045	0.01			
January	0.035	0.001			
February	0.035	0.002			
March	0.035	0.003			
April	0.04	0.005			
May	0.05	0.01			
June	0.06	0.02	3-8	4	2
July	0.08	0.03	3-8	4	2
August	0.11	0.05	3-8 33-55	4; 10	2; 3
September	0.11	0.05	3-8 6-18	4; 6	2; 3

7.4.4 IFR assurance rules for alternative EC: D

Desktop Version 2, Printed on 2004/09/22

Summary of IFR rule curves for: kromme_1 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: S.Karoo EC = D

Data are given in m³/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.561	0.497	0.441	0.386	0.291	0.242	0.181	0.119	0.073	0.060
Nov	0.429	0.422	0.408	0.382	0.340	0.279	0.203	0.125	0.068	0.051
Dec	0.083	0.081	0.079	0.074	0.066	0.054	0.039	0.025	0.014	0.010
Jan	0.064	0.063	0.061	0.056	0.049	0.039	0.027	0.014	0.004	0.001
Feb	0.064	0.063	0.061	0.057	0.050	0.040	0.027	0.015	0.005	0.002
Mar	0.064	0.063	0.061	0.057	0.050	0.040	0.028	0.015	0.006	0.003
Apr	0.073	0.072	0.070	0.065	0.057	0.046	0.033	0.019	0.008	0.005
May	0.092	0.090	0.087	0.082	0.073	0.060	0.043	0.026	0.014	0.011
Jun	0.500	0.435	0.379	0.326	0.235	0.194	0.142	0.090	0.052	0.040
Jul	0.524	0.461	0.405	0.352	0.261	0.216	0.160	0.104	0.062	0.050
Aug	1.819	1.555	1.328	1.060	0.771	0.636	0.467	0.296	0.170	0.133
Sep	1.372	1.180	1.014	0.864	0.604	0.499	0.369	0.237	0.139	0.110

Reserve flows without High Flows

Oct	0.184	0.181	0.176	0.166	0.150	0.127	0.098	0.069	0.047	0.041
Nov	0.165	0.163	0.158	0.149	0.134	0.112	0.085	0.057	0.037	0.031
Dec	0.083	0.081	0.079	0.074	0.066	0.054	0.039	0.025	0.014	0.010
Jan	0.064	0.063	0.061	0.056	0.049	0.039	0.027	0.014	0.004	0.001
Feb	0.064	0.063	0.061	0.057	0.050	0.040	0.027	0.015	0.005	0.002
Mar	0.064	0.063	0.061	0.057	0.050	0.040	0.028	0.015	0.006	0.003
Apr	0.073	0.072	0.070	0.065	0.057	0.046	0.033	0.019	0.008	0.005
May	0.092	0.090	0.087	0.082	0.073	0.060	0.043	0.026	0.014	0.011
Jun	0.110	0.109	0.105	0.099	0.089	0.075	0.057	0.038	0.025	0.021
Jul	0.147	0.145	0.141	0.133	0.120	0.101	0.077	0.054	0.036	0.031
Aug	0.202	0.200	0.194	0.184	0.167	0.142	0.112	0.081	0.058	0.051
Sep	0.202	0.200	0.194	0.184	0.167	0.142	0.112	0.081	0.058	0.051

Natural Duration curves

Oct	4.047	2.046	1.307	1.090	0.963	0.836	0.687	0.493	0.358	0.149
Nov	3.889	1.420	0.980	0.718	0.640	0.517	0.463	0.401	0.270	0.069
Dec	1.180	0.732	0.523	0.426	0.321	0.269	0.231	0.209	0.157	0.052
Jan	0.777	0.366	0.269	0.217	0.157	0.127	0.112	0.097	0.075	0.030
Feb	1.744	0.422	0.306	0.198	0.174	0.141	0.091	0.083	0.066	0.041
Mar	1.501	0.612	0.381	0.284	0.239	0.209	0.172	0.112	0.067	0.045
Apr	1.188	0.725	0.486	0.378	0.278	0.255	0.170	0.131	0.108	0.062

May	4.891	1.441	0.650	0.463	0.336	0.254	0.224	0.202	0.119	0.052
Jun	2.230	1.150	0.895	0.687	0.594	0.386	0.301	0.216	0.154	0.108
Jul	2.322	1.389	1.187	0.896	0.739	0.620	0.538	0.336	0.239	0.097
Aug	7.490	2.300	1.508	1.060	0.933	0.732	0.582	0.493	0.381	0.142
Sep	4.182	1.844	1.443	1.204	0.949	0.787	0.640	0.502	0.409	0.201

7.5 Confidence

The confidence is evaluated according to a score of 0 - 5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence. The confidence scores are summarised as follows:

0 (no confidence)	1 (low confidence)
2 (low to medium confidence)	3 (medium confidence)
4 (medium to high confidence)	5 (high confidence)

Results per component are shown in Table 7-3.

Table 7-3 Confidence ratings for EWR 1

Discipline	Ecoclassification	Available data	Suitability of EWR site	Flow requirements	
				High	Low
	Confidence	Confidence	Confidence	Confidence	Confidence
Hydrology	2	1			
Hydraulics		2	3	2	4
Geomorphology	4	3	3	3	N/a
Water quality	1	1			
Riparian vegetation	4	2	3	4	2
Aquatic invertebrates	3	3	3	3	2
Fish	2	3	1	4	4

(1) The shaded blocks indicate where confidence is not applicable

7.5.1 Explanations of confidence ratings

Hydraulics: Measured flows of 0.028 and 0.13m³/s. No measured moderate and high flow data is available. Recommended low flows are in the range 0.001 to 0.22m³/s and high flows are in the range 2-18 (within year) to 50m³/s. As the range of measured flows is close to the recommended low flows, the low flow confidence is much higher than the high flows.

Geomorphology:

- The site is strongly impacted by aliens and human disturbance of the left bank has led to a presence of modified morphological features.
- Aerial photographs were available and site visits were undertaken by both specialists.
- Good bed material data is available but no information is available on sediment transport.
- A moderately high confidence in flood classes is linked to morphological indicators, and the medium confidence in the frequency of higher flood classes is based on available flood information

- The low confidence in the frequency of level II flood classes is due to a lack of hydrological information, resulting in a medium confidence in the EWR site.

Water quality: Confidence is low because the only available data was collected during the study period (October to May 2004), resulting in a small sample size (n = 4).

Riparian vegetation: Confidence for high flows is high because good high flow cues were present; despite the fact that exotic vegetation predominates at the site. Low flows described for fish and invertebrates were checked for low flow vegetation cues at the site, however, not many good cues were present; resulting in low confidence. Site data was confined to information collected at two site visits only and therefore the site confidence was limited. The confidences for site suitability and the ecoclassification confidences were medium to high, based on a good understanding of the natural and present day conditions and the associated impacts.

Fish: There were no indigenous fish found at this site due to predation. During assessments the impact of alien fish was ignored and the indigenous fish species that should be there; depending on habitat availability; were used for assessments. As no indigenous fish were found during the survey, it means that no field data on presence, population density and health of indigenous fish is available. This resulted in a low to medium confidence in Ecoclassification and available data.

For the low and high flows, the recommended flows will also cater for fish; as the recommended flows set for invertebrates require more flows than fish. The confidence is therefore medium to high.

Aquatic invertebrates: No historic data is available. Only sampling data was available (two sampling surveys), leading to a medium confidence.

8 EWR 2 – KROMMERIVIERSPOORT: ECOCLASSIFICATION

8.1 Reference conditions

8.1.1 Geomorphology

The channel is likely to have been in transition between transport-limited and supply-limited. Flood and sediment load characteristics will be similar to those described for EWR 1. The aerial photograph taken in 1942 prior to the filling and operation of Churchill Dam suggests that this reach should consist of a series of alternating pools and braided sections (300 to 600m in length), both extending across the width of the valley bottom. The braiding may be associated with underlying bedrock controls, but there is no available evidence to support this. There is local evidence of lateral cobble bars.

8.1.2 Riparian vegetation

An intact and connected riparian zone, from the upper zone through to the marginal zone, defines the reference condition. The upper riparian zone comprises species more similar to that of Valley Bushveld than the surrounding false Karoo (Acocks, 1989). Low and Rebello (1996) describe this as south west coast Renosterveld. It comprises a closed thicket of shrubs and trees featuring *Podocarpus latifolius*, *Carissa bispinosa*, *Scutia myrtina*, *Rhus lucida*, *Maytenus heterophylla*, *Ehretia rigida*, *Acacia karroo*, *Euclea undulata*, *Cassine aethiopica* and many others. The lower riparian zone features *Diospyros lyciodes*, *Rhus dentata*, and palmiet. The palmiet forms large clumps on the edges of pools. Palmiet also dominates the marginal zone with smaller clumps of *Juncus* and other sedges and Restionaceae spp. featuring in other open areas.

No exotic species are present under the reference condition and cultivation is absent in the upper riparian zone.

8.1.3 Water quality

Water quality data from Churchill Dam (K9R001Q01) was rejected for reference condition as these data were patchy and may have yielded unreliable results. Similarly, data from K9H002Q01 (Kromme River: left pipe at Churchill Dam) were also rejected as reference condition data, because the data record was considered too recent (sampling commenced in 1984) and was intermittent. Therefore the default boundary tables were used for RC.

8.1.4 Fish

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Kromme River at EWR 2:

- *Pseudobarbus afer*
- *Sandelia capensis*
- *Anguilla mossambica*
- *Anguilla marmorata*
- *Anguilla bicolor bicolor*.

8.1.5 Aquatic invertebrates

Under natural conditions, base flows would have been higher and the causeway would not have been present. This would have increased inundation of all habitats, particularly marginal vegetation, and would have ensured flushing of sediments out of the (currently embedded) 'stones' habitats. Deeper pools would have been present. Water quality would have been similar to present. This environment would have encouraged an invertebrate fauna with a greater number of mayfly families (Heptageniidae, Leptophlebiidae and Tricorythidae), caddisfly families (Leptoceridae, Ecnomidae and Hydroptilidae), beetles (Dytiscidae and Helodidae), Odonata (Chlorolestidae, Lestidae and Corduliidae), Hemiptera (Corixidae, Hydrometridae, Naucoridae, Nepidae and Pleidae), and Gastropoda (Physidae and Lymnaeidae).

8.2 Present Ecological State (PES)

8.2.1 Habitat Driver PES

The hydrology PES (E) and geomorphology PES (E) information is available in Appendix A and Appendix B respectively. Water quality PES is a B/C category. The driver category is a D/E and the composition of the driver category is provided in Table 8-1.

The reasoning for the geomorphology category (E) is provided below.

PES	Causes	Sources	Flow/Non flow related
E	Change in morphology and therefore habitat type.	Alteration to flow and sediment regimes.	Flow related.
	Change in stability of banks and bed material.	Encroachment by alien vegetation.	Non flow related.

Table 8-1 Habitat driver category for EWR 2

Components	Weighted driver score
GEOMORPHOLOGY	10.29 (E)
HYDROLOGY	17.20 (E)
WATER QUALITY	12.70 (B/C)
Weighted driver status (%)	40.18
HABITAT DRIVER CATEGORY	D/E

8.2.2 Biological response PES

8.2.2.1 Riparian vegetation (D)

The PES is poor mainly due to the impact of the invasion of exotic species and the impact of flow regulation (reductions in low flows and flood removals) imposed by Churchill Dam immediately upstream of the site.

PES	Causes	Sources	Flow/Non flow related
D	General degeneration of the riparian zone and isolation of upper riparian zone.	Invasion of exotic species and subsequent river incision.	Non flow related.
	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Cultivation in upper riparian zone and removal of vegetation.	Non flow related.
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Cattle grazing in riparian zone.	Non flow related.
	Changes in abundance of vegetation.	Cultivation in upper riparian zone and removal of vegetation.	Non flow related.
	Changes in vegetation cover.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
Reduced impact of flooding as a consequence of exotic species invasion.		Flow related.	

8.2.3 Fish (C)

Species found at the site included the alien predatory largemouth bass, *Micropertus salmoides* and the non-endemic banded tilapia or vleikurper, *Tilapia sparrmanii*. Again no indigenous fish species, *Pseudobarbus afer* and *Sandelia capensis*, were found. One eel species, *Anguilla mossambica*, was seen.

PES	Causes	Sources	Flow/Non flow related
C	Flow Modification – reduced high flows, non-seasonal flows.	<ul style="list-style-type: none"> Churchill Dam upstream intercepting all flows, apart from but very high floods. Un-seasonal flows released from dam. 	Flow related. Flow related.
	Reduced sediment and nutrient, detritus input.	Capture by upstream Churchill Dam.	Non flow related.
	Encroachment of alien vegetation into channel.	<ul style="list-style-type: none"> Invasion by alien Black Wattle. Reduced scouring by floods. 	Non flow related. Flow related.
	Increased predation.	Presence of highly effective alien predator under favourable conditions for predation. (Note: this factor ignored in evaluation)	Non flow related.

8.2.3.1 Aquatic invertebrates (D)

The faunal diversity at this site is approximately 50% of that expected under reference conditions. The stones habitat was imbricated (packed), disallowing colonisation on the underside of stones by taxa with a preference for this biotope (particularly caddisflies and certain mayflies). Only the root-zones of the marginal and instream vegetation were inundated on both surveys, which represent

reasonable loss of a significant habitat type at this level in the catchment. Overall, despite the lack of diversity at the site, the taxa present were fairly sensitive as reflected in the relatively high ASPT values (> 5.7). This indicates that the instream environment at this site is in a fair condition and has likely adjusted to the altered hydrology (although it should be borne in mind that the baseflow is provided here by a leak in the dam wall). The key issues affecting the aquatic invertebrates at this site are the altered sediment and hydrological regimes.

PES	Causes	Sources	Flow/Non flow related
D	Flow reduction.	Upstream dam.	Flow related.
	Loss of natural vegetation.	Alien infestation.	Non flow related.
	Altered sediment regime.	Upstream dam, causeway.	Flow related.
	Embedded stones habitats.	Causeway, road.	Flow related.

8.2.4 Instream PES (C/D)

The results of the assessment are shown in Table 8-2.

Table 8-2 Instream PES for EWR 2

Criteria	Rating (0=low, 5=high)				
	Conf Rating	Ave	Weight	PES	Category
Availability of high confidence fish information	2				C
1 Diversity of fish species with different flow requirements	2				
2 Diversity of fish species with a preference for different cover types	2				
3 Diversity of fish species with a preference for different flow depth classes	1				
4 Diversity of fish species with various tolerances to modified water quality	2.5	1.88	0.39	74.9	
Availability of high confidence invertebrate information					D
5 Diversity of invertebrate biotopes	3				
6 Diversity of invertebrate taxa with different velocity requirements	3				
7 Diversity of invertebrate taxa with different tolerances to modified water quality	3	3	0.62	51.6	
		4.88	1	60.6	C/D

8.2.5 PES Ecostatus (D)

The Ecostatus is summarised in Table 8-3 and the PES summary shown in Table 8-4.

Table 8-3 Summary of the Ecostatus for EWR 2

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		3		
Fish: What is the general level of trophic specialisation?		2		
What is the general level of habitat specialisation?		3		
What is the general level of flow intolerance?		3	2.75	0.51
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		2		
How sensitive are hydraulic habitats to flow change? ¹		3		
How sensitive is water quality to flow change?		3	2.67	0.49
Total			5.42	1
INSTREAM CATEGORY	PES	60.56	Category	
DRIVER CATEGORY	40.2		C/D	
ECOSTATUS	50.53		D	

⁽¹⁾ This rating is applicable to low flows
 (%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

Table 8-4 Summary of the PES categories for EWR 2

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	E	D/E	D
GEOMORPHOLOGY	E		
WATER QUALITY	B/C		
Response components	Component PES	Instream PES	
FISH	C	C/D (C)	
AQUATIC INVERTEBRATES	D	D	
RIPARIAN VEGETATION	D		

8.2.6 Trends

Geomorphology – Negative due to non flow related issues.

Vegetation – Negative.

Fish – Stable.

Aquatic Invertebrates – Stable.

8.3 Importance

8.3.1 Ecological Importance and Sensitivity

The EIS was rated as moderate (present), as there are rare fish species (*P. afer*) and invertebrate families (Teloganodidae and Notonemouridae) present. There are also invertebrate families present that are sensitive to flow changes. Riparian and instream habitats include pools, riffles, undercut banks, instream vegetation and backwaters.

8.3.2 Socio-cultural Importance

Land use for Resource Unit B (Segment 14 – 15, EWR 2: Segment 14) is almost exclusively agricultural. Formal rural settlements with limited dependence on the river, with the exception of direct economic exploitation, can be seen.

The SI was rated as low and the confidence was moderate.

8.4 Range of Ecological Categories

8.4.1 Recommended Ecological Category (REC)

The PES Ecostatus is in a D category (Table 8-5). The geomorphology component is in an E category and can only be improved to a D category if alien vegetation is removed i.e. a non flow related issue.

The EIS and SI are moderate and low respectively and therefore the aim is to maintain the PES of a D category, apart from the geomorphology and hydrology; which must be improved. The improvement in geomorphology relates to the clearing of alien vegetation. When flow requirements are set, it will be assumed that these flows will be provided in conjunction with alien clearing.

Table 8-5 Summary of the Recommended Ecological categories for EWR 2

Driver Components	Component REC	Driver REC	ECOSTATUS
HYDROLOGY	D	D	D
GEOMORPHOLOGY	D		
WATER QUALITY	B/C		
Response components	Component REC	Instream REC	
FISH	C	C/D (C)	
AQUATIC INVERTEBRATES	D	D	
RIPARIAN VEGETATION	D		

8.4.2 Alternative Ecological Categories

As some of the components are at present in D and E categories, a lower alternative category cannot be considered. An upper alternative category was not considered as improvements are already recommended in the REC to improve the component categories, where relevant, from an E to a D category.

9 EWR 2 – KROMMERIVIERSPOORT: STRESS INDICES

9.1 Stress Index: Fish

The indicator species is *Pseudobarbus afer*, which is a semi-rheophilic species. This species requires flowing water for spawning in riffle areas where it needs depths of over 10 – 15 cm and velocities of >0.3 m/s. This species is sensitive to water quality and requires flows especially in the wet season, but can tolerate short periods of no flows.

Availability of cover in the form of undercut banks and overhanging vegetation only became available to the fish at higher flows. The lack of cover at low flows leads to higher stress due to increased predation. Water quality is thought to deteriorate at low flows (higher temperatures, lower DO, algal growth, iron bacterial growth) as well as abundance of food drops.

Fast-shallow riffle habitats are thus required for spawning in summer, while critical preferred habitats are slow deep and slow shallow with sufficient shelter from predation (substrate, undercut banks and overhanging vegetation). Habitat suitability, from which species stress is derived, is shown in Table 9-1.

Table 9-1 Habitat suitability at EWR 2

	FLOW (m ³ /s)						
	2.000	1.000	0.500	0.200	0.054	0.042	0.01
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING:							
0=NONE; 1=RARE; 2=SPARSE; 3=MODERATE; 4=ABUNDANT; 5=VERY ABUNDANT							
FAST DEEP	3.0	2.0	1.0	0.0	0.0	0.0	0.00
Overhanging vegetation	5.0	4.0	3.0	0.0	0.0	0.0	0.00
Undercut banks & root wads	4.0	4.0	4.0	0.0	0.0	0.0	0.00
Substrate	4.0	4.0	3.0	0.0	0.0	0.0	0.00
Aquatic macrophytes	3.0	2.0	1.0	0.0	0.0	0.0	0.00
Water column	3.0	2.0	2.0	0.0	0.0	0.0	0.00
FAST SHALLOW	3.0	4.0	3.0	3.0	1.0	1.0	1.00
Overhanging vegetation	5.0	4.0	4.0	3.0	2.0	2.0	0.00
Undercut banks & root wads	5.0	5.0	5.0	4.0	2.0	2.0	0.00
Substrate	5.0	5.0	5.0	4.0	2.0	2.0	1.00
Aquatic macrophytes	5.0	4.0	3.0	2.0	1.0	1.0	0.00
Water column	0.0	0.0	0.0	0.0	0.0	0.0	0.00
SLOW DEEP	5.0	5.0	5.0	5.0	4.0	4.0	4.00
Overhanging vegetation	5.0	5.0	5.0	4.0	3.0	2.0	1.00
Undercut banks & root wads	5.0	5.0	5.0	4.0	4.0	3.0	3.00
Substrate	3.0	3.0	3.0	3.0	3.0	2.0	2.00
Aquatic macrophytes	4.0	3.0	2.0	1.0	1.0	0.0	0.00
SLOW SHALLOW	3.0	3.0	4.0	4.0	5.0	5.0	5.00
Overhanging vegetation	5.0	5.0	4.0	3.0	2.0	1.0	1.00

	FLOW (m ³ /s)						
	2.000	1.000	0.500	0.200	0.054	0.042	0.01
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE; 1=RARE; 2=SPARSE; 3=MODERATE; 4=ABUNDANT; 5=VERY ABUNDANT							
Undercut banks & root wads	4.0	4.0	3.0	2.0	1.0	1.0	1.00
Substrate	5.0	4.0	3.0	3.0	2.0	2.0	0.00
Aquatic macrophytes	5.0	4.0	3.0	2.0	1.0	2.0	0.00
Water column	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Flow		2.00	1.00	0.50	0.20	0.05	0.04
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD							
SEMI-RHEOPHILIC	<i>P. afer</i>						
Breeding and early life-stages	5.0	5.0	5.0	3.0	1.0	1.0	0.00
Survival /Abundance	5.0	5.0	5.0	4.0	2.0	2.0	1.00
Cover	5.0	5.0	5.0	4.0	2.0	2.0	1.00
Health and condition	5.0	5.0	5.0	5.0	3.0	3.0	2.00
Water quality	5.0	5.0	5.0	4.0	2.0	2.0	1.00
Rheophilic stress - (breeding requirements included)	0.0	0.0	0.0	2.0	6.0	6.0	8.00
Flow-depth converted to habitat response (10=All flow-depth classes absent (River dry); 0=Flow-depth classes optimum for site; 9=No flow)	2.00	1.00	0.50	0.20	0.05	0.04	0.01
Fast deep	4.0	6.0	8.0	10.0	10.0	10.0	10.00
Fast shallow	4.0	2.0	4.0	4.0	8.0	8.0	8.00
Slow deep	0.0	0.0	0.0	0.0	2.0	2.0	2.00
Slow shallow	4.0	4.0	2.0	2.0	0.0	0.0	0.00
OVERALL HABITAT RESPONSE	3.0	3.0	3.5	4.0	5.0	5.0	5.00

9.2 Stress Index: Aquatic invertebrates

The indicators for the low stresses at this site are Philopotamids, Heptageniids, Hydropsychids and Simuliids, all of which display a preference for higher velocities. Elmids beetles are indicators of moderate stress, with a preference for flow classes between 0.3 - 0.6 m/s. The indicator taxa for high stresses are Leptophlebiids, which distinguish between a stress of 8 and 9. The MV biotopes are the first to disappear at this site when flows are reduced. The SIC and SOOC biotopes are therefore the indicator biotopes, and the aquatic invertebrates which have a preference for these, are considered the best indicator biota.

Table 9-2 summarises detailed invertebrate information.

Table 9-2 Stress table –flow dependant invertebrate at EWR 2

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow
Rating (site at observed flow)						0			All habitats in excess, very high quality, most very fast, deep, wide wetted perimeter (WP).			
0	5	5	3	5	3	21		1.28	Most plentiful, VIC reduced, mostly high quality: very fast and fast, deep, wide WP.	Max depth 0.38 Av depth 0.19 Area 1.91 Width 10.04 WP 11.18 Av velocity 0.67	0.64	0
1	4	5	2	5	2	18		1.07	Critical stones habitats sufficient; marginal vegetation habitats slightly reduced; quality slightly reduced, fast and very fast, deep,	Max depth 0.36 Av depth 0.18 Area 1.72 Width		1

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
									wide WP slightly reduced.	9.53 WP 10.62 Av velocity 0.62			
2	4	4	2	4	2	16		0.64	Reduced critical SIC and VIC habitat, reduced critical quality, moderate and fast velocity, moderately deep, WP slightly/moderately reduced.	Max depth 0.32 Av depth 0.16 Area 1.36 Width 8.53 WP 9.53 Av velocity 0.47	Slight reduction for sensitive rheophilic species. All healthy in some areas, all species persist.	0.5	2
3	3	4	1	4	2	14		0.33	SIC reasonably abundant, of good quality, VIC virtually absent, VOOC reduced, moderate fast.	Max depth 0.28 Av depth 0.15 Area 1.05 Width 7.02 WP 7.93	Reduction of all rheophilic species, all healthy in limited areas, all species persist.		3

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
										Av velocity 0.31			
4	3	3	1	3	2	12		0.15	Critical stones habitat reduced, VIC absent, low quality; mix of velocity classes, some deep areas, WP moderately/very reduced.	Max depth 0.24 Av depth 0.12 Area 0.78 Width 6.27 WP 7.07 Av velocity 0.19		Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist.	4
5	2	3	0	2	1	8		0.06	Critical habitat (SIC and SOOC) reduced. Reduced quality; low velocity, limited deep areas. Moderate WP.	Max depth 0.2 Av depth 0.1 Area 0.55 Width 5.57 WP 6.21 Av velocity 0.11	0.1	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species (Elmids) at risk or non-viable (disappear at <0.3m/s); most species persist.	5
6	2	3	0	1	1	7		0.04	Very reduced critical	Max depth		Sensitive rheophilic	6

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE		
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow	Community stress
									habitat, Other habitats of low quality, shallow. WP.	0.18 Av depth 0.08 Area 0.44 Width 5.27 WP 5.83 Av velocity 0.08	species rare, critical stages of sensitive rheophilic species (Elmids) non-viable, and at risk for some less sensitive species. Most species persist in the short-term.		
7	1	2	0	1	0	4		0.02	Flowing water habitats residual. No vegetation. Slow quality. Slow Trickle, small WP.	Max depth 0.16 Av depth 0.07 Area 0.34 Width 4.66 WP 5.12 Av velocity 0.06	Most rheophilic species rare. All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear.		7
8	1	1	0	0	0	2		0.01	Standing water habitats only, very low quality, no flow. SOOC only available	Max depth 0.14 Av depth 0.06	Remnant populations of some rheophilic species; most life stages of most	0.02	8

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE		
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow	Community stress
									habitat.	Area 0.25 Width 4.07 WP 4.43 Av velocity 0.04	rheophilic species at risk or non-viable, Leptophlebiids threatened.		
9	0	1	0	0	0	1		0	Only hyporheic refugia, no surface water.	Max depth 0.12 Av depth 0.05 Area 0.18 Width 3.48 WP 3.76 Av velocity 0.03	Mostly pool dwellers, most life stages of most rheophilic species non-viable; Leptophlebiids likely to disappear.	0	9
10	0	0	0	0	0	0		0	All habitats in excess, very high quality, most very fast, deep, wide WP.		Unlikely.	0	10

(1) SIC: Partially submerged hard substrate in current >0.1m/s

(2) SOOC: Partially submerged hard substrate in current <0.1m/s

(3) VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1m/s

(4) VOOC: Submerged vegetation (at least 2-3cm submerged) in current <0.1m/s

(5) GSM: Small particles submerged

9.2.1 Integrated stress curve

The individual component stresses are illustrated in Figure 9-1 as well as the integrated stress line (black line). Note that the invertebrate line (purple line) falls under the integrated stress line and cannot be seen.

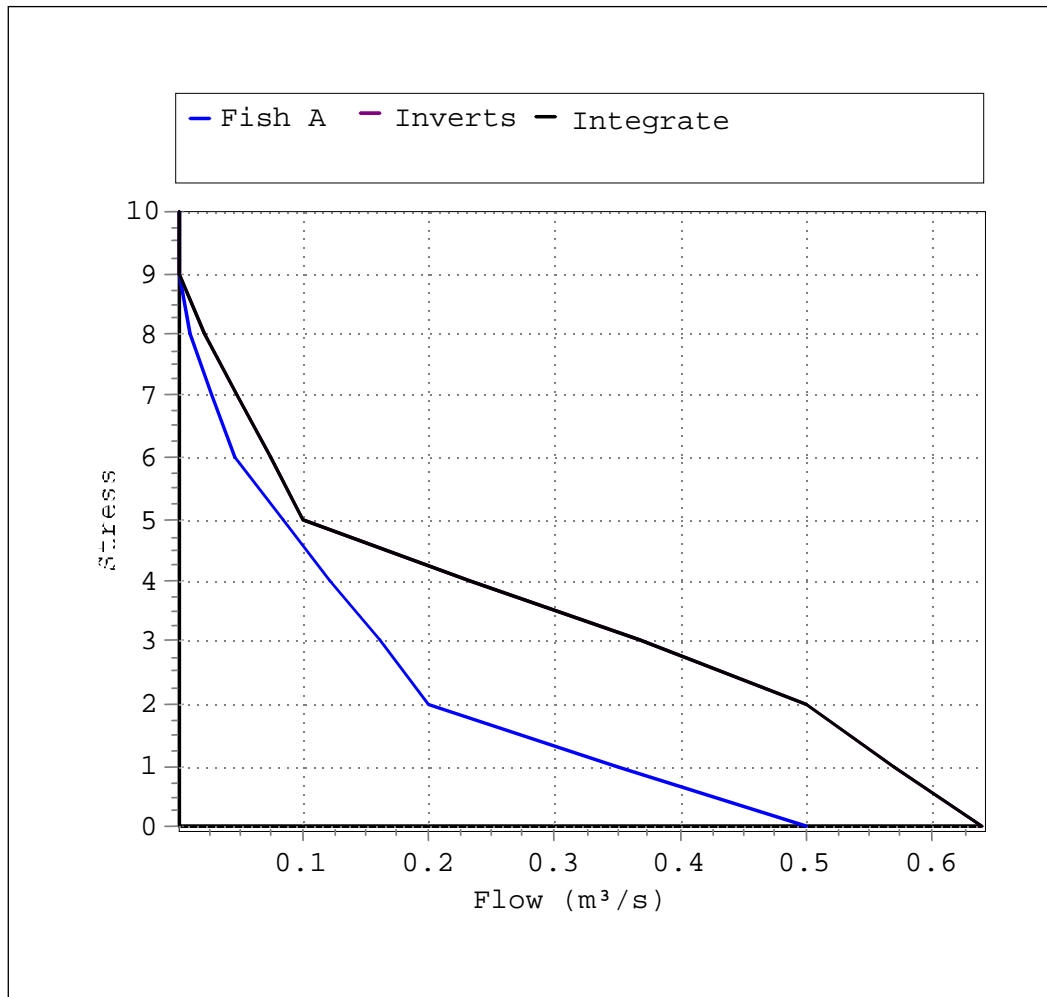


Figure 9-1 Component and integrated stress curves for EWR 2

10 EWR 2 – KROMMERIVIERSPOORT: DETERMINATION OF EWR SCENARIOS

10.1 Low flow requirements

The integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month/season. Drought flows were set as 95 to 100% assurance (i.e. stress durations of 5 to 0%) and, based on the hydrological characteristics, maintenance flows were set as 70% assurance (i.e. stress durations of 30 %).

Figure 10-1 illustrates the stress duration curve.

Dry season (January D category)

Wet season (August D category)

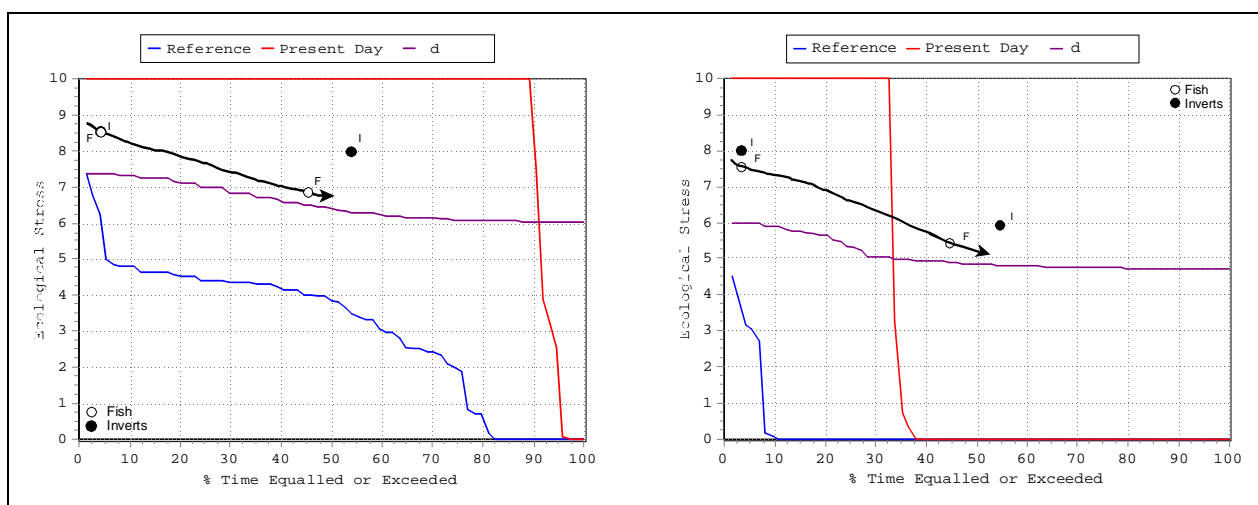


Figure 10-1 EWR 2 – Stress duration curve for a D REC

10.1.1 Stress duration motivations: Fish

Note – this motivation is similar for all EWR sites due to use of the same indicator species, *B. afer*.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: <i>Pseudobarbus afer</i> The indicator is a semi-rheophilic species that is dependant on the flow for breeding in riffles at suitable velocities and depths. Note peak spawning activities take place in Spring (September to December) and possibly some limited spawning in late summer, but main spawning requirements for species in terms of stress requirements included in wet season.</p>
FISH STRESS REQUIREMENTS
DRY SEASON (January)
<p>DROUGHT: 5% of the time at stress level of 9 equalled or exceeded Fish confined totally to pool with limited cover available, poor water quality and limited food available.</p>
<p>MAINTENANCE (D): 45% of the time at stress level of 7 Provides more cover and improved water quality and food.</p>
WET SEASON (August)
<p>DROUGHT: Stress of 7.5 or less for 5% of the time There is very limited breeding capability as in no shallow fast habitat remaining.</p>
<p>MAINTENANCE (D): 45% of the time at stress at level 5.5 equalled or exceeded Providing some habitat for spawning and habitat slow shallow for larval growth. Sufficient cover and habitats, but limiting factor will be breeding habitat.</p>
<p>Indicator: <i>Pseudobarbus afer</i> Breeding thought to start in Spring (September to December) and require clean riffles plus suitable depths and velocities. Juvenile: Feeding and growth: Mostly slow shallow habitat. Cover: Overhanging vegetation and emergent vegetation. Duration 3 - 4 months. Adult: Cue: Increased temperature and flow.</p>

10.1.2 Stress duration motivations: Aquatic invertebrates

AQUATIC INVERTEBRATES: URATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: Invertebrate community Indicator taxa with a preference for moderate to fast flows at this site are Philopotamid, Hydropsychid caddisflies and Chlorocyphids.</p>
INVERTEBRATE STRESS REQUIREMENTS
DRY SEASON (January)
<p>DROUGHT: Stress of 9 or less for 5% of the time At the higher stresses there will be no SIC habitat, however the majority of the community will endure for short periods in SOOC and pool habitats. The more flow-sensitive taxa (e.g. Elmids, Sericostomatids, Simuliids) will reduce in number and may disappear. As it is a summer month this could affect the age-structure of the population, with significant losses of critical life stages of Simuliids, for example. At a stress of 9, although there is zero flow, there is likely to be fair surface water connectivity at this site due to its relatively low gradient. This will ensure survival of the more resilient elements of the fauna (at least 50% of observed fauna).</p>

<p>MAINTENANCE: (D): Stress of 8 or less for 55% of the time</p> <p>During the high-stress periods there is likely to be a loss or reduction of taxa that are sensitive to loss of flow or deterioration in water quality. For at least half the time, there is sufficient flow for sufficient periods to maintain the majority of the community, although the community structure and age distributions may alter significantly if flow ceases (Stress 9) for a continuous period of up to two weeks.</p>
<p>WET SEASON (August)</p>
<p>DROUGHT: Stress of 8 or less for 95% of the time</p> <p>There is enough SOOC and pool habitat to maintain the majority of the late-winter invertebrate community (about 70%), during short periods of high stress. If flow reduction is followed by no-flow conditions that persist for longer than 2 - 3 days, the indicator taxa are likely to be eliminated or severely impacted. The effect of this will be a change in community structure and a reduction in the diversity of the breeding community in early summer, which relates to longer-term changes in the invertebrate biodiversity.</p>
<p>MAINTENANCE: (D): Stress of 6 or less for 55% of the time</p> <p>The river has enough flow to ensure a healthy population of the more sensitive and flow-dependent components of the invertebrate community, and to ensure a viable breeding community. Availability and quality of summer breeding habitat is threatened if there is continual higher stress (>6 - 7) for longer than 2 weeks. The low stresses (4 and less) equate to flows that will maintain those taxa with preferences for moderate flows.</p>

10.1.3 Riparian vegetation

The recommended low flows were checked to determine whether the riparian vegetation, specifically the marginal zones will be maintained. The two main vegetation components in the marginal zone are various Restionaceae, sedges and *Miscanthus*. Their distributions are scattered on the riffle area amongst rocks and small boulders. The Restionaceae and *Miscanthus* are located in the main channel. Their roots are located in the main channel and water will inundate the majority of the roots for all the recommended flows. This ensures that the majority of the marginal vegetation will be maintained, for both drought and maintenance flows, for both dry and wet years.

10.2 Final low flow requirements

The following adjustments to the Desktop Reserve Model D requirements had to be made to fit the specialist requirements:

- Region 6 monthly Desktop Reserve Model distributions are not suitable for this catchment and the shape factor had to be changed to 6, while the drought duration was changed to 5% (lower parameter at 95%).
- The Desktop Reserve Model provided 3 % of the virgin MAR for the Maintenance Low Flow (MLF).
- The Desktop Reserve Model provided 3% of the virgin MAR for the droughts.
- The requirements as set indicated that the Desktop Reserve Model MLF must be increased to 3.1% of the virgin MAR.
- The requirements as set indicated that the Desktop Reserve Model drought flows can be reduced from 3% to 0.6% of the virgin MAR.

The final curves for EWR 2 are shown in Figure 10-2.

Dry season (January)

Wet season (August)

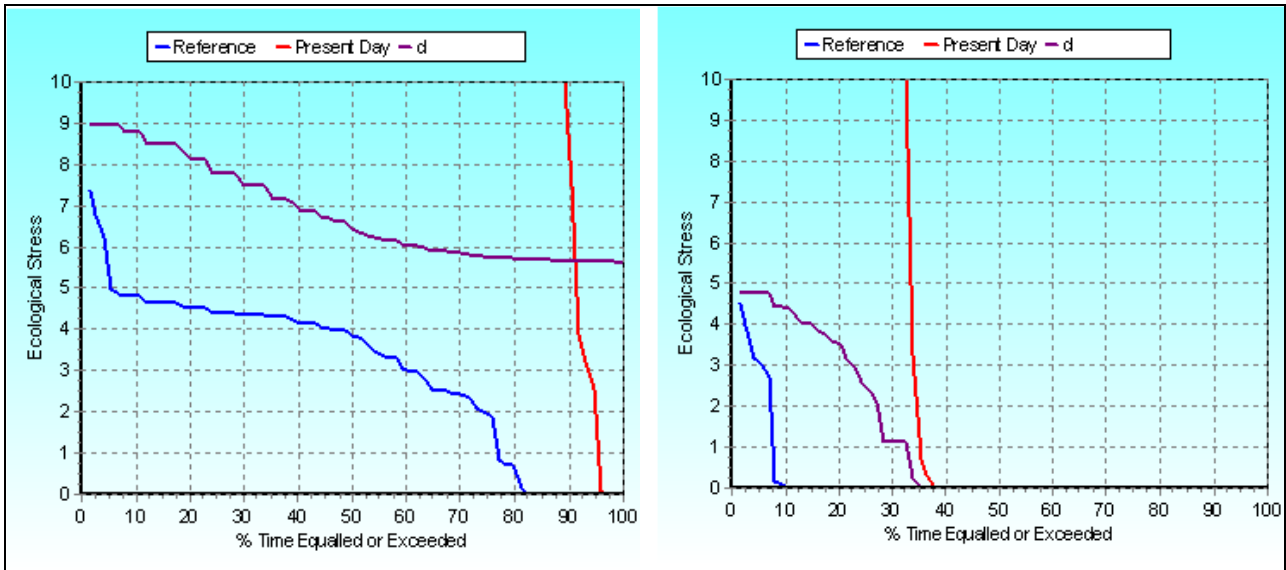


Figure 10-2 EWR 2 – Final curve

10.3 High flow requirements

The functions for each Flood Class are described in spreadsheets (Appendix I). A summary of the flood class ranges and the recommended high flow events for EWR 2 is shown in Table 10-1.

Table 10-1 Flood class ranges, and the recommended high flow events for each scenario at EWR 2

Component	Flood classes (m ³ /s)				
	I	II	III	IV	V
Fish	1-2	3-5	>5		
Invertebrates	1.5-3	3-5			
Vegetation		1.5-5.5	6-23	28-63	65-100
Geomorphology					90-150
Integrated	1-3	3-5	6-23	28-63	90-150
Daily average		4	7	15	
Duration (days)		2	3	3	

The number of high flow events required for each EC is provided in Table 10-2.

Table 10-2 The recommended number of high flow events required for each EC at EWR 2

Flood classes	NUMBER OF EVENTS: EC C					
	Invert	Fish	Veg	Geom	INTEG ¹	FINAL
Class I	2 (Sept & Dec)	4			4	0
Class II	1 (Oct)	2	6		6	6
Class III		1	1		1	1
Class IV			1:2		1:2	1:2
Class V			1:3		1:3	1:3

(1) Integ = Integrated

These results were checked against the hydrology and were found to be acceptable.

10.4 Final results

The results are summarised as follows as well as providing a comparison with the Desktop Reserve Model.

	Desktop Reserve Model	2004 requirements
MLF (D)	3	3.1
High flows (D)	9.4	10.9
Droughts (D)	3	0.6
Long Term mean (D)	13.7	14.5

10.4.1 IFR table for REC: D

Please note: The low flows in the table are therefore not specific values set, but those derived from the stress requirements. The high flows are according to those specified.

Desktop Version 2, printed on 2004/09/22

Virgin MAR (MCM): 58.39

BFI index: 0.25

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows		
			Peak flow range	Average daily (m ³ /s)	Durations (days)
October	0.07	0.018	3-8	4	2
November	0.06	0.016	3-8	4	2
December	0.05	0.005			
January	0.045	0.001			
February	0.045	0.002			
March	0.05	0.003			
April	0.05	0.005			
May	0.05	0.008			
June	0.055	0.012		4	2
July	0.06	0.016		4	2
August	0.08	0.02		4; 15	2; 3
September	0.08	0.02		4; 7	2; 3

10.4.2 IFR assurance rules for REC: D

Desktop Version 2, Printed on 2004/09/22

Summary of IFR rule curves for: kromme_2 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: S.Karoo EC = D

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.506	0.443	0.387	0.334	0.244	0.200	0.146	0.091	0.050	0.038
Nov	0.373	0.367	0.355	0.332	0.295	0.240	0.172	0.103	0.052	0.037
Dec	0.092	0.090	0.087	0.081	0.072	0.058	0.040	0.022	0.009	0.006
Jan	0.082	0.081	0.078	0.073	0.064	0.050	0.034	0.017	0.005	0.002
Feb	0.082	0.081	0.078	0.073	0.064	0.051	0.035	0.018	0.006	0.003
Mar	0.092	0.090	0.087	0.081	0.071	0.057	0.039	0.021	0.007	0.004
Apr	0.092	0.090	0.087	0.081	0.072	0.058	0.040	0.022	0.009	0.006
May	0.092	0.090	0.087	0.082	0.072	0.059	0.042	0.025	0.012	0.009
Jun	0.491	0.426	0.370	0.317	0.226	0.185	0.134	0.082	0.044	0.032
Jul	0.487	0.425	0.370	0.318	0.229	0.188	0.137	0.085	0.047	0.036
Aug	2.370	2.008	1.700	1.424	0.948	0.776	0.560	0.342	0.181	0.133
Sep	1.442	1.230	1.048	0.884	0.601	0.492	0.356	0.218	0.116	0.086

Reserve flows without High Flows

Oct	0.129	0.127	0.122	0.115	0.103	0.085	0.063	0.040	0.024	0.019
Nov	0.110	0.108	0.105	0.099	0.088	0.073	0.054	0.035	0.021	0.017
Dec	0.092	0.090	0.087	0.081	0.072	0.058	0.040	0.022	0.009	0.006
Jan	0.082	0.081	0.078	0.073	0.064	0.050	0.034	0.017	0.005	0.002
Feb	0.082	0.081	0.078	0.073	0.064	0.051	0.035	0.018	0.006	0.003
Mar	0.092	0.090	0.087	0.081	0.071	0.057	0.039	0.021	0.007	0.004
Apr	0.092	0.090	0.087	0.081	0.072	0.058	0.040	0.022	0.009	0.006
May	0.092	0.090	0.087	0.082	0.072	0.059	0.042	0.025	0.012	0.009
Jun	0.101	0.099	0.096	0.090	0.080	0.066	0.048	0.030	0.017	0.013
Jul	0.110	0.108	0.105	0.099	0.088	0.073	0.054	0.035	0.021	0.017
Aug	0.147	0.145	0.140	0.131	0.117	0.097	0.071	0.046	0.026	0.021
Sep	0.147	0.145	0.140	0.131	0.117	0.097	0.071	0.046	0.026	0.021

Natural Duration curves

Oct	6.892	3.487	2.225	1.859	1.643	1.426	1.172	0.844	0.612	0.254
Nov	6.628	2.415	1.667	1.219	1.088	0.880	0.787	0.679	0.463	0.116
Dec	2.009	1.247	0.896	0.724	0.545	0.455	0.396	0.358	0.269	0.090
Jan	1.322	0.627	0.455	0.373	0.261	0.217	0.187	0.164	0.127	0.052
Feb	2.968	0.719	0.521	0.339	0.298	0.240	0.157	0.141	0.107	0.074
Mar	2.561	1.045	0.650	0.485	0.411	0.351	0.291	0.187	0.112	0.075
Apr	2.022	1.235	0.826	0.640	0.471	0.432	0.293	0.224	0.185	0.100
May	8.341	2.457	1.105	0.792	0.575	0.433	0.381	0.343	0.202	0.090
Jun	3.804	1.960	1.528	1.173	1.011	0.656	0.509	0.370	0.262	0.185
Jul	3.958	2.367	2.024	1.531	1.262	1.060	0.918	0.575	0.403	0.164
Aug	12.761	3.920	2.569	1.807	1.591	1.247	0.993	0.844	0.650	0.239
Sep	7.130	3.148	2.461	2.052	1.613	1.343	1.088	0.856	0.694	0.347

10.5 Confidence

The confidence is evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence. The confidence scores are summarised as follows:

- 0 (no confidence)
- 1 (low confidence)
- 2 (low to medium confidence)
- 3 (medium confidence)
- 4 (medium to high confidence)
- 5 (high confidence)

Results per component are shown in Table 10-3.

Table 10-3 Confidence ratings for EWR 2

Discipline	Ecoclassification	Available data	Suitability of EWR site	Flow requirements	
				High	Low
	Confidence	Confidence	Confidence	Confidence	Confidence
Hydrology	2	1			
Hydraulics		3	3.5	3	4
Geomorphology	3	2	2	2	N/a
Water quality	1	1			
Riparian vegetation	3	2	2	2	N/a
Aquatic invertebrates	2	2	2	3.5	3.5
Fish	2	3	3	4	4

⁽¹⁾ Note: Shaded blocks indicate where confidence is not applicable

10.5.1 Confidence explanations

Hydraulics: Measured flows of 0.042 and 0.054m³/s. No measured moderate and high flow data is available. Recommended low flows are in the range 0.001 to 0.082m³/s and high flows in the range 3 - 23 (within year) to 60m³/s. The low flow confidence will therefore be higher than the high flow confidence.

Geomorphology: The site is highly disturbed and all fine material has been removed. There was a lack of aerial photos and the specialist did not visit the site. The impact of high flows in the sediment poor system was difficult to assess. There is low confidence in high flow hydraulics. All of this resulted in a general low to medium confidence.

Water quality: Although there was available data for this site, no oxygen or temperature data was available resulting in low confidence.

Riparian vegetation: Available data was confined to one site visit. Low flow output was in terms of fish. The proximity of the upstream dam clearly had an impact on the high flow assessments, the suitability of the site and the ecoclassification, which were limited to low and medium confidence only.

Fish: There were no indigenous fish found at this site due to predation. The impact of alien fish was ignored, which means that no field data on presence, population density and health of indigenous fish is available. The impact of observed and anticipated changes in habitat was used to derive the probable impact on fish, which are expected to be present.

Aquatic invertebrates: Poor understanding of hydrology confounds decision-making. Output low and higher flows are set higher for fish requirements than that required for invertebrates; therefore the confidence is medium to medium-high.

11 EWR 3 – DYKE: ECOCLASSIFICATION

11.1 Reference conditions

11.1.1 Geomorphology

This reach is located in a confined valley with a narrow valley floor and good coupling between the hill slope and the channel. The gradient of the site was estimated as between 0.003 and 0.0037 that places it in the lower foothills category. The mean annual discharge at this site is approximately three times that of EWR 1. Therefore, one would expect the channel capacity to increase accordingly. Flood frequency and sediment load characteristics would be similar to those described for EWR 1.

Evidence from the 1942 aerial photograph would suggest that the Reference Condition for the reach is a bedrock or mixed anabranching channel with narrow passageways passing through dense *Phragmites*. Locally, pools form stretches of open water.

11.1.2 Riparian vegetation

The reference condition is defined by dense clumps of riparian vegetation on sandy bars between the many pools and multiple small channels. Marginal vegetation is characterised by clumps of *Miscanthus*, *Cyperus textilis*, *Cliffortia* and Palmiet on the water edges and on small islands.

The lower riparian zone is characterised by dense stands of *Podocarpus latifolius*, *Ficus sur*, *Erica*, *Rhus* and *Euclea* species. The upper riparian zone is visibly different from the lower riparian zone and is characterised by dense valley bushveld species that colonise the steep slopes of the deeply incised river valley.

11.1.3 Water quality

The DWAF water quality monitoring point K8H005Q01, in the Tsitsikamma River (Ecoregion Level I: Southern Coastal Belt), was assessed as a reference site for the lower Kromme River catchment (WQSU 3 - 11, and incorporating EWR 2 - 6). Due to the unsuitability of this site as a proxy site for the Kromme River system, default benchmark boundary tables were used for Reference Condition.

11.1.4 Fish

From historical records and general fish distribution data, a total of approximately 8 indigenous fish species are expected to be present in the Kromme River at EWR 3. The relatively high species number expected at this site is due to catadromous species migrating up from the nearby estuary. The expected species are:

- *Pseudobarbus afer*
- *Sandelia capensis*
- *Anguilla mossambica*
- *Anguilla marmorata*
- *Anguilla bicolor bicolor*

- *Myxus capensis*
- *Monodactylus falciformi*
- *Glossogobius callidus*.

11.1.5 Aquatic invertebrates

This site is reasonably close to the estuary and some marine influence may be expected under natural conditions, for example the presence of small numbers of freshwater shrimps moving up from the estuary (*Macrobrachium* sp and *Palaeomon capensis*). Overall there would be a greater habitat diversity and abundance, with less pool environments and more flowing environments, favouring a greater diversity and abundance of rheophilic groups, such as mayflies (Baetidae, Leptophlebiidae and Heptageniidae), certain Dipterans (Simuliidae), caddisflies (greater number of Hydropsychid species, Polycentropodidae and Philopotamidae), some Coleoptera (Elmidae). There would be also be variability within the flow environments, favouring those taxa with a preference for slower flowing water e.g. Caddisflies (Hydroptilidae and Pisullidae), Coleoptera (Gyrinidae and Psephenidae), Odonata (Corduliidae and Chlorocyphidae). The increase in available marginal vegetation habitat would likely favour an increase in certain Hemipterans (Naucoridae, Pleidae and Corixidae), and certain Odonata (Calopterygidae and Chlorolestidae).

11.2 Present Ecological State (PES)

11.2.1 Habitat Driver PES

The hydrology PES (F) and geomorphology PES (D) information is available in Appendix A and Appendix B respectively. Water quality PES is a C category. The driver category is a D/E and the composition of the driver category is provided in Table 11-1.

The reasoning for the geomorphology category (D) is provided below.

PES	Causes	Sources	Flow/Non flow related
D	Change in morphology and therefore habitat type.	Alteration to flow and sediment regimes.	Flow related.
	Change in stability of bed material.	Consolidation of <i>Phragmites</i> .	Flow related.

Table 11-1 Habitat driver category for EWR 3

Components	Weighted driver score
GEOMORPHOLOGY	9.97 (D)
HYDROLOGY	8.92 (F)
WATER QUALITY	20.86 (C)
Weighted driver status (%)	39.74
HABITAT DRIVER CATEGORY	D/E

11.2.2 Biological response PES

11.2.2.1 Riparian vegetation (D)

This is largely due to the invasion of exotic species and degeneration of the riparian zone due to reduced and regulated flows imposed by Impofu Dam and the significant abstraction of water from the river for farming purposes.

PES	Causes	Sources	Flow/Non flow related
D	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Reduced and regulated low flows due to Impofu Dam.	Flow related.
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Reduced and regulated low flows due to Impofu Dam.	Flow related.
	Changes in vegetation cover.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
		Reduced impact of flooding as a consequence of exotic species invasion and the presence of Impofu Dam.	Flow related.
		Reduced and regulated low flows due to Impofu Dam.	Flow related.

11.2.2.2 Fish (D)

Only the alien predatory largemouth bass, *Micropertus salmoides*, was found at this site. Again no indigenous fish species were seen at all. Apart from the serious impact of predation, flow related impacts in this reach are particularly severe due to:

- No flow in river for long periods in normally perennial system. This will impact severely on semi-rheophilic species (*P. afer* and *A. mossambica*).
- Upstream migration of catadromous species over the bedrock rapid will be prevented by low and no flows (also reduce freshwater cue to attract fish into the estuary from marine spawning grounds).

The determination of the PES using the Fish Response Assessment Index (FRAI) requires that the responses of indigenous fish species found at the particular site to flow-related habitat changes, are assessed. If no indigenous fish are sampled at a site, and if this is considered to be due to the presence of alien predatory fish such as bass and not due to flow-related habitat changes, then the FRAI should be applied using the expected natural species composition (from historical records, similar adjacent rivers).

Thus, at the EWR sites in question, the PES was assessed by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes caused by alterations to the habitat drivers. Taking the impact of alien predatory fish into account will reduce the PES to a category E or F due to the apparent total elimination of indigenous fish.

PES	Causes	Sources	Flow/Non Flow related
D	Flow Modification – no flow for long periods, reduced high flows, non-seasonal flows.	<ul style="list-style-type: none"> Upstream Impofu Dam intercepts all flows, apart from very high floods. Un-seasonal flows released from dam. Farmer abstracting all flows and reducing pool levels drastically. 	Flow related. Flow related. Flow related.
	Reduced sediment and nutrient, detritus input.	<ul style="list-style-type: none"> Capture by upstream Impofu Dam. 	Flow related.
	Encroachment of alien vegetation into channel.	<ul style="list-style-type: none"> Invasion by alien Black Wattle. Reduced scouring by floods. 	Non Flow related. Flow related.
	Increased predation.	Presence of highly effective alien predator under favourable conditions for predation. (Note: this factor ignored in evaluation).	Non Flow related.

11.2.2.3 Aquatic invertebrates (D)

The invertebrate fauna at this site was severely impaired by the lack of flow and resulting poor water quality. The SASS5 scores were less than 40% of those expected under reference conditions, and the ASPT of <5 indicates a paucity of sensitive taxa. There was no satisfactory flow habitat at the time of the site visit, and only areas in which there was a trickle over bedrock could be sampled. The surface water at this site was restricted to a series of various-sized pools, some of which were connected. Reeds had encroached into the smaller pools, and exotic woody debris made access to many of the pools difficult. The fauna collected was hardy, with very low abundances of the few flow-dependent taxa present and generally low diversity of taxa with a preference for flowing water and for relatively unimpaired water quality. The migrating species which would be expected in this lower section of the river; (such as freshwater prawn *Macrobrachium sp.*) were not collected. The bedrock sill across the site represents a barrier to migrating species, particularly with the current system hydrology.

PES	Causes	Sources	Flow/Non flow related
E	Flow reduction.	Upstream dam, abstractions for farming.	Flow related.
	Altered flow variability.	Upstream dam.	Flow related.
	Altered sediment regime.	Upstream dam.	Flow related.
	Altered temperature regime.	Loss of surface water.	Flow and non flow related.

11.2.3 Instream PES (E)

The Instream PES is summarised in Table 11-2.

Table 11-2 Instream PES for EWR 3

Criteria	Rating (0=low, 5=high)				
	Conf Rating	Ave	Weight	PES	Category
Availability of high confidence fish information	2				D
1 Diversity of fish species with different flow requirements	2				
2 Diversity of fish species with a preference for different cover types	3				
3 Diversity of fish species with a preference for different flow depth classes	3				
4 Diversity of fish species with various tolerances to modified water quality	2.5	2.63	0.61	43.6	
Availability of high confidence invertebrate information					E
5 Diversity of invertebrate biotopes	1				
6 Diversity of invertebrate taxa with different velocity requirements	2				
7 Diversity of invertebrate taxa with different tolerances to modified water quality	2	1.67	0.39	28.1	
		4.29	1	37.6	E

11.2.4 PES Ecostatus (D/E)

The Ecostatus is summarised in Table 11-3 and the overall PES shown in Table 11-4.

Table 11-3 Summary of the Ecostatus for EWR 3

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		2		
Fish: What is the general level of trophic specialisation?		3		
What is the general level of habitat specialisation?		3		
What is the general level of flow intolerance?		2	2.5	0.48
<i>Habitat Driver questions</i>				
How sensitive is channel type to change in geomorphological drivers?		2		
How sensitive are hydraulic habitats to flow change? ¹		4		
How sensitive is water quality to flow change?		2	2.67	0.52
Total			5.17	1
PES	37.57	Category		
INSTREAM CATEGORY	37.57	E		
DRIVER CATEGORY	39.7	D/E		
ECOSTATUS	38.69	D/E		

⁽¹⁾ This rating is applicable to low flows:

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

Table 11-4 Summary of the PES categories for EWR 3

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	F	D/E (E)	D/E (D)
GEOMORPHOLOGY	D		
WATER QUALITY	C		
Response components	Component PES	Instream PES	
FISH	C	D	
AQUATIC INVERTEBRATES	E	D	
RIPARIAN VEGETATION	D	D	

11.2.5 Trends

Geomorphology – Negative within the category.

Vegetation – Stable.

Fish – Stable.

Aquatic Invertebrates – Negative.

11.3 Importance

11.3.1 Socio-cultural Importance

Land use for Resource Unit D is the Kromme River Estuary. Recreational use of the estuary is an important feature. The SI was rated as high and the confidence was moderate.

11.4 Range of Ecological Categories

11.4.1 Recommended Ecological Category (REC)

The PES was maintained except where categories were below a D. In these cases the PES was improved to a D as indicated in Table 11-5.

Table 11-5 Summary of the Recommended Ecological Category for EWR 3

Driver Components	Component REC	Driver REC	ECOSTATUS
HYDROLOGY	D	D	D
GEOMORPHOLOGY	D		
WATER QUALITY	C		
Response components	Component PES	Instream PES	
FISH	C	D	
AQUATIC INVERTEBRATES	D	D	
RIPARIAN VEGETATION	D	D	

11.5 Recommendations

Initial discussions during the delineation of the study area led to the decision that no EWR sites would be situated in RU C. The overall objective of the RU where EWR 3 was located was explored further during the EWR site visit and workshop. The RU consists of a very small section of river that is not inundated by the downstream dam. Goods and services that can be provided in this section are limited and it was suspected that the Ecological Importance and Sensitivity (EIS) would be low. This RU and associated EWR site were selected as it was suspected that it could provide important information regarding the operation of Impofu Dam, and acknowledging that the section of river downstream of Impofu Dam and upstream of the estuary is short. Specialists indicated during the EWR site selection that this section of river, even though short, plays a vital role for fish species and aquatic invertebrates that move between the marine, estuarine and freshwater systems. As no movement is possible beyond the Impofu Dam, this increases the importance of the limited section of freshwater downstream of Impofu Dam. Acknowledging this fact, the river downstream of Impofu Dam was investigated for a potential EWR site. No suitable (from a hydraulics viewpoint) EWR site could however be found. In order to provide quantitative information for this short section of river, the following approach was recommended:

- An EWR site was selected downstream of Impofu Dam (EWR site 3) at which the PES, EIS and EC will be determined (see preceding sections).
- Qualitative guidelines to improve conditions at EWR 3 will be provided.

11.6 Guidelines

The EWR 3 site consists of the riffle pool section immediately upstream of the dyke that separates the estuary and the river.

Fish will migrate during a flood and the estuarine requirements will probably be adequate to stimulate migration as well as for the flushing and maintenance of pools. Prawns (*Macrobrachium*) also migrate and should be able to move in the slower areas. However, more than one flood will be required, which could be more than the estuary requirements. One of the floods should be followed by a base flow of about 10 days to ensure that the migration is taking place. Pool cover is important with respect to refuge for indigenous fish against alien species. Pools should therefore be kept full during this period. Furthermore, pools should not be allowed to be drawn down to such a level that they cannot provide adequate cover for fish.

It is highly likely that these requirements would be superseded by the estuary requirements. During the estuary assessment (results are outlined in DWAF Report Number RDM/EWR001/ER0005/CON/CES/1105), this will be checked and verified. If the estuary requirements do not cater for the river section then the estuary requirements will be adjusted.

12 EWR 4 – GEELHOUTBOOM RIVER: ECOCLASSIFICATION

12.1 Reference conditions

12.1.1 Hydrology

A major issue identified for this site was whether the river was perennial under natural conditions. Although the modelled data indicated perennality, the confidence is low as some of the biological indicators indicated a seasonal ephemeral system.

12.1.2 Geomorphology

This site is located on an alluvial gravel bed reach with a narrow flood bench between high terraces. The gradient of the site is approximately 0.003 which places it in the lower foothills category. Flood frequency characteristics will be similar to those described for EWR 1, although this is a much smaller river. Sediment delivered to the channel by tributaries would consist primarily of gravel.

Evidence from a series of aerial photographs since 1942 suggests that the reference condition for this site is a narrow, single thread channel (probably displaying pool-riffle morphology) with a dense canopy of indigenous woody riparian vegetation.

12.1.3 Riparian vegetation

A dense thicket of shrubs and trees with a closed canopy defines the reference condition. Species composition conforms to that of valley bushveld (Acocks, 1989) and is characterised by *Podocarpus latifolius*, *Carissa bispinosa*, *Maytenus heterophylla*, *Azima tetracantha*, *Scutia myrtina*, *Ehretia rigida*, *Acacia karroo*, *Euclea undulata* and others. Species diversity is high. Marginal vegetation is abundant on the edges of pools and dominated by *Miscanthus junceus*, *Cyperus textilis* and other sedges. Riparian vegetation significantly stabilises the banks. The channel is incised, however, and the reason for this is uncertain. While exotic species are absent at the site they do exist in small, localised patches within the reach.

12.1.4 Water quality

There were no appropriate data within this Water Quality Sub-Unit; which could be used for determining Reference Condition and the default benchmark boundary tables were used. An additional monitoring site was instituted for the purposes of this study (WQ9) and was used for the present ecological state assessment. These data are of limited value as only three samples (February to May) were collected.

12.1.5 Fish

From general fish distribution data, up to 5 indigenous fish species are expected to be present in the Kromme River at EWR 4. However, the small size of the system and relatively low river flows would mean that freshwater eels would be very scarce, if present at all. Species expected are:

- *Pseudobarbus afer*
- *Sandelia capensis*
- *Anguilla mossambica*
- *Anguilla marmorata*
- *Anguilla bicolor bicolor*.

12.1.6 Aquatic invertebrates

It is difficult to assess what this stream would have looked like in a natural condition. Its size and geographic locality suggests that it may have been a temporary system, in which case the fauna would have been typical of such a river, and would have included largely resilient taxa suited to shaded, sand bed pool-type environments with little predictable flow component, and little or no stones and marginal vegetation environments. This fauna would include baetid and caenid mayflies, Oligochaetae, certain Odonata (Gomphidae, Aeshnidae, Libellulidae, Chlorolestidae, Coenagrionidae and Lestids), Dipterans (Ceratopogonids, Chironomidae, Culicidae, Dixidae, Psychodidae, Tabanidae and Tipulidae), certain Coleoptera (Gyrinidae and Gerridae) and Hemipterans (Hydrometridae, Notonectidae, Pleidae and Corixidae).

12.2 Present Ecological State (PES)

12.2.1 Habitat Driver PES

The hydrology PES (D) and geomorphology PES (C) information is available in Appendix A and Appendix B respectively. Water quality PES is a C/D category. The driver category is a C/D and the composition of the driver category is provided in Table 12-1.

The reasoning for the geomorphology category (C) is provided below.

PES	Causes	Sources	Flow/Non flow related
C	Moderately altered flow and sediment regimes.	Changes to catchment land use; bridge with side supports.	Non-flow related.
		Dam upstream.	Flow related.

Table 12-1 Habitat driver category for EWR 4

Components	Weighted driver score
GEOMORPHOLOGY	18.88 (C)
HYDROLOGY	24.55 (D)
WATER QUALITY	17.83 (C/D)
Weighted driver status (%)	61.26
HABITAT DRIVER CATEGORY	C/D

12.2.2 Biological Response PES

12.2.2.1 Riparian vegetation (A/B)

The PES is close to natural due to the fact that little to no change is evident in the riparian vegetation abundance, cover, species diversity and composition. The structure appears to be subtly altered by the reduction, in abundance and cover, of marginal vegetation. This is due to the low flows resulting from the impact of upstream impoundments. The riparian forest has a closed canopy for most of the length of the river and it contains *Podocarpus latifolius*; which is a threatened species.

PES	Causes	Sources	Flow/Non flow related
A/B	Changes in vegetation structure.	Reduced and regulated low flows due to upstream impoundments.	Flow related
		Reduced impact of flooding as a consequence of upstream impoundments.	Flow related

12.2.2.2 Fish (D)

No indigenous fish species or alien fish species were seen at all. Flow related impacts in this reach are particularly severe due to lack of flow in the river for long periods. This will impact severely on semi-rheophilic species (*Pseudobarbus afer* and *Anguilla mossambica*).

PES	Causes	Sources	Flow/Non Flow related
D	Flow modification – no flow for long periods.	<ul style="list-style-type: none"> Upstream abstraction and impoundments reducing low flows and levels drastically. 	Flow related.
	Increased sediment deposition.	<ul style="list-style-type: none"> Cattle trampling (in past), poor catchment management. 	Non Flow related. Non Flow related.

12.2.2.3 Aquatic invertebrates (D)

The results at this site were difficult to interpret due to the uncertain hydrology of this river. At the first site visit, only trickling flows were observed, and at the second visit, flow had ceased and surface water continuity had been lost. Nonetheless, an unexpectedly diverse fauna was collected in the restricted areas where sampling was possible. The SASS5 scores were over 75% of what would have been expected under natural conditions at this site, assuming that it was not naturally a perennial system. The ASPT values of > 5 were higher than expected, and reflect the presence of a small number of pollution-sensitive taxa. The instream habitat was restricted to an earth/gravel bed channel with few areas of small stones, and in the pools the substrate was overlain with allochthonous matter, as one would expect in such a highly-shaded stream. The lack of marginal vegetation at the site was a factor contributing to the low numbers of taxa present with a preference for sheltered habitats and/or low flow conditions.

PES	Causes	Sources	Flow/Non flow related
D	Altered flow.	Upstream abstraction; upstream roads and causeways.	Flow related.

12.2.3 Instream PES (D)

The Instream PES is summarised in Table 12-2.

Table 12-2 Instream PES for EWR 4

Criteria	Rating (0=low, 5=high)				
	Conf Rating	Ave	Weight	PES	Category
Availability of high confidence fish information	2				
1 Diversity of fish species with different flow requirements	2				
2 Diversity of fish species with a preference for different cover types	2				
3 Diversity of fish species with a preference for different flow depth classes	1				
4 Diversity of fish species with various tolerances to modified water quality	2	0.512	50.5	D	0.512
Availability of high confidence invertebrate information					
5 Diversity of invertebrate biotopes	1				
6 Diversity of invertebrate taxa with different velocity requirements	2				
7 Diversity of invertebrate taxa with different tolerances to modified water quality	2	0.488	45.4	D	0.488
	2	1	48.0	D	1

12.3 PES Ecostatus (D)

The Ecostatus is summarised in Table 12-3 and the overall PES categories shown in Table 12-4.

Table 12-3 Summary of the Ecostatus for EWR 4

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		2		
Fish: What is the general level of trophic specialisation?		1		
What is the general level of habitat specialisation?		1		
What is the general level of flow intolerance?		1	1.25	0.32
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3		
How sensitive are hydraulic habitats to flow change? ¹		2		
How sensitive is water quality to flow change?		3	2.67	0.68
Total			3.92	1
INSTREAM CATEGORY	PES	Category		
	47.97	D		
DRIVER CATEGORY	61.3	C/D		
ECOSTATUS	57.02	D		

⁽¹⁾ This rating is applicable to low flows

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

Table 12-4 Summary of the PES categories for EWR 4

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C	C	C/D (D)
GEOMORPHOLOGY	C		
WATER QUALITY	C/D		
Response components	Component PES	Instream PES	
FISH	D	D	
AQUATIC INVERTEBRATES	D		
RIPARIAN VEGETATION	A/B (A)	A/B (A)	

12.3.1 Trends

Geomorphology – Slow negative within category
 Vegetation – Slow negative potentially from an A/B to a B
 Fish – Stable
 Aquatic Invertebrates – Stable

12.4 Importance

12.4.1 Ecological Importance and Sensitivity

The EIS was rated as moderate (present). *Podocarpus latifolius*, a red data species, are abundant. The whole length of the system is under a closed vegetation canopy and the vegetation is species-rich and plays an important role with regard to refuge for birds.

12.5 Socio-cultural Importance (SI)

Land use for Resource Unit E (Segment 1 - 4, EWR 4: Segment 3) entails some estuarine utilisation for recreation purposes.

The SI was rated as moderate and the confidence was moderate.

12.6 Range of Ecological Categories

12.6.1 Recommended Ecological Category

The Ecostatus without considering vegetation is a high D. Considering the very high category for vegetation, the Recommended Ecological Category was raised to a C/D. No alternative state will however be considered as the Ecostatus (without vegetation) is already a D and the knowledge of this site and uncertainty around hydrology does not provide the resolution to address alternative flows.

13 EWR 4 – GEELHOUTBOOM RIVER: STRESS INDICES

13.1 Stress Index: Fish

The indicator species is *Pseudobarbus afer*, which is a semi-rheophilic species. This species requires flowing water for spawning in riffle areas where it needs depths of over 10 – 15 cm and velocities of >0.3 m/s. This species is sensitive to water quality and requires perennial flows, but can tolerate short periods of low flows. Habitat suitability, from which species stress is derived, is shown in Table 13.1.

Table 13-1 Habitat suitability at EWR 4

	FLOW (m ³ /s)				
	0.15	0.100	0.050	0.010	0.000
RELATIVE ABUNDANCE OF FLOW-DEPTH & COVER RATING: 0=NONE; 1=RARE; 2=SPARSE; 3=MODERATE; 4=ABUNDANT; 5=VERY ABUNDANT					
FAST DEEP	2	1.0	0.0	0.0	0.0
Overhanging vegetation	2.0	2.0	1.0	1.0	0.0
Undercut banks & root wads	3.0	2.0	2.0	1.0	0.0
Substrate	0.0	0.0	0.0	0.0	0.0
Aquatic macrophytes	2.0	1.0	1.0	0.0	0.0
Water column	1.0	1.0	0.0	0.0	0.0
FAST SHALLOW	4.0	3.0	2.0	1.0	0.0
Overhanging vegetation	2.0	1.0	1.0	0.0	0.0
Undercut banks & root wads	2.0	1.0	1.0	1.0	0.0
Substrate	0.0	0.0	0.0	0.0	0.0
Aquatic macrophytes	1.0	1.0	0.0	0.0	0.0
Water column					0.0
SLOW DEEP	4.0	3.0	3.0	3.0	2.0
Overhanging vegetation	3.0	2.0	2.0	1.0	1.0
Undercut banks & root wads	4.0	3.0	3.0	2.0	2.0
Substrate	2.0	2.0	2.0	1.0	1.0
Aquatic macrophytes	2.0	2.0	1.0	1.0	1.0
Water column	2.0	2.0	1.0	1.0	1.0
SLOW SHALLOW	3.0	3.0	2.0	2.0	1.0
Overhanging vegetation	2.0	2.0	1.0	1.0	0.0
Undercut banks & root wads	2.0	1.0	1.0	1.0	0.0
Substrate	0.0	0.0	0.0	0.0	0.0
Aquatic macrophytes	2.0	2.0	1.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0
FLOW	0.15	0.10	0.05	0.01	0.00

SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD					
SEMI-RHEOPHILIC	<i>P. afer</i>				
Breeding and early life-stages	3.0	2.0	0.0	0.0	0.0
Survival /Abundance	4.0	3.0	1.0	1.0	0.0
Cover	3.0	3.0	2.0	1.0	1.0
Health and condition	4.0	3.0	2.0	1.0	0.0
Water quality	4.0	3.0	2.0	1.0	0.0
Rheophilic stress - (breeding requirements included)	2.8	4.4	7.2	8.4	9.6
Flow-depth converted to habitat response (10=All flow-depth classes absent (River dry); 0=Flow-depth classes optimum for site; 9=No flow)	0.15	0.10	0.05	0.01	0.00
Fast deep	6.0	8.0	10.0	10.0	10.0
Fast shallow	2.0	4.0	6.0	8.0	10.0
Slow deep	2.0	4.0	4.0	4.0	6.0
Slow shallow	4.0	4.0	6.0	6.0	8.0
OVERALL HABITAT RESPONSE	3.5	5.0	6.5	7.0	8.5

13.2 Stress Index: Aquatic invertebrates

There is very sparse marginal vegetation habitat present, and this is only likely to be inundated at higher flows. As a result, the invertebrate fauna has a relatively low diversity, and the taxa are largely resilient. Simuliids are the only indicator taxa for equalled or exceeded stress conditions. Chlorolestidae and Helodids, which have a preference for slower flows, are good indicators of the higher stress conditions. Stones out of Current (SOOC) and Gravel/Sand/Mud (GSM) are the biotopes likely to be most persistent.

Table 13-2 summarises detailed invertebrate information.

Table 13-2 Stress table – Flow dependant invertebrate at EWR 4

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE		
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow	Community stress
Rating (site at observed flow)						0		0.13					
0	5	5	0	1	5	16		0.13	All available habitat in excess, high quality: most very fast, deep, wide wetted perimeter (WP).	Max depth 0.18 Av depth 0.1 Area 0.27 Width 2.68 WP 2.7 Av velocity 0.47	All very abundant. All healthy, all species persist.	0.1	0
1	4	5	0	1	4	14		0.09	Most plentiful, VIC reduced, mostly high quality; very fast and fast, deep, wide WP.	Max depth 0.16 Av depth 0.09 Area 0.22 Width 2.46 WP	All abundant. All healthy, all species persist.		1

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
										2.5 Av velocity 0.39			
2	3	4	0	1	4	12		0.06	Critical stones habitats sufficient; quality slightly reduced; fast and very fast, deep, wide WP slightly reduced.	Max depth 0.14 Av depth 0.08 Area 0.18 Width 2.24 WP 2.31 Av velocity 0.32	Slight reduction for sensitive rheophilic species. All healthy in some areas, all species persist.		2
3	3	4	0	0	3	10		0.03	Reduced critical SIC and VIC habitat, reduced critical quality; moderate and fast velocity, moderately deep, WP slightly/moderately reduced.	Max depth 0.12 Av depth 0.07 Area 0.13 Width 1.93 WP 1.99 Av velocity 0.26	Reduction of all rheophilic species, all healthy in limited areas, all species persist.	0.05	3

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	Biotic Response	Flow	Community stress	
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present			
4	3	3	0	0	3	9		0.02	SIC reasonably abundant, of good quality, VIC virtually absent, VOOC reduced, moderately fast.	Max depth 0.1 Av depth 0.06 Area 0.1 Width 1.64 WP 1.68 Av velocity 0.2			Further reduction for all rheophilic species. All viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist.	4
5	2	3	0	0	3	8			Critical stones habitat reduced; VIC absent, low quality; mix of velocity classes, some deep areas, WP moderately/very reduced.			0.01	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable (disappear at < 0.3m/s); most species persist.	5
6	2	2	0	0	3	7		0.01	Critical habitat (SIC and SOOC) very reduced. Reduced quality; low velocity, limited deep areas, moderate WP.	Max depth 0.08 Av depth 0.05 Area 0.07			Sensitive rheophilic species rare, critical stages of sensitive rheophilic species (Elmids) non-viable, and at risk for some	6

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
										Width 1.41 WP 1.44 Av velocity 0.14			less sensitive species. Most species persist in the short-term.
7	1	2	0	0	3	6			Very reduced critical habitat, Other habitats of low quality; shallow, moderate WP.	Max depth 0.06 Av depth 0.04 Area 0.04 Width 1.19 WP 1.2 Av velocity 0.09			Most rheophilic species rare. All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear.
8	1	1	0	0	3	5			Flowing water habitats residual. No vegetation. Low quality, slow trickle, small WP.	Max depth 0.04 Av depth 0.02 Area 0.02 Width 0.96 WP			Remnant populations of some rheophilic species; most life stages of most rheophilic species at risk or non-viable, Leptophlebiids threatened.

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
										0.96 Av velocity 0.05			
9	1	1	0	0	3	5		0	Standing water habitats only, very low quality, no flow. SOOC only available habitat.	Max depth 0.02 Av depth 0.01 Area 0.01 Width 0.54 WP 0.55 Av velocity 0.02	Mostly pool dwellers, most life stages of most rheophilic species non-viable; Leptophlebiids likely to disappear.	0	9
10	0	0	0	0	0	0		0	Only hyporheic refugia, no surface water.		No invertebrates likely.	0	10

- (1) SIC: Partially submerged hard substrate in current >0.1m/s
(2) SOOC: Partially submerged hard substrate in current <0.1m/s
(3) VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1m/s
(4) VOOC: Submerged vegetation (at least 2-3cm submerged) in current <0.1m/s
(5) GSM: Small particles submerged

13.2.1 Integrated Stress Curve

The individual component stresses are illustrated in Figure 13-1 as well as the integrated stress line (black line). Note that the invertebrate line (purple line) falls under the integrated stress line and cannot be seen.

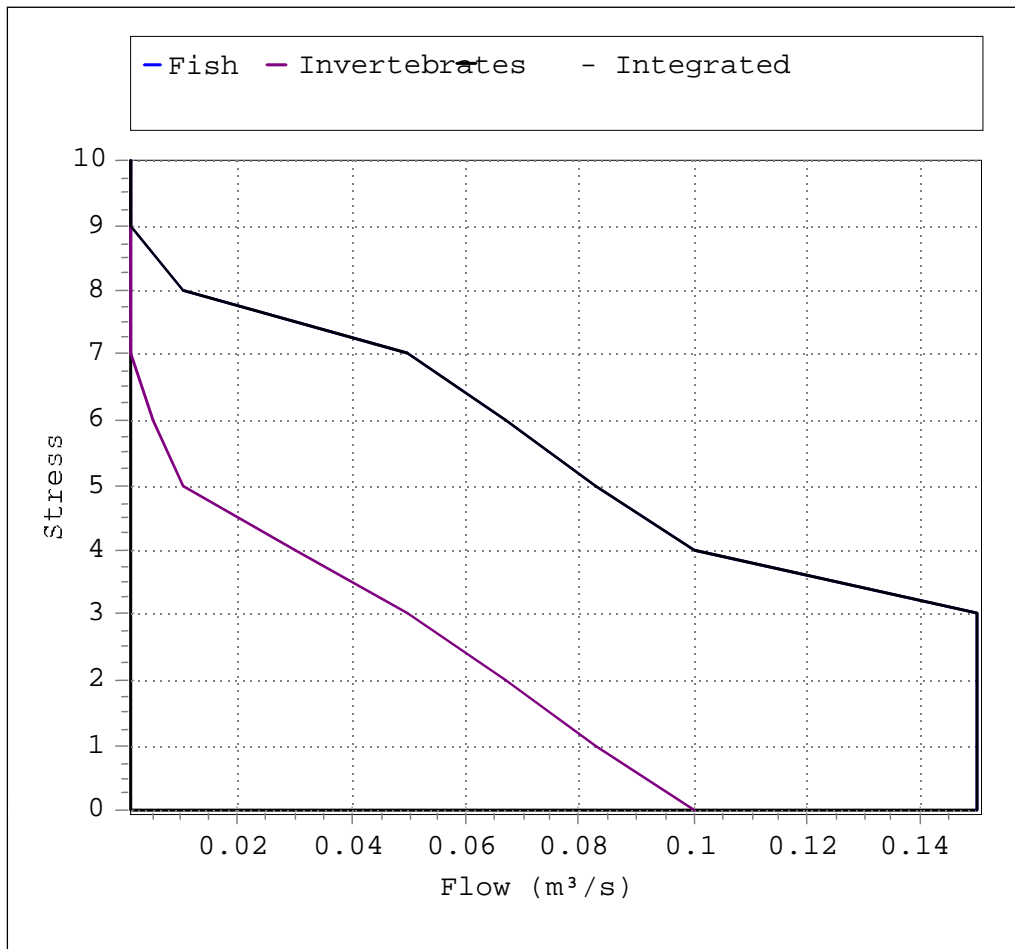


Figure 13-1 Component and integrated stress curves for EWR 4

14 EWR 4 – GEELHOUTBOOM RIVER: DETERMINATION OF EWR SCENARIOS

14.1 Low flow requirements

The integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month/season. Drought flows were set as 95 to 100% assurance (i.e. stress durations of 5 to 0%) and, based on the hydrological characteristics, maintenance flows were set as 70% assurance (i.e. stress durations of 30 %).

Dry season (January C/D category)

Wet season (August C/D category)

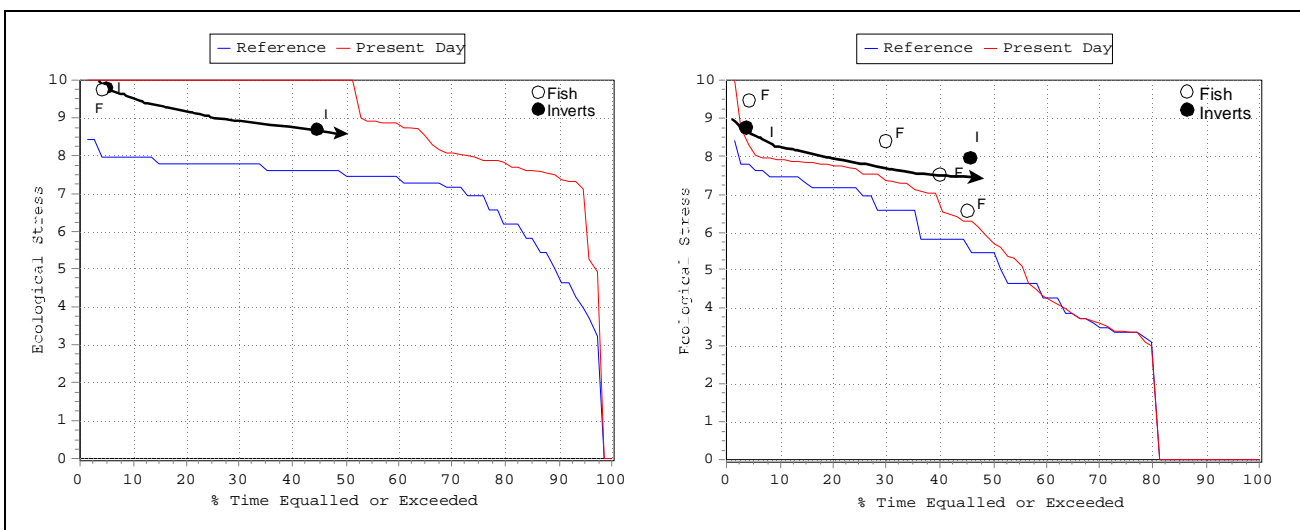


Figure 14-1 EWR 4 – Stress duration curve for a C/D REC

14.1.1 Stress duration motivations: Fish

The indicator species is *Pseudobarbus afer* (refer to EWR 1 for explanation). The lack of optimum spawning habitat (silt-free riffles with cobbles) means that the stress value never reaches zero in spite of suitable flows. The lack of cover at low flows was the main factor taken into account in this assessment and the lack of suitable substrate in pools was also taken into account.

14.1.2 Stress duration motivations: Aquatic invertebrates

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: Aquatic Invertebrate community
Indicator taxa with a preference for slow to moderate flows and moderately good water quality at this site are Leptophlebiid mayflies. The invertebrate fauna collected at this site is resilient.
<i>INVERTEBRATE STRESS REQUIREMENTS</i>
<i>DRY SEASON (January)</i>
DROUGHT: Stress of 10 or less for 95% of the time
As this is a seasonal system, presently flowing only after rainfall, it is likely to be a dry channel with pools (Stress 9) for at least half the time. During these conditions, indicator species are unlikely to survive,

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS

however the rest of the taxa present may maintain. There will be no SIC or MV habitat, and if no-flow conditions persist, water quality conditions will deteriorate in pools. Community structure will alter and food resources will be limited for all taxa. Continuation of these conditions for 1 - 2 months is likely to result in a significant loss of taxa. Breeding success is likely to be low.

MAINTENANCE (C/D): Stress of 8.6 or less for 45% of the time

During the high-stress periods there is likely to be a loss or reduction of indicator taxa. The majority of the community will withstand a loss of surface flow and connectivity and will retreat to pools habitats. Breeding success is likely to be limited. For at least half the time, there is a trickling flow that will maintain the majority of the community, although the community structure and age distributions may alter significantly during periods of sustained flow cessation.

WET SEASON (August)

DROUGHT: Stress of 8.6 and less for 95% of the time

There is sufficient pool habitat to maintain the majority of the late-winter invertebrate community (about 70%), during short periods of high stress. If flow reduction is followed by no-flow conditions that persist for longer than 2 - 3 days, the indicator taxa are likely to be eliminated or severely impacted. The effect of this will be a change in community structure and a reduction in the diversity of the breeding community in early summer, which relates to longer-term changes in the invertebrate biodiversity.

MAINTENANCE (C/D): Stress of 8 and less for 55% of the time

The river has enough trickling flow to ensure maintenance of the population of the majority of the invertebrate community, and to ensure a reasonable breeding community. Availability and quality of summer breeding habitat is threatened if there is continual higher stress (>6 - 7) for longer than 2 weeks. The low stresses (4 and less) equate to flows that will maintain those taxa with preferences for moderate flows.

14.2 Final low flow requirements

The following adjustments to the Desktop Reserve Model D requirements had to be made to fit the specialist requirements. The final curves for EWR 4 are shown in Figure 14-2.

- The Desktop Reserve Model provided 6.17 % of the virgin MAR for the Maintenance Low Flow (MLF).
- The Desktop Reserve Model provided 3.51% of the virgin MAR for the droughts.
- The DLF was reduced to 1% MAR with no flow in the dry season and reducing the wet season.
- The MLF was decreased from the Desktop Reserve Model to 5.76% (reduced dry season and increased wet season).

Dry season (January)

Wet season (August)

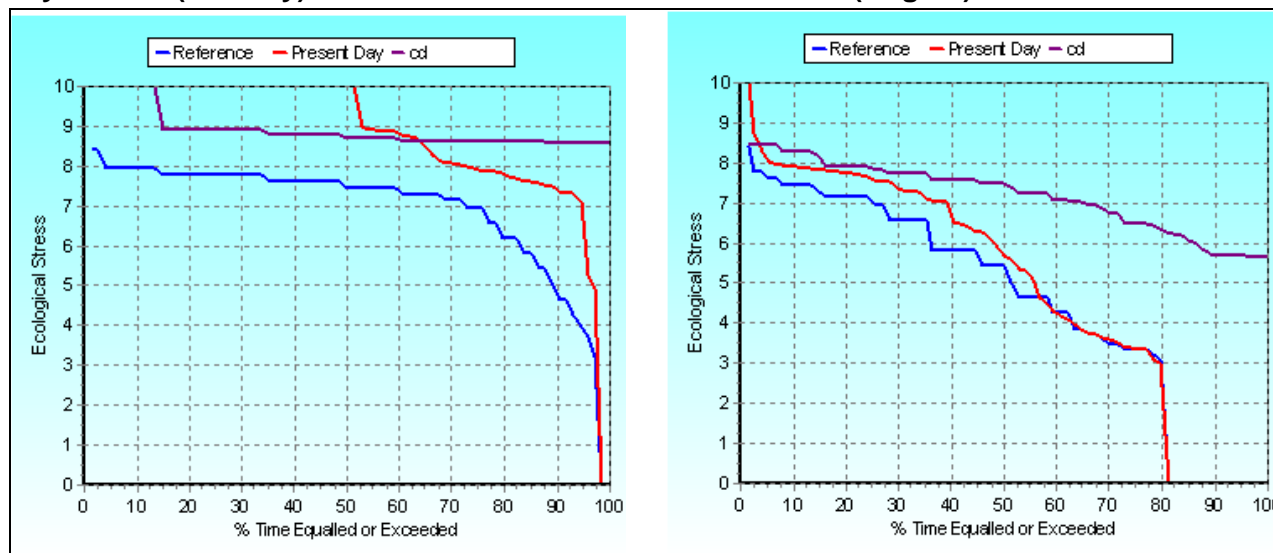


Figure 14-2 EWR 4 – Final curve

14.3 High flow requirements

The functions for each Flood Class are described in spreadsheets (Appendix I). A summary of the flood class ranges and the recommended high flow events for EWR 2 is shown in Table 14-1.

Table 14-1 Flood class ranges, and the recommended high flow events for each scenario at EWR 4

Component	Flood classes (m ³ /s)		
	I	II	III
Fish	0.1 – 0.3	0.3 – 0.5	
Invertebrates	0.1 – 0.3	0.3 – 0.5	
Vegetation		0.18 – 0.8	0.8 – 1.08
Geomorphology			0.8 – 1.4
Integrated	0.1 – 0.3	0.3 – 0.8	0.8 – 1.4
Daily average		0.3	1
Duration (days)		2	2

The number of high flow events required for each EC is provided in Table 14-2.

Table 14-2 The recommended number of high flow events required for each EC – EWR 4

Flood classes	NUMBER OF EVENTS: EC C/D					
	Invert	Fish	Veg	Geom	INTEG ¹	FINAL
Class I	5	5			5	
Class II	3	3	6 - 8		8	8
Class III			1	1	1	1
Class IV						
Class V						

(1) Integ = Integrated

These results were checked with the hydrology and were found to be acceptable.

14.4 Final results

Note: The model output refers to IFRs, which reflect the flow component of EWR (the other being quality).

C/D category:

The results are summarised as follows and provides a comparison with the Desktop Reserve Model.

	Desktop Reserve Model	2004 requirements
MLF (C/D)	6.17	5.76
High flows (C/D)	10	11.3
Droughts (C/D)	3.51	1
Long Term mean (C/D)	16.9	17.1

14.4.1 IFR table for REC: C/D

Please note: The IFR table generated from the Desktop Reserve Model and the IFR assurance rule tables. The low flows in the table are therefore not specific values set, but those derived from the stress requirements. The high flows are according to those specified.

Desktop Version 2, printed on 2004/09/23

Virgin MAR (MCM): 3.61

BFI index: 0.27

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows	
			Average daily (m ³ /s)	Durations (days)
October	0.009	0.002	0.3	2
November	0.009	0.001	0.3	1
December	0.005	0.0		
January	0.003	0.0		
February	0.003	0.0		
March	0.004	0.0		
April	0.005	0.0		
May	0.006	0.001		
June	0.007	0.002	0.3	1
July	0.008	0.002	0.3	1
August	0.010	0.003	0.3	2
September	0.010	0.003	0.3; 1	1; 2

14.4.2 IFR assurance rules for REC: C/D

Desktop Version 2, Printed on 2004/09/23

Summary of IFR rule curves for: Kromme_4 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: S.Karoo EC = C/D

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.071	0.061	0.053	0.045	0.032	0.027	0.019	0.012	0.007	0.005
Nov	0.032	0.031	0.030	0.028	0.025	0.020	0.014	0.008	0.004	0.003
Dec	0.008	0.008	0.007	0.007	0.006	0.005	0.003	0.002	0.000	0.000
Jan	0.005	0.005	0.004	0.004	0.004	0.003	0.002	0.001	0.000	0.000
Feb	0.005	0.005	0.004	0.004	0.004	0.003	0.002	0.001	0.000	0.000
Mar	0.006	0.006	0.006	0.005	0.005	0.004	0.003	0.001	0.000	0.000
Apr	0.008	0.008	0.007	0.007	0.006	0.005	0.003	0.002	0.000	0.000
May	0.009	0.009	0.009	0.008	0.007	0.006	0.004	0.003	0.001	0.001
Jun	0.040	0.035	0.031	0.027	0.020	0.016	0.012	0.008	0.004	0.004
Jul	0.041	0.036	0.032	0.028	0.021	0.017	0.012	0.008	0.004	0.003
Aug	0.072	0.063	0.055	0.047	0.034	0.028	0.021	0.013	0.008	0.006
Sep	0.142	0.121	0.104	0.088	0.060	0.049	0.036	0.022	0.012	0.009

Reserve flows without High Flows

Oct	0.014	0.014	0.013	0.012	0.011	0.009	0.007	0.004	0.003	0.002
Nov	0.014	0.014	0.013	0.012	0.011	0.009	0.006	0.004	0.002	0.001
Dec	0.008	0.008	0.007	0.007	0.006	0.005	0.003	0.002	0.000	0.000
Jan	0.005	0.005	0.004	0.004	0.004	0.003	0.002	0.001	0.000	0.000
Feb	0.005	0.005	0.004	0.004	0.004	0.003	0.002	0.001	0.000	0.000
Mar	0.006	0.006	0.006	0.005	0.005	0.004	0.003	0.001	0.000	0.000
Apr	0.008	0.008	0.007	0.007	0.006	0.005	0.003	0.002	0.000	0.000
May	0.009	0.009	0.009	0.008	0.007	0.006	0.004	0.003	0.001	0.001
Jun	0.011	0.011	0.010	0.010	0.009	0.007	0.006	0.004	0.002	0.002
Jul	0.012	0.012	0.012	0.011	0.010	0.008	0.006	0.004	0.003	0.002
Aug	0.016	0.015	0.015	0.014	0.013	0.011	0.008	0.006	0.004	0.003
Sep	0.016	0.015	0.015	0.014	0.013	0.011	0.008	0.006	0.004	0.003

Natural Duration curves

Oct	0.419	0.248	0.165	0.121	0.102	0.083	0.070	0.063	0.051	0.025
Nov	0.334	0.171	0.131	0.105	0.079	0.072	0.066	0.052	0.039	0.020
Dec	0.152	0.108	0.083	0.063	0.044	0.044	0.038	0.032	0.025	0.019
Jan	0.089	0.063	0.044	0.038	0.032	0.025	0.019	0.019	0.013	0.006
Feb	0.134	0.070	0.042	0.035	0.021	0.014	0.014	0.014	0.007	0.007
Mar	0.159	0.089	0.057	0.038	0.025	0.019	0.019	0.013	0.013	0.006

Apr	0.171	0.072	0.059	0.046	0.033	0.026	0.020	0.020	0.013	0.007
May	0.241	0.127	0.063	0.044	0.038	0.032	0.025	0.019	0.013	0.006
Jun	0.289	0.144	0.092	0.066	0.046	0.039	0.033	0.026	0.013	0.007
Jul	0.197	0.127	0.089	0.076	0.070	0.057	0.044	0.038	0.025	0.006
Aug	0.394	0.159	0.127	0.095	0.083	0.070	0.057	0.044	0.032	0.019
Sep	0.531	0.230	0.171	0.118	0.105	0.079	0.066	0.052	0.039	0.026

14.5 Confidence

The confidence is evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence. The confidence scores are summarised as follows:

0 (no confidence)	1 (low confidence)
2 (low to medium confidence)	3 (medium confidence)
4 (medium to high confidence)	5 (high confidence)

Results per component are shown in Table 14-3.

Table 14-3 Confidence ratings for EWR 4

Discipline	Ecoclassification	Available data	Suitability of IFR site	Flow requirements	
	Confidence	Confidence	Confidence	High	Low
				Confidence	Confidence
Hydrology	2	1			
Hydraulics		1	5	3	2
Geomorphology	3	2	4	2	N/a
Water quality	1	1			
Riparian vegetation	3	1	3	2	N/a
Aquatic invertebrates	1	1	2	3	2
Fish	1	1	1	3	3

(1) The shaded blocks indicate where confidence is not applicable.

Confidence explanations

Hydraulics: Measured flow of 0.000086m³/s (86ml/s). No measured low to moderate and high flow data. Recommended low flows are in the range 0 to 0.01m³/s and high flows in the range 0.3 - 1.4m³/s (within year). The high flow confidence is higher than the low flows as high flows are usually easier to model than the low flows if no flow data is available.

Geomorphology: This site was representative of the present system but bank erosion may have removed morphological clues. The stream was too small to give sufficient detail on the aerial photos and there was a lack of field evidence on the catchment condition. A low confidence in hydraulics was applied to an incised and widened channel. The general confidence in data and requirements was therefore low to moderate.

Water quality: Confidence is low due to the limited data (n = 3; monthly monitoring February – May 2003).

Riparian vegetation: Available data was confined to one site visit. Low flow output was in terms of fish and aquatic invertebrates therefore the confidence is in the low to medium range.

Fish: There were no suitable riffles present and fish habitat is very marginal. There is no historical data on this site and fieldwork was limited and the confidence is in a general low to medium range.

Aquatic invertebrates: This site had low habitat diversity. It was not possible to sample with high confidence due to lack of flow depth. The hydrology at this site is uncertain and therefore it is difficult to derive a reference state with any confidence as well as flow requirements.

15 EWR 5 – SEEKOEI RIVER: ECOCLASSIFICATION

15.1 Reference conditions

15.1.1 Geomorphology

This site is located on an alluvial gravel bed reach with a narrow flood bench with low gradient valley side slopes. The gradient of the site could not be calculated due to discrepancies between adjacent maps. This reach lies immediately downstream of a gorge. Flood frequency characteristics would be similar to those described for EWR 1, although this is a much smaller river. Strong coupling between tributaries and the main channel in the upper catchment would deliver coarse sediment to the channel. Evidence from a series of aerial photographs since 1942 suggest that the reference condition for this site is a narrow, single thread channel (probably displaying pool-riffle morphology) with an open canopy of indigenous woody riparian vegetation.

15.1.2 Riparian vegetation

The riparian vegetation reference condition for the river reach is characterised mainly by shrubs such as *Maytenus heterophylla*, *Diospyros sp.*, *Azima tetracantha*, and *Carissa bispinosa*. The canopy is open and grasses are common in the open spaces between shrubs. Exotic species are absent.

15.1.3 Water quality

The DWAF monitoring point K9H007Q01 (at the lower end of the WQSU around Kruisfontein / Humansdorp) was used for the PES assessment in preference to the additional monitoring point (WQ10 at Bergplaas) due to sample size and length of data record (although it is still limited). The default boundary tables were used for Reference Condition.

15.1.4 Fish

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Seekoei River at EWR 5, although eels are expected in low numbers only:

- *Pseudobarbus afer*
- *Sandelia capensis*
- *Anguilla mossambica*
- *Anguilla marmorata*
- *Anguilla bicolor bicolor*

15.1.5 Aquatic invertebrates

A reasonable diversity of undisturbed physical and hydraulic habitats would be expected. These would include a low diversity of stones habitats and a higher diversity of pools, marginal vegetation and sand/gravel/mud environments. Bank stability would be high, and disturbance to the channel morphology low. Shading would be approximately 30 - 50%, with some leaf-fall into the system.

The expected fauna would include Turbellarians, Oligochaetae, Hydracarina, baetid and caenid mayflies, Aeshnid, Gomphid and Libellulid Odonata, Belostomatid, Corixid, Gerrid and Pleid Hemipterans, Hydropsychid caddis, Elmid, Gyrinid and Hydraenid Hemipterans, Ephydrid, Tipulid and Tabanid Dipterans, and Ancyloid, Lymnaeid and Physid Gastropods.

15.2 Present Ecological State (PES)

It must be noted that this site changed considerably during the study period. It was first visited during a wet period and the marginal vegetation was abundant. Since then the site was accessed by cattle and the cross-section and surrounding areas have been severely trampled. During the last visit, dry conditions and anthropogenic impacts (fence maintenance) increased the pressure. It was therefore difficult to assess the PES of the site, especially a PES representative of this site and the reach considering these fluctuations.

15.2.1 Habitat Driver PES

The hydrology PES (B) and geomorphology PES (D) information is available in Appendix A and Appendix B respectively. Water quality PES is a B/C category. The driver category is a C and the composition of the driver category is provided in Table 15-1.

The reasoning for the geomorphology category (D) is provided below.

PES	Causes	Sources	Flow/Non flow related
D	Channel widening and increased sand on bed.	Black Wattles.	Non flow related.
	Backing up water.	Bridge.	Non flow related.

Table 15-1 Habitat driver category for EWR 5

Components	Weighted driver score
GEOMORPHOLOGY	15.24 (D)
HYDROLOGY	43.86 (B)
WATER QUALITY	17.35 (B/C)
Weighted driver status (%)	76.45
HABITAT DRIVER CATEGORY	C

15.2.2 Biological response PES

15.2.2.1 Riparian vegetation (F)

The reach is dominated by Black Wattle, Bramble and Kikuyu. Marginal vegetation is largely absent due to grazing. Cattle have trampled the riparian zone and riparian shrubs have been browsed and removed. Species diversity, composition and structure have therefore been seriously impacted. Vegetation cover and abundance have been less affected due to the fact that the cover and abundance provided by exotic species is high.

PES	Causes	Sources	Flow/Non flow related
F	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in vegetation cover and abundance.	Invasion of exotic species and exclusion and removal of indigenous species.	Non flow related.
	Changes in vegetation structure.	Invasion of exotic species and exclusion and removal of indigenous species.	Non flow related.
		Invasion of exotic species and exclusion and removal of indigenous species.	Flow related.

15.2.2.2 Fish (C)

No *Micopterus salmoides* was found at this site, but are very likely to be present downstream. Only *Sandelia capensis* was caught (n = 6), with the more sensitive *P. afer* absent. Serious habitat destruction is apparent in the downstream section of this Resource Unit. Apart from the suspected serious impact of predation by bass, mostly non flow related impacts in sections of this reach are severe.

The PES was assessed, by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes caused by alterations to the habitat drivers. Taking the impact of alien predatory fish into account will reduce the PES to a category E or F due to the apparent total elimination of indigenous fish.

PES	Causes	Sources	Flow/Non Flow related
C	Flow Modification – reduced or no flows, low flows for long periods.	• Farmer abstracting flows.	Flow related.
		• Thirsty alien trees upstream of site.	Non flow related.
	Increased sediment input.	• Roads, cattle trampling, bad agricultural practices, bank collapse, trees in riparian zone.	Non flow related.

15.2.2.3 Aquatic invertebrates (D)

This site was difficult to interpret due to the uncertainty of its natural hydrology. It was sampled only once, during low flow conditions. The channel and margins had been recently severely trampled by cattle, and water quality was expected to be poor. The flow and marginal vegetation habitats sampled upstream of the road-crossing yielded a low-diversity and a hardy fauna, with a low ASPT of 4.3, indicating a hardy fauna, with the majority of taxa having some tolerance for organically polluted water.

PES	Causes	Sources	Flow/Non flow related
D	Altered hydraulic habitat.	Road bridge.	Flow related.
	Deterioration in channel bed morphology, loss of instream and riparian habitat.	Cattle trampling, clearing, bank instability.	Non flow related.
	Deterioration in water quality.	Cattle, farming activities, sedimentation.	Non flow related.

15.2.3 Instream PES (D)

The Instream PES is summarised in Table 15-2.

Table 15-2 Instream PES for EWR 5

Criteria	Rating (0=low, 5=high)				
	Conf Rating	Ave	Weight	PES	Category
1 Availability of high confidence fish information	2				C
2 Diversity of fish species with different flow requirements	2				
3 Diversity of fish species with a preference for different cover types	2				
4 Diversity of fish species with a preference for different flow depth classes	2				
5 Diversity of fish species with various tolerances to modified water quality	2	2	0.50	66.6	C
6 Availability of high confidence invertebrate information	2				D
7 Diversity of invertebrate biotopes	2				
8 Diversity of invertebrate taxa with different velocity requirements	2				
9 Diversity of invertebrate taxa with different tolerances to modified water quality	2	2	0.50	49.2	D
		4	1	57.9	D

15.2.4 PES Ecostatus (C)

The Ecostatus is summarised in Table 15-3 and the PES categories shown in Table 15-4.

Table 15-3 Summary of the Ecostatus for EWR 5

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		2		
Fish: What is the general level of trophic specialisation?		2		
What is the general level of habitat specialisation?		2		
What is the general level of flow intolerance?		2	2	0.46
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3		
How sensitive are hydraulic habitats to flow change? ¹		2		
How sensitive is water quality to flow change?		2	2.33	0.54
Total			4.33	1
PES	Category			
INSTREAM CATEGORY	D	57.92		
DRIVER CATEGORY	C	76.4		
ECOSTATUS	C	67.90		

⁽¹⁾ This rating is applicable to low flows

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

Table 15-4 Summary of the PES categories for EWR 5

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	C
GEOMORPHOLOGY	D		
WATER QUALITY	B/C		
Response components	Component PES	Instream PES	
FISH	C	D	
AQUATIC INVERTEBRATES	D		
RIPARIAN VEGETATION	D	D	

15.2.5 Trends

Geomorphology – Long term negative trend within the same class.

Vegetation – Long term negative within the same class.

Fish - Negative trend, half a category - possibly short-term.

Aquatic Invertebrates – Negative trend, half a category - possibly short-term.

15.3 Importance

15.3.1 Ecological Importance and Sensitivity

The EIS was rated as moderate (present), as there are rare fish species (*P. afer*) and vegetation (*Podocarpus latifolius*) present in the RU. There are a number of invertebrate taxa and fish that are intolerant to flow and flow related water quality triggers. There is a diversity of habitat types.

The confidence ranged from low to high for the different matrices.

15.3.2 Socio-cultural Importance

Land use for Resource Unit F (Segment 1 – 3 EWR 5: Segment 2) is of importance to irrigated agriculture and to the town of Humansdorp but direct dependence as defined for the purposes of socio-cultural importance is limited.

The SI was rated as low and the confidence was medium.

15.4 Range of Ecological Categories

15.4.1 Recommended Ecological Category (REC)

The EWR site was evaluated in relation to the rest of the RU. The EWR site is in worse condition than the river upstream to its source. However, due to the steep gradient and bedrock nature of the upstream river, a suitable site could not be found for hydraulics in the Resource Unit. The EWR site selected had to be used to set flow requirements, but in determining the PES and the flows, the upstream section should be considered. A further complication was that the EWR site was damaged since selection by extreme cattle-trampling on the cross-section and further by fencing activities immediately downstream of the cross-section.

The main purpose of the site so far upstream in the river would be to protect the upper river. The lower river is severely degraded and consists mostly of back-to-back dams. Considering the moderate EIS and low SI, the REC of a C is set to maintain the PES.

15.4.2 Alternative Ecological Categories

All response components apart from fish were in a D category. The geomorphology was also in a D category. To set an alternative category of an Ecstatus of a D (PES Ecstatus is a C) would mean that only fish must be changed. Taking into account the confidence in the resolution of these extremely small flows, and the lack of ecological knowledge, it was decided that alternative categories would not be recommended.

15.4.2.1 Fish

In reduction of the EC from a C to a D, the reduction in flows will mainly affect the low flows i.e. longer periods of low flows are experienced, including periods of critically low flows (possibly no flow periods). The fish stress will increase during extended low flow periods due to:

- Increased predation on fish due to reduced cover in the form of undercut banks, root wads and marginal vegetation. Fish crowded in shallow and open water and thus are vulnerable to increased predation.
- At low or NO flows the water quality will deteriorate (increased temperatures, lowered DO levels and growth of iron bacteria on substrate surfaces), resulting in a drop in available food items, poor fish health and increased mortalities due to disease.
- Spawning success may be slightly impacted due to reduction in number and size of optimum spawning sites – e.g. for *P. afer* areas of optimum water depths and current velocities over riffle habitats.

Thus numbers of fish will drop and although no species will disappear, they will become even more rare and isolated in small pockets. The component alternative categories are provided in Table 15-5.

Table 15-5 Summary of the Alternative Ecological Category D for EWR 5

Driver Components	Component EC	Driver EC	ALTERNATIVE ECOSTATUS
HYDROLOGY	C	D	D
GEOMORPHOLOGY	D		
WATER QUALITY	C/D		
Response components	Component PES	Instream PES	
FISH	D	D	
AQUATIC INVERTEBRATES	D	D	
RIPARIAN VEGETATION	D	D	

16 EWR 5 – SEEKOEI RIVER: STRESS INDICES

16.1 Stress Index: Fish

Pseudobarbus afer was used as the indicator species. The lack of optimum spawning habitat (silt-free riffles with cobbles) means that the stress will be high in spite of suitable flows.

Lack of cover at low flows was the main factor taken into account in the assessment as well as the lack of suitable substrate in pools. Habitat suitability, from which species stress is derived, is shown in Table 16.1.

16.2 Stress Index: Aquatic invertebrates

The fauna at this site is affected by both flows and water quality. The fauna is resilient, with few sensitive taxa to serve as indicators. Simuliids and Hydropsychiids are indicators of moderate to fast flow conditions (>0.3 m/s). Leptophlebiids and Caenids have a preference for slower flow conditions (<0.1 and 0.1 - 0.3 respectively), and are threatened by flow cessation and by water quality impairment. The fauna is dominated by taxa which prefer low flow conditions, and which can largely survive standing water (for a short period), as long as water quality is not seriously impaired. As surface water and connectivity diminishes, this fauna will reach maximum stress.

Table 16-1 Habitat suitability at EWR 5

	FLOW (m ³ /s)			
	0.10	0.050	0.016	0.001
RELATIVE ABUNDANCE OF FLOW-DEPTH & COVER RATING: 0=NONE; 1=RARE; 2=SPARSE; 3=MODERATE; 4=ABUNDANT; 5=VERY ABUNDANT				
FAST DEEP	0	0.0	0.0	0.0
Overhanging vegetation	0.0	0.0	0.0	0.0
Undercut banks & root wads	0.0	0.0	0.0	0.0
Substrate	0.0	0.0	0.0	0.0
Aquatic macrophytes	0.0	0.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0
FAST SHALLOW	3.0	2.0	2.0	1.0
Overhanging vegetation	4.0	4.0	3.0	2.0
Undercut banks & root wads	3.0	3.0	2.0	2.0
Substrate	4.0	3.0	3.0	2.0
Aquatic macrophytes	4.0	3.0	2.0	1.0
Water column	0.0	0.0	0.0	0.0
SLOW DEEP	2.0	2.0	1.0	1.0
Overhanging vegetation	3.0	3.0	2.0	1.0
Undercut banks & root wads	3.0	3.0	2.0	2.0
Substrate	3.0	3.0	2.0	2.0
Aquatic macrophytes	3.0	3.0	2.0	2.0
Water column	2.0	2.0	2.0	2.0
SLOW SHALLOW	5.0	5.0	4.0	2.0
Overhanging vegetation	5.0	4.0	3.0	2.0
Undercut banks & root wads	3.0	2.0	2.0	1.0
Substrate	4.0	3.0	3.0	2.0
Aquatic macrophytes	4.0	3.0	2.0	1.0
Water column	0.0	0.0	0.0	0.0
FLOW	0.10	0.05	0.02	0.00
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD				
SEMI-RHEOPHILIC	<i>P. afer</i>			
Breeding and early life-stages	5.0	5.0	3.0	0.0
Survival /Abundance	5.0	5.0	3.0	2.0
Cover	5.0	4.0	3.0	2.0
Health and condition	5.0	5.0	5.0	2.0
Water quality	5.0	5.0	4.0	2.0
Rheophilic stress - (breeding requirements included)	0.0	0.4	2.8	6.8

Flow-depth converted to habitat response (10=All flow-depth classes absent (River dry); 0=Flow-depth classes optimum for site; 9=No flow)	0.10	0.05	0.02	0.00
Fast deep	10.0	10.0	10.0	10.0
Fast shallow	4.0	6.0	6.0	8.0
Slow deep	6.0	6.0	8.0	8.0
Slow shallow	0.0	0.0	2.0	6.0
OVERALL HABITAT RESPONSE	5.0	5.5	6.5	8.0

Table 16-2 Stress table – Flow dependant invertebrate at EWR 5

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
Rating (site at observed flow)	3	2	2	1	5	13		0.13					
0	5	4	4	2	5	20		0.1	All available habitats in excess, high quality: most very fast, deep, wide wetted perimeter (WP).	Max depth 0.24 Av depth 0.075 Area 0.3 Width 4.06 WP 4.93 Av velocity 0.306	All very abundant. All healthy, all species persist.	0.1	0
1	4	3	4	2	5	18			Most plentiful, VIC reduced, mostly high quality; very fast and fast, deep, wide WP.		All abundant. All healthy, all species persist.		1
2	4	3	3	2	4	16		0.05	Critical stones habitats sufficient; quality slightly reduced; fast and very fast, deep, wide	Max depth 0.22 Av depth 0.062 Area	Slight reduction for sensitive rheophilic species. All healthy in some areas, all species persist.		2

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
									WP slightly reduced.	0.23 Width 3.67 WP 4.47 Av velocity 0.19			
3	3	2	3	1	4	13			Reduced critical SIC and VIC habitat, reduced critical quality; moderate and fast velocity, moderately deep, WP slightly/moderately reduced.				3
4	3	2	2	1	4	12		0.016	SIC reasonably abundant, of good quality, VIC very reduced, VOOC reduced, slow with rare moderately fast areas.	Max depth 0.2 Av depth 0.065 Area 0.16 Width 2.49 WP 3.22 Av velocity 0.106	0.05		4

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
5	2	2	2	1	4	11		0.006	Critical stones habitat reduced; VIC absent, low quality; mix of velocity classes, some deep areas, WP moderately/very reduced.	Max depth 0.18 Av depth 0.062 Area 0.12 Width 1.92 WP 2.55 Av velocity 0.51	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable (disappear at < 0.3m/s); most species persist.		5
6	1	2	2	1	3	9		0.002	Critical habitat (SIC and SOOC) very reduced. Reduced quality; low velocity, limited deep areas, moderate WP.	Max depth 0.16 Av depth 0.067 Area 0.09 Width 1.3 WP 1.81 Av velocity 0.021	Sensitive rheophilic species rare, critical stages of sensitive species (Helodid larvae) non-viable due to water quality impairment, risk for some less sensitive species. Most species persist in the short-term.	0.016	6
7	1	2	1	0	3	7		0.0005	Very reduced critical habitat, Other habitats of low	Max depth 0.14 Av depth	Rheophilic taxa rare; all life-stages of sensitive rheophilic species at	0.006	7

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress	
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present			
									quality; slow, shallow, moderate WP.	0.063 Area 0.06 Width 1.01 WP 1.42 Av velocity 0.008			risk or non-viable. Sensitive rheophilic species will disappear with sufficient duration of these conditions.	
8	1	1	1	0	2	5		0.0001	Flowing water habitats residual, no vegetation, low quality: slow trickle, small WP.	Max depth 0.12 Av depth 0.067 Area 0.05 Width 0.07 WP 1.0 Av velocity 0.002			Remnant populations of some rheophilic species; most life stages of most rheophilic species at risk or non-viable, Leptophlebiids threatened.	
9	0	1	0	0	1	2		0	Standing water habitats only, very low quality, no flow. SOOC only available habitat.	Max depth 0.1 Av depth 0.06 Area 0.03			0.001	Mostly pool dwellers, most life stages of most rheophilic species non-viable; Leptophlebiids likely to disappear.

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE		Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow	
										Width 0.57 WP 0.79 Av velocity 0.0			
10	0	0	0	0	0	0		0	Only hyporheic refugia, no surface water.		No invertebrates likely.	10	

- (1) SIC: Partially submerged hard substrate in current >0.1m/s
- (2) SOOC: Partially submerged hard substrate in current <0.1m/s
- (3) VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1m/s
- (4) VOOC: Submerged vegetation (at least 2-3cm submerged) in current <0.1m/s
- (5) GSM: Small particles submerged

16.2.1 Integrated stress curve

The individual component stresses are illustrated in Figure 16-1, as well as the integrated stress line (black line).

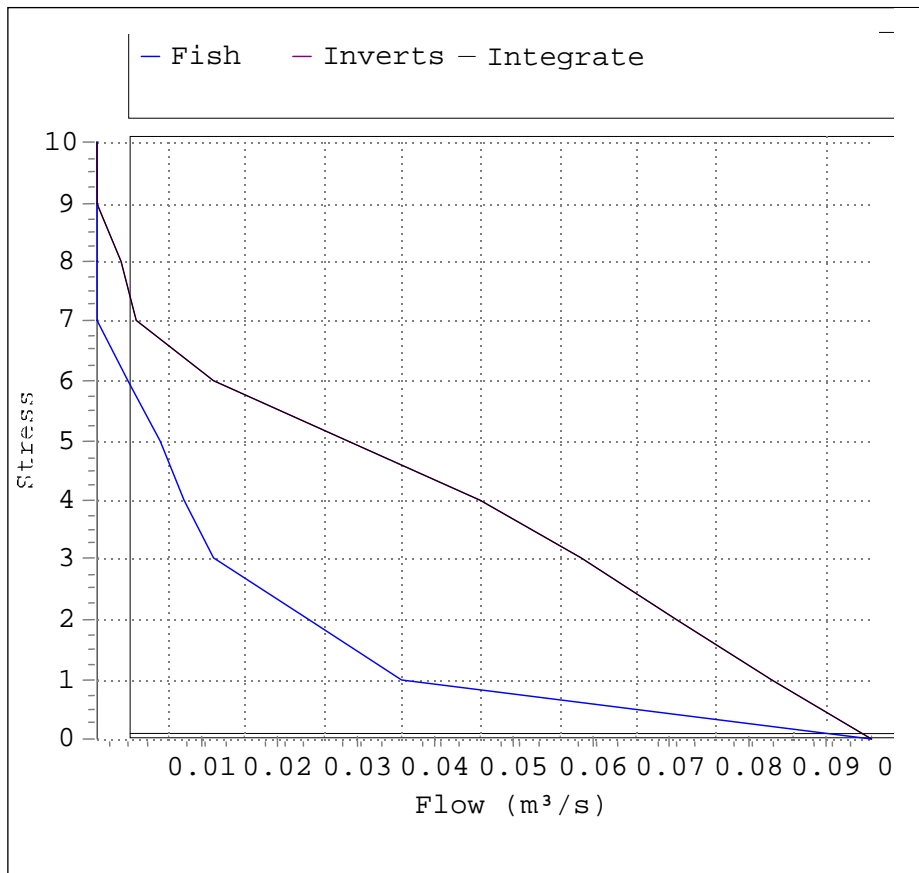


Figure 16-1 Component and integrated stress curves for EWR 5

17 EWR 5 – SEEKOEI RIVER: DETERMINATION OF EWR SCENARIOS

17.1 Low flow requirements

The integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month/season. Drought flows were set as 95 to 100% assurance (i.e. stress durations of 5 to 0%) and, based on the hydrological characteristics, maintenance flows were set as 70% assurance (i.e. stress durations of 30 %). Stress duration curves for the REC are shown in Figure 17-1.

Dry season (January C category)

Wet season (August C category)

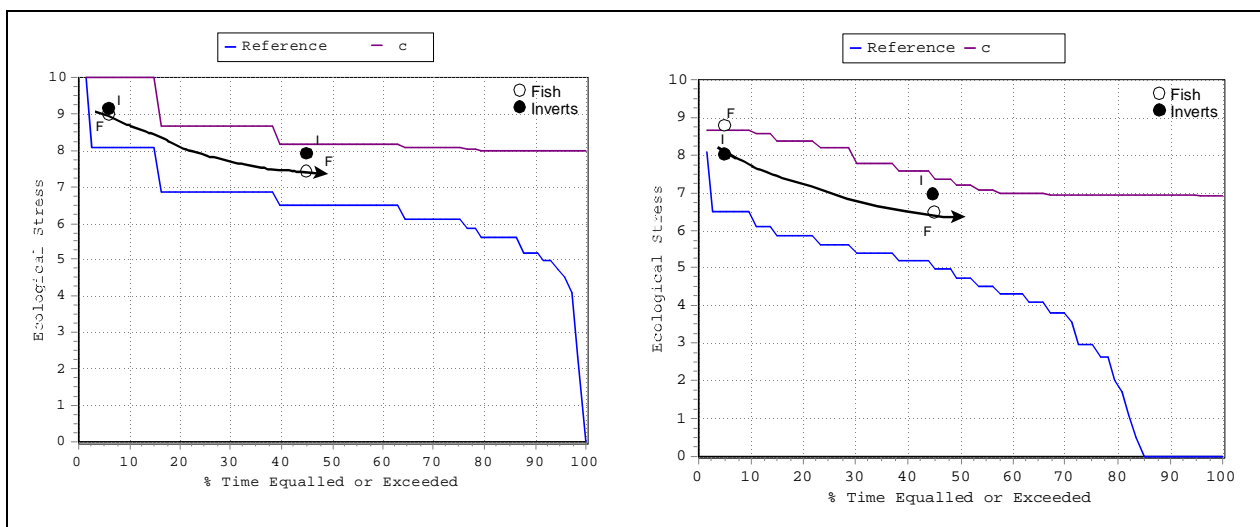


Figure 17-1 EWR 5 – Stress duration curve for a C REC

17.1.1 Stress duration motivations: Fish

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: <i>Pseudobarbus afer</i>
The indicator is a semi-rheophilic species, which is dependant on the flow for breeding in riffles at suitable velocities and depths. Note that peak spawning activities take place in Spring (September to December) and possibly some limited spawning in late summer, but main spawning requirements for species in terms of stress requirements are included in wet season.
<i>FISH STRESS REQUIREMENTS FOR THE REC</i>
<i>DRY SEASON (January)</i>
DROUGHT: Stress of 9 or less for 5% of the time Fish confined totally to pool with limited cover available, poor water quality and limited food available.
MAINTENANCE (C): 45% of the time at stress level of 7.5 Provides more cover and improved water quality and food.
<i>WET SEASON (August)</i>
DROUGHT: Stress of 9 or less for 5% of the time

<p>There is very limited breeding capability as no shallow fast habitat remaining. 5% at stress level 8.9 - there will be limited fast shallow habitat and very limited breeding.</p>
<p>MAINTENANCE (C): 45% of the time at stress of level 6.5 equalled or exceeded Provides some habitat for spawning and habitat slow shallow for larval growth. Sufficient cover and habitats, but limiting factor will be breeding habitat.</p> <p>Indicator: <i>Pseudobarbus afer</i> Breeding thought to start in Spring (September to December) and need clean riffles plus suitable depths and velocities. <i>Juvenile</i>: Feeding and growth: Mostly slow shallow. Cover: Overhanging vegetation and emergent vegetation. Duration 3 - 4 months. <i>Adult</i>: Cue: Increased temperature and flow.</p>

17.1.2 Stress duration motivations: Aquatic invertebrates

<p>AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS</p>
<p>Indicator: Aquatic Invertebrate community Indicator taxa with a preference for slow to moderate flows and moderately good water quality at this site are Leptophlebiid mayflies and Simuliids. The invertebrate fauna collected at this site is of low diversity and resilient.</p>
<p><i>INVERTEBRATE STRESS REQUIREMENTS</i></p>
<p><i>DRY SEASON (January)</i></p>
<p>DROUGHT: Stress of 9 or less for 5% of the time At a stress of 9, the maximum depth is 18cm and the channel width 1.3 m. This results in low habitat availability (no SIC or MV) and indicators are likely to disappear if this condition (and the likely preconditions) persists for a few days. The balance of the taxa is likely to survive in pools and SOOC habitats. With ongoing high stresses, water quality conditions will deteriorate in pools. Community structure will alter and food resources will be limited for all taxa. Continuation of these conditions for sufficient time is likely to result in a significant loss of taxa. Breeding success is likely to be low, and juvenile life stages may be threatened.</p>
<p>MAINTENANCE (C): Stress of 8 or less for 45% of the time During the high-stress periods there is likely to be a loss or reduction of indicator taxa. The majority of the community will withstand a loss of surface flow and connectivity and will retreat to pools and SOOC habitats. At stresses over 8 breeding success is likely to be limited, and juvenile life stages will be threatened. For at least half the time, there is a trickling flow that will maintain the majority of the community although the community structure and age distributions may alter significantly during periods of sustained flow cessation.</p>
<p><i>WET SEASON (August)</i></p>
<p>DROUGHT: Stress of 8 and less for 5% of the time There is sufficient pool habitat to maintain the majority of the late-winter invertebrate community (about 70%), during short periods of high stress. If flow reduction is followed by no-flow conditions that persist for longer than 2 - 3 days, the indicator taxa are likely to be eliminated or severely impacted. The effect of this will be a change in community structure and a reduction in the diversity of the breeding community in early summer, which relates to longer-term changes in the invertebrate biodiversity.</p>
<p>MAINTENANCE (C): Stress of 7 and less for 45% of the time The river has enough trickling flow to ensure maintenance in the population of the majority of the invertebrate community, and to ensure a reasonable breeding community. Availability and quality of summer breeding habitat is threatened if there is continual higher stress (>6 - 7) for longer than 2 weeks. The low stresses (4 and less) equate to flows that will maintain those taxa with preferences for moderate flows.</p>

17.2 Final low flow requirements

The following adjustments to the Desktop Reserve Model C requirements had to be made to fit the specialist requirements. Final curves are shown in Figure 17-2.

C category:

- The Desktop Reserve Model provided 22.5% of the virgin MAR (MFL and high flows).
- The Desktop Reserve Model provided 8.2% of the virgin MAR for the Maintenance Low Flow (MLF).
- The Desktop Reserve Model provided 2.2% of the virgin MAR for the droughts.
- The DLF was reduced to 2.1% MAR with no flow in the dry season and reducing the wet season.
- The MLF was increased from the Desktop Reserve Model to 12.2%.

Dry season (January)

Wet season (August)

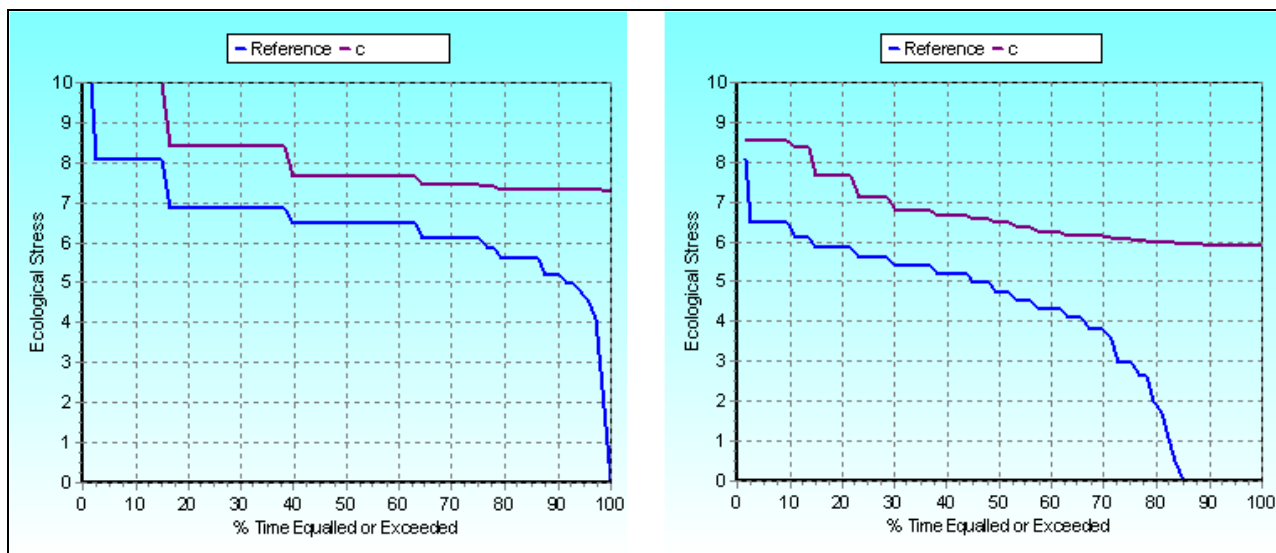


Figure 17-2 EWR 5 – Final curve

17.3 High flow requirements

The functions for each Flood Class are described in spreadsheets (Appendix I). A summary of the flood class ranges and the recommended high flow events for EWR 1 is shown in Table 17-1.

Table 17-1 Flood class ranges, and the recommended high flow events for each scenario at EWR 5

Component	Flood classes (m ³ /s)		
	I	II	III
Fish	0.1 - 0.3	0.3 - 1	
Invertebrates	0.1 - 0.3	0.3 - 1	
Vegetation	0.1 - 0.16		0.16 - 1.9
Geomorphology	0.15 - 0.3		1 - 1.9
Integrated	0.1 - 0.3	0.3 - 1	1 - 1.9
Daily average	0.1	0.3	0.7
Duration (days)	1	2	2

The number of high flow events required for each EC is provided in Table 17-2.

Table 17-2 The recommended number of high flow events required for each EC at EWR 5

Flood classes	NUMBER OF EVENTS: EC C					FINAL
	Invert	Fish	Veg	Geom	INTEG ¹	
Class I	3	4	8	4	8	6 (May, Jun., Jul., Aug., Oct., Nov)
Class II	1	2			2	1 (Oct)
Class III			1	1	1	1 (Sept)

(1) Integ = Integrated

These results were checked with the hydrology and were found to be acceptable.

17.4 Final results

Note: The model output refers to IFRs, which reflect the flow component of EWR (the other being quality). C category: The results are summarised as follows as well as providing a comparison with the DRM.

	Desktop Reserve Model	2004 requirements
MLF (C)	8.2	12.2
High flows (C)	11.2	11.2
Droughts (C)	2.2	2.1
Long Term mean (C)	18.8	22.5

17.4.1 IFR table for REC: C

Please note: The IFR table generated from the Desktop Reserve Model and the IFR assurance rule tables. The low flows in the table are therefore not specific values set, but those derived from the stress requirements. The high flows are according to those specified.

Desktop Version 2, printed on 2004/09/23

Virgin MAR (MCM): 1.54

BFI index: 0.25

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows	
			Average daily (m ³ /s)	Durations (days)
October	0.007	0.002	0.3	1
November	0.006	0.002	0.3	1
December	0.005	0.001		
January	0.004	0.0		
February	0.004	0.0		
March	0.005	0.0		
April	0.005	0.0		
May	0.006	0.001	0.3	1
June	0.006	0.0	0.3	1
July	0.007	0.002	0.3	1
August	0.008	0.002	0.3; 0.6	1; 2
September	0.008	0.002	2	2

17.4.2 IFR assurance rules for REC: C

Desktop Version 2, Printed on 2004/09/23

Summary of IFR rule curves for : Kromme_5 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: S.Karoo REC = C

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.044	0.039	0.034	0.029	0.021	0.017	0.013	0.008	0.005	0.004
Nov	0.012	0.012	0.011	0.011	0.010	0.008	0.006	0.004	0.003	0.002
Dec	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.002	0.001	0.001
Jan	0.005	0.005	0.005	0.005	0.004	0.003	0.002	0.001	0.000	0.000
Feb	0.005	0.005	0.005	0.005	0.004	0.003	0.002	0.001	0.000	0.000
Mar	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.001	0.000	0.000
Apr	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.001	0.000	0.000
May	0.015	0.014	0.012	0.011	0.009	0.007	0.005	0.003	0.002	0.001
Jun	0.015	0.014	0.012	0.011	0.009	0.007	0.005	0.002	0.001	0.000
Jul	0.016	0.015	0.014	0.012	0.010	0.009	0.006	0.004	0.003	0.002
Aug	0.017	0.016	0.015	0.014	0.011	0.009	0.007	0.005	0.003	0.002

Sep 0.079 0.068 0.058 0.049 0.034 0.028 0.021 0.013 0.007 0.006

Reserve flows without High Flows

Oct	0.009	0.009	0.009	0.009	0.008	0.006	0.005	0.003	0.002	0.002
Nov	0.008	0.008	0.008	0.007	0.007	0.006	0.004	0.003	0.002	0.002
Dec	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.002	0.001	0.001
Jan	0.005	0.005	0.005	0.005	0.004	0.003	0.002	0.001	0.000	0.000
Feb	0.005	0.005	0.005	0.005	0.004	0.003	0.002	0.001	0.000	0.000
Mar	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.001	0.000	0.000
Apr	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.001	0.000	0.000
May	0.008	0.008	0.008	0.007	0.006	0.005	0.004	0.002	0.001	0.001
Jun	0.008	0.008	0.008	0.007	0.006	0.005	0.003	0.002	0.000	0.000
Jul	0.009	0.009	0.009	0.009	0.008	0.006	0.005	0.003	0.002	0.002
Aug	0.011	0.011	0.010	0.010	0.009	0.007	0.006	0.004	0.002	0.002
Sep	0.011	0.011	0.010	0.010	0.009	0.007	0.006	0.004	0.002	0.002

Natural Duration curves

Oct	0.220	0.101	0.071	0.052	0.045	0.034	0.034	0.022	0.019	0.011
Nov	0.162	0.073	0.058	0.046	0.035	0.031	0.023	0.023	0.015	0.008
Dec	0.067	0.037	0.026	0.026	0.019	0.015	0.015	0.011	0.011	0.007
Jan	0.034	0.022	0.015	0.011	0.011	0.011	0.007	0.007	0.004	0.004
Feb	0.033	0.017	0.012	0.008	0.008	0.008	0.004	0.004	0.004	0.000
Mar	0.067	0.026	0.019	0.011	0.007	0.007	0.004	0.004	0.004	0.000
Apr	0.069	0.042	0.027	0.015	0.012	0.012	0.008	0.008	0.004	0.000
May	0.123	0.041	0.030	0.022	0.019	0.015	0.011	0.007	0.004	0.004
Jun	0.089	0.050	0.039	0.027	0.023	0.015	0.012	0.012	0.008	0.004
Jul	0.127	0.052	0.041	0.037	0.030	0.026	0.022	0.015	0.011	0.004
Aug	0.131	0.078	0.056	0.045	0.037	0.030	0.026	0.019	0.015	0.011
Sep	0.235	0.123	0.066	0.054	0.046	0.039	0.027	0.023	0.015	0.012

17.5 Confidence

The confidence is evaluated according to a score of 0 - 5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence. The confidence scores are summarised as follows:

0 (no confidence)	1 (low confidence)
2 (low to medium confidence)	3 (medium confidence)
4 (medium to high confidence)	5 (high confidence)

Results per component are shown in Table 17-3.

Table 17-3 Confidence ratings for EWR 5

Discipline	Ecoclassification	Available data	Suitability of EWR site	Flow requirements	
				High	Low
	Confidence	Confidence	Confidence	Confidence	Confidence
Hydrology	2	1			
Hydraulics		1	4	2	3
Geomorphology	4	2	1	2	N/a
Water quality	1	1			
Riparian vegetation	3	2	2	2	N/a
Aquatic invertebrates	2	2	2	3.5	3.5
Fish	2	3	2	3	3

Confidence explanations:

Hydraulics: Measured flow of 0.016m³/s. No measured moderate and high flow data. Recommended low flows are in the range 0 to 0.008m³/s and high flows in the range 0.3 - 1.9m³/s (within year).

Geomorphology: The site is situated in a badly degraded reach of the Resource Unit, which is in a better state upstream. The EWR site did not provide morphological clues to flows for the upper reaches within the same resource and thus the confidence is low. The site has been modified from natural conditions and the morphology is unlikely to represent the adjustment to present flows. There is a low confidence in high flows as no daily hydrological data and low confidence hydraulic data is available. The site is unrepresentative of the reach and is highly disturbed (further disturbance due to trampling and grazing happened after site selection).

Water quality: Confidence is low due to the limited data (n = 3; monthly monitoring February to May 2003).

Riparian vegetation: Available data was confined to one site visit. The site was badly degraded and consequently the confidences for the high flows and site value were low. A reasonable understanding of the reference and present day conditions provided medium confidence for the ecoclassification. Checking of the low flows against those established for fish was difficult due to confusing low flow cues at the site resulting in low confidence.

Fish: This site was an unsuitable habitat for fish, and a survey was undertaken 1km upstream of the site. Good historical data was available but sampling was limited. Flood classes were based on the upper, less disturbed reach. The confidence in the fish data and requirements was therefore higher than the information linked to the IFR site, i.e. Ecoclassification and suitability of EWR site.

Aquatic invertebrates: This site had a diversity of habitats. The reference condition was difficult to assess as there is no historic data available and only one sampling was undertaken. The confidence was therefore low to medium; apart from the flow requirements; which were higher. Flows were set in terms of fish and requirements were therefore higher than that requested for aquatic invertebrates.

18 EWR 6 – SWART RIVER: ECOCLASSIFICATION

18.1 Reference conditions

18.1.1 Geomorphology

This site is located on an alluvial cobble/gravel bed reach with a flood bench extending across a narrow valley floor between steep valley side slopes. Upstream the valley narrows and the channel gradient steepens. The gradient of the site is approximately 0.0133 (important: This includes the higher gradient section upstream) which places it in the upper foothills category. Flood frequency characteristics would be similar to those described for EWR 1, although this is a much smaller river. Sediment delivered to the channel by tributaries would consist primarily of coarse gravel. Evidence from a series of aerial photographs, since 1942, suggest that the reference condition for this site is a narrow, meandering, single thread channel (probably displaying pool-riffle morphology) with secondary channels probably activated during floods. The riparian vegetation in 1942 was probably mixed woody scrub and grass that would have stabilised channel platform.

18.1.2 Riparian vegetation

The reference condition at the site is characterised by valley bushveld on the left bank. *Podocarpus*, *Maytenus*, *Diospyros spp.*, occur in the riparian zone. Palmiet, *Miscanthus* and sedges are dominant in the marginal zone. Exotic species are absent.

18.1.3 Water quality

The default boundary tables were used for Reference Condition as no suitable data were available. Note that the PES assessment for this stretch of the river was based on professional judgement only as no data exists for this upper portion of the river.

18.1.4 Fish

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Swart/Rondebos River at EWR 6, although eels are expected in low numbers only:

- *Pseudobarbus afer*
- *Sandelia capensis*
- *Anguilla mossambica*
- *Anguilla marmorata*
- *Anguilla bicolor bicolor*

18.1.5 Aquatic invertebrates

This site is not considered to be significantly altered from natural. The expected reference fauna and SASS5 scores are similar to those recorded on site. However, the low flows (reportedly due to low summer rainfall) have led to a slight reduction in diversity and abundance of particular taxa.

Taxa that would be expected at this site in a natural condition could include (at least) Heptageniid and Tricorythid mayflies, a greater number of baetid mayfly species, Chlorocyphid dragonflies, Veliid hemipterans, Pissulid caddisflies, Psephenid beetles, Dixid and Tipulid dipterans, and Lymnaeid and Physid gastropods.

18.2 Present Ecological State (PES)

18.2.1 Habitat Driver PES

The hydrology PES (A) and geomorphology PES (C) information is available in Appendix A and Appendix B respectively. Water quality PES was assessed to be in an A/B category and the overall A/B category is given in Table 18-1 below.

The reasoning for the geomorphology category (C) is provided below.

PES	Causes	Sources	Flow/Non flow related
C	Bank and flood zone instability.	Black Wattle.	Non flow related.

Table 18-1 Habitat driver category for EWR 6

Components	Weighted driver score
GEOMORPHOLOGY	18.42 (C)
HYDROLOGY	52.28 (A)
WATER QUALITY	19.10 (A/B)
Weighted driver status (%)	89.80
HABITAT DRIVER CATEGORY	A/B

18.2.2 Biological response PES

18.2.2.1 Riparian vegetation (D)

The PES is largely due to the invasion of Black Wattle at the site and the associated exclusion of indigenous vegetation.

PES	Causes	Sources	Flow/Non flow related
D	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in vegetation cover and abundance.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.
	Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Non flow related.

18.2.2.2 Fish (C)

Only *Micopterus salmoides* (n = 12) found at this site, and in surprisingly high densities in marginal habitat in this small stream. Apart from the serious impact of predation by bass in this reach, flow related and non-flow related impacts in sections of this Resource Unit will vary from low to moderate in the upper reaches to critical in the lower reaches. The PES was assessed, by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes caused by alterations to the habitat drivers. Taking the impact of alien predatory fish into account will reduce the PES to a category E or F due to the apparent total elimination of indigenous fish.

PES	Causes	Sources	Flow/Non flow related
D	Flow modification – smaller low flows for longer periods.	<ul style="list-style-type: none"> Farmer abstracting flows from river mainly via catchment dams. Thirsty alien trees in riparian zone and upper catchment. 	Flow related.
	Increased sediment input, reducing pool depths, silting up riffles.	Roads, cattle trampling, bad agricultural practices, bank collapse, alien trees in riparian zone.	Non flow related.

18.2.2.3 Aquatic invertebrates (B)

The fauna at this site was considered to be close to a natural state. The habitat diversity was high, with areas of stones in flow, marginal vegetation, runs and small pools. The high water quality, close-to-natural hydrology, and plentiful, diverse habitat favours a community with a relatively high sensitivity (ASPT > 5.5) and with the majority of expected invertebrate families present at low abundances. The SASS scores of > 170 and number of taxa present (31) further illustrate its 'good' condition. In its present state, this site could be considered a reference site for the system.

PES	Causes	Sources	Flow/Non flow related
B	Abstraction.	Small amount of pumping for farming activities.	Flow related.
	Low disturbance to water quality.	Farming activities.	Non flow related.

18.2.3 Instream PES (B/C)

The Instream PES is summarised in Table 18-2.

Table 18-2 Instream PES for EWR 6

Criteria	Rating (0=low, 5=high)				
	Conf Rating	Ave	Weight	PES	Category
Availability of high confidence fish information	3				C
1 Diversity of fish species with different flow requirements	2				
2 Diversity of fish species with a preference for different cover types	2				
3 Diversity of fish species with a preference for different flow depth classes	2				
4 Diversity of fish species with various tolerances to modified water quality	2	2	0.43	77.9	C
Availability of high confidence invertebrate information					B
5 Diversity of invertebrate biotopes	3				
6 Diversity of invertebrate taxa with different velocity requirements	3				
7 Diversity of invertebrate taxa with different tolerances to modified water quality	2	2.67	0.57	82.1	B
		4.67	1	80.3	B/C

18.2.4 PES Ecostatus (B)

The Ecostatus is summarised in Table 18-3.

Table 18-3 Summary of the Ecostatus for EWR 6

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		3		
Fish: What is the general level of trophic specialisation?		2		
What is the general level of habitat specialisation?		3		
What is the general level of flow intolerance?		3	2.75	0.49
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3.5		
How sensitive are hydraulic habitats to flow change? ¹		3		
How sensitive is water quality to flow change?		2	2.83	0.51
Total			5.58	1
PES	80.32	Category		
INSTREAM CATEGORY		B/C		
DRIVER CATEGORY	89.8	A/B		
ECOSTATUS	85.13	B		

¹ This rating is applicable to low flows

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F

Table 18-4 Summary of the PES categories for EWR 6

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	A	A/B (B)	B
GEOMORPHOLOGY	C		
WATER QUALITY	A/B (B)		
Response components	Component PES	Instream PES	
FISH	C	B/C (B)	
AQUATIC INVERTEBRATES	B		
RIPARIAN VEGETATION	D	D	

18.2.5 Trends

Geomorphology – Negative within category.

Vegetation – Negative.

Fish – Stable.

Aquatic Invertebrates – Stable.

Note: Clearing of alien vegetation could have a stabilising (halt trend) effect at this site and possibly improve the trend. The removal of alien fish could have the same effect as the clearing of alien vegetation.

18.3 Importance

18.3.1 Ecological Importance and Sensitivity

The EIS was rated as moderate (present). There are rare fish species (*P. afer*) and invertebrate families (Teloganodidae) present as well as good invertebrate taxon richness and the presence of Notonemouridae (unique sp.). There are also invertebrate families present that are intolerant to flow changes and flow related water quality changes. Habitat types include pools, riffles and backwaters.

18.3.2 Socio-cultural Importance

Land use for Resource Unit H (Segment 1– 3, EWR 6: Segment 1) consists of formal rural settlements with limited dependence on the river.

The SI was rated as low and the confidence was medium.

18.4 Range of Ecological Categories

18.4.1 Recommended Ecological Category (REC)

Due to the moderate EIS and low SI and taking into account that the PES is in a B category, the REC was set to maintain the PES.

18.4.2 Alternative Ecological Categories

Only one alternative category, a C is considered. The situation for a C category is described below.

Riparian vegetation has a negative trajectory and the geomorphological response will be a widening channel that has less depth and is incised. This will result in a decrease within the geomorphology category. No foreseen decrease in the hydrology category is expected unless a dam is built upstream, which would impact on the flood regime. The general assumption is that water quality will drop a category, mainly the components oxygen, temperature and turbidity (which is the most sensitive for the fish and invertebrates at this site).

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios; the matrices that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

The EC results for the components and the Ecostatus is provided in Table 18-5.

Table 18-5 Summary of the Alternative Ecological Category for EWR 6

Driver Components	Component EC	Driver EC	ALTERNATIVE ECOSTATUS
HYDROLOGY	B	B/C (B)	C
GEOMORPHOLOGY	D		
WATER QUALITY	B/C		
Response components	Component EC	Instream EC	
FISH	D	C/D (C)	
AQUATIC INVERTEBRATES	C		
RIPARIAN VEGETATION	D	D	

The integrated rule-based model results are available in Appendix J for the alternative EC.

19 EWR 6 – SWART RIVER: STRESS INDICES

19.1 Stress index: Fish

The indicator species is *Pseudobarbus afer*, which is a semi-rheophilic species. This species requires flowing water for spawning in riffle areas where it needs fast-shallow habitat (i.e. depths of over 10 to 15 cm and velocities of >0.3 m/s). This species is sensitive to water quality and requires flow especially during the wet season, but can tolerate short periods of no flow.

Availability of cover in the form of undercut banks and overhanging vegetation is available at fairly low flows mainly in the pools, but aquatic macrophytes only become available to the fish at higher flows.

The lack of cover at low flows led to higher stress, due to increased predation at low flows. Water quality is thought to deteriorate in this stream at low flows (higher temperatures, lower DO, algal growth, iron bacterial growth) as well as a decrease in food abundance. This is more serious in this river at this site due to high organic matter (leaf-litter, organic benthic material) present in slow flow areas as well as lack of deep pools (>1.0m). This will result in low DO levels and high temperatures at low flows.

Fast-shallow riffle habitats thus required for spawning in summer, while critical preferred habitats are slow deep and slow shallow with sufficient shelter from predation (substrate, undercut banks, overhanging vegetation). Habitat suitability, from which species stress is derived, is shown in Table 19.1.

Table 19-1 Habitat suitability at EWR 6

	FLOW (m ³ /s)				
	0.20	0.100	0.050	0.006	0.001
RELATIVE ABUNDANCE OF FLOW-DEPTH & COVER RATING:					
0=NONE; 1=RARE; 2=SPARSE; 3=MODERATE; 4=ABUNDANT; 5=VERY ABUNDANT					
FAST DEEP	1	0.0	0.0	0.0	0.0
Overhanging vegetation	1.0	0.0	0.0	0.0	0.0
Undercut banks & root wads	1.0	0.0	0.0	0.0	0.0
Substrate	0.0	0.0	0.0	0.0	0.0
Aquatic macrophytes	1.0	0.0	0.0	0.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0
FAST SHALLOW	4.0	3.0	2.0	1.0	0.0
Overhanging vegetation	3.0	3.0	2.0	2.0	0.0
Undercut banks & root wads	4.0	3.0	3.0	2.0	0.0
Substrate	3.0	3.0	3.0	2.0	0.0
Aquatic macrophytes	4.0	3.0	3.0	2.0	0.0
Water column	0.0	0.0	0.0	0.0	0.0
SLOW DEEP	4.0	4.0	4.0	3.0	2.0
Overhanging vegetation	5.0	5.0	5.0	4.0	3.0

Undercut banks & root wads	5.0	5.0	5.0	4.0	3.0
Substrate	1.0	1.0	1.0	1.0	1.0
Aquatic macrophytes			2.0	1.0	1.0
Water column	4.0	4.0	3.0	2.0	2.0
SLOW SHALLOW	3.0	4.0	4.0	5.0	4.0
Overhanging vegetation	5.0	5.0	4.0	4.0	3.0
Undercut banks & root wads	5.0	5.0	5.0	4.0	3.0
Substrate	2.0	2.0	2.0	2.0	1.0
Aquatic macrophytes	4.0	3.0	2.0	2.0	1.0
Water column	0.0	0.0	0.0	0.0	0.0
FLOW	0.20	0.10	0.05	0.01	0.00
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD					
SEMI-RHEOPHILIC	<i>P. afer</i>				
Breeding and early life-stages	5.0	5.0	3.0	1.0	0.0
Survival /Abundance	5.0	5.0	4.0	2.0	1.0
Cover	5.0	4.0	3.0	2.0	1.0
Health and condition	5.0	5.0	4.0	2.0	1.0
Water quality	5.0	5.0	4.0	2.0	1.0
Rheophilic stress - (breeding requirements included)	0.0	0.4	2.8	6.4	8.4
Flow-depth converted to habitat response (10=All flow-depth classes absent (River dry); 0=Flow-depth classes optimum for site; 9=No flow)	0.20	0.10	0.05	0.01	0.00
Fast deep	8.0	10.0	10.0	10.0	10.0
Fast shallow	2.0	4.0	6.0	8.0	10.0
Slow deep	2.0	2.0	2.0	4.0	6.0
Slow shallow	4.0	2.0	2.0	0.0	2.0
OVERALL HABITAT RESPONSE	4.0	4.5	5.0	5.5	7.0

19.2 Stress index: Aquatic invertebrates

This site is in relatively good condition. Perlid stoneflies serve as indicators of very fast flow conditions, good water quality and inundated cobble habitat with surface flows. As flow is reduced, habitat depth reduces rapidly, and the SIC biotope will disappear, further impacting on the aquatic invertebrates with even a marginal preference for swift or moderately fast flows (Hydropsychids, Simuliids). Populations of Leptophlebiids and other mayflies will diminish in number at flows less than 0.01m³/s. Increases in flows will correspond to rapid increases in inundated areas of marginal vegetation, and the likelihood of increased diversity in the invertebrate community, particularly Coleopterans, Hemipterans and Odonata.

Table 19-2 Stress table – Flow dependant invertebrate at EWR 6

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE		
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present	Flow	Community stress
Rating (site at observed flow)	3	1	1	2	4	11	3	1					
0	4	3	4	3	5	19		0.2	All available habitat in excess, high quality: mix of moderate, fast or very fast, deep, wide wetted perimeter (WP).	Max depth 0.28 Av depth 0.151 Area 0.39 Width 2.56 WP 2.81 Av velocity 0.502	All very abundant, All healthy, all species persist	0.2	0
1	3	3	3	3	4	16		0.1	Most plentiful, VIC reduced, mostly high quality; very fast, fast and moderate, mix of depth classes, wide WP.	Max depth 0.24 Av depth 0.126 Area 0.29 Width 2.31 WP	All abundant, All healthy, all species persist	0.1	1

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE Using the full community of aquatic invertebrates present	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵								
										2.54 Av velocity 0.379			
2	3	3	3	2	4	15		0.05	Critical stones habitats sufficient; quality slightly reduced; fast and very fast, deep, wide, WP slightly reduced.	Max depth 0.2 Av depth 0.099 Area 0.2 Width 2.05 WP 2.26 Av velocity 0.252	Slight reduction for sensitive rheophilic species, All healthy in some areas, all species persist	0.05	2
3	3	2	2	2	3	12		0.016	Reduced critical and VIC habitat, reduced critical quality; moderate and fast velocity, moderately deep, WP slightly/moderately reduced.	Max depth 0.16 Av depth 0.074 Area 0.13 Width 1.72 WP 1.92 Av velocity 0.126	Reduction of all rheophilic species, all healthy in limited areas, all species persist		3
4	2	3	1	2	3	11		0.0031	SIC reasonably abundant, of good quality, VIC and	Max depth 0.12 Av depth	Further reduction for rheophilic species (Perlidae, Simuliidae);		4

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE Using the full community of aquatic invertebrates present	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵								
									VOOC reduced, mostly slow with some moderately fast areas.	0.045 Area 0.06 Width 1.44 WP 1.63 Av velocity 0.049	viable in SIC areas, critical life stages of some sensitive rheophilic species at risk, all species persist.		
5	2	3	1	1	2	9			Critical stones habitat reduced; VIC low quality; mix of velocity classes, some deep areas, WP moderately/very reduced		Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic taxa (Perlids, Simuliids, Hydropsychids) at risk; most species persist.	0.0055	5
6	2	2	1	1	2	8		0.0013	Critical habitat (SIC, SOOC, MV) very reduced. Reduced quality; low velocity, limited deep areas. Moderate WP.	Max depth 0.1 Av depth 0.037 Area 0.04 Width 1.09 WP 1.25 Av velocity	Sensitive rheophilic species rare, critical stages of sensitive species (Perlidae) becoming non-viable due to water quality impairment, risk for some less sensitive species. Most species persist in the short-term.		6

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE Using the full community of aquatic invertebrates present	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵								
										0.031			
7	1	2	1	1	2	7		0.0004	Very reduced critical habitat, Other habitats of low quality; shallow, moderate WP.	Max depth 0.08 Av depth 0.029 Area 0.02 Width 0.75 WP 0.87 Av velocity 0.019	Rheophilic taxa rare; all life-stages of sensitive rheophilic species at risk or non-viable. Sensitive rheophilic species will disappear with sufficient duration of these conditions.		7
8	1	1	1	1	2	6		0.0001	Flowing water habitats residual. Low quality: slow trickle, small WP.	Max depth 0.06 Av depth 0.027 Area 0.01 Width 0.41 WP 0.47 Av velocity 0.009	Remnant populations of some rheophilic species; most life stages of mayflies diminishing in number, Leptophlebiids threatened.	0.0004	8
9	0	1	0	1	1	3		0	Standing water habitats only, very	Max depth 0.04	Mostly pool dwellers, most life stages of	0	9

Habitat Flow Response Index	Habitat abundance and suitability					Total	Modifier	Flow	HABITAT RESPONSE	HABITAT CHARACTERISTICS (Hydraulic parameters as measured by Dr Birkhead)	BIOTIC RESPONSE	Flow	Community stress
	SIC ¹	SOOC ²	VIC ³	VOOC ⁴	GSM ⁵						Using the full community of aquatic invertebrates present		
									low quality, no flow. SOOC, GSM and little MV are only available habitat.	Av depth 0.019 Area 0.0 Width 0.24 WP 0.27 Av velocity 0.003	most rheophilic species non-viable; Leptophlebiids likely to disappear.		
10	0	0	0	0	0	0			Only hyporheic refugia, no surface water.		No invertebrates likely.	0	10

- (1) SIC: Partially submerged hard substrate in current >0.1m/s
- (2) SOOC: Partially submerged hard substrate in current <0.1m/s
- (3) VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1m/s
- (4) VOOC: Submerged vegetation (at least 2-3cm submerged) in current <0.1m/s
- (5) GSM: Small particles submerged

19.2.1 Integrated stress curve

The individual component stresses are illustrated in Figure 19-1 as well as the integrated stress line (black line).

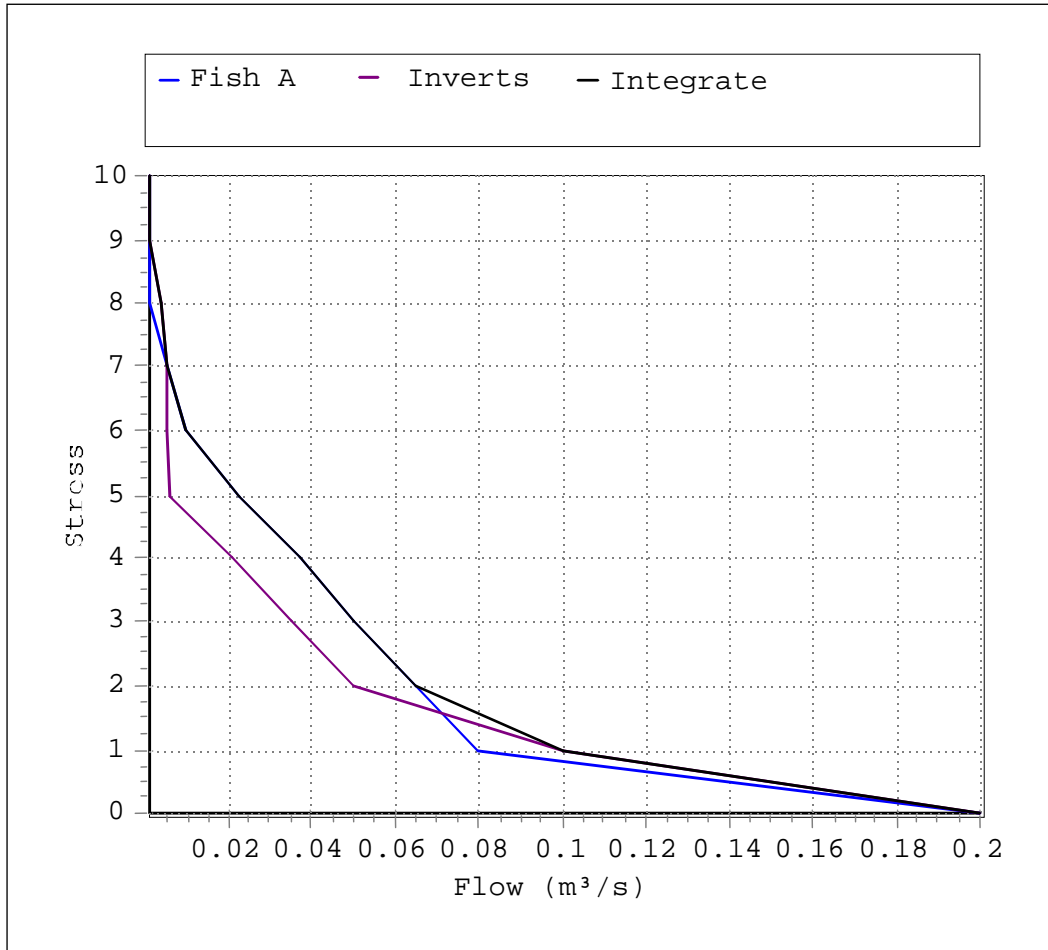


Figure 19-1 Component and Integrated Stress Curves for EWR 6

20 EWR 6 – SWART RIVER: DETERMINATION OF EWR SCENARIOS

20.1 Low flow requirements

The integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month/season. Drought flows were set as 95 to 100% assurance (i.e. stress durations of 5 to 0%) and, based on the hydrological characteristics, maintenance flows were set as 70% assurance (i.e. stress durations of 30 %). Integrated stress curves are shown as figures 20-1 and 20-2.

Dry season (January B category)

Wet season (August B category)

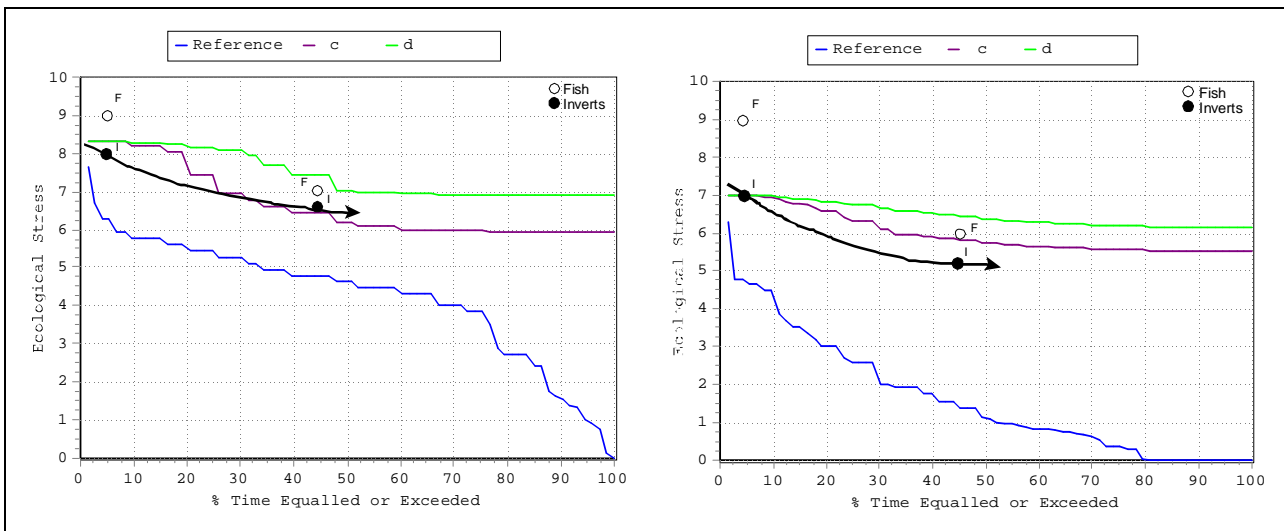


Figure 20-1 EWR 6 – Stress duration curve for a B REC

Dry season (January C category)

Wet season (August C category)

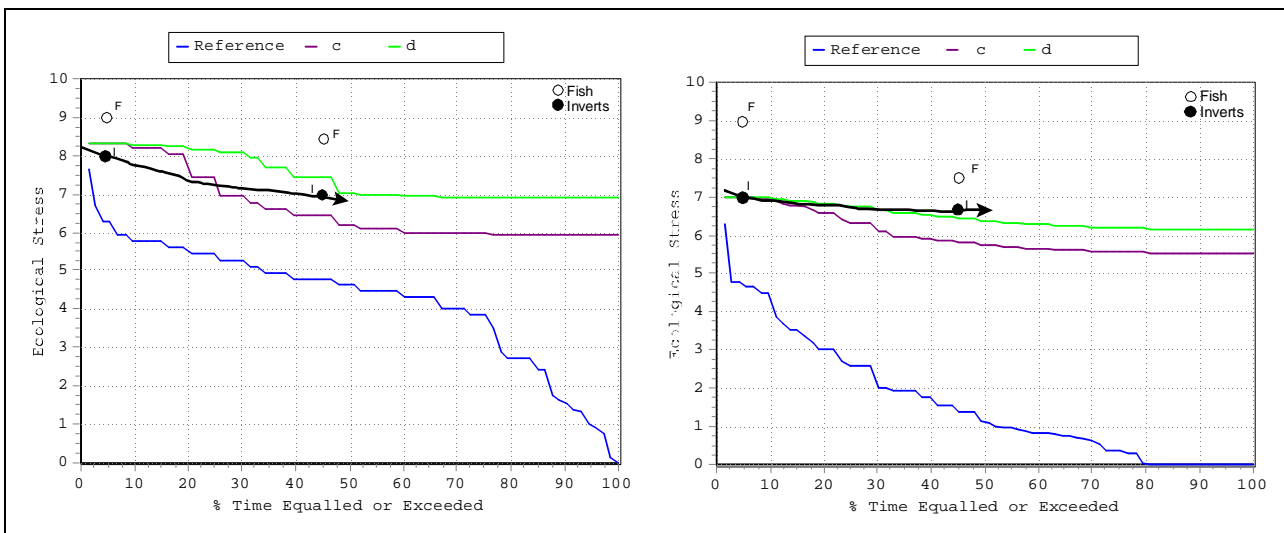


Figure 20-2 EWR 6 – Stress duration curve for an alternative scenario of a C EC

20.1.1 Stress duration motivations: Fish

Note – this motivation is similar for all EWR sites due to use of the same indicator species, *P. afer*.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: <i>Pseudobarbus afer</i> The indicator is a semi-rheophilic species, which is dependant on the flow for breeding in riffles at suitable velocities and depths. Note that peak spawning activities take place in Spring (September to December) and possibly some limited spawning in late summer, but that main spawning requirements for species in terms of stress requirements are included in wet season.</p>
FISH STRESS REQUIREMENTS
DRY SEASON (January)
<p>DROUGHT: Stress of 9 or less for 5% of the time Fish confined totally to pool with limited cover available, poor water quality and limited food available.</p>
<p>MAINTENANCE (C): 45% of the time at a stress level of 7 Provides more cover and improved water quality and food.</p>
WET SEASON (August)
<p>DROUGHT: Stress of 9 or less for 5% of the time There is very limited breeding capability as in no shallow fast habitat remaining.</p>
<p>MAINTENANCE (C): 45% of the time at stress of 7.6 equalled or exceeded Providing some habitat for spawning and habitat slow shallow for larval growth. Sufficient cover and habitats, but limiting factor will be breeding habitat.</p>
<p>Indicator: <i>Pseudobarbus afer</i> Breeding thought to start in Spring (September to December) and need clean riffles plus suitable depths and velocities.</p>
<p>Juvenile: Feeding and growth: Mostly slow shallow habitat. Cover: Overhanging vegetation and emergent vegetation. Duration 3 - 4 months.</p>
<p>Adult: Cue: Increased temperature and flow.</p>

20.1.2 Stress duration motivations: Aquatic invertebrates

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
<p>Indicator: Aquatic Invertebrate community Taxa with a preference for very fast flows at this site are Philopotamid caddisflies and Perlid stoneflies. Indicators for moderate to fast flows are Hydropsychids, Elmids and Simuliids. The invertebrate fauna collected at this site is of relatively high diversity and the majority of taxa show moderate sensitivity to changes in habitat availability, flow and water quality.</p>
INVERTEBRATE STRESS REQUIREMENTS
DRY SEASON (January)
<p>DROUGHT: Stress of 8 or less for 45% of the time (critical stress 6.9) At the higher stresses there will be no SIC habitat; however the majority of the community will endure for short periods in SOOC and pool habitats. The more flow-sensitive taxa (particularly Perlids and Philopotamids) may disappear. As it is a summer month, a high stress for duration of 2 - 3 days (together with antecedent conditions) could affect the age-structure of the population, with significant losses of critical life stages of flow-dependent taxa. At a stress of 9, although there is zero flow, however there is likely to</p>

be fair surface water connectivity at this site due to its relatively low gradient. This will ensure survival of the more resilient elements of the fauna (at least 50% of observed fauna).

MAINTENANCE (B): Stress of 6.7 or less for 45% of the time (Critical stress 5.1)

During the high-stress periods there is likely to be a loss or reduction of taxa which are sensitive to loss of flow or deterioration in water quality. For at least half the time, there is sufficient flow for sufficient periods to maintain the majority of the community, although the community structure and age distributions may alter significantly if flow ceases (Stress 9) for a continuous period of up to two weeks.

MAINTENANCE (C): Stress of 7 or less for 45% of the time (Critical stress 7)

The river has enough flow for sufficient duration to ensure a healthy community of aquatic invertebrates, although the indicator taxa with a preference for moderate and high flow conditions will disappear if the stress is consistently high (5 - 7) continuously for periods of greater than 2 - 3 weeks, or higher (8 - 10) for periods of a few days. As this is midsummer this could affect the structure (and particularly the age structure) of the invertebrate community.

WET SEASON (August)

DROUGHT: Stress of 7 or less for 5% of the time (critical stress 8)

There is enough SOOC and pool habitat to maintain the majority of the late-winter invertebrate community (about 70%), during short periods of high stress. If flow reduction is followed by no-flow conditions which persist for longer than 2 - 3 days, the indicator taxa are likely to be eliminated or severely impacted. The effect of this will be a change in community structure and a reduction in the diversity of the breeding community in early summer, which relates to longer-term changes in the invertebrate biodiversity.

MAINTENANCE (B): Stress of 5 or less for 45% of the time (Critical stress 6.9)

The river has enough flow to ensure a healthy population of the more sensitive and flow-dependent components of the invertebrate community, and to ensure a viable breeding community. Availability and quality of summer breeding habitat is threatened if there is continual higher stress (>6 - 7) for longer than 2 weeks. The low stresses (4 and less) equate to flows which will maintain those taxa with preferences for moderate flows.

MAINTENANCE (C): Stress of 7 or less for 45% of the time (Critical stress 6.8)

The reductions in flow associated with higher stresses, although they are relatively small in this case, will have consequences for the community composition in early summer. Indicator taxa are likely to be excluded if stresses of 6 or more persist for longer than 3 - 5 days. A proportion of the breeding community will be absent, and juveniles of even moderately sensitive taxa will be threatened as flows reduce further. The more resilient taxa are likely to relocate to pools and SOOC habitats as flow decreases, and at least 50% of the community should endure.

20.2 Final low flow requirements

The following adjustments to the Desktop Reserve Model B requirements had to be made to fit the specialist requirements. Figure 20-3 shows the final curve for this site.

- The Desktop Reserve Model provided 14.6 % of the virgin MAR for the Maintenance Low Flow (MLF) for the B EC.
- The Desktop Reserve Model provided 3.2% of the virgin MAR for the droughts.
- The MLF was decreased from the Desktop Reserve Model to 12.3%
- The droughts were virtually the same.

Dry season (January)

Wet season (August)

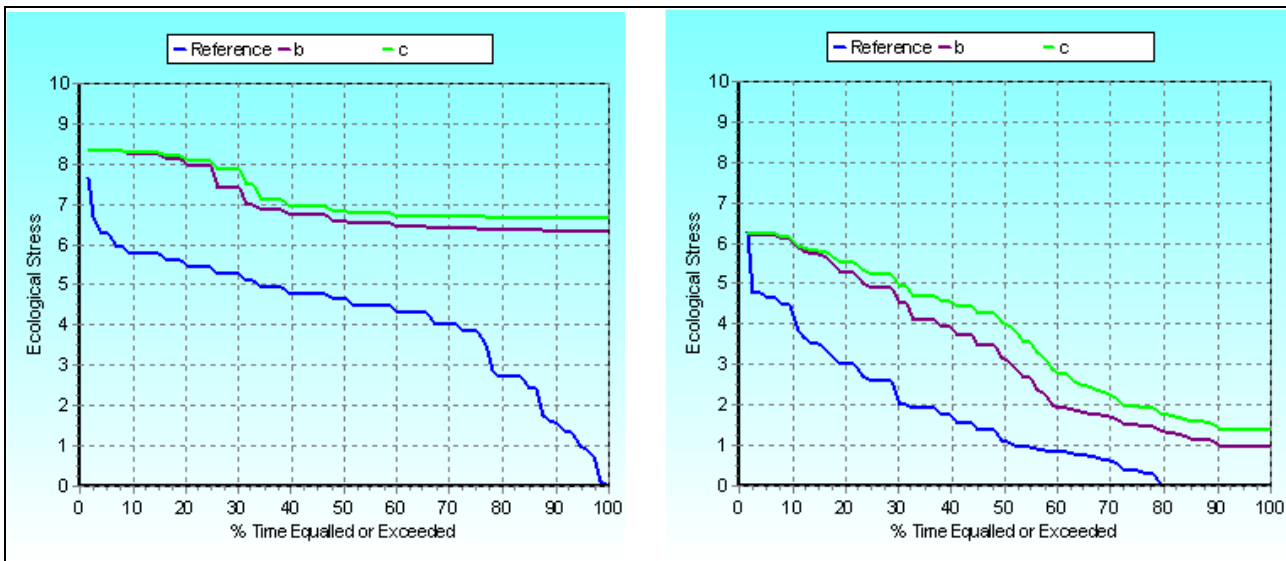


Figure 20-3 EWR 6 – Final curve

20.3 High flow requirements

The functions for each Flood Class are described in spreadsheets (Appendix I). A summary of the flood class ranges and the recommended high flow events for EWR 6 is shown in Table 20-1.

Table 20-1 Flood class ranges, and the recommended high flow events for each scenario at EWR 6

Component	Flood classes (m ³ /s)				
	I	II	III	IV	V
Fish	0.1 - 0.2	0.4 - 0.6			
Invertebrates	0.2 - 0.3	0.3 - 0.5			
Vegetation		0.05 - 0.6	0.6 - 3.5	3.5 - 13	
Geomorphology		0.15 - 0.4		3 - 7.5	7.5 - 27
Integrated	0.2 - 0.3	0.4 - 0.6	0.6-3.5	3.5 - 13	13 - 27
Daily average		0.3	0.6	2	
Duration (days)		1	2	2	

The number of high flow events required for each EC is provided in Table 20-2.

Table 20-2 The recommended number of high flow events required for each EC at EWR 6

Flood classes	NUMBER OF EVENTS: EC B						NUMBER OF EVENTS: EC C					
	Invert	Fish	Veg	Geom	INTEG ¹	FINAL	Invert	Fish	Veg	Geom	INTEG ¹	FINAL
Class I	3	4			4		2	2			2	
Class II	2	2	6	5	6	6	1	1	6	5	6	6
Class III			1		1	1			1		1	1
Class IV			1:3	1	1	1			1:3	1:2	1:2	1:2
Class V				1:2.5	1:2.5	1:2.5						

⁽¹⁾ Integ = Integrated

These results were checked with the hydrology and were found to be acceptable.

20.4 Final results

Note: The model output refers to IFRs, which reflect the flow component of EWR (the other being quality).

B category:

The results are summarised as follows as well as providing a comparison with the Desktop Reserve Model.

	Desktop Reserve Model	2004 requirements
MLF (B)	14.6	12.3
High flows (B)	14.4	12
Droughts (B)	3.2	3.3
Long Term mean (B)	25.5	21.9
MLF (C)	8.2	5
High flows (C)	11.2	10.4
Droughts (C)	3.2	3.3
Long Term mean (C)	18.7	15.5

20.4.1 IFR tab table for REC: B

Note: The IFR table generated from the Desktop Reserve Model and the IFR assurance rule tables. The low flows in the table are therefore not specific values set, but those derived from the stress requirements. The high flows are according to those specified.

Desktop Version 2, printed on 2004/09/23

Virgin MAR (MCM): 3.93

BFI index: 0.26

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows	
			Average daily (m ³ /s)	Durations (days)
October	0.022	0.006	0.3	1
November	0.02	0.005	0.3	1
December	0.15	0.004		
January	0.007	0.003		
February	0.007	0.003		
March	0.010	0.003		
April	0.011	0.002		
May	0.014	0.004	0.3	1
June	0.016	0.004	0.3	1
July	0.016	0.004	0.3	1
August	0.021	0.005	0.3; 0.6	1; 2
September	0.025	0.006	2	2

20.4.2 IFR assurance rules for REC: B

Desktop Version 2, Printed on 2004/09/23

Summary of IFR rule curves for: Kromme_6 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: S.Karoo EC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.046	0.043	0.039	0.035	0.029	0.024	0.019	0.013	0.008	0.007
Nov	0.035	0.034	0.033	0.031	0.028	0.023	0.018	0.012	0.007	0.006
Dec	0.018	0.018	0.017	0.016	0.015	0.012	0.010	0.007	0.005	0.004
Jan	0.008	0.008	0.008	0.008	0.007	0.006	0.005	0.004	0.003	0.003
Feb	0.008	0.008	0.008	0.008	0.007	0.006	0.005	0.004	0.003	0.003
Mar	0.012	0.012	0.011	0.011	0.010	0.008	0.007	0.005	0.003	0.003
Apr	0.013	0.013	0.012	0.012	0.010	0.009	0.006	0.004	0.003	0.002
May	0.037	0.033	0.030	0.027	0.021	0.018	0.014	0.009	0.006	0.004
Jun	0.040	0.036	0.033	0.029	0.023	0.019	0.015	0.010	0.006	0.004
Jul	0.039	0.036	0.032	0.029	0.023	0.019	0.015	0.010	0.006	0.005
Aug	0.102	0.089	0.078	0.067	0.049	0.041	0.030	0.019	0.011	0.009
Sep	0.225	0.193	0.165	0.134	0.097	0.080	0.058	0.037	0.021	0.016

Reserve flows without High Flows

Oct	0.026	0.026	0.025	0.024	0.021	0.018	0.014	0.010	0.007	0.006
Nov	0.024	0.023	0.023	0.021	0.019	0.016	0.013	0.009	0.006	0.005
Dec	0.018	0.018	0.017	0.016	0.015	0.012	0.010	0.007	0.005	0.004
Jan	0.008	0.008	0.008	0.008	0.007	0.006	0.005	0.004	0.003	0.003
Feb	0.008	0.008	0.008	0.008	0.007	0.006	0.005	0.004	0.003	0.003
Mar	0.012	0.012	0.011	0.011	0.010	0.008	0.007	0.005	0.003	0.003
Apr	0.013	0.013	0.012	0.012	0.010	0.009	0.006	0.004	0.003	0.002
May	0.017	0.016	0.016	0.015	0.014	0.012	0.009	0.007	0.005	0.004
Jun	0.019	0.019	0.018	0.017	0.015	0.013	0.010	0.007	0.005	0.004
Jul	0.019	0.019	0.018	0.017	0.015	0.013	0.010	0.007	0.005	0.004
Aug	0.025	0.025	0.024	0.022	0.020	0.017	0.013	0.009	0.006	0.005
Sep	0.030	0.029	0.028	0.027	0.024	0.020	0.016	0.011	0.007	0.006

Natural Duration curves

Oct	0.563	0.256	0.180	0.134	0.110	0.089	0.082	0.061	0.045	0.030
Nov	0.414	0.192	0.154	0.119	0.085	0.074	0.063	0.056	0.043	0.022
Dec	0.173	0.095	0.071	0.065	0.045	0.043	0.039	0.030	0.026	0.015
Jan	0.087	0.054	0.037	0.032	0.028	0.026	0.022	0.017	0.013	0.006
Feb	0.079	0.048	0.031	0.026	0.019	0.017	0.014	0.012	0.012	0.005
Mar	0.171	0.069	0.045	0.030	0.024	0.017	0.015	0.011	0.009	0.004
Apr	0.177	0.105	0.072	0.045	0.034	0.027	0.022	0.016	0.011	0.004
May	0.312	0.108	0.080	0.058	0.045	0.039	0.028	0.022	0.011	0.004
Jun	0.224	0.132	0.103	0.074	0.060	0.045	0.034	0.029	0.020	0.004
Jul	0.325	0.139	0.102	0.093	0.071	0.065	0.054	0.043	0.028	0.009
Aug	0.338	0.206	0.145	0.117	0.097	0.080	0.065	0.050	0.039	0.026
Sep	0.609	0.316	0.172	0.134	0.116	0.096	0.074	0.056	0.040	0.027

20.4.3 IFR table for alternative EC: C

Desktop Version 2, printed on 2004/09/23

Virgin MAR (MCM): 3.93

BFI index: 0.26

Distribution Type: S. Karoo

Months	MLF (m ³ /s)	DLF (m ³ /s)	High flows	
			Average daily (m ³ /s)	Durations (days)
October	0.009	0.006	0.3	1
November	0.008	0.005	0.3	1
December	0.006	0.004		
January	0.005	0.003		
February	0.004	0.003		
March	0.005	0.003		
April	0.005	0.002		
May	0.005	0.004	0.3	1
June	0.006	0.004	0.3	1
July	0.006	0.004	0.3	1
August	0.007	0.005	0.3; 0.6	1; 2
September	0.009	0.006	1.5	2

20.4.4 IFR assurance rules for alternative EC: C

Desktop Version 2, Printed on 2004/09/23

Summary of IFR rule curves for : Kromme_6 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: S.Karoo REC = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.032	0.029	0.026	0.023	0.018	0.016	0.013	0.010	0.008	0.007
Nov	0.022	0.022	0.022	0.020	0.019	0.016	0.013	0.009	0.007	0.006
Dec	0.008	0.008	0.008	0.008	0.007	0.006	0.006	0.005	0.004	0.004
Jan	0.007	0.007	0.007	0.006	0.006	0.005	0.005	0.004	0.003	0.003
Feb	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.003	0.003	0.003
Mar	0.007	0.007	0.007	0.006	0.006	0.005	0.005	0.004	0.003	0.003
Apr	0.007	0.007	0.006	0.006	0.006	0.005	0.004	0.003	0.002	0.002
May	0.027	0.024	0.021	0.018	0.014	0.012	0.010	0.007	0.006	0.004
Jun	0.029	0.026	0.023	0.020	0.015	0.013	0.010	0.008	0.006	0.004
Jul	0.028	0.025	0.022	0.019	0.015	0.013	0.010	0.008	0.006	0.005
Aug	0.086	0.074	0.063	0.054	0.037	0.031	0.024	0.016	0.011	0.009
Sep	0.158	0.135	0.114	0.096	0.065	0.054	0.041	0.027	0.016	0.013

Reserve flows without High Flows

Oct	0.012	0.012	0.012	0.011	0.011	0.010	0.008	0.007	0.006	0.006
Nov	0.011	0.011	0.010	0.010	0.009	0.009	0.007	0.006	0.005	0.005
Dec	0.008	0.008	0.008	0.008	0.007	0.006	0.006	0.005	0.004	0.004
Jan	0.007	0.007	0.007	0.006	0.006	0.005	0.005	0.004	0.003	0.003
Feb	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.003	0.003	0.003
Mar	0.007	0.007	0.007	0.006	0.006	0.005	0.005	0.004	0.003	0.003
Apr	0.007	0.007	0.006	0.006	0.006	0.005	0.004	0.003	0.002	0.002
May	0.007	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.004	0.004
Jun	0.008	0.008	0.008	0.008	0.007	0.006	0.006	0.005	0.004	0.004
Jul	0.008	0.008	0.008	0.008	0.007	0.006	0.006	0.005	0.004	0.004
Aug	0.009	0.009	0.009	0.009	0.008	0.008	0.007	0.006	0.005	0.005
Sep	0.012	0.012	0.012	0.011	0.011	0.010	0.008	0.007	0.006	0.006

Natural Duration curves

Oct	0.563	0.256	0.180	0.134	0.110	0.089	0.082	0.061	0.045	0.030
Nov	0.414	0.192	0.154	0.119	0.085	0.074	0.063	0.056	0.043	0.022
Dec	0.173	0.095	0.071	0.065	0.045	0.043	0.039	0.030	0.026	0.015
Jan	0.087	0.054	0.037	0.032	0.028	0.026	0.022	0.017	0.013	0.006
Feb	0.079	0.048	0.031	0.026	0.019	0.017	0.014	0.012	0.012	0.005
Mar	0.171	0.069	0.045	0.030	0.024	0.017	0.015	0.011	0.009	0.004
Apr	0.177	0.105	0.072	0.045	0.034	0.027	0.022	0.016	0.011	0.004
May	0.312	0.108	0.080	0.058	0.045	0.039	0.028	0.022	0.011	0.004
Jun	0.224	0.132	0.103	0.074	0.060	0.045	0.034	0.029	0.020	0.004
Jul	0.325	0.139	0.102	0.093	0.071	0.065	0.054	0.043	0.028	0.009
Aug	0.338	0.206	0.145	0.117	0.097	0.080	0.065	0.050	0.039	0.026
Sep	0.609	0.316	0.172	0.134	0.116	0.096	0.074	0.056	0.040	0.027

20.5 Confidence

The confidence is evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence. The confidence scores are summarised as follows:

0 (no confidence)	1 (low confidence)
2 (low to medium confidence)	3 (medium confidence)
4 (medium to high confidence)	5 (high confidence)

Results per component are shown in Table 20-3.

Table 20-3 Confidence ratings for EWR 6

Discipline	Ecoclassification	Available data	Suitability of IFR site	Flow requirements	
				High	Low
	Confidence	Confidence	Confidence	Confidence	Confidence
Hydrology	2	1			
Hydraulics		1	3	1	3
Geomorphology	4	4	3	2	N/a
Water quality	0.5	0.5			
Riparian vegetation	4	2	3	3	N/a
Aquatic invertebrates	3	2	3	4	4
Fish	3	3	2	3	3

⁽¹⁾ Note: Shaded blocks indicate where confidence is not applicable

20.5.1 Confidence explanations

Hydraulics: Measured flow of 0.0055m³/s. No measured moderate and high flow data. Recommended low flows are in the range 0.001 to 0.22m³/s and high flows in the range 0.3-1.3 (within year) to 27m³/s.

Geomorphology: Good morphological indicators are present to represent local conditions, but the confidence is reduced, because the site does not provide morphological clues to set flows for upper reaches within the same Resource Unit. Local flood knowledge was obtained from the farmer. Although there was good morphological data, there is low confidence in hydraulics and no data is available for flood hydrology.

Water quality: Confidence is low as the site was visited by the invertebrate specialist and the water quality assessment was based on her input. The water quality assessment was based in the lower Swart River catchment as the upper site was not visited by the team. The assessment is therefore based on expert judgement and biotic categories.

Fish: Critical habitats were represented at this site and were sampled; however this site is not representative of the reach. There was good historical data available but the alien species have predated on all the indigenous fish. Confidence is reasonable in the output as the invertebrate requirements are driving the system.

Aquatic invertebrates: There was good diversity of habitat but this site was sampled only once and therefore biotic data is limited. This site is close to reference condition and was easier to assess as the hydrology was better understood.

Riparian vegetation: Available data was confined to one site visit. Low flow output was in terms of fish. Checking of these flows against those established for fish and invertebrates was difficult due to confusing low flow cues at the site; resulting in low confidence. A reasonable understanding of the reference and present day conditions provided medium confidence for the ecoclassification. While high flow cues were present these only provided medium confidence to the assessment.

21 CONCLUSIONS AND RECOMMENDATIONS

21.1 Ecoclassification

21.1.1 Results

The results are summarised in the following table

EWR sites	Driver PES	Instream PES	Ecstatus PES	Ecstatus trend	EIS	SI	REC	Alternative scenario
EWR 1	C	C	C	Stable	Moderate	Low	C	D
EWR 2	D/E	C/D	D	Stable	Moderate	Low	D	-
EWR 3	D/E	E	D/E	Stable	High?	Low	D	-
EWR 4	C/D	D	C/D	Stable	Moderate	Moderate	C/D	-
EWR 5	C	D	C	Stable	Moderate	Low	C	
EWR 6	A/B	B/C	B	Stable	Moderate	Low	B	C

The Kromme River upstream of the dams (Churchill and Impofu) is in a C state with most of the problems being associated with the presence of alien vegetation, alien fish and upstream land use. This is however the best section of the Kromme River and should not be allowed to degrade further.

The section downstream of the Churchill Dam is affected by severely decreased flow and an abnormal flow regime as well as the presence of alien vegetation and fish. The same is true for the section downstream of Impofu Dam. The lack of releases and abstractions from the downstream pool, have exacerbated the situation. This section of river, although short, is very important as it forms the only freshwater link between the marine, estuarine and freshwater environments. During most of the year, no link is possible with the freshwater environment due to the lack of releases and the abstraction from the pool.

The PES categories for both EWR 5 and 6 are representative of the upstream sections of the Seekoei and Swart rivers. In both cases the downstream sections have been severely modified and in some cases, there are no river left as the dams form a continuum. It must also be noted that in the case of EWR 5, the river is in a better condition further upstream.

21.1.2 Confidence

The confidence in the ecoclassification is summarised as follows, and is shown on tables 21-1 and 21-2.

0 (no confidence)	1 (low confidence)
2 (low to medium confidence)	3 (medium confidence)
4 (medium to high confidence)	5 (high confidence)

Table 21-1 Confidence – Availability of data

EWR site	Hydrology	Geomorphology	Water quality	Vegetation	Aquatic invertebrates	Fish	OVERALL
1	1	3	1	2	3	3	2 – 3: Low to medium confidence
2	1	2	1	2	2	3	2: Low confidence
4	1	2	1	1	1	1	1: Low confidence
5	1	2	1	2	2	3	2: Low confidence
6	1	4	0.5	2	2	3	2: Low confidence

Table 21-2 Confidence – Ecoclassification

EWR site	Hydrology	Geomorphology	Water quality	Vegetation	Aquatic invertebrates	Fish	OVERALL
1	2	4	1	4	3	2	2 – 3: Low to medium confidence. Note that the drivers, especially hydrology, will carry a higher weight than the responses.
2	2	3	1	3	2	2	2 – 3: Low to medium confidence. The geomorphology weighting increases the overall evaluation, as the drivers carry a higher weight than the biological responses.
4	2	3	1	3	1	1	1 – 2: Low confidence.
5	2	4	1	3	2	2	2 – 3: Low to medium confidence. The confidence is higher than the average due to the higher weight that would be allocated to geomorphology.
6	3	4	0.5	4	3	2	3 – 4: Medium to high confidence. The low water quality confidence does not carry as much weight as water quality problems can be derived through fish and invertebrate responses.

From Table 21-1 it is clear that the data availability is poor. This will effect the confidence evaluation of the Ecoclassification results, as Ecoclassification is based and derived on available data. The lack of data and resulting lack of understanding of the system is centred around the reduced confidence in the hydrology and the lack of understanding as to whether the system was perennial or seasonal, and if it has been modelled as being much wetter than it would normally be. Reference conditions for biota is dependent on this understanding, and this factor, combined with the lack of historical data and the minimal present day surveys undertaken, results in a lack of confidence in reference conditions and therefore a lack of confidence in the degree of change

under present conditions. The dearth of water quality data further compounds the general uncertainty.

EWR 1 and 4 have the lowest confidence evaluation due to the uncertainty around the perenniality of the system. The confidence increases for EWR 5 and 6 as the perennial sites are far upstream in the system.

21.1.3 Recommendations

No additional work will improve the hydrological modelling due to the lack of gauges in the system and the dearth of historical hydrological data. It is therefore more important to implement a monitoring programme targeted towards water quality, fish and aquatic invertebrates to ensure that the presence/absence of biota is clearly understood. For example, in this case it is not so important to know with accuracy whether fish is in a C or a D state, as long as the species present is known so that the flow requirements for those species can be checked or refined if necessary.

21.2 EWR: Flow component

21.2.1 Results

EWRs represent the flow component of the Ecological Reserve. The results are summarised in the following table as a percentage of the virgin MAR. It must be noted that these percentages must be used with caution due to the uncertainty of the naturalised hydrology. If the hydrology is re-assessed and the natural hydrology changes, then the EWR percentages may be different.

EWR site	REC	Maintenance low flows (%)	Drought low flows (%)	High flows (%)	Long term mean of VMAR (%)
EWR 1	C	13.76	1.93	15.94	29.7
EWR 2	D	3.13	0.57	10.95	14.08
EWR 4	C/D	5.76	1.02	11.38	17.14
EWR 5	C	12.17	2.07	11.25	23.43
EWR 6	B	12.32	3.28	11.95	24.27

21.2.2 Confidence

Confidences for low and high flow assessments are shown in tables 21-3 and 21-4 respectively.

The confidence in the EWR is summarised as follows:

- | | |
|-------------------------------|-----------------------|
| 0 (no confidence) | 1 (low confidence) |
| 2 (low to medium confidence) | 3 (medium confidence) |
| 4 (medium to high confidence) | 5 (high confidence) |

Table 21-3 Confidence - Low flows

EWR site	Hydraulics	Geomorphology	Vegetation	Aquatic invertebrates	Fish	OVERALL
1	4	0	2	2	4	3: Medium confidence. Hydraulics carries the largest weight of all the components.
2	4	0	4	3	4	3 - 4: Medium confidence to high. Hydraulics is evaluated as high. Aquatic Invertebrates however are the primary motivator for the flows and the low confidence modifies the hydraulic confidence to an overall of 3.
4	2	0	0	2	3	2 - 3: Low to medium confidence. Both fish and aquatic invertebrates are primary motivators for flow and evaluation is therefore between 3 and 4; probably being closer to 4.
5	3	0	0	3.5	3.5	3: Medium confidence. The higher invertebrate confidence is discounted as the fish is the primary motivator and therefore carries a higher weight.
6	3	0	0	4	3	3 - 4: Medium to high confidence. Invertebrate confidence is primary and the evaluation is therefore probably slightly higher than 3, but would be more towards 3 than 4.

The evaluation ranges from medium to medium - high. This is mostly due to the reasonable hydraulic confidence as most hydraulic calibrations were obtained during low flow conditions.

Table 21-4 Confidence – High flows

EWR site	Hydraulics	Geomorphology	Vegetation	Aquatic invertebrates	Fish	OVERALL
1	2	3	4	3	4	2: Low confidence. Lack of confidence in hydraulics overrides the higher confidence in fish and aquatic invertebrates.
2	3	2	2	3	4	2 - 3: Low to medium confidence. The higher confidences in components other than hydraulics are linked to the confidence in the water levels/velocity etc required. As the hydraulics are of low confidence and the conversion from hydraulic parameters is low, the hydraulic confidence overrides the other higher confidences.
4	3	2	2	3	3	2: Low confidence. Both geomorphology and vegetation have been evaluated as low and are therefore more important high flow components. The higher biota confidences are therefore modified by the lower hydraulics and driver confidence.
5	2	2	2	3	3	2: Low confidence. Geomorphology, vegetation and hydraulics have

EWR site	Hydraulics	Geomorphology	Vegetation	Aquatic invertebrates	Fish	OVERALL
						a low evaluation. Linked to the low hydraulics motivation, the higher biota evaluation is ignored.
6	1	2	3	4	3	2 - 3: Low to medium confidence. The low hydraulic confidence overrides all the other confidences that are linked to water levels etc. and not to flow.

Four of the five high flow EWR site evaluations are of low confidence. This is purely based on the lack of high flows experienced during the data collection phase and the resulting low confidence in converting water levels to flow.

21.3 Recommendations

Low flows: No additional data collection is required apart from a Reserve monitoring programme.

High flows: Any additional work outside of a Reserve monitoring programme should be centred around obtaining additional hydraulic calibrations during high flow conditions. High flows can then be modified accordingly and new flow results can be generated. Further work regarding the biophysical components can be undertaken as part of a Reserve monitoring programme.

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APPENDIX A

HYDROLOGY

Prof D.A. Hughes, IWR, Rhodes University

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1 INTRODUCTION

There is very little observed hydrology for this catchment and the majority of the assessment is based upon simulated hydrology provided by Ninham Shand Inc. The data that is available is briefly discussed in this document, while additional analyses will be available interactively at the workshops.

1.1 Available Data

There are only two available flow gauges in the Kromme River; K9H001, downstream of Churchill Dam at the outlet of quaternary catchment K90B (records for 1992 to 2003) and K9H003, downstream of Impofu Dam at the outlet of quaternary catchment K9H003 (records for 1983 to 2003). As Churchill Dam (capacity of about $36 \times 10^6 \text{ m}^3$) was constructed in 1943 and Impofu Dam (capacity of about $107 \times 10^6 \text{ m}^3$) in 1982, both of these records are severely impacted by development.

The remaining data have been provided by Ninham Shand Inc. based on monthly rainfall-runoff and systems model simulations. There are three simulated scenarios for EWR 2 (downstream of Churchill Dam), which represent year 2000 abstractions from the dam (Scenario 1), 1967 - 2000 average abstractions (Scenario 2) and 1:50 year firm yield abstractions (Scenario 3).

Figure A-1 illustrates the position of the EWRs and flow gauges, while Table A-1 summarises the observed and simulated data. Comparisons between natural and present day annual flow-duration curves based on monthly volumes are provided in Figures A-2 to A-5 for EWR 1, 2, 4 and 6. No hydrology data was provided for EWR 3, and for EWR 5 the natural and present day conditions are considered to be the same. The location of EWR 6 is in the upper reaches of the Swart River.

1.2 Hydrological characteristics and Impacts

It is clear that all the lower Kromme River EWRs (2, 3 and the estuary) are heavily impacted by the influences of one or both of the two major dams. There are now extensive periods of zero flow and many of the intermediate events have been completely removed. The modifications that have occurred at EWR 4 and 6 are similar, largely due to the presence of many quite substantial farm dams and extensive irrigation.

The impacts at EWR 1 are largely due to farm dams and some irrigation, while the impacts on the main Kromme River further downstream are due to the operation of Churchill and Impofu dams for irrigation and water supply. At the upstream EWR site, the main impact is on the low flows and the fact that zero flow conditions now prevail for about 15% of the time. Lower down, zero flow conditions can prevail for over 50% of the time and many intermediate runoff events have been removed completely.

The situation is similar in the Geelhoutboom catchment (part of quaternary K90E), which is dominated by the impact of many farm dams. Zero flows occur about 15% of the time and the impacts on other flows extend to intermediate flow events.

In many respects the impact on the downstream part of the Swart River appears to be the greatest (although Figure A-5 represents the conditions at the upper end of the Swart River, where the impacts of farm dams is expected to be less). The impacts appear to extend to almost the full range of flows suggesting that many of the farm dams are large relative to the size of events that occur within this basin.

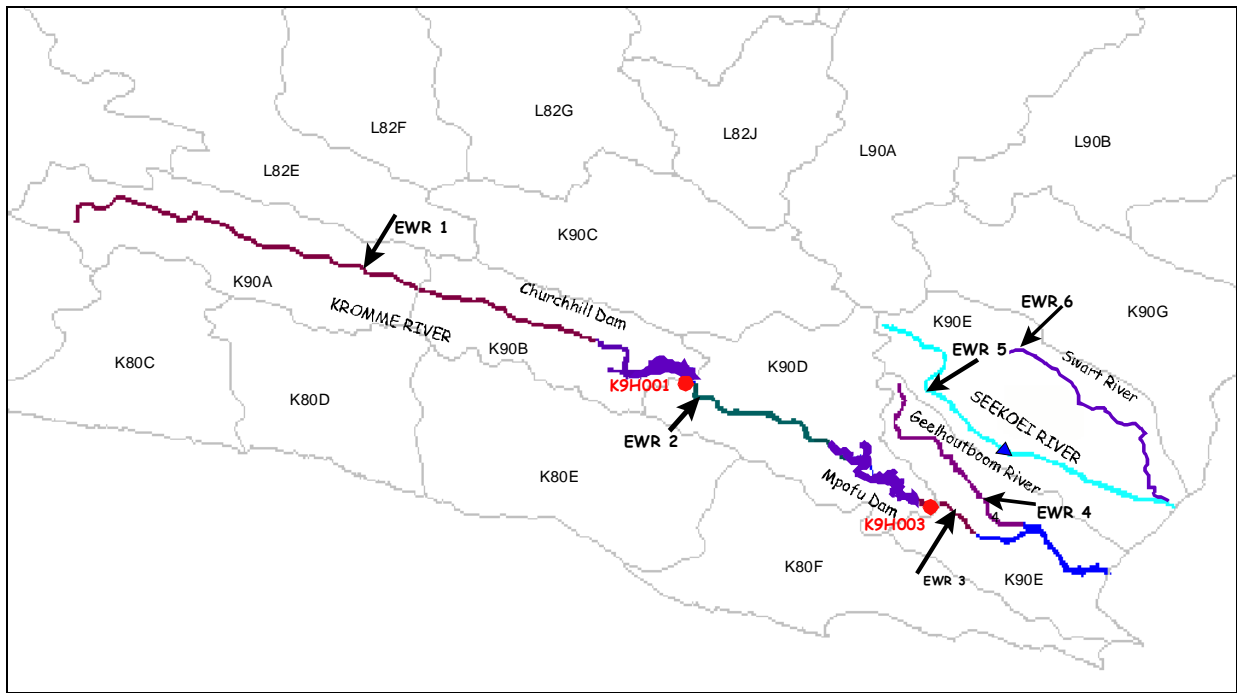


Figure A-1 Quaternary catchments, gauges and EWR sites

Table A-1 Available flow data, mean annual runoff and impacts

EWR Site or Gauge	River	Catchment Area (km ²)	Data Source	MAR (m ³ *10 ⁶)	Impacts
Kromme 1	Kromme	213	Natural	34.26	Mainly low flows due to irrigation and farm dams.
			P.Day	32.26	
Kromme 2	Kromme	363	Natural	58.38	Large reduction in low and moderate flows due to Churchill Dam, irrigation, farm dams and some forest.
			P.Day (1)	37.56	
			P.Day (2)	34.54	
			P.Day (3)	27.41	
K9H001		357	K9H001	23.97	As above.
K9H003	Kromme	851	K9H003	10.75	
Kromme 3	Kromme	870			
Kromme Est.	Kromme	1022	Natural	98.48	Same impacts as Kromme 2.
			P.Day (1)	54.41	
			P.Day (3)	44.57	
Kromme 4	Geelhoutboom	65	Natural	3.61	Major impacts on low to moderate flows.
			P.Day	2.97	
Seekoei 5	Seekoei	23	Natural	1.54	Assumed natural.
			P.Day	1.54	
Swart 6	Swart	??	Natural	3.94	Assumed natural in Swart upper reaches.
			P.Day	3.94	
Swart Est.	Swart	251	Natural	19.99	Big reductions in all but the wettest months.
			P.Day	11.21	

2 CONCLUSIONS

The dominant issue, from a hydrological point of view, would therefore appear to be the substantial length of time that zero flow conditions occur within the present day hydrological regime, and the fact that even quite substantial events are being stored within the existing main dams and farm dams.

It should be recognised that while the Churchill and Impofu dam operations may be able to be modified to allow for low-flow releases, it is unlikely to be a practical proposition to modify the many farm dams that exist to allow for releases.

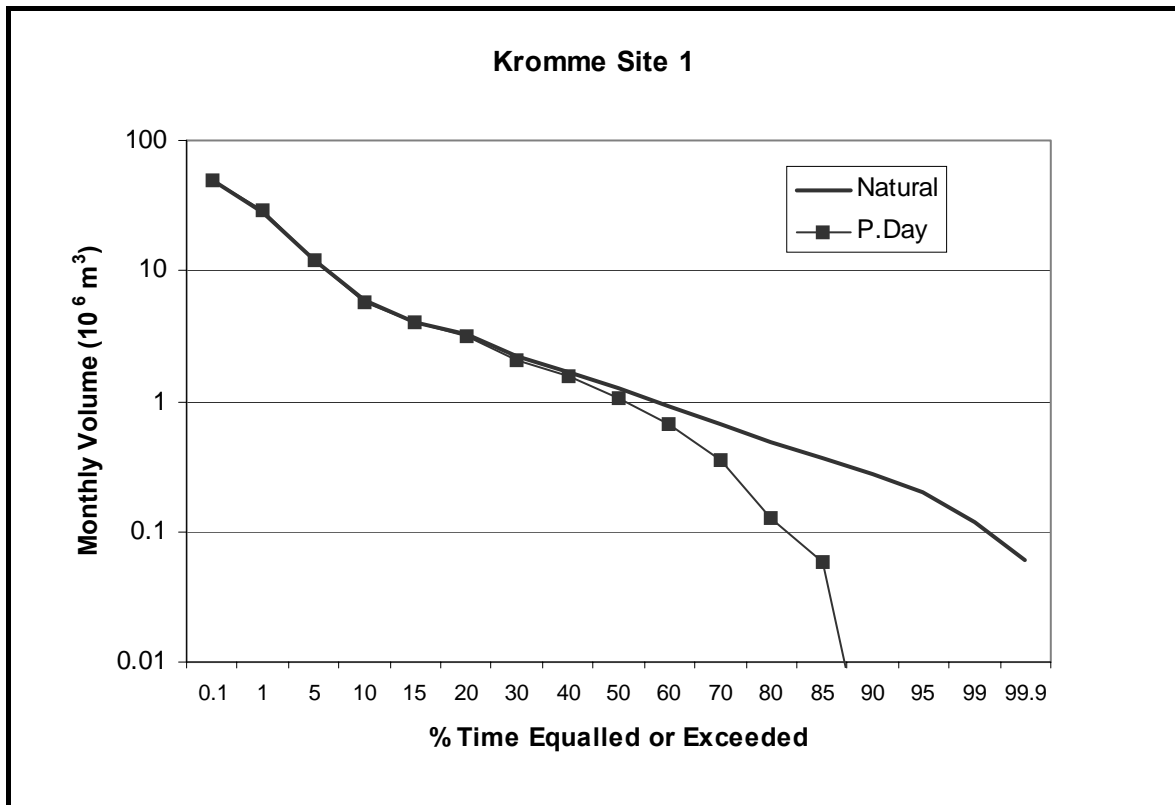


Figure A-2 Annual flow-duration curve for natural and present day for EWR 1

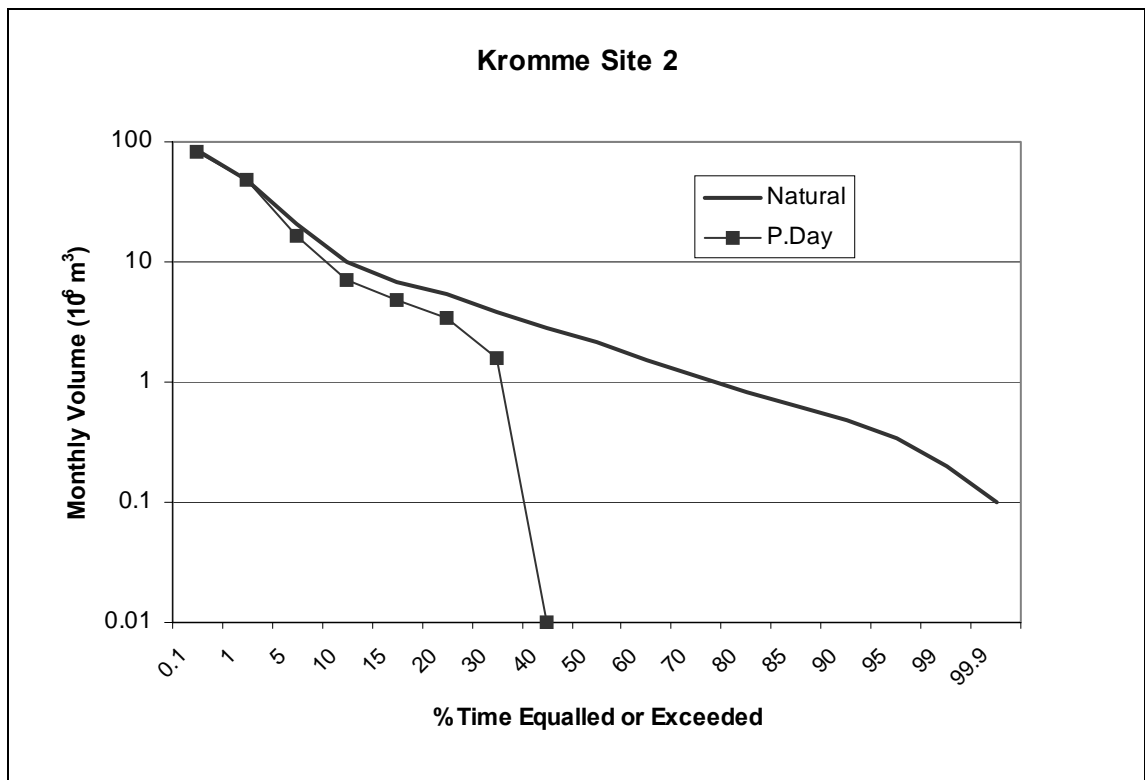


Figure A-3 Annual flow-duration curve for natural and present day (Scenario 1) for EWR 2

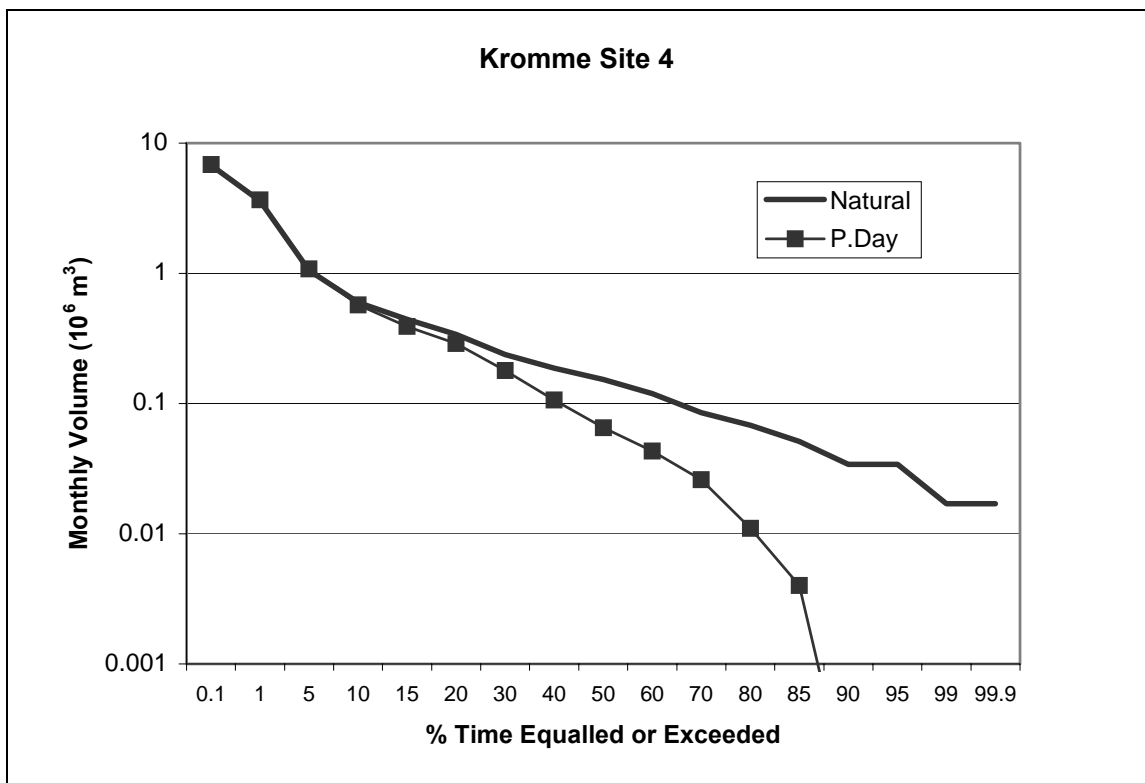


Figure A-4 Annual flow-duration curve for natural and present day for EWR 4

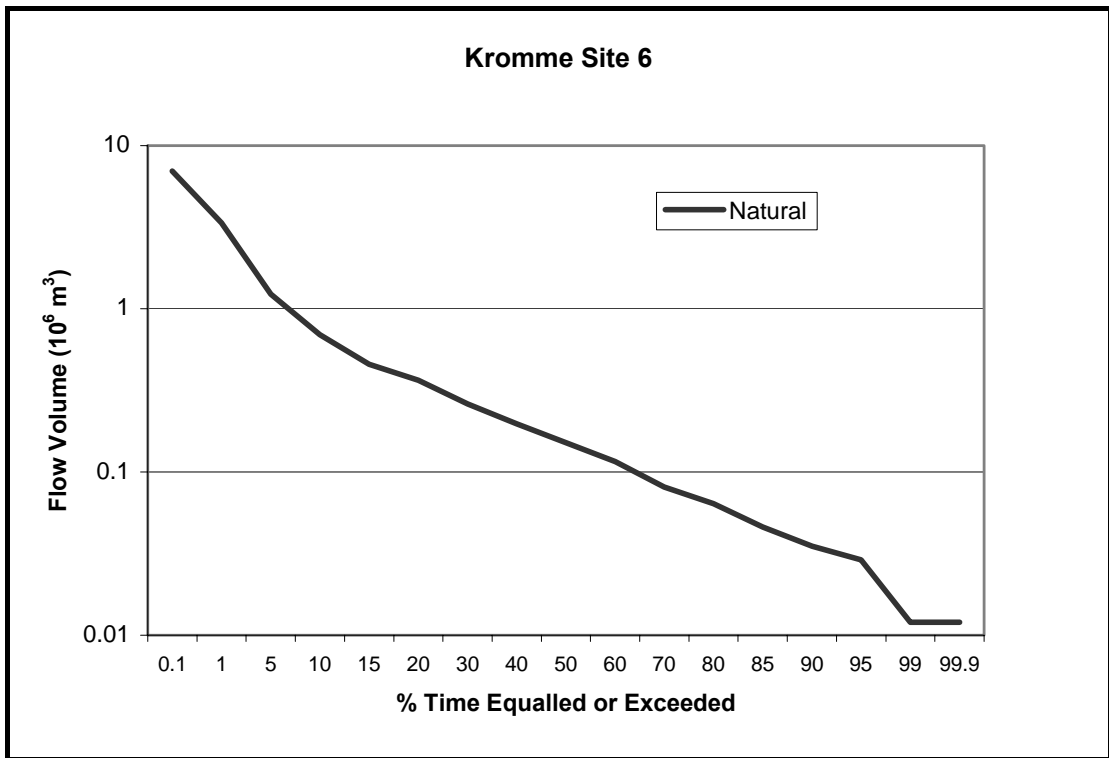


Figure A-5 Annual flow-duration curve for natural and present day for the upper River (downstream of EWR 6)

3 HYDROLOGY PES INFO

3.1 EWR 1: REC C

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	3.00	0.21	0.64
ZERO FLOW DURATION	1	100	3.00	0.24	0.71
SEASONALITY	2	90	0.00	0.21	0.00
MODERATE EVENTS	3	70	2.00	0.17	0.33
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	1.00	0.17	0.17
TOTALS		420	9.00	1.00	1.86
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					62.86
HABITAT DRIVER CATEGORY					C

3.2 EWR 1: Alternative REC D

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	4.00	0.21	0.86
ZERO FLOW DURATION	1	100	3.00	0.24	0.71
SEASONALITY	2	90	1.00	0.21	0.21
MODERATE EVENTS	3	70	2.00	0.17	0.33
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	1.00	0.17	0.17
TOTALS		420	11.00	1.00	2.29
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					54.29
HABITAT DRIVER CATEGORY					D

3.3 EWR 2: REC D

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	5.00	0.21	1.07
ZERO FLOW DURATION	1	100	4.00	0.24	0.95
SEASONALITY	2	90	2.00	0.21	0.43
MODERATE EVENTS	3	70	4.00	0.17	0.67
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	2.00	0.17	0.33
TOTALS		420	17.00	1.00	3.45
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					30.95
HABITAT DRIVER CATEGORY					E

3.4 EWR 3: REC E

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	5.00	0.21	1.07
ZERO FLOW DURATION	1	100	5.00	0.24	1.19
SEASONALITY	2	90	4.00	0.21	0.86
MODERATE EVENTS	3	70	4.00	0.17	0.67
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	2.00	0.17	0.33
TOTALS		420	20.00	1.00	4.12
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					17.62
HABITAT DRIVER CATEGORY					F

3.5 EWR 4: REC D

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	3.00	0.21	0.64
ZERO FLOW DURATION	1	100	3.00	0.24	0.71
SEASONALITY	2	90	0.00	0.21	0.00
MODERATE EVENTS	3	70	3.00	0.17	0.50
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	2.00	0.17	0.33
TOTALS		420	11.00	1.00	2.19
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					56.19
HABITAT DRIVER CATEGORY					D

3.6 EWR 5: REC C

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	2.00	0.21	0.43
ZERO FLOW DURATION	1	100	1.00	0.24	0.24
SEASONALITY	2	90	0.00	0.21	0.00
MODERATE EVENTS	3	70	0.00	0.17	0.00
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	0.00	0.17	0.00
TOTALS		420	3.00	1.00	0.67
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					86.67
HABITAT DRIVER CATEGORY					B

3.7 EWR 6: REC B

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	1.00	0.21	0.21
ZERO FLOW DURATION	1	100	0.00	0.24	0.00
SEASONALITY	2	90	0.00	0.21	0.00
MODERATE EVENTS	3	70	0.00	0.17	0.00
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	0.00	0.17	0.00
TOTALS		420	1.00	1.00	0.21
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					95.71
HABITAT DRIVER CATEGORY					A

3.8 EWR 6: Alternative REC C

HYDROLOGY					
COMPONENTS	Rank	%wt	Rating	Weight	Weighed score
LOW FLOWS	2	90	2.00	0.21	0.43
ZERO FLOW DURATION	1	100	0.00	0.24	0.00
SEASONALITY	2	90	0.50	0.21	0.11
MODERATE EVENTS	3	70	0.00	0.17	0.00
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	70	0.00	0.17	0.00
TOTALS		420	2.50	1.00	0.54
Driver status:(%):>89=A;80-89=B;60-79=C;40-59=D;20-39=E;<20=F					89.29
HABITAT DRIVER CATEGORY					B

APPENDIX B

GEOMORPHOLOGY

Prof K. Rowntree and Ms L. du Preez, IWR, Geography Department, Rhodes University

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4 EWR 1: MELKHOUTBOSKRAAL – KROMME RIVER

4.1 Data availability

Data used in the assessment of the geomorphology at this site was obtained in the field. Standardized field forms were used to assess the geomorphological condition of the site. Most of the data collected was qualitative in nature.

On a scale of 0 to 5, a confidence rating of 3 would be awarded. This is because some geomorphological cues (e.g. terraces etc.) were present, and accessibility was good, allowing easy observation of bed conditions; however at the same time, the data is qualitative and thus stands to be somewhat subjective. In addition, reference was made to a report by Haigh et al. (2004) entitled "Inventory of the Wetlands in Selected Eastern Cape catchments" (report to DWAF), as well as aerial photographs of the area.

4.2 Reference condition

Within this reach, the river has a narrow valley bottom confined within a steep-sided valley. The channel gradient at the site is 0.0034 which places it in the upper end of the lower foothills category. This is a river subject to a flashy flood regime and a relatively high bedload of coarse material. Haigh et al. (2004) records 17 major (destructive) floods recorded since 1868 (an average of one major flood every 8 years). Strong coupling to hillslopes provides a ready source of mixed bedload. The reference condition for this reach would probably consist of a cobble bed river with a high width-depth ratio and a propensity to braiding (main channel with secondary channels subject to channel switching). Due to the unstable nature of the valley floor, there would be limited woody riparian vegetation. This condition is similar to that shown on the aerial photographs of 1942. A number of wetland basins exist in the valley floor above this site.

4.3 PES

Geomorphologically, this site has been awarded a D rating. Scores given to drivers in the geomorphology spreadsheet are substantiated by Tables B-1 to B-4 below.

The site is located in an alluvial plane-bed reach with boulders and cobbles as dominant bed materials (over 70% of bed material). A loss of gravels and sand is indicated. Bed material is loosely packed and not embedded. Bank stability is moderate and has been influenced by the invasion of alien plant species (*Acacia mearnsii*, Black Wattle). Banks have become temporarily over-stabilised by the Black Wattle resulting in bank undercutting and collapse in sections, as well as channel incision. Main sources of change noted along this reach include gabion structures upstream of the site as part of a wetland rehabilitation project, alien invasion (high impact) and recent alien vegetation clearance from the riparian zone. It is also thought that there are probably a few storage weirs on this reach. Marked channel incision is linked to the stabilization of the valley floor by alien vegetation which has been well established since 1983 (aerial photo evidence). Habitat diversity at this site is thought to be reasonable.

Table B-1 Guidelines for rating changes to event hydrology

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the frequency of event-flows that are contained within the active channel?	2.5		Impaired wetlands upstream results in reduction of flood storage.

Has there been a change in the frequency of event-flow that fill or overtop the active channel?		2.5	Channel incision.
Has the channel been impacted recently by an extreme event?	Yes / No	Date 1997; 2000	Description: extreme flood events.

Table B-2 Guidelines for rating changes to sediment supply

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the amount of sediment supplied from the catchment?			
Has there been a change in sediment supplied from the upstream channel?	2		Wetland erosion.
Has there been a change in the size of sediment supplied to the stream?		2	Fines from wetland deposits contribute to washload.
Have changes been due to a discrete event such as a landslide or dam burst?	Yes / No		Description.

Table B-3 Guidelines for rating changes to vegetation

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Have vegetation changes affected the stability of the riverbank?	3		Alien vegetation.
Have vegetation changes affected the stability of sediment deposits within the active channel or within secondary or distributary channels?	3		Alien vegetation.
Have vegetation changes affected the stability of the flood plain?	3		Alien vegetation.
Combined rating	4		

Table B-4 Guidelines for rating morphological changes due to instream engineered structures

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change to the composition and/or mobility of the bed?		1	Causeway.
Has there been a change to the composition and/or stability of the banks?		1	Bridge.
Has there been a change to the size and/or shape of the channel?		1	Causeway.
Has there been a change to the channel sinuosity? (e.g. straightening)			
Has there been a change in the reach long profile? (e.g. due to a weir across the channel)		1	Causeway.

PES	Causes	Sources	Flow/Non flow related
D	Channel incision	Alien vegetation encroachment	Non flow related
	Bed armouring	Channel incision leading to increase in stream power plus increase in floods.	Flow related

4.4 Trend and reasons

The channel is probably still changing, though the rate of change has probably significantly reduced over time. The main reason for this change is the invasion of alien vegetation which has over-stabilized channel banks since at least 1983. Major trends are that the channel depth has increased, channel width has decreased, there has been a loss of secondary channels and mid-channel bars and islands, and average bed material size has increased. Clearance of alien vegetation could lead to short-term instability but improvement over the long term.

PES	Trend	Resulting PES	Time	Reasons
D	Negative	Low D	Long term	System stabilizing (no rehabilitation).
D	Positive	C	Long term	Rehabilitation following alien clearance.

4.5 Alternative ECs

No alternative categories were evaluated.

5 EWR 2: KROMMERIVIERS POORT - KROMME RIVER

5.1 Data availability

See EWR 1.

5.2 Reference condition

This reach of the river is contained in a v-shaped valley with moderately steep sides. The site channel gradient is 0.01 which means that it is classified as a rejuvenated foothills river. The channel is likely to have been in the transition between transport limited and supply limited. Flood and sediment load characteristics would be similar to those described for EWR 1. The aerial photograph taken in 1942 prior to the filling and operation of Churchill Dam suggests that this reach should consist of a series of alternating pools and braided sections (300 to 600m in length) both extending across the width of the valley bottom. The braiding may be associated with underlying bedrock controls, but there is no available evidence to support this. There is local evidence of lateral cobble bars.

5.3 PES

Geomorphologically, this site has been awarded an E rating. Scores allocated to drivers are substantiated by Tables B-5 to B-8 below.

The site is located on an alluvial reach immediately below Churchill Dam. This situation will have impacted both floods and sediment availability. There has been severe encroachment of Black Wattle, which has caused both a loss of pools and a reduction of secondary channels in the braided sections. This impact is already evident in the 1961 aerial photograph. The site inspected for the geomorphological survey was dominated by cobble with significant amounts of gravel and a small percentage of boulders. The bed material is loosely packed with no evidence of embeddedness. Moderate erosion on the left hand bank was attributed to dam releases.

Table B-5 Guidelines for rating changes to event hydrology

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the frequency of event-flows that are contained within the active channel?		4	Churchill Dam.
Has there been a change in the frequency of event-flow that fill or overtop the active channel?		4	Churchill Dam.
Has the channel been impacted recently by an extreme event?	Yes / No	Date 1997; 2000	Description: extreme flood events.

Table B-6 Guidelines for rating changes to sediment supply

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the amount of sediment supplied from the catchment?			
Has there been a change in sediment supplied from the upstream channel?		5	Churchill Dam.
Has there been a change in the size of sediment supplied to the stream?			Fines from wetland deposits contribute to washload.

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Yes / No	Date -	Description.
Have changes been due to a discrete event such as a landslide or dam burst?			

Table B-7 Guidelines for rating changes to vegetation

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Have vegetation changes affected the stability of the riverbank?	3		Alien vegetation.
Have vegetation changes affected the stability of sediment deposits within the active channel or within secondary or distributary channels?	3		Alien vegetation.
Have vegetation changes affected the stability of the flood plain?			No flood plain.
Combined rating.	3		

Table B-8 Guidelines for rating morphological changes due to instream engineered structures

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change to the composition and/or mobility of the bed?			
Has there been a change to the composition and/or stability of the banks?			
Has there been a change to the size and/or shape of the channel?			
Has there been a change to the channel sinuosity? (e.g. straightening)			
Has there been a change in the reach long profile? (e.g. due to a weir across the channel)	2		Storage weirs in reach.

PES	Causes	Sources	Flow/Non flow related
E	Change in morphology and therefore habitat type.	Alteration to flow and sediment regimes.	Flow related.
	Change in stability of banks and bed material.	Encroachment by alien vegetation.	Non flow related.

5.4 Trend and reasons

The channel has been adjusting since the dam was closed in 1943 and alien vegetation was well established by 1961. The channel is therefore likely to have adjusted to these new conditions.

PES	Trend	Resulting PES	Time	Reasons
E	Negative	Low E	Long term	Continued effects of dam on flow and sediment supply.
E	Positive	High D	Long term	Rehabilitation following alien clearance.

5.5 Alternative ECs

No alternative categories were evaluated.

6 EWR 3: DYKE - KROMME RIVER

6.1 Data availability

See EWR 1. Aerial photographs only available for 1942 and 1985.

6.2 Reference condition

This reach is located in a confined valley with a narrow valley floor and good coupling between the hillslope and the channel. The gradient of the site was estimated as between 0.003 and 0.0037 which places it in the lower foothills category. The mean annual discharge at this site is approximately three times that at EWR 1 and one would therefore expect the channel capacity to increase accordingly. Flood frequency and sediment load characteristics would be similar to those described for EWR 1.

Evidence from the 1942 aerial photograph would suggest that the reference condition for the reach is a bedrock or mixed anabranching channel with narrow passageways passing through dense *Phragmites*. Locally, pools form stretches of open water.

6.3 PES

Geomorphologically, this site has been awarded a D rating. Scores given to drivers are substantiated by Tables B-9 to B-12 below.

The site is located downstream of Mpofu Dam and immediately upstream of the estuary. The dam is thought to have a high impact on the channel at this point in terms of its alteration to the natural flow and sediment regimes. The site is bedrock dominated and displays pool-rapid morphology. There has been recent removal of alien vegetation from the riparian zone, which may have a destabilizing effect in the short term. However, the site is thought to be largely resistant to change due to the fact that the channel consists primarily of bedrock at this point. *Phragmites* sections upstream of the site seem to have become consolidated over time, causing a reduction in secondary channels in these sections. At the site, the river forms a natural "weir" behind a sandstone dyke that extends across the width of the channel. Water is abstracted from this "weir" which has most probably affected habitat availability.

Table B-9 Guidelines for rating changes to event hydrology

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the frequency of event-flows that are contained within the active channel?		4	Impofu dam.
Has there been a change in the frequency of event-flow that fill or overtop the active channel?		4	Impofu dam.
Has the channel been impacted recently by an extreme event?	Yes / No	Date 1997; 2000	Description: extreme flood events.

Table B-10 Guidelines for rating changes to sediment supply

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the amount of sediment supplied from the catchment?			
Has there been a change in sediment supplied from the upstream channel?		5	Impofu dam.
Has there been a change in the size of sediment supplied to the stream?			
Have changes been due to a discrete event such as a landslide or dam burst?	Yes / No	Date -	Description.

Table B-11 Guidelines for rating changes to vegetation

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Have vegetation changes affected the stability of the riverbank?			No clear banks.
Have vegetation changes affected the stability of sediment deposits within the active channel or within secondary or distributary channels?	3		Consolidation of <i>Phragmites</i> has made them more homogenous across the channel floor.
Have vegetation changes affected the stability of the flood plain?			No clear floodplain.
Combined rating.	3		

Table B-12 Guidelines for rating morphological changes due to instream engineered structures

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change to the composition and/or mobility of the bed?			
Has there been a change to the composition and/or stability of the banks?			
Has there been a change to the size and/or shape of the channel?			
Has there been a change to the channel sinuosity? (e.g. straightening)			
Has there been a change in the reach long profile? (e.g. due to a weir across the channel)			

PES	Causes	Sources	Flow/Non flow related
D	Change in morphology and therefore habitat type.	Alteration to flow and sediment regimes.	Flow related.
	Change in stability of bed material.	Consolidation of <i>Phragmites</i> .	Flow related.

6.4 Trend and reasons

Channel is unlikely to change further due to its transformation into a bedrock channel.

PES	Trend	Resulting PES	Time	Reasons
D	Negative	Low D	Long term	System stabilizing (no rehabilitation).

6.5 Alternative ECs

No alternative categories were evaluated.

7 EWR 4: GEELHOUTBOOM RIVER

7.1 Data availability

See EWR 1.

7.2 Reference condition

This site is located on an alluvial gravel bed reach with a narrow flood bench between high terraces. The gradient of the site is approximately 0.003 which places it in the lower foothills category. Flood frequency characteristics would be similar to those described for EWR 1, although this is a much smaller river. Sediment delivered to the channel by tributaries would consist primarily of gravel. Evidence from a series of aerial photographs since 1942 suggest that the reference condition for this site is a narrow, single thread channel (probably displaying pool-riffle morphology) with a dense canopy of indigenous woody riparian vegetation.

7.3 PES

Geomorphologically, this site has been awarded a C rating.

The scores given for each of the drivers in the geomorphology spreadsheet are substantiated in Tables B-13 to B-16 below.

This is an alluvial reach with gravel as the predominant substrate. Bed material is loosely packed and moderately embedded. Exposure of tree roots on banks indicates moderate channel widening and incision. Changes to catchment land use since 1975 will have reduced the catchment sediment yield, while two upstream dams will have trapped sediment and reduced flood flows. The indigenous woody riparian vegetation zone is still intact. There is a bridge upstream of the site, within the reach.

Table B-13 Guidelines for rating changes to event hydrology

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the frequency of event-flows that are contained within the active channel?		2	Dams upstream.
Has there been a change in the frequency of event-flow that fill or overtop the active channel?		1	Dams upstream.
Has the channel been impacted recently by an extreme event?	Yes / No	Date 1997; 2000	Description: extreme flood events.

Table B-14 Guidelines for rating changes to sediment supply

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the amount of sediment supplied from the catchment?		2	Slight gully erosion upstream, reduced since 1942, decreased sediment yield following reduced cultivation.
Has there been a change in sediment supplied from the upstream channel?		3	Dams upstream.
Has there been a change in the size of sediment supplied to the stream?			

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Yes / No	Date	Description.
Have changes been due to a discrete event such as a landslide or dam burst?			

Table B-15 Guidelines for rating changes to vegetation

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Have vegetation changes affected the stability of the riverbank?			
Have vegetation changes affected the stability of sediment deposits within the active channel or within secondary or distributary channels?			
Have vegetation changes affected the stability of the flood plain?			
Combined rating.			

Table B-16 Guidelines for rating morphological changes due to instream engineered structures

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change to the composition and/or mobility of the bed?			
Has there been a change to the composition and/or stability of the banks?			
Has there been a change to the size and/or shape of the channel?	0.5		Upstream bridge.
Has there been a change to the channel sinuosity? (e.g. straightening)			
Has there been a change in the reach long profile? (e.g. due to a weir across the channel)			

PES	Causes	Sources	Flow/Non flow related
C	Moderately altered flow and sediment regimes.	Changes to catchment land use; bridge with side supports.	Non flow related.
		Dam upstream.	Flow related.

7.4 Trend and reasons

This site is not seen to be on any trajectory of change as a result of human activity.

PES	Trend	Resulting PES	Time	Reasons
C	Negative	Low C	Long term	Continued effects of dam.

7.5 Alternative ECs

No alternative categories were evaluated.

8 EWR 5: SEEKOEI RIVER

8.1 Data availability

See EWR 1.

8.2 Reference condition

This site is located on an alluvial gravel bed reach with a narrow flood bench with low gradient valley side slopes. The gradient of the site could not be calculated due to discrepancies between adjacent maps. This reach lies immediately downstream of a gorge. Flood frequency characteristics would be similar to those described for EWR 1, although this is a much smaller river. Strong coupling between tributaries and main channel in the upper catchment would deliver coarse sediment to the channel. Evidence from a series of aerial photographs since 1942 suggest that the reference condition for this site is a narrow, single thread channel (probably displaying pool-riffle morphology) with an open canopy of indigenous woody riparian vegetation.

8.3 PES

Geomorphologically, this site has been awarded a D rating.

The scores given for each of the drivers in the geomorphology spreadsheet are substantiated in Tables B-17 to B-20 below.

This is an alluvial reach with cobble and boulders as the predominant substrate in riffles (at the site), but sand dominates large areas of the channel within the wattle-infested sections. Bed material is loosely packed, but not embedded at the site. Exposure of tree roots (Black Wattle) on banks indicates moderate channel widening and incision. There is a bridge with culverts immediately upstream of the site. The biggest impact is due to invasion by alien vegetation.

Table B-17 Guidelines for rating changes to event hydrology

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the frequency of event-flows that are contained within the active channel?			
Has there been a change in the frequency of event-flow that fill or overtop the active channel?			
Has the channel been impacted recently by an extreme event?	Yes / No	Date 1997; 2000	Description: extreme flood events.

Table B-18 Guidelines for rating changes to sediment supply

	Rating of magnitude of change rated from 1(small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the amount of sediment supplied from the catchment?			
Has there been a change in sediment supplied from the upstream channel?	2		
Has there been a change in the size of sediment supplied to the stream?		2.5	
Have changes been due to a discrete event such as a landslide or dam burst?	Yes / No	Date	Description.

Table B-19 Guidelines for rating changes to vegetation

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Have vegetation changes affected the stability of the riverbank?		3	Black Wattle on banks.
Have vegetation changes affected the stability of sediment deposits within the active channel or within secondary or distributary channels?		1	Kikuyu on in-channel bench.
Have vegetation changes affected the stability of the flood plain?		2	Black Wattle in flood zone.
Combined rating.			

Table B-20 Guidelines for rating morphological changes due to instream engineered structures

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change to the composition and/or mobility of the bed?			
Has there been a change to the composition and/or stability of the banks?			
Has there been a change to the size and/or shape of the channel?			
Has there been a change to the channel sinuosity? (e.g. straightening)			
Has there been a change in the reach long profile? (e.g. due to a weir across the channel)	1		Bridge with culverts.

PES	Causes	Sources	Flow/Non flow related
D	Channel widening and increased sand on bed.	Black Wattles.	Non flow related.
	Backing up water.	Bridge.	Non flow related.

8.4 Trend and reasons

This site is not seen to be on any trajectory of change as a result of human activity.

PES	Trend	Resulting PES	Time	Reasons
D	Negative	Low D	Long term	Continued effects of wattles.
D	Positive	C	Long term	Rehabilitation after removing wattles.

8.5 Alternative ECs

No alternative categories were evaluated.

9 EWR 6: SWART RIVER

9.1 Data availability

See EWR 1.

9.2 Reference condition

This site is located on an alluvial cobble/gravel bed reach with a flood bench extending across a narrow valley floor between steep valley side slopes. Upstream the valley narrows and the channel gradient steepens. The gradient of the site is approximately 0.0133 (Important: This includes the higher gradient section upstream), which places it in the upper foothills category. Flood frequency characteristics would be similar to those described for EWR 1, although this is a much smaller river. Sediment delivered to the channel by tributaries would consist primarily of coarse gravel. Evidence from a series of aerial photographs since 1942 suggest that the reference condition for this site is a narrow, meandering, single thread channel (probably displaying pool-riffle morphology) with secondary channels probably activated during floods. The riparian vegetation in 1942 was probably mixed woody scrub and grass that would have stabilised channel planform.

9.3 PES

Geomorphologically, this site has been awarded a C rating.

The scores given for each of the drivers in the geomorphology spreadsheet are substantiated in Tables B-21 to B-24 below.

This is an alluvial reach with coarse gravel and cobble as the predominant substrate. Bed material in riffles is loosely packed. Fine gravels and sand dominate pool/run sections. Aerial photographic evidence indicates that by 1962 the riparian zone had been affected by fire, causing grass to replace clumped woody scrub. The riparian zone was still open in 1985. At the time of the site visit closed canopy mature Black Wattle occupied the riparian zone. This condition has persisted for less than twenty years. The ground cover under the wattles is low, allowing floods to scour channels through the riparian zone. Exposure of tree roots on banks indicates localised channel widening and incision. The wattles have had the general effect of destabilising both the channel and the flood zone.

Table B-21 Guidelines for rating changes to event hydrology

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the frequency of event-flows that are contained within the active channel?			
Has there been a change in the frequency of event-flow that fill or overtop the active channel?			
Has the channel been impacted recently by an extreme event?	Yes / No	Date 1997; 2000	Description: Extreme flood events.

Table B-22 Guidelines for rating changes to sediment supply

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change in the amount of sediment supplied from the catchment?			
Has there been a change in sediment supplied from the upstream channel?	1		Wattle in flood zone.
Has there been a change in the size of sediment supplied to the stream?		1	Wattle in flood zone.
Have changes been due to a discrete event such as a landslide or dam burst?	Yes/No	Date -	

Table B-23 Guidelines for rating changes to vegetation

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Have vegetation changes affected the stability of the riverbank?		2	Black Wattle.
Have vegetation changes affected the stability of sediment deposits within the active channel or within secondary or distributary channels?			
Have vegetation changes affected the stability of the flood plain?		2.5	Black Wattle.
Combined rating.	2		

Table B-24 Guidelines for rating morphological changes due to instream engineered structures

	Rating of magnitude of change rated from 1 (small) to 5 (extreme)		Reason for change
	Increased	Decreased	
Has there been a change to the composition and/or mobility of the bed?			
Has there been a change to the composition and/or stability of the banks?			
Has there been a change to the size and/or shape of the channel?			
Has there been a change to the channel sinuosity? (e.g. straightening)			
Has there been a change in the reach long profile? (e.g. due to a weir across the channel)			

PES	Causes	Sources	Flow/Non flow related
C	Bank and flood zone instability	Black Wattle.	Non flow related.

9.4 Trend and reasons

This site is not seen to be on any trajectory of change as a result of human activity.

PES	Trend	Resulting PES	Time	Reasons
C	Negative	Low C	Long term	Continued effects of Black Wattle.
	Positive	B	Long term	Alien clearance and rehabilitation.

9.5 Alternative ECs

This driver template assumes a D category due to an increased impact of *Acacia mearnsii* (Black Wattle) on channel stability and morphology.

GEOMORPHOLOGY DRIVERS							
Components	Rank	% Weight	Rating	Weight	Weighed score	Flow related (event hydrology; high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	2	0.43	2.61	0.00	4.00
RIPARIAN VEGETATION	2.00	80.00	3.00	0.35	3.13	0.00	4.00
CHANNEL PATTERN & MORPHOLOGY	3.00	50.00	0.00	0.22	0.00	0.00	5.00
TOTALS		230.00	3.00	1.00	5.74		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					61.00		
HABITAT DRIVER CATEGORY					C		

9.5.1 Rating for flood –sediment

A **further increased sediment input** is envisaged due to disturbance of riparian zone by Black Wattle.

9.5.2 Rating for riparian vegetation

Closed canopy of mature Black Wattle, increased wattle on river banks and loss of ground bank vegetation: limited ground cover on floodplain and increased bank instability leading to **channel widening and some incision**.

10 GEOMORPHOLOGY PES INFO

10.1 EWR 1: REC C

GEOMORPHOLOGY DRIVERS							
COMPONENTS	Rank	% Weight	Rating	Weight	Weighed score	Flow-related (event hydrology; high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	2	0.43	2.61	4.00	3.00
RIPARIAN VEGETATION	2.00	80.00	4.00	0.35	4.17	0.00	4.00
CHANNEL PATTERN & MORPHOLOGY	3.00	50.00	1.00	0.22	0.65	0.00	4.00
TOTALS		230.00	5.00	1.00	7.43		
Driver status:(%): >89=A;80-89=B;60-79=C; 40-59=D;20-39=E;<20=F					50.00		
HABITAT DRIVER CATEGORY					D		

10.2 EWR 2: REC D

GEOMORPHOLOGY DRIVERS							
COMPONENTS	Rank	% Weight	Rating	Weight	Weighed score	Flow-related (event hydrology; high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	4	0.42	5.00	4.00	4.00
RIPARIAN VEGETATION	3.00	80.00	3.00	0.33	3.00	3.00	4.00
CHANNEL PATTERN & MORPHOLOGY	2.00	60.00	2.00	0.25	1.50	0.00	4.00
TOTALS		240.00	5.00	1.00	9.50		
Driver status:(%): >89=A;80-89=B;60-79=C; 40-59=D;20-39=E;<20=F					36.00		
HABITAT DRIVER CATEGORY					E		

10.3 EWR 3: REC E

GEOMORPHOLOGY DRIVERS							
COMPONENTS	Rank	% Weight	Rating	Weight	Weighed score	Flow-related (event hydrology; high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	4	0.45	5.45	4.00	4.00
RIPARIAN VEGETATION	2.00	60.00	3.00	0.27	2.45	3.00	4.00
CHANNEL PATTERN & MORPHOLOGY	2.00	60.00	0.00	0.27	0.00	0.00	4.00
TOTALS		220.00	3.00	1.00	7.91		
Driver status:(%): >89=A;80-89=B;60-79=C; 40-59=D;20-39=E;<20=F					47.00		

HABITAT DRIVER CATEGORY					D
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10.4 EWR 4: REC D

GEOMORPHOLOGY DRIVERS							
COMPONENTS	Rank	% Weight	Rating	Weight	Weighed score	Flow-related (event hydrology;high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	3	0.43	3.91	3.00	3.00
RIPARIAN VEGETATION	2.00	80.00	0.00	0.35	0.00	0.00	4.00
CHANNEL PATTERN & MORPHOLOGY	3.00	50.00	0.50	0.22	0.33	0.00	3.00
TOTALS		230.00	0.50	1.00	4.24		
Driver status:(%): >89=A;80-89=B;60-79=C; 40-59=D;20-39=E;<20=F					71.00		
HABITAT DRIVER CATEGORY					C		

10.5 EWR 5: REC C

GEOMORPHOLOGY DRIVERS							
COMPONENTS	Rank	% Weight	Rating	Weight	Weighed score	Flow-related (event hydrology;high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	2	0.43	2.61	0.00	3.00
RIPARIAN VEGETATION	2.00	80.00	3.00	0.35	3.13	0.00	4.00
CHANNEL PATTERN & MORPHOLOGY	3.00	50.00	1.50	0.22	0.98	0.00	4.00
TOTALS		230.00	4.50	1.00	6.72		
Driver status:(%): >89=A;80-89=B;60-79=C; 40-59=D;20-39=E;<20=F					55.00		
HABITAT DRIVER CATEGORY					D		

10.6 EWR 6: REC B

GEOMORPHOLOGY DRIVERS							
COMPONENTS	Rank	% Weight	Rating	Weight	Weighed score	Flow-related (event hydrology;high flows, floods)	Confidence
EVENT HYDROLOGY & SEDIMENT SUPPLY	1.00	100.00	1	0.43	1.30	0.00	4.00
RIPARIAN VEGETATION	2.00	80.00	2.00	0.35	2.09	0.00	4.00
CHANNEL PATTERN & MORPHOLOGY	3.00	50.00	0.00	0.22	0.00	0.00	5.00
TOTALS		230.00	2.00	1.00	3.39		
Driver status:(%): >89=A;80-89=B;60-79=C; 40-59=D;20-39=E;<20=F					77.00		

HABITAT DRIVER CATEGORY					C
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APPENDIX C

RIPARIAN VEGETATION

Mr N.P. Kemper, Integrated Environmental Assessments cc

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1 EWR 1: MELKHOUTBOSKRAAL – KROMME RIVER

1.1 Data availability

Available data is confined to that observed and collected during the site selection trip undertaken in November 2003.

1.2 Reference condition

An intact and connected riparian zone from the upper zone through to the marginal zone defines the reference condition. The upper riparian zone comprises of species more similar to that of valley bushveld than the surrounding false Karoo (Acocks, 1989). Low and Rebello (1996) describe this as south west coast Renosterveld. It comprises a closed thicket of shrubs and trees featuring *Podocarpus* (yellow wood), *Carissa bispinosa*, *Scutia myrtina*, *Rhus lucida*, *Maytenus heterophylla*, *Ehretia rigida*, *Acacia karroo*, *Euclea undulata*, *Cassine aethiopica* and many others. The lower riparian zone features *Diospyros lyciodes*, *Rhus dentata*, and Palmiet. Palmiet forms large clumps on the edges of pools. Palmiet also dominates the marginal zone, with smaller clumps of *Juncus* and other sedges and Restionaceae featuring in other open areas.

No exotic species are present under the reference condition and cultivation is absent in the upper riparian zone.

1.3 PES

PES: D

The PES is poor due to the removal of indigenous vegetation and cultivation in the upper riparian zone. In addition, the infestation of the upper and middle riparian zones by Black Wattle is extensive. This has led to extensive stabilisation of the riparian zone and the subsequent incision of the river and the marginal zone. The riparian zone has therefore become significantly disconnected leaving the upper zone isolated from the middle and lower parts. It is uncertain whether the remaining vegetation of the upper riparian zone, in its present location, is still dependent on the river for its supply of water.

PES	Causes	Sources	Non flow related	Flow related
D	General degeneration of the riparian zone and isolation of upper riparian zone.	Invasion of exotic species and subsequent river incision.	Yes	No
	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Cultivation in upper riparian zone and removal of vegetation.	Yes	No
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Cattle grazing in riparian zone.	Yes	No
	Changes in abundance of vegetation.	Cultivation in upper riparian zone and removal of vegetation.	Yes	No
	Changes in vegetation cover.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Yes	No	
	Reduced impact of flooding as a consequence of exotic species invasion.	No	Yes	

Data confidence: PES evaluation and data confidence is High.

1.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
E	-	F	10 years	Further invasion of exotic species and removal of indigenous vegetation for cultivation, fuels and browsing.

Data confidence: The confidence in trend evaluation data is Medium since it is uncertain to what extent further exotic invasion will take place and whether further cultivation in the catchment will impact on the riparian zone and result in further decline in the PES.

1.5 Alternative ECs

The recommended EC is a D or higher. However, a D would be costly to maintain since the vegetation would have a negative trend and would require the continuous removal of exotic vegetation using effective eradication programmes. It would be more practical to recommend a C (absence of exotics). Provided the Reserve is supplied, further improvement of the riparian vegetation would result in a long term positive trend.

2 EWR 2: KROMMERIVIERS POORT – KROMME RIVER

2.1 Data availability

Available data is confined to that observed and collected during the site selection trip undertaken in November 2003.

2.2 Reference condition

An intact and connected riparian zone, from the upper zone through to the marginal zone, defines the reference condition. The upper riparian zone comprises species more similar to that of valley bushveld than the surrounding false Karoo (Acocks, 1989). Low and Rebello (1996) describe this as south west coast Renosterveld. It comprises a closed thicket of shrubs and trees featuring *Podocarpus latifolius*, *Carissa bispinosa*, *Scutia myrtina*, *Rhus lucida*, *Maytenus heterophylla*, *Ehretia rigida*, *Acacia karroo*, *Euclea undulata*, *Cassine aethiopica* and many others. The lower riparian zone features *Diospyros lyciodes*, *Rhus dentata*, and Palmiet. The Palmiet forms large clumps on the edges of pools. Palmiet also dominates the marginal zone with smaller clumps of *Juncus* and other sedges and Restionaceae spp. featuring in other open areas.

No exotic species are present under the reference condition and cultivation is absent in the upper riparian zone.

2.3 PES

PES: D

The PES is poor mainly due to the impact of the invasion of exotic species and the impact of flow regulation (reductions in low flows and flood removals) imposed by Churchill Dam immediately upstream.

PES	Causes	Sources	Non flow related	Flow related
D	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Reduced low flows.	No	Yes
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Reduced low flows.	No	Yes
	Changes in abundance of vegetation.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in vegetation cover.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Reduced impact of flooding as a consequence of exotic species invasion.	No	Yes
Reduced low flows.		No	Yes	

Data confidence: PES evaluation and data confidence is High.

2.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
D	-	E	10-15 years	Further invasion of exotic species in riparian zone.

Data confidence: The confidence in trend evaluation data is Low to Medium since it is uncertain to what extent further exotic invasion will take place and bring about additional reductions in the PES.

2.5 Alternative ECs

The recommended EC is a D. In addition to the provision of the Reserve for a Category D, this will also require mainly non flow related management of the exotic species in the upper riparian zone, along with regular follow-up management.

3 EWR 3: DYKE - KROMME RIVER

3.1 Data availability

Available data is confined to that observed and collected during the site selection trip undertaken in November 2003. No vegetation surveys were undertaken since the site was selected as an important access route for fish and invertebrates between the estuary and Impofu Dam.

3.2 Reference condition

The reference condition is defined by dense clumps of riparian vegetation on sandy bars between the many pools and multiple small channels. Marginal vegetation is characterised by clumps of *Miscanthus*, *Cyperus textilis*, *Cliffortia* and Palmiet on the water edges and on small islands.

The lower riparian zone is characterised by dense stands of *Podocarpus latifolius*, *Ficus sur*, *Erica*, *Rhus* and *Euclea* species. The upper riparian zone is visibly different from the lower riparian zone and is characterised by dense Valley Bushveld species that colonise the steep slopes of the deeply incised river valley.

3.3 PES

PES: D

This is largely due to the invasion of exotic species and degeneration of the riparian zone due to reduced and regulated flows imposed by Impofu Dam and the significant abstraction of water from the river for farming purposes.

PES	Causes	Sources	Non flow related	Flow related
D	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Reduced and regulated low flows due to Impofu Dam.	No	Yes
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Reduced and regulated low flows due to Impofu Dam.	No	Yes
	Changes in vegetation cover.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
		Reduced impact of flooding as a consequence of exotic species invasion and the presence of Impofu Dam.	No	Yes
		Reduced and regulated low flows due to Impofu Dam.	No	Yes

Data confidence: PES evaluation and data confidence is High.

3.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
D	0	D	-	Site seems to have reached an equilibrium which is unlikely to change significantly under present management conditions.

Data confidence: The confidence in trend evaluation data is Medium since it is uncertain whether the vegetation has reached equilibrium and to what extent further exotic invasion may take place.

3.5 Alternative ECs

No alternative ECs were considered.

4 EWR 4: GEELHOUTBOOM RIVER

4.1 Data availability

Available data is confined to that observed and collected during the site selection trip undertaken in November 2003.

4.2 Reference condition

The reference condition is defined by a dense thicket of shrubs and trees with a closed canopy. Species composition conforms to that of Valley bushveld (Acocks, 1989) and is characterised by *Podocarpus latifolius*, *Carissa bispinosa*, *Maytenus heterophylla*, *Azima tetracantha*, *Scutia myrtina*, *Ehretia rigida*, *Acacia karroo*, *Euclea undulata* and many other. Species diversity is high. Marginal vegetation is abundant on the edges of pools and dominated by *Miscanthus junceus*, *Cyperus textilis* and other sedges. Riparian vegetation significantly stabilises the banks. The channel is incised; however, the reason for this is uncertain. Exotic species are absent at the site, but do exist in small, localised patches within the reach.

4.3 PES

PES: A/B

The PES is close to natural due to the fact that little to no change is evident in the riparian vegetation abundance, cover, species diversity and composition. Structure appears to be subtly altered by the reduction in abundance and cover of marginal vegetation. This is due to the regulation of low flows due to the impact of upstream impoundments. The riparian forest has a closed canopy for most of the length of the river and contains *Podocarpus latifolius* that is a threatened species.

PES	Causes	Sources	Non flow related	Flow related
A/B	Changes in vegetation structure.	Reduced and regulated low flows due to upstream impoundments.	No	Yes
		Reduced impact of flooding as a consequence of upstream impoundments.	No	Yes

Data confidence: PES evaluation and data confidence is High.

4.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
A/B	-	B	10 years	Vegetation seems to have reached equilibrium; however, continued incision may result in the degradation of the vegetation.

Data confidence: Confidence is Medium to High. Uncertainties do exist regarding the nature of the grazing by cattle and the impact on low flows and floods by the upstream impoundments.

4.5 Alternative ECs

No alternative ECs were considered.

5 EWR 5: SEEKOEI RIVER

5.1 Data availability

Available data is confined to that observed and collected during the site selection trip undertaken in September 2004 on the day prior to the specialist meeting.

5.2 Reference condition

The riparian vegetation reference condition for the river reach is characterised mainly by shrubs such as *Maytenus heterophylla*, *Diospyros* sp., *Azima tetraacantha*, and *Carissa bispinosa*. The canopy is open and grasses are common in the open spaces between shrubs. Exotic species are absent.

5.3 PES

PES: F

The reach is dominated by Black Wattle, bramble and Kikuyu. Marginal vegetation is largely absent due to grazing. The riparian zone is trampled by cattle and riparian shrubs have been browsed and removed. Species diversity, composition and structure have therefore been seriously impacted. Vegetation cover and abundance have been less affected due to the fact that the cover and abundance provided by exotic species is high.

PES	Causes	Sources	Non flow related	Flow related
F	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in vegetation cover and abundance.	Invasion of exotic species and exclusion and removal of indigenous species.	Yes	No
	Changes in vegetation structure.	Invasion of exotic species and exclusion and removal of indigenous species.	Yes	No
		Invasion of exotic species and exclusion and removal of indigenous species.	Yes	No

Data confidence: PES evaluation and data confidence is High. Extent of exotic invasion is highly significant.

5.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
F	-	F	10 years	Vegetation seems to have reached an equilibrium state dominated by Black Wattle, however, continued changes in channel structure (widening) will eventually lead to further degradation in the vegetation.

Data confidence: Confidence is Medium to High. Uncertainties do exist regarding the nature and extend of future channel widening.

5.5 Alternative ECs

No alternative ECs were considered.

6 EWR 6: SWART RIVER

6.1 Data availability

Available data is confined to that observed and collected during the site selection trip undertaken in September 2004 on the day prior to the specialist meeting.

6.2 Reference condition

The reference condition at the site is characterised by Valley Bushveld on the left bank. *Podocarpus latifolius*, *Maytenus heterophylla*, *Diospyros* sp., in the riparian zone. Palmiet, *Miscanthus* and sedges are dominant in the marginal zone. Exotic species are absent.

6.3 PES

PES: D

The PES is largely due to the invasion of Black Wattle at the site and the associated exclusion of indigenous vegetation

PES	Causes	Sources	Non flow related	Flow related
D	Decreased species diversity.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in species composition.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in vegetation cover and abundance.	Invasion of exotic species and exclusion of indigenous species.	Yes	No
	Changes in vegetation structure.	Invasion of exotic species and exclusion of indigenous species.	Yes	No

Data confidence: PES evaluation and data confidence is High. Extent of exotic species invasion is extensive.

6.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
D	-	E	10 years	Vegetation is on a long term decline due to the invasion of Black Wattle and exclusion of indigenous vegetation.

Data confidence: Confidence is Medium to High.

6.5 Alternative ECs

No alternative ECs were considered.

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APPENDIX D

FISH

Dr A. Bok, Anton Bok & Associates

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1 EWR 1: MELKHOUTBOSKRAAL - KROMME RIVER

1.1 Data Availability

Historical data

The Kromme River system has been relatively well-surveyed in the past and a total of 48 records are contained on the Albany Museum Fish Database for the period 1959 – 2001. The Melkhoutboskraal site was last surveyed in 1983.

Project survey data

Two fish surveys were carried out at EWR 1 in the Kromme River in November 2003 and March 2004. During these field surveys an electric fish shocker was used extensively, as well as (where feasible) a 6m minnow seine net.

Confidence of data: A moderate confidence level (score = 3 out of 5), due to limited fishing effort of about 90 minutes and about 130m of river surveyed (due to time constraints), and extrapolation of catch data to RU. More extensive surveys could possibly reveal small numbers of indigenous fish in selective habitats in this reach.

1.2 Reference condition

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Kromme River at EWR 1 – see Table D-1 below.

Table D-1 Fish species expected at EWR 1 in the Kromme River

Species Expected	Found	Discussion
<i>Pseudobarbus afer</i>	No	High densities, readily seen and caught, if present.
<i>Sandelia capensis</i>	No	High densities, readily seen and caught, if present.
<i>Anguilla mossambica</i>	No	Moderate densities, adults not easily caught.
<i>Anguilla marmorata</i>	No	Low densities, not easily caught.
<i>Anguilla bicolor bicolor</i>	No	Low densities, not easily caught.

1.3 PES

It should be noted that the presence at this site of large numbers of highly effective alien predatory largemouth bass, *Micopterus salmoides*, has resulted in the local extermination of the indigenous fish species *P. afer* and *S. capensis* from the main channel of the Kromme River. These native species, which should be present in large numbers (see above), do not have effective predator-avoidance behavior and are very vulnerable to predation in clear, shallow streams.

The PES was assessed using two approaches:

- a) Ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes; and
- b) taking into account the impact of alien fish.

The evaluation taking the impact of alien fish into account was undertaken for EWR 1 as an example to illustrate the effect of this factor on the final assessment in the FRAI protocol. The main aim of the fish assessment protocol is to evaluate the present condition of the aquatic habitats available to the indigenous fish species, i.e. the fish habitat integrity. It was thus decided that the impact of alien fish should not be taken into account (Dr Neels Kleynhans, *pers comm.*). In some instances where no or few indigenous fish were caught,

this meant that the response of the indigenous fish species *expected to present* at the site to the existing fish habitat integrity, was evaluated in terms of the protocol.

a) PES - Excluding the impact of alien fish

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	51.76	0.28	14.56	2.00	90.00
FLOW MODIFICATION METRICS	FM	55.20	0.31	17.25	1.00	100.00
COVER METRICS	CM	65.38	0.22	14.30	3.00	70.00
HEALTH/CONDITION METRICS	HM	84.74	0.19	15.89	4.00	60.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	91.30	0.00	0.00	0.00	0.00
			1.00			320.00
Fish PES				62.00		
Fish PES Category				C		

b) PES - Including the impact of alien fish

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	51.76	0.09	4.44	3.00	30.00
FLOW MODIFICATION METRICS	FM	55.20	0.11	6.31	2.00	40.00
COVER METRICS	CM	65.38	0.03	1.87	4.00	10.00
HEALTH/CONDITION METRICS	HM	84.74	0.01	1.21	5.00	5.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	91.30	0.29	-26.09	1.00	100.00
			1.00			350.00
Fish PES				-12.26		
Fish PES Category				F		

PES	Causes	Sources	Flow/Non flow related	Confidence
D	Reduction in river flows, particularly low flows and increased periods of extremely low flows (possibly no flows at times).	i) Destruction of Palmiet wetlands.	Non flow related.	4
		ii) Direct abstraction and/or via farm dams for farming.	Flow related.	3
		iii) Increased evapotranspiration due to forestry and alien vegetation.	Non flow related.	3
	Increased sediment load, silting up of pools, embedding rock substrate cover.	i) Soil erosion due to bad farming practices.	Non Flow related.	2
		ii) Bank erosion and collapse due to alien trees (e.g. black wattles).	Non flow related.	3
	Reduced water quality, including increased nutrients, increased temperatures, and reduced DO levels.	i) Fertilizer input from farms.	Non flow related.	2
		ii) Increased silt load and turbidity at high flows.	Non flow related.	2
		iii) Reduced DO and increased temperature during low flows in summer.	Flow related.	2

PES	Causes	Sources	Flow/Non flow related	Confidence
	Increased predation.	Presence of highly effective alien predator under favourable conditions for predation. (Note: this factor ignored in evaluation)	Non flow related.	5

1.4 Trend and Reasons

PES	Trend	Resulting PES	Time	Reasons
C (low)	Stable	C	N/a	Working for Water (WfW) programme clearing alien trees in catchment and riparian zones; but this impact considered secondary to flow modification which is unlikely to change.

2 EWR 2: KROMMERIVIERS POORT - KROMME RIVER

2.1 Data Availability

Historical data

This section of the Kromme River system has been relatively well surveyed in the past and good historical records are available in the Albany Museum Fish Database for the period 1959 – 2001.

Project survey data

Two fish surveys were carried out at EWR 2 in the Kromme River in November 2003 and March 2004. During these field surveys an electric fish shocker was used extensively in the range of habitats, apart from deep pools >1.5 m in depth.

Confidence of data: A moderate confidence level (score = 3 out of 5). This confidence level is due to limited fishing effort and the possibility that more extensive surveys could produce small numbers of indigenous fish in selective habitats in this reach.

2.2 Reference condition

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Kromme River at EWR 2 – see Table D-2 below.

Table D-2 Fish species expected at EWR 2 in the Kromme River

Species Expected	Found	Discussion (Expected densities etc.)
<i>Pseudobarbus afer</i>	No	High densities, readily seen and caught, if present.
<i>Sandelia capensis</i>	No	High densities, readily seen and caught, if present.
<i>Anguilla mossambica</i>	Yes	Moderate densities, adults not easily caught.
<i>Anguilla marmorata</i>	No	Low densities, not easily caught.
<i>Anguilla bicolor bicolor</i>	No	Low densities, not easily caught.

2.3 PES

Species found at the site included the alien predatory largemouth bass, *Micopterus salmoides* and the non-endemic banded tilapia or vleikurper, *Tilapia sparrmanii*. Again no indigenous fish species, e.g. *P. afer* and *S. capensis* were found. One eel, *Anguilla mossambice*, was seen.

a) PES - Excluding the impact of alien fish

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	84.83	0.36	30.30	1.00	100.00
FLOW MODIFICATION METRICS	FM	53.46	0.32	17.18	2.00	90.00
COVER METRICS	CM	85.65	0.25	21.41	3.00	70.00
HEALTH/CONDITION METRICS	HM	84.44	0.07	6.03	4.00	20.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	89.57	0.00	0.00	0.00	0.00
			1.00			280.00
Fish PES				74.92		
Fish PES Category				C		

A summary of the causes and sources for the change from reference condition is given in the table below.

PES	Causes	Sources	Flow/Non flow related	Confidence
C	Flow modification – reduced high flows, non-seasonal flows.	• Upstream Churchill Dam. Intercepting all flows, apart from but very high floods.	Flow related.	4
		• Un-seasonal flows released from dam.	Flow related.	3
	Reduced sediment and nutrient, detritus input.	• Capture by upstream Churchill Dam.	Non flow related.	3
	Encroachment of alien vegetation into channel.	• Invasion by alien Black Wattle.	Non flow related.	2
• Reduced scouring by floods.		Flow related.	2	
Increased predation.	• Presence of highly effective alien predator under favourable conditions for predation. (Note: this factor ignored in evaluation)	Non flow related.	5	

2.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
C (low)	Stable	C	N/a	Situation has stabilised due to age of Churchill Dam. WfW programme underway to clear alien trees in catchment and riparian zones; but this impact considered secondary to flow modification which is unlikely to change.

2.5 Alternative ECs

No alternative ecological categories were considered.

3 EWR 3: DYKE - KROMME RIVER

3.1 Data Availability

Historical data

Good historical records are available in the Albany Museum Fish Database for the period 1959 – 2001.

Project survey data

Only one fish survey was carried out at EWR 3 in the Kromme River in November 2003. Only an electric fish shocker was used in the range of still water habitats, including pools <1.5 m in depth. NO FLOW was seen during the survey and levels were further reduced by extension pumping by farmer.

Confidence of data: A low to moderate confidence level (score = 2 out of 5). A reduced confidence is due to limited fishing effort and the possibility that more extensive surveys could produce small numbers of indigenous fish in selective habitats in this reach.

3.2 Reference condition

From historical records and general fish distribution data, a total of approximately 8 indigenous fish species are expected to be present in the Kromme River at EWR 3 – see Table D-3 below. The relatively high species number expected at this site is due to catadromous species migrating up from the nearby estuary.

Table D-3 Fish species expected at EWR 3 in the Kromme River

Species Expected	Found	Discussion (Expected densities etc.)
<i>Pseudobarbus afer</i>	No	High densities, readily seen and caught, if present.
<i>Sandelia capensis</i>	No	High densities, readily seen and caught, if present.
<i>Anguilla mossambica</i>	No	Moderate densities, adults not easily caught.
<i>Anguilla marmorata</i>	No	Low densities, not easily caught.
<i>Anguilla bicolor bicolor</i>	No	Low densities, not easily caught.
<i>Myxus capensis</i>	No	Catadromous species, usually very numerous in lower reach of coastal rivers.
<i>Monodactylus falciformis</i>	No	Catadromous species, usually very numerous in lower reach of coastal rivers.
<i>Glossogobius callidus</i>	No	Catadromous species, usually very numerous in lower reach of coastal rivers.

3.3 PES

Only the alien predatory largemouth bass, *Micropodus salmoides*, was found at this site. Again no indigenous fish species at all were seen. Apart from the serious impact of predation, flow related impacts in this reach are particularly severe due to:

- No flow in river for long periods in a normally perennial system will impact severely on semi-rheophilic species (*P. afer* and *A. mossambica*).
- Upstream migration of catadromous species over the bedrock rapid will be prevented by low and no flows (also reduce freshwater cue to attract fish into the estuary from marine spawning grounds).

The PES was assessed by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes caused by alterations to the habitat drivers. Taking the impact of alien predatory fish into account will reduce the PES to a category E or F due to the apparent total elimination of indigenous fish.

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	45.00	0.38	17.23	2.00	90.00
FLOW MODIFICATION METRICS	FM	40.00	0.43	17.02	1.00	100.00
COVER METRICS	CM	48.00	0.17	8.17	3.00	40.00
HEALTH/CONDITION METRICS	HM	53.68	0.02	1.14	4.00	5.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	85.38	0.00	0.00	0.00	0.00
			1.00			235.00
Fish PES				43.57		
Fish PES Category				D		

A summary of the causes and sources for the change from reference condition is given in the table below.

PES	Causes	Sources	Flow/Non Flow related	Confidence
D	Flow Modification – no flow for long periods, reduced high flows, non-seasonal flows.	• Upstream Impofu dam intercepting all flows, apart from but very high floods.	Flow related.	5
		• Un-seasonal flows released from dam.	Flow related.	3
		• Farmer abstracting all flows and reducing pool levels drastically.	Flow related.	4
	Reduced sediment and nutrient, detritus input.	• Capture by upstream Impofu Dam.	Flow related.	3
Encroachment of alien vegetation into channel.	• Invasion by alien Black Wattle. • Reduced scouring by floods.	Non Flow related. Flow related.	3 3	
Increased predation.	Presence of highly effective alien predator under favorable conditions for predation. (Note: this factor ignored in evaluation).	Non Flow related.	5	

3.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
D	Stable	D	10 yrs	Flow modification which is unlikely to change in future unless new release policy adopted and enforced (low confidence). Environmental flows should theoretically be released – but not done in practice.

4 EWR 4: GEELHOUTBOOM RIVER

4.1 Data Availability

Historical data

No historical data from the Geelhoutboom River was available in the Albany Museum Fish Database, but as a major tributary of the Kromme River, is expected to have similar species.

Project survey data

Only one fish survey was carried out at EWR 4 in the Kromme River in November 2003. Shallow pools were Seine netted, but no fish were seen or caught. Water was very low, with no flow at the time of sampling.

Confidence of data: A low confidence level (score = 1 out of 5 was recorded). A reduced confidence is due to limited fishing effort and the possibility that more extensive surveys could produce small numbers of indigenous fish in selective habitats in this reach.

4.2 Reference condition

From general fish distribution data, up to 5 indigenous fish species are expected to be present in the Geelhoutboom River at EWR 4 – see Table D-4 below. However, the small size of the system and relatively low river flows would mean that freshwater eels would be very scarce, if present at all.

Table D-4 Fish species expected at EWR 4 in the Geelhoutboom tributary of the Kromme River

Species Expected	Found	Discussion (Expected densities etc.)
<i>Pseudobarbus afer</i>	No	High densities, readily seen and caught, if present.
<i>Sandelia capensis</i>	No	High densities, readily seen and caught, if present.
<i>Anguilla mossambica</i>	No	Moderate densities, adults not easily caught.
<i>Anguilla marmorata</i>	No	Low densities, not easily caught.
<i>Anguilla bicolor bicolor</i>	No	Low densities, not easily caught.

4.3 PES

No indigenous fish species or alien fish species at all were seen. Flow related impacts in this reach are particularly severe due to lack of flow in river for long periods in (probably) a normally perennial system and this will impact severely on semi-rheophillic species (*P. afer* and *A. mossambica*).

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	56.19	0.38	21.61	1.00	100.00
FLOW MODIFICATION METRICS	FM	26.06	0.35	9.02	2.00	90.00
COVER METRICS	CM	72.00	0.23	16.62	3.00	60.00
HEALTH/CONDITION METRICS	HM	83.33	0.04	3.21	4.00	10.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	0.00	0.00	0.00	0.00	0.00
			1.00			260.00
Fish PES				50.45		
Fish PES Category				D		

A summary of the causes and sources for the change from reference condition is given in the table below.

PES	Causes	Sources	Flow/Non flow related	Confidence
D	Flow modification – no flow for long periods.	<ul style="list-style-type: none"> Farmer abstracting relatively large volumes, thirsty alien trees upstream of site reducing low flows and reducing pool levels drastically. 	Flow related.	3
	Increased sediment deposition.	<ul style="list-style-type: none"> Invasion by alien Black Wattle, destabilising banks. Cattle trampling (in past), bad catchment management. 	Non flow related. Non flow related.	2 2

PES	Trend	Resulting PES	Time	Reasons
D	Negative (slight)	E/F	10 yrs	Poor catchment management, alien tree density and abstraction unlikely to improve in future with increased human pressure in catchment.

5 EWR 5: SEEKOEI RIVER

5.1 Data Availability

Historical data

Historical records are available from surveys done in 1976 and 1983 in the Albany Museum Fish Database.

Project survey data

Only one fish survey was carried out at EWR 5 in the Seekoei River in March 2004. Only an electric fish shocker was used in the range of still water habitats, including pools <1.5m in depth. NOTE: Survey undertaken about 2km upstream of actual EWR 5 site, i.e. upstream of barrier weir.

Confidence of data: A low confidence level (score = 2 out of 5 was ascribed to this site). A reduced confidence is due to limited fishing effort and the possibility that more extensive surveys could produce small numbers of indigenous fish in selective habitats in this reach.

5.2 Reference condition

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Seekoei River at EWR 5, although eels are expected in low numbers only– see Table D-5 below.

Table D-5 Fish species expected at EWR 5 in the Seekoei River

Species Expected	Found	Discussion (Expected densities etc.)
<i>Pseudobarbus afer</i>	No	High densities, readily seen and caught, if present.
<i>Sandelia capensis</i>	Yes	High densities, readily seen and caught, if present (6 caught during survey).
<i>Anguilla mossambica</i>	No	Moderate densities, adults not easily caught.
<i>Anguilla marmorata</i>	No	Low densities, not easily caught.
<i>Anguilla bicolor bicolor</i>	No	Low densities, not easily caught.

5.3 PES

No *Micopterus salmoides* was found at this site, but are very likely to be present downstream. Only *Sandelia capensis* was caught (n = 6), with the more sensitive *P. afer* absent. Serious habitat destruction is apparent in the downstream section of this Habitat Unit. Apart from the suspected serious impact of predation by bass, flow related and non flow related impacts in sections of this reach are severe.

The PES was assessed by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes caused by alterations to the habitat drivers. Taking the impact of alien predatory fish into account will reduce the PES to a category E or F due to the apparent total elimination of indigenous fish.

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	63.64	0.28	17.55	3.00	80.00
FLOW MODIFICATION METRICS	FM	75.86	0.34	26.16	1.00	100.00
COVER METRICS	CM	54.81	0.31	17.01	2.00	90.00
HEALTH/CONDITION METRICS	HM	85.79	0.07	5.92	4.00	20.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	39.05	0.00	0.00	0.00	0.00
			1.00			290.00
Fish PES				66.64		
Fish PES Category				C		

A summary of the causes and sources for the change from reference condition is given in the table below.

PES	Causes	Sources	Flow/Non Flow related	Confidence
C	Flow modification – reduced (or no) low flows for long periods.	<ul style="list-style-type: none"> Farmer abstracting flows. Thirsty alien trees upstream of site. 	Flow related.	2
	Increased sediment input.	<ul style="list-style-type: none"> Roads, cattle trampling, bad agricultural practices, bank collapse, alien trees in riparian zone. 	Non flow related.	3
			Non Flow related.	2

PES	Trend	Resulting PES	Time	Reasons
C	Negative	C/D	5 yrs	Both flow related and non-flow related impacts likely to get worse in the short-term, before (if) existing trend could be improved.

6 EWR 6: SWART RIVER

6.1 Data Availability

Historical data

Historical records are available in the Albany Museum Fish Database from surveys done in 1983 in the upper Swart/Rondebosch tributary of the Seekoei River.

Project survey data

Only one fish survey was carried out at EWR 6 in the Swart/Rondebosch River in March 2004. Only an electric fish shocker was used.

Confidence of data: A low confidence level (score = 2 out of 5 was ascribed to this site). A reduced confidence is due to limited fishing effort and the possibility that more extensive surveys could produce small numbers of indigenous fish in selective habitats in this reach.

6.2 Reference condition

From historical records and general fish distribution data, a total of approximately 5 indigenous fish species are expected to be present in the Swart/Rondebosch River at EWR 6, although eels are expected in low numbers only, see Table D-6 below.

Table D-6 Fish species expected at EWR 6 in the Swart/Rondebosch River

Species Expected	Found	Discussion (Expected densities etc.)
<i>Pseudobarbus afer</i>	No	High densities, readily seen and caught, if present.
<i>Sandelia capensis</i>	No	High densities, readily seen and caught, if present.
<i>Anguilla mossambica</i>	No	Moderate densities, adults not easily caught.
<i>Anguilla marmorata</i>	No	Low densities, not easily caught.
<i>Anguilla bicolor bicolor</i>	No	Low densities, not easily caught.

6.3 PES

Only *Micopterus salmoides* (n = 12) was found at this site, and in surprisingly high densities in marginal habitat in this small stream. Apart from the serious impact of predation by bass in this reach, flow related and no flow related impacts in sections of this Resource Unit will vary from low to moderate in the upper reaches to critical in the lower reaches.

The PES was assessed by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes caused by alterations to the habitat drivers. Taking the impact of alien predatory fish into account will reduce the PES to a category E or F due to the apparent total elimination of indigenous fish.

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	76.55	0.32	24.69	1.00	100.00
FLOW MODIFICATION METRICS	FM	80.00	0.29	23.23	2.00	90.00
COVER METRICS	CM	73.85	0.29	21.44	3.00	90.00
HEALTH/CONDITION METRICS	HM	88.40	0.10	8.55	4.00	30.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	93.04	0.00	0.00	0.00	0.00
			1.00			310.00
Fish PES				77.91		
Fish PES Category				C		

A summary of the causes and sources for the change from reference condition in the RU at EWR 6 in the Swart/Rondebosch River, is given in the table below.

PES	Causes	Sources	Flow/Non flow related	Confidence
D	Flow modification – smaller low flows for longer periods.	<ul style="list-style-type: none"> Farmer abstracting flows from river mainly via catchment dams. Thirsty alien trees in riparian zone and upper catchment. 	Flow related.	2
	Increased sediment input, reducing pool depths, silting up riffles.	<ul style="list-style-type: none"> Roads, cattle trampling, bad agricultural practices, bank collapse, alien trees in riparian zone. 	Non flow related.	2

PES	Trend	Resulting PES	Time	Reasons
D	Negative (slight)	D	5 yrs	Both flow related and non-flow related impacts likely to get worse in the short-term, before (if) existing trend could be improved.

7 FISH PES INFORMATION

7.1 EWR 1

7.1.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
ABIC	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.0
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	4.0	2.8	1.0	4.0	4.0	4.2	4.3	#DIV/0!	#DIV/0!	3.5	2.5	1.0
MEDIAN	3.4	3.3	4.0	3.6	#NUM!	4.0	2.8	1.0	4.0	4.0	4.1	4.3	#NUM!	#NUM!	3.5	2.5	1.0
NUMBER	1.0	1.0	3.0	2.0	0.0	1.0	2.0	2.0	1.0	3.0	4.0	2.0	0.0	0.0	1.0	2.0	2.0

SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
MSAL	FALSE	FALSE	4.5	FALSE	FALSE	FALSE	FALSE	1.1	3.1	FALSE	3.1	3.2	FALSE	FALSE	FALSE	2.3	FALSE
LMAC	FALSE	FALSE	4.6	3.9	FALSE	FALSE	FALSE	1.1	4.0	FALSE	FALSE	4.2	FALSE	FALSE	FALSE	2.2	FALSE
AVERAGE	#DIV/0!	#DIV/0!	4.6	3.9	#DIV/0!	#DIV/0!	#DIV/0!	1.1	3.6	#DIV/0!	3.1	3.7	#DIV/0!	#DIV/0!	#DIV/0!	2.3	#DIV/0!
MEDIAN	#NUM!	#NUM!	4.6	3.9	#NUM!	#NUM!	#NUM!	1.1	3.6	#NUM!	3.1	3.7	#NUM!	#NUM!	#NUM!	2.3	#NUM!

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
NUMBER	0.0	0.0	2.0	1.0	0.0	0.0	0.0	2.0	2.0	0.0	1.0	2.0	0.0	0.0	0.0	2.0	0.0

7.1.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-2.00	0.24	-1.41	2.00	40.00	0.24
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-3.00	0.59	-5.29	1.00	100.00	0.59
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-1.00	0.18	-0.53	3.00	30.00	0.18
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	1.00	0.00	0.00	0.00	0.00	0.00
Absolute sum			1.00	7.24	3.00	170.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				48.24			

7.1.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.000	0.00	0.0	0.0	0.000
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-3.00	0.400	-6.00	1.0	100.0	0.400
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-2.00	0.280	-2.80	2.0	70.0	0.280
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.080	0.00	3.0	20.0	0.080
Presence of catadromous spp.	CAT	-2.00	0.120	-1.20	4.0	30.0	0.120
Presence of migratory spp.	MIG	-2.00	0.120	-1.20	5.0	30.0	0.120
			1.00	11.20	5.0	250.0	1.0
Absolute overall % change in flow dependence of assemblage				44.80			

7.1.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-1.0	0.27	-1.1	3	70.0	0.27
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-1.0	0.31	-1.2	2	80.0	0.31
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-3.0	0.38	-4.6	1	100.0	0.38
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-1.0	0.00	0.0	4	0.0	0.00
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.04	0.0	0	10.0	0.04
			1.0	6.9	4.0	260.0	1.0
Absolute overall % change in habitat assemblages				34.62			

7.1.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighed abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	-1.00	0.53	-1.05	1.00	100.00	0.53
Health of species moderately intolerant of modified water quality	MIH	-0.50	0.47	-0.47	2.00	90.00	0.47
Health of species moderately tolerant of modified water quality	MTH	0.00	0.00	0.00	0.00	0.00	0.00
Health of species tolerant of modified water quality	HT	0.00	0.00	0.00	0.00	0.00	0.00
Sum			1.00	1.53	2.00	190.00	1.00
Overall % change to indicators of modified water quality				15.26			

7.1.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1	Natural reference
The potential impact of introduced predatory spp?	IP	5.0	0.43	8.70	1.0	100.0	0.435	0.0
How widespread (frequency of occurrence) are introduced predatory spp?	FP	5.0	0.39	7.83	2.0	90.0	0.391	0.0
The potential impact of introduced habitat modifying spp?	IH	3.0	0.09	1.04	3.0	20.0	0.087	0.0
How widespread (frequency of occurrence) are habitat modifying spp?	FH	2.0	0.09	0.70	4.0	20.0	0.087	0.0
Sum			1.0	18.26	4.0	230.0		
Overall % potential impact of introduced spp				91.30				

7.1.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	51.76	0.28	14.56	2.00	90.00
FLOW MODIFICATION METRICS	FM	55.20	0.31	17.25	1.00	100.00
COVER METRICS	CM	65.38	0.22	14.30	3.00	70.00
HEALTH/CONDITION METRICS	HM	84.74	0.19	15.89	4.00	60.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	91.30	0.00	0.00	0.00	0.00
			1.00			320.00
Fish PES				62.00		
Fish PES Category				C		

7.2 EWR 1: Alternative REC

7.2.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
ABIC	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.0
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	4.0	2.8	1.0	4.0	4.0	4.2	4.3	#DIV/0!	#DIV/0!	3.5	2.5	1.0
MEDIAN	3.4	3.3	4.0	3.6	#NUM!	4.0	2.8	1.0	4.0	4.0	4.1	4.3	#NUM!	#NUM!	3.5	2.5	1.0
NUMBER	1.0	1.0	3.0	2.0	0.0	1.0	2.0	2.0	1.0	3.0	4.0	2.0	0.0	0.0	1.0	2.0	2.0
SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
MSAL	FALSE	FALSE	4.5	FALSE	FALSE	FALSE	FALSE	1.1	3.1	FALSE	3.1	3.2	FALSE	FALSE	FALSE	2.3	FALSE
LMAC	FALSE	FALSE	4.6	3.9	FALSE	FALSE	FALSE	1.1	4.0	FALSE	FALSE	4.2	FALSE	FALSE	FALSE	2.2	FALSE
AVERAGE	#DIV/0!	#DIV/0!	4.6	3.9	#DIV/0!	#DIV/0!	#DIV/0!	1.1	3.6	#DIV/0!	3.1	3.7	#DIV/0!	#DIV/0!	#DIV/0!	2.3	#DIV/0!
MEDIAN	#NUM!	#NUM!	4.6	3.9	#NUM!	#NUM!	#NUM!	1.1	3.6	#NUM!	3.1	3.7	#NUM!	#NUM!	#NUM!	2.3	#NUM!

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE				TOLERANCE: MODIFIED WQ				
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
NUMBER	0.0	0.0	2.0	1.0	0.0	0.0	0.0	2.0	2.0	0.0	1.0	2.0	0.0	0.0	0.0	2.0	0.0

7.2.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-3.00	0.24	-2.12	2.00	40.00	0.24
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-3.00	0.59	-5.29	1.00	100.00	0.59
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-1.00	0.18	-0.53	3.00	30.00	0.18
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	1.00	0.00	0.00	0.00	0.00	0.00
Absolute sum			1.00	7.94	3.00	170.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				52.94			

7.2.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.000	0.00	0.0	0.0	0.000
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-4.00	0.400	-8.00	1.0	100.0	0.400
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-2.00	0.280	-2.80	2.0	70.0	0.280
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.080	0.00	3.0	20.0	0.080
Presence of catadromous spp.	CAT	-2.00	0.120	-1.20	4.0	30.0	0.120
Presence of migratory spp.	MIG	-2.00	0.120	-1.20	5.0	30.0	0.120
			1.00	13.20	5.0	250.0	1.0
Absolute overall % change in flow dependance of assemblage				52.80			

7.2.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-3.0	0.27	-3.2	3	70.0	0.27
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-3.0	0.31	-3.7	2	80.0	0.31
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-3.0	0.38	-4.6	1	100.0	0.38
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-1.0	0.00	0.0	4	0.0	0.00
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.04	0.0	0	10.0	0.04
			1.0	11.5	4.0	260.0	1.0
Absolute overall % change in habitat assemblages				57.69			

7.2.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighted abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	-2.00	0.53	-2.11	1.00	100.00	0.53
Health of species moderately intolerant of modified water quality	MIH	-2.00	0.47	-1.89	2.00	90.00	0.47
Health of species moderately tolerant of modified water quality	MTH	-1.00	0.00	0.00	0.00	0.00	0.00
Health of species tolerant of modified water quality	HT	0.00	0.00	0.00	0.00	0.00	0.00
Sum			1.00	4.00	2.00	190.00	1.00
Overall % change to indicators of modified water quality				40.00			

7.2.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	5.0	0.43	8.70	1.0	100.0	0.435
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	5.0	0.39	7.83	2.0	90.0	0.391
The potential impact of introduced habitat modifying spp?	IH	3.0	0.09	1.04	3.0	20.0	0.087
How widespread (frequency of occurrence) are habitat modifying spp?	FH	2.0	0.09	0.70	4.0	20.0	0.087
Sum			1.0	18.26	4.0	230.0	
Overall % potential impact of introduced spp				91.30			

7.2.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	47.06	0.28	13.24	2.00	90.00
FLOW MODIFICATION METRICS	FM	47.20	0.31	14.75	1.00	100.00
COVER METRICS	CM	42.31	0.22	9.25	3.00	70.00
HEALTH/CONDITION METRICS	HM	60.00	0.19	11.25	4.00	60.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	91.30	0.00	0.00	0.00	0.00
			1.00			320.00
Fish PES				48.49		
Fish PES Category				D		

7.3 EWR 2

7.3.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE				TOLERANCE: MODIFIED WQ				
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
ABIC	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.0
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
MCAP	FALSE	FALSE	3.8	FALSE	FALSE	3.5	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	3.8	FALSE	FALSE	3.0	FALSE

SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE				TOLERANCE: MODIFIED WQ				
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
MSAL	FALSE	FALSE	4.5	FALSE	FALSE	FALSE	FALSE	1.1	3.1	FALSE	3.1	3.2	FALSE	FALSE	FALSE	2.3	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
TSPA	FALSE	FALSE	FALSE	4.3	FALSE	FALSE	FALSE	0.9	4.5	FALSE	FALSE	3.6	FALSE	FALSE	FALSE	FALSE	1.4
AVERAGE	3.4	3.3	4.0	4.3	#DIV/0!	#DIV/0!	2.8	1.0	3.8	4.1	4.0	3.4	#DIV/0!	#DIV/0!	#DIV/0!	2.4	1.4
MEDIAN	3.4	3.3	4.0	4.3	#NUM!	#NUM!	2.8	1.0	3.8	4.1	4.0	3.4	#NUM!	#NUM!	#NUM!	2.4	1.4

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE				TOLERANCE: MODIFIED WQ				
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
NUMBER	1.0	1.0	2.0	1.0	0.0	0.0	1.0	2.0	2.0	1.0	2.0	2.0	0.0	0.0	0.0	2.0	1.0

7.3.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-2.00	0.21	-1.66	3.00	60.00	0.21
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-1.00	0.34	-1.38	1.00	100.00	0.34
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	0.00	0.28	0.00	2.00	80.00	0.28
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	0.00	0.17	0.00	4.00	50.00	0.17
Absolute sum			1.00	3.03	4.00	290.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				15.17			

7.3.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.000	0.00			0.000
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-3.00	0.385	-5.77	1.0	100.0	0.385
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-2.00	0.231	-2.31	2.0	60.0	0.231
Frequency of occurrence of species tolerant of no flow conditions	FT	-0.50	0.038	-0.10	5.0	10.0	0.038
Presence of catadromous spp.	CAT	-2.00	0.192	-1.92	3.0	50.0	0.192
Presence of migratory spp.	MIG	-2.00	0.154	-1.54	4.0	40.0	0.154
			1.00	11.63	5.0	260.0	1.0
Absolute overall % change in flow dependance of assemblage				46.54			

7.3.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-0.5	0.26	-0.4	3	60.0	0.26
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-0.5	0.30	-0.5	2	70.0	0.30
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	1.0	0.43	1.3	1	100.0	0.43
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	0.0	0.00	0.0	0	0.0	0.00
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.00	0.0	0	0.0	0.00
			1.0	2.2	3.0	230.0	1.0
Absolute overall % change in habitat assemblages				14.35			

7.3.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	abundance, health and condition	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	-1.00	0.56	-2.22	1.00	100.00	0.56
Health of species moderately intolerant of modified water quality	MIH	-0.50	0.44	-0.89	2.00	80.00	0.44
Health of species moderately tolerant of modified water quality	MTH	0.00	0.00	0.00	3.00	0.00	0.00
Health of species tolerant of modified water quality	HT	0.00	0.00	0.00	4.00	0.00	0.00
Sum			1.00	3.11	4.00	180.00	1.00
Overall % change to indicators of modified water quality				15.56			

7.3.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced spp. impact score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	5.0	0.43	8.70	1.0	100.0	0.435
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	5.0	0.35	6.96	2.0	80.0	0.348
The potential impact of introduced habitat modifying spp?	IH	3.0	0.13	1.57	4.0	30.0	0.130
How widespread (frequency of occurrence) are habitat modifying spp?	FH	2.0	0.09	0.70	3.0	20.0	0.087
Sum			1.0	17.91	4.0	230.0	
Overall % potential impact of introduced spp				89.57			

7.3.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	84.83	0.36	30.30	1.00	100.00
FLOW MODIFICATION METRICS	FM	53.46	0.32	17.18	2.00	90.00
COVER METRICS	CM	85.65	0.25	21.41	3.00	70.00
HEALTH/CONDITION METRICS	HM	84.44	0.07	6.03	4.00	20.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	89.57	0.00	0.00	0.00	0.00
			1.00			280.00
Fish PES				74.92		
Fish PES Category				C		

7.4 EWR 3

7.4.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
MCAP	FALSE	FALSE	3.8	FALSE	FALSE	3.5	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	3.8	FALSE	FALSE	3.0	FALSE
MCEP	FALSE	FALSE	3.8	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	FALSE	FALSE	FALSE	3.8	FALSE	FALSE	2.5	FALSE
MFAL	FALSE	FALSE	FALSE	3.5	FALSE	FALSE	3.0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	3.8	2.9	2.0	4.0	4.0	4.2	4.3	3.8	#DIV/0!	3.5	2.6	2.0
MEDIAN	3.4	3.3	3.8	3.5	#NUM!	3.8	2.8	2.0	4.0	4.0	4.1	4.3	3.8	#NUM!	3.5	2.5	2.0
NUMBER	1.0	1.0	5.0	3.0	0.0	2.0	4.0	1.0	1.0	3.0	4.0	2.0	2.0	0.0	1.0	4.0	2.0
SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
MSAL	FALSE	FALSE	4.5	FALSE	FALSE	FALSE	FALSE	1.1	3.1	FALSE	3.1	3.2	FALSE	FALSE	FALSE	2.3	FALSE
AVERAGE	#DIV/0!	#DIV/0!	4.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.1	3.1	#DIV/0!	3.1	3.2	#DIV/0!	#DIV/0!	#DIV/0!	2.3	#DIV/0!
MEDIAN	#NUM!	#NUM!	4.5	#NUM!	#NUM!	#NUM!	#NUM!	1.1	3.1	#NUM!	3.1	3.2	#NUM!	#NUM!	#NUM!	2.3	#NUM!

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
NUMBER	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0

7.4.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-2.00	0.29	-2.33	2.00	70.00	0.29
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-3.00	0.42	-5.00	1.00	100.00	0.42
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-3.00	0.25	-3.00	3.00	60.00	0.25
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	-4.00	0.04	-0.67	4.00	10.00	0.04
Absolute sum			1.00	11.00	4.00	240.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				55.00			

7.4.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	%weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.091	0.00	0.0	20.0	0.091
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-2.00	0.318	-3.18	3.0	70.0	0.318
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-4.00	0.182	-3.64	4.0	40.0	0.182
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.000	0.00	5.0	0.0	0.000
Presence of catadromous spp.	CAT	-4.00	0.045	-0.91	1.0	10.0	0.045
Presence of migratory spp.	MIG	-4.00	0.364	-7.27	2.0	80.0	0.364
			1.00	15.00	5.0	220.0	1.0
Absolute overall % change in flow dependance of assemblage				60.00			

7.4.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-3.0	0.28	-4.2	2	90.0	0.28
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-3.0	0.31	-4.6	1	100.0	0.31
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-0.5	0.15	-0.4	4	50.0	0.15
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-3.0	0.25	-3.7	3	80.0	0.25
Frequency of occurrence of species with a very high to high preference for the water column	WC	-2.0	0.02	-0.2	4	5.0	0.02
			1.0	13.0	5.0	325.0	1.0
Absolute overall % change in habitat assemblages				52.00			

7.4.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighed abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	0.00	0.00	0.00	5.00	0.00	0.00
Health of species moderately intolerant of modified water quality	MIH	-3.00	0.53	-6.32	1.00	100.00	0.53
Health of species moderately tolerant of modified water quality	MTH	-2.00	0.37	-2.95	2.00	70.00	0.37
Health of species tolerant of modified water quality	HT	0.00	0.11	0.00	4.00	20.00	0.11
Sum			1.00	9.26	4.00	190.00	1.00
Overall % change to indicators of modified water quality				46.32			

7.4.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	5.0	0.38	7.69	1.0	100.0	0.385
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	5.0	0.35	6.92	2.0	90.0	0.346
The potential impact of introduced habitat modifying spp?	IH	1.0	0.15	0.62	3.0	40.0	0.154
How widespread (frequency of occurrence) are habitat modifying spp?	FH	4.0	0.12	1.85	3.0	30.0	0.115
Sum			1.0	17.08	4.0	260.0	
Overall % potential impact of introduced spp				85.38			

7.4.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	45.00	0.38	17.23	2.00	90.00
FLOW MODIFICATION METRICS	FM	40.00	0.43	17.02	1.00	100.00
COVER METRICS	CM	48.00	0.17	8.17	3.00	40.00
HEALTH/CONDITION METRICS	HM	53.68	0.02	1.14	4.00	5.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	85.38	0.00	0.00	0.00	0.00
			1.00			235.00
Fish PES				43.57		
Fish PES Category				D		

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7.5.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	4.0	2.8	2.0	4.0	4.0	4.2	4.3	#DIV/0!	#DIV/0!	3.5	2.5	2.0
MEDIAN	3.4	3.3	4.0	3.6	#NUM!	4.0	2.8	2.0	4.0	4.0	4.1	4.3	#NUM!	#NUM!	3.5	2.5	2.0
NUMBER	1.0	1.0	3.0	2.0	0.0	1.0	2.0	1.0	1.0	3.0	4.0	2.0	0.0	0.0	1.0	2.0	1.0
SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
AVERAGE	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MEDIAN	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE				TOLERANCE: MODIFIED WQ				
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO- FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH- >VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH- >VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH- >VERY HIGH (>3)	WATER COLUMN: HIGH- >VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
NUMBER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

7.5.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-1.00	0.19	-0.76	3.00	40.00	0.19
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-3.00	0.48	-5.71	1.00	100.00	0.48
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-2.00	0.24	-1.90	2.00	50.00	0.24
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	-1.00	0.10	-0.38	4.00	20.00	0.10
Absolute sum			1.00	8.76	4.00	210.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage		-1.00	0.19	-0.76	3.00	40.00	0.19

7.5.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	%weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	-0.50	0.061	-0.15	5.0	20.0	-0.50
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-5.00	0.303	-7.58	1.0	100.0	-5.00
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-3.00	0.212	-3.18	3.0	70.0	-3.00
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.000	0.00	0.0	0.0	0.00
Presence of catadromous spp.	CAT	-4.00	0.242	-4.85	2.0	80.0	-4.00
Presence of migratory spp.	MIG	-3.00	0.182	-2.73	4.0	60.0	-3.00
			1.00	18.48	5.0	330.0	
Absolute overall % change in flow dependance of assemblage				73.94			

7.5.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	%weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-1.0	0.32	-1.3	2	80.0	0.32
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-1.0	0.28	-1.1	3	70.0	0.28
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-2.0	0.40	-3.2	1	100.0	0.40
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-1.0	0.00	0.0	4	0.0	0.00
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.00	0.0	0	0.0	0.00
			1.0	5.6	4.0	250.0	1.0
Absolute overall % change in habitat assemblages				28.00			

7.5.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighed abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	0.00	0.00	0.00	0.00	0.00	0.00
Health of species moderately intolerant of modified water quality	MIH	-1.00	0.67	-1.33	1.00	100.00	0.67
Health of species moderately tolerant of modified water quality	MTH	-0.50	0.33	-0.33	2.00	50.00	0.33
Health of species tolerant of modified water quality	HT	0.00	0.00	0.00	0.00	0.00	0.00
Sum			1.00	1.67	2.00	150.00	1.00
Overall % change to indicators of modified water quality				16.67			

7.5.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	0.0	0.41	0.00	1.0	70.0	0.412
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	0.0	0.59	0.00	1.0	100.0	0.588
The potential impact of introduced habitat modifying spp?	IH	0.0	0.00	0.00	0.0	0.0	0.000
How widespread (frequency of occurrence) are habitat modifying spp?	FH	0.0	0.00	0.00	0.0	0.0	0.000
Sum			1.0	0.00	2.0	170.0	
Overall % potential impact of introduced spp				0.00			

7.5.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	56.19	0.38	21.61	1.00	100.00
FLOW MODIFICATION METRICS	FM	26.06	0.35	9.02	2.00	90.00
COVER METRICS	CM	72.00	0.23	16.62	3.00	60.00
HEALTH/CONDITION METRICS	HM	83.33	0.04	3.21	4.00	10.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	0.00	0.00	0.00	0.00	0.00
			1.00			260.00
Fish PES				50.45		
Fish PES Category				D		

7.6 EWR 5

7.6.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	4.0	2.8	2.0	4.0	4.0	4.2	4.3	#DIV/0!	#DIV/0!	3.5	2.5	2.0
MEDIAN	3.4	3.3	4.0	3.6	#NUM!	4.0	2.8	2.0	4.0	4.0	4.1	4.3	#NUM!	#NUM!	3.5	2.5	2.0
NUMBER	1.0	1.0	3.0	2.0	0.0	1.0	2.0	1.0	1.0	3.0	4.0	2.0	0.0	0.0	1.0	2.0	1.0
SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	#DIV/0!	#DIV/0!	#DIV/0!	3.7	#DIV/0!	#DIV/0!	#DIV/0!	2.0	#DIV/0!	#DIV/0!	3.5	4.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	2.0
MEDIAN	#NUM!	#NUM!	#NUM!	3.7	#NUM!	#NUM!	#NUM!	2.0	#NUM!	#NUM!	3.5	4.5	#NUM!	#NUM!	#NUM!	#NUM!	2.0
NUMBER	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0

7.6.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-1.00	0.18	-0.73	3.00	40.00	0.18
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-2.00	0.45	-3.64	1.00	100.00	0.45
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-2.00	0.27	-2.18	2.00	60.00	0.27
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	-2.00	0.09	-0.73	4.00	20.00	0.09
Absolute sum			1.00	7.27	4.00	220.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				36.36			

7.6.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.000	0.00	0.0		0.000
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-2.00	0.345	-3.45	1.0	100.0	0.345
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-1.00	0.276	-1.38	2.0	80.0	0.276
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.069	0.00	5.0	20.0	0.069
Presence of catadromous spp.	CAT	-1.00	0.172	-0.86	3.0	50.0	0.172
Presence of migratory spp.	MIG	-0.50	0.138	-0.34	4.0	40.0	0.138
			1.00	6.03	5.0	290.0	1.0
Absolute overall % change in flow dependance of assemblage				24.14			

7.6.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-2.0	0.30	-2.4	2	80.0	0.30
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-3.0	0.37	-4.4	1	100.0	0.37
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-2.0	0.22	-1.8	3	60.0	0.22
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-1.0	0.11	-0.4	4	30.0	0.11
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.00	0.0	0	0.0	0.00
			1.0	9.0	4.0	270.0	1.0
Absolute overall % change in habitat assemblages				45.19			

7.6.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighed abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	0.00	0.00	0.00	0.00	0.00	0.00
Health of species moderately intolerant of modified water quality	MIH	-1.00	0.53	-1.58	1.00	100.00	0.53
Health of species moderately tolerant of modified water quality	MTH	0.50	0.37	0.55	2.00	70.00	0.37
Health of species tolerant of modified water quality	HT	0.00	0.11	0.00	3.00	20.00	0.11
Sum			1.00	2.13	3.00	190.00	1.00
Overall % change to indicators of modified water quality				14.21			

7.6.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	3.0	0.48	5.71	1.0	100.0	0.476
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	1.0	0.38	1.52	2.0	80.0	0.381
The potential impact of introduced habitat modifying spp?	IH	1.0	0.10	0.38	3.0	20.0	0.095
How widespread (frequency of occurrence) are habitat modifying spp?	FH	1.0	0.05	0.19	4.0	10.0	0.048
Sum			1.0	7.81	4.0	210.0	
Overall % potential impact of introduced spp				39.05			

7.6.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	63.64	0.28	17.55	3.00	80.00
FLOW MODIFICATION METRICS	FM	75.86	0.34	26.16	1.00	100.00
COVER METRICS	CM	54.81	0.31	17.01	2.00	90.00
HEALTH/CONDITION METRICS	HM	85.79	0.07	5.92	4.00	20.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	39.05	0.00	0.00	0.00	0.00
			1.00			290.00
Fish PES				66.64		
Fish PES Category				C		

7.7 EWR 6

7.7.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	4.0	2.8	2.0	4.0	4.0	4.2	4.3	#DIV/0!	#DIV/0!	3.5	2.5	2.0
MEDIAN	3.4	3.3	4.0	3.6	#NUM!	4.0	2.8	2.0	4.0	4.0	4.1	4.3	#NUM!	#NUM!	3.5	2.5	2.0
NUMBER	1.0	1.0	3.0	2.0	0.0	1.0	2.0	1.0	1.0	3.0	4.0	2.0	0.0	0.0	1.0	2.0	1.0
SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE: FS	PREFERENCE: SD	PREFERENCE: SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
MSAL	FALSE	FALSE	4.5	FALSE	FALSE	FALSE	FALSE	1.1	3.1	FALSE	3.1	3.2	FALSE	FALSE	FALSE	2.3	FALSE
AVERAGE	#DIV/0!	#DIV/0!	4.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.1	3.1	#DIV/0!	3.1	3.2	#DIV/0!	#DIV/0!	#DIV/0!	2.3	#DIV/0!
MEDIAN	#NUM!	#NUM!	4.5	#NUM!	#NUM!	#NUM!	#NUM!	1.1	3.1	#NUM!	3.1	3.2	#NUM!	#NUM!	#NUM!	2.3	#NUM!
NUMBER	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0

7.7.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-1.00	0.21	-0.83	3.00	60.00	0.21
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-1.00	0.28	-1.10	2.00	80.00	0.28
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-2.00	0.34	-2.76	1.00	100.00	0.34
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	0.00	0.17	0.00	4.00	50.00	0.17
Absolute sum			1.00	4.69	4.00	290.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				23.45			

7.7.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.000	0.00	0.0		0.000
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-1.00	0.345	-1.38	1.0	100.0	0.345
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-1.00	0.276	-1.10	2.0	80.0	0.276
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.000	0.00	0.0		0.000
Presence of catadromous spp.	CAT	-1.00	0.207	-0.83	3.0	60.0	0.207
Presence of migratory spp.	MIG	-1.00	0.172	-0.69	4.0	50.0	0.172
			1.00	4.00	4.0	290.0	1.0
Absolute overall % change in flow dependance of assemblage				20.00			

7.7.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	%weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	0.0	0.27	0.0	2	70.0	0.27
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-0.5	0.31	-0.6	3	80.0	0.31
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-3.0	0.38	-4.6	1	100.0	0.38
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	0.0	0.00	0.0	0	0.0	0.00
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.04	0.0	4	10.0	0.04
			1.0	5.2	4.0	260.0	1.0
Absolute overall % change in habitat assemblages				26.15			

7.7.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighed abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	-1.00	0.40	-1.60	1.00	100.00	0.40
Health of species moderately intolerant of modified water quality	MIH	-0.50	0.36	-0.72	2.00	90.00	0.36
Health of species moderately tolerant of modified water quality	MTH	0.00	0.20	0.00	3.00	50.00	0.20
Health of species tolerant of modified water quality	HT	0.00	0.04	0.00	4.00	10.00	0.04
Sum			1.00	2.32	4.00	250.00	1.00
Overall % change to indicators of modified water quality				11.60			

7.7.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	5.0	0.43	6.52	1.0	100.0	0.435
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	5.0	0.39	5.87	2.0	90.0	0.391
The potential impact of introduced habitat modifying spp?	IH	3.0	0.09	0.78	3.0	20.0	0.087
How widespread (frequency of occurrence) are habitat modifying spp?	FH	3.0	0.09	0.78	0.0	20.0	0.087
Sum			1.0	13.96	3.0	230.0	
Overall % potential impact of introduced spp				93.04			

7.7.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	76.55	0.32	24.69	1.00	100.00
FLOW MODIFICATION METRICS	FM	80.00	0.29	23.23	2.00	90.00
COVER METRICS	CM	73.85	0.29	21.44	3.00	90.00
HEALTH/CONDITION METRICS	HM	88.40	0.10	8.55	4.00	30.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	93.04	0.00	0.00	0.00	0.00
			1.00			310.00
Fish PES				77.91		
Fish PES Category				C		

7.8 EWR 6: Alternative REC

7.8.1 Assemblage

SPECIES EXPECTED: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
PAFE	FALSE	FALSE	4.0	3.5	FALSE	4.0	FALSE	FALSE	4.0	4.0	4.0	4.0	FALSE	FALSE	3.5	FALSE	FALSE
AMOS	3.4	3.3	3.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	4.1	4.9	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
AMAR	FALSE	FALSE	4.4	FALSE	FALSE	FALSE	2.8	FALSE	FALSE	3.9	4.2	FALSE	FALSE	FALSE	FALSE	2.5	FALSE
SCAP	FALSE	FALSE	FALSE	3.7	FALSE	FALSE	FALSE	2.0	FALSE	FALSE	3.5	4.5	FALSE	FALSE	FALSE	FALSE	2.0
AVERAGE	3.4	3.3	3.9	3.6	#DIV/0!	4.0	2.8	2.0	4.0	4.0	4.2	4.3	#DIV/0!	#DIV/0!	3.5	2.5	2.0
MEDIAN	3.4	3.3	4.0	3.6	#NUM!	4.0	2.8	2.0	4.0	4.0	4.1	4.3	#NUM!	#NUM!	3.5	2.5	2.0
NUMBER	1.0	1.0	3.0	2.0	0.0	1.0	2.0	1.0	1.0	3.0	4.0	2.0	0.0	0.0	1.0	2.0	1.0
SPECIES OBS: REFERENCE	FLOW-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED WQ			
	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW (>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
MSAL	FALSE	FALSE	4.5	FALSE	FALSE	FALSE	FALSE	1.1	3.1	FALSE	3.1	3.2	FALSE	FALSE	FALSE	2.3	FALSE
AVERAGE	#DIV/0!	#DIV/0!	4.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.1	3.1	#DIV/0!	3.1	3.2	#DIV/0!	#DIV/0!	#DIV/0!	2.3	#DIV/0!
MEDIAN	#NUM!	#NUM!	4.5	#NUM!	#NUM!	#NUM!	#NUM!	1.1	3.1	#NUM!	3.1	3.2	#NUM!	#NUM!	#NUM!	2.3	#NUM!
NUMBER	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0

7.8.2 Flow Depth

Flow-Depth class metrics with reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	-4.00	0.21	-3.31	3.00	60.00	0.21
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	-2.00	0.28	-2.21	2.00	80.00	0.28
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-4.00	0.34	-5.52	1.00	100.00	0.34
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	0.00	0.17	0.00	4.00	50.00	0.17
Absolute sum			1.00	11.03	4.00	290.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				55.17			

7.8.3 Flow modification

Flow modification metrics with reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependance metric scores	Weight of flow metrics	Flow dependance: weighted score per metric (out of 5)	Ranking of metrics	%weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	-1.00	0.000	0.00	0.0		0.000
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-3.00	0.345	-4.14	1.0	100.0	0.345
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-2.00	0.276	-2.21	2.0	80.0	0.276
Frequency of occurrence of species tolerant of no flow conditions	FT	0.00	0.000	0.00	0.0		0.000
Presence of catadromous spp.	CAT	-1.00	0.207	-0.83	3.0	60.0	0.207
Presence of migratory spp.	MIG	-1.00	0.172	-0.69	4.0	50.0	0.172
			1.00	7.86	4.0	290.0	1.0
Absolute overall % change in flow dependance of assemblage				39.31			

7.8.4 Cover

Cover metrics: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	%weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-3.0	0.27	-3.2	2	70.0	0.27
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-3.0	0.31	-3.7	3	80.0	0.31
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-3.0	0.38	-4.6	1	100.0	0.38
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-2.0	0.00	0.0	0	0.0	0.00
Frequency of occurrence of species with a very high to high preference for the water column	WC	-1.0	0.04	-0.2	4	10.0	0.04
			1.0	11.7	4.0	260.0	1.0
Absolute overall % change in habitat assemblages				58.46			

7.8.5 Health condition

Health/condition of species (introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighed abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	-3.00	0.40	-4.80	1.00	100.00	0.40
Health of species moderately intolerant of modified water quality	MIH	-4.00	0.36	-5.76	2.00	90.00	0.36
Health of species moderately tolerant of modified water quality	MTH	-3.00	0.20	-2.40	3.00	50.00	0.20
Health of species tolerant of modified water quality	HT	0.00	0.04	0.00	4.00	10.00	0.04
Sum			1.00	12.96	4.00	250.00	1.00
Overall % change to indicators of modified water quality				64.80			

7.8.6 Introduced species

Introduced species metrics, with reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced impact spp score	Introduced spp. weight	Weighted introduced species score	Ranking of metrics	% Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	5.0	0.43	6.52	1.0	100.0	0.435
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	5.0	0.39	5.87	2.0	90.0	0.391
The potential impact of introduced habitat modifying spp?	IH	3.0	0.09	0.78	3.0	20.0	0.087
How widespread (frequency of occurrence) are habitat modifying spp?	FH	3.0	0.09	0.78	0.0	20.0	0.087
Sum			1.0	13.96	3.0	230.0	
Overall % potential impact of introduced spp				93.04			

7.8.7 PES

			Fish PES: Based on weights of metric groups			
Fish PES Metric group		Metric group: Calculated score	Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	44.83	0.32	14.46	1.00	100.00
FLOW MODIFICATION METRICS	FM	60.69	0.29	17.62	2.00	90.00
COVER METRICS	CM	41.54	0.29	12.06	3.00	90.00
HEALTH/CONDITION METRICS	HM	35.20	0.10	3.41	4.00	30.00
IMPACT OF INTRODUCED SPP (NEGATIVE)	IS	93.04	0.00	0.00	0.00	0.00
			1.00			310.00
Fish PES				47.55		
Fish PES Category				D		

APPENDIX E

AQUATIC INVERTEBRATES

Dr A.C. Uys, Laughing Waters

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1 EWR 1: MELKHOUTBOSKRAAL - KROMME RIVER

1.1 Data availability

Historical data

The only data available for invertebrates of this site was one set of SASS5 data collected by Ms Pumza Maseti (IWR, Rhodes), during the first water quality assessment (October 2003).

Project survey data

This site was sampled by invertebrate specialists twice, during November 2003 and March 2004.

Confidence in available data - 3

1.2 Reference condition

Under natural conditions, this site would be expected to have similar habitat diversity to that found on the site visit, however with more sustained inundation of marginal vegetation. Greater shading would be expected from riparian vegetation, which would lead to a higher leaf-fall, heterotrophic conditions, and the presence of a greater diversity of leaf-shredders such as stoneflies and mayflies. No alien vegetation would be present. There would be less mobile sediment in the stones habitats, and no algal growth. Water temperature may be reduced, and water quality similar to present. These conditions would favour a sensitive macroinvertebrate fauna with a greater number of mayfly families (Tricorythidae), the possibility of stoneflies, caddisflies (Philopotamidae, Pisullidae) and an enhanced community of invertebrates with a preference for marginal vegetation e.g. Odonata (Lestidae), Coleoptera (Belostomatidae, Nepidae, Pleidae), some Corixidae (Naucoridae), and Gastropoda (Physidae, Lymnaeidae). Sponges (Porifera) would likely be present on rock surfaces.

Likely SASS5 scores: 220+

Likely number of taxa: 45+

Likely ASPT: 5.9+

1.3 PES

Instream habitat at this site was plentiful and in relatively good condition. Stones were mobile, allowing for invertebrate colonisation on upper side and lower surfaces, which typically relates to a healthy biodiversity of stone-dwelling fauna at a site. Only the root zones of the marginal vegetation were inundated. The lack of a robust vegetation zone limits the number of invertebrates with a preference for this biotope, and also results in a paucity of cover for juveniles in early summer. SASS5 scores here were approximately 70% of assumed reference conditions, and the high ASPT (>6) indicates that the fauna included a healthy proportion of sensitive taxa.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	55.6	0.380	21.1	38.0	0.380	FT	1	100	0.476	1
HABITAT	72.5	0.264	19.1	26.4	0.264	VTA	3	50	0.238	0.5
WATER QUALITY	67.5	0.356	24.0	35.6	0.356	HQA	2	60	0.286	0.6
	195.6	1		100	1.000				0.476	
Invertebrate PES			64.3					210	1	
Category	39.11		C							

Taxa collected (2 site visits): Porifera, Turbellaria, Oligochaeta, Potamonautidae, Hydracarina, Baetidae 2sp., Caenidae, Heptageniidae, Leptophlebiidae, Teloganonidae, Chlorocyphidae, Chlorolestidae, Aeshnidae, Coenagrionidae, Platycnemidae, Aeshnidae, Gomphidae, Libellulidae, Corixidae, Gerridae, Veliidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae 1sp, Hydroptilidae, Leptoceridae, Sericostomatidae, Dytiscidae, Elmidae, Gyrinidae, Helodidae, Ceratopogonidae, Chironomidae, Culicidae, Simuliidae, Tabanidae, Tipulidae, Ancyliidae.

PES	Causes	Sources	Flow / Non flow related.
C	Loss of flow.	Abstraction.	Flow related.
	Sedimentation of stones habitat.	Agricultural practices. Bank clearing.	Non flow related.
	Loss of riparian and vegetation habitat.	Alien invasion.	Non flow related.

Confidence: 3

1.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
C	Stable	C	1-2 years	Invertebrate fauna has adjusted to alterations in hydrology and invasion by alien fish.

Confidence: 2

1.5 Alternative EC: D

The reduction in flows and the change in habitat abundances associated with a D category are likely to remove the most sensitive invertebrates from this community, e.g. Teloganonids and Sericostomatids. Some of the invertebrates that are moderately sensitive to flow and water quality changes may also be lost e.g. Helodid beetles and Heptageniid mayflies.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	46.8	0.380	17.8	38.0	0.380	FT	1	100	0.476	1
HABITAT	66.8	0.264	17.7	26.4	0.264	VTA	3	50	0.238	0.5
WATER QUALITY	55.9	0.356	19.9	35.6	0.356	HQA	2	60	0.286	0.6
	169.6	1		100	1.000				0.476	
Invertebrate PES			55.4					210	1	
Category	33.92		D							

2 EWR 2: KROMMERIVIERS POORT – KROMME RIVER

2.1 Data availability

Historical data

No data available.

Project survey data

This site was sampled once in November 2003 and once in March 2004 by the invertebrate specialists.

Confidence in available data – 2

2.2 Reference condition

Under natural conditions, base flows would have been higher and the causeway would not have been present. This would have increased inundation of all habitats, particularly marginal vegetation and ensured flushing of sediments out of the (currently embedded) 'stones' habitats. Deeper pools would have been present. Water quality would have been similar. This environment would have encouraged an invertebrate fauna with a greater number of mayfly families (Heptageniidae, Leptophlebiidae, Tricorythidae), caddisfly families (Leptoceridae, Ecnomidae, Hydroptilidae), beetles (Dytiscidae, Helodidae), Odonata (Chlorolestidae, Lestidae, Corduliidae), Hemiptera (Corixidae, Hydrometridae, Naucoridae, Nepidae, Pleidae), and Gastropoda (Physidae, Lymnaeidae).

Likely SASS5 scores: 230+

Likely number of taxa: 40+

Likely ASPT: 5.6+

2.3 PES

The faunal diversity at this site was approximately 50% of that expected under reference conditions. The stones habitat was imbricated (packed), disallowing colonisation on the underside of stones by taxa with a preference for this biotope (particularly caddisflies and certain mayflies). Only the root-zones of the marginal and instream vegetation were inundated on both visits, representing reasonable loss of a significant habitat type at this level in the catchment. Overall, despite the lack of diversity at the site, the taxa present were fairly sensitive as reflected in the relatively high ASPT values (> 5.7). This indicates that the instream environment at this site is in a Fair condition and has likely adjusted to the altered hydrology (although it should be borne in mind that the baseflow is provided here by a leak in the dam wall!). The key issues affecting the invertebrates at this site are the altered sediment and hydrological regimes.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	47.4	0.401	19.0	40.1	0.401	FT	1	100	0.476	1
HABITAT	53.8	0.297	15.9	29.7	0.297	VTA	3	50	0.238	0.5
WATER QUALITY	55.0	0.303	16.6	30.3	0.303	HQA	2	60	0.286	0.6
	156.2	1		100	1.000				0.476	
Invertebrate PES			51.6					210	1	
Category	31.23		D							

Taxa collected: Turbellarians, Potamonautidae, Baetidae 2sp., Caenidae, Leptophlebiidae, Chlorocyphidae, Coenagrionidae, Platycnemidae, Aeshnidae, Gomphidae, Libellulidae,

Notonectidae, Veliidae, Hydropsychidae, Sericostomatidae, Gyrinidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Simuliidae, Tabanidae.

PES	Causes	Sources	Flow/Non flow related
D	Flow reduction.	Upstream dam.	Flow related.
	Loss of natural vegetation.	Alien infestation.	Non flow related.
	Altered sediment regime.	Upstream dam, causeway	Flow related.
	Embedded stones habitats.	Causeway, road	Flow related.

Confidence: 3

2.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
D	Stable	Same	N/a	System has adjusted to upstream changes and SASS5 still reasonably high.

Confidence: 2

2.5 Alternative ECs

No alternative ecological categories were considered.

3 EWR 3: DYKE - KROMME RIVER

3.1 Data availability

Historical data

No data available.

Project survey data

Invertebrate specialists sampled this site once during November 2003.

3.2 Reference condition

This site is reasonably close to the estuary and some marine influence may be expected under natural conditions, for example the presence of small numbers of freshwater shrimps moving up from the estuary (*Macrobrachium* sp., *Palaeomon capensis*). Overall there would be a greater habitat diversity and abundance, with less pool environments and more flowing environments, favouring a greater diversity and abundance of rheophilic groups, such as mayflies (Baetidae, Leptophlebiidae, Heptageniidae), certain dipteran species (Simuliidae), caddisflies (greater number of Hydropsychid species, Polycentropodidae, Philopotamidae), and some Coleoptera (Elmidae). There would be also be variability within the flow environments, favouring those taxa with a preference for slower-flowing water, e.g. caddisflies (Hydroptilidae, Pisullidae), Coleoptera (Gyrinidae, Psephenidae), and Odonata (Corduliidae, Chlorocyphidae). The increase in available marginal vegetation habitat would likely favour an increase in a number of certain Hemipterans (Naucoridae, Pleidae, Corixidae) and certain Odonata (Calopterygidae, Chlorolestidae).

Likely SASS5 scores: 210 +

Likely number of taxa: 40+

Likely ASPT: 5.4+

3.3 PES

The invertebrate fauna at this site was severely impaired by the lack of flow and resulting poor water quality. The SASS5 scores were less than 40% of those expected under reference conditions, and the ASPT of <5 indicates a paucity of sensitive taxa. There was no satisfactory flow habitat at the time of the site visit, and only areas in which there was a trickle over bedrock could be sampled. The surface water at this site was restricted to a series of various-sized pools, some of which were connected. Reeds had encroached into the smaller pools, and exotic woody debris made access to many of the pools difficult. The fauna collected was hardy, with very low abundances of the few flow-dependent taxa present and generally low diversity of taxa with a preference for flowing water and relatively unimpaired water quality. The migrating species which would be expected in this lower section of the river (such as freshwater prawn *Macrobrachium* sp.) were not collected. The bedrock sill across the site represents a barrier to migrating species, particularly with the current system hydrology.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	30.6	0.412	12.6	41.2	0.412	FT	1	100	0.476	1
HABITAT	26.8	0.311	8.3	31.1	0.311	VTA	3	50	0.238	0.5
WATER QUALITY	26.0	0.277	7.2	27.7	0.277	HQA	2	60	0.286	0.6
	83.4	1		100	1.000				0.476	
Invertebrate PES			28.1					210	1	
Category	16.67		E							

Taxa collected: Oligochaeta, Hydracarina, Baetidae, Caenidae, Coenagrionidae, Lestidae, Libellulidae, Corixidae, Notonectidae, Veliidae, Hydroptilidae, Leptoceridae, Dytiscidae, Gyrinidae, Hydrophilidae, Chironomidae, Simuliidae, Tipulidae, Lymnaeidae.

PES	Causes	Sources	Flow/Non flow related
E	Flow reduction.	Upstream dam, abstractions for farming.	Flow related.
	Altered flow variability.	Upstream dam.	Flow related.
	Altered sediment regime.	Upstream dam.	Flow related.
	Altered temperature regime.	Loss of surface water.	Flow and non flow related.

Confidence: 4

3.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
E	Negative	Half to one category lower	5 years	Ongoing and increased agricultural activities and abstraction increase in alien vegetation due to disturbance, likelihood of encroachment of reeds into channel areas, nutrient enrichment.

Confidence: 3

3.5 Alternative ECs

No alternative ecological categories were considered.

4 EWR 4: GEELHOUTBOOM RIVER

4.1 Data availability

Historical data

The only data available for invertebrates of this site was one set of SASS5 data collected by Ms Pumza Maseti (IWR, Rhodes), during the first water quality assessment (October 2003).

Project survey data

This site was sampled in trickle flow conditions during November 2003. It was not possible to sample it at the second site visit in March 2004.

Confidence in available data – 2

4.2 Reference condition

It is difficult to assess what this stream would have looked like in a natural condition. Its size and geographic locality suggests that it may have been a temporary system, in which case the fauna would have been typical of such a river, and would have included largely resilient taxa suited to shaded, sandbed pool-type environments with little predictable flow component, and little or no stones and marginal vegetation environments. This fauna would include baetid and caenid mayflies, Oligochaetae, certain Odonata (Gomphidae, Aeshnidae, Libellulidae, Clorolestidae, Coenagrionidae, Lestidae), Diptera (Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Psychodidae, Tabanidae, Tipulidae), certain Coleoptera (Gyrinidae, Gerridae), Hemipterans (Hydrometridae, Notonectidae, Pleidae, Corixidae).

Likely SASS Scores: 114+

Likely number of Taxa: 24+

Likely ASPT: 4.8+

4.3 PES

The results at this site were difficult to interpret due to the uncertain hydrology of this river. At the first site visit, only trickling flows were observed, and at the second visit, flow had ceased and surface water continuity had been lost. Nonetheless, an unexpectedly diverse fauna was collected in the restricted areas where sampling was possible. The SASS5 scores were over 75% of what would have been expected under natural conditions at this site, assuming that it was not naturally a perennial system. The ASPT values of > 5 were higher than expected, and reflect the presence of a small number of pollution-sensitive taxa. The instream habitat was restricted to an earth/gravel bed channel with few areas of small stones, and in the pools the substrate was overlain with allochthonous matter, as one would expect in such a highly shaded stream. The lack of marginal vegetation at the site was a factor contributing to the low numbers of taxa present with a preference for sheltered habitats and/or low-flow conditions.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	25.2	0.380	9.6	38.0	0.380	FT	1	100	0.435	1
HABITAT	56.4	0.353	19.9	35.3	0.353	VTA	2	70	0.304	0.7
WATER QUALITY	59.4	0.268	15.9	26.8	0.268	HQA	3	60	0.261	0.6
	141.1	1		100	1.000				0.435	
Invertebrate PES			45.4					230	1	
Category	28.21		D							

Taxa collected: Turbellaria, Oligochaeta, Leeches, Hydracarina, Baetidae 1 sp., Caenidae, Chloroslestidae, Lestidae, Libellulidae, Veliidae, Dytiscidae, Gyrinidae, Helodidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Simuliidae, Ancyliidae.

PES	Causes	Sources	Flow/Non flow related
D	Altered flow.	Upstream abstraction; upstream roads and causeways.	Flow related.

Confidence: 2 (due to trickling flows)

4.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
D	Stable	Same		Unlikely that upstream uses and land-use will change dramatically, cannot get much worse in terms of flow (but this may be part-natural).

Confidence: 1 (Difficult to ascertain reference conditions for this site)

4.5 Alternative ECs

No alternative ecological categories were considered.

5 EWR 5: SEEKOEI RIVER

5.1 Data availability

Historical data

The only data available for invertebrates of this site was one set of SASS5 data collected by Ms Pumza Maseti (IWR, Rhodes), during the first water quality assessment (October 2003).

Project survey data

Invertebrate specialists sampled this site once in March 2003.

Confidence in Available Data – 3

5.2 Reference condition

A reasonable diversity of undisturbed physical and hydraulic habitats would be expected. These would include a low diversity of stones habitats and a higher diversity of pools, marginal vegetation and sand/gravel/mud environments. Bank stability would be high, and disturbance to the channel morphology low. Shading would be approximately 30-50%, with some leaf-fall into the system. The expected fauna would include Turbellaria, Oligochaetae, Hydracarina, baetid and caenid mayflies, Aeshnidae, Gomphidae, Libellulidae Belostomatidae, Corixidae, Gerridae Pleidae, Hydropsychid caddisflies, Elmidae, Gyrinidae Hydraenidae, Ephydriidae, Tipulidae and Tabanidae, and ancyloid, lymnaeid and physid Gastropods.

Likely SASS5 Scores: 100+

Likely number of taxa: 22+

Likely ASPT: 4.7 +

5.3 PES

This site was again difficult to interpret due to the uncertainty of its natural hydrology. It was sampled only once during low flow conditions. The channel and margins had been recently severely trampled by cattle, and water quality was expected to be poor. The flow and marginal vegetation habitats sampled just upstream of the road-crossing yielded a low diversity and a hardy fauna, with a low ASPT of 4.3, indicating a hardy fauna, with the majority of taxa having some tolerance for organically polluted water.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	37.8	0.419	15.8	41.9	0.419	FT	1	100	0.435	1
HABITAT	45.4	0.334	15.2	33.4	0.334	VTA	2	70	0.304	0.7
WATER QUALITY	73.8	0.247	18.2	24.7	0.247	HQA	3	60	0.261	0.6
	156.9	1		100	1.000				0.435	
Invertebrate PES			49.2					230	1	
Category	31.38		D							

Taxa collected: Turbellaria, Potamonautidae, Baetidae 2sp., Caenidae, Leptophlebiidae, Coenagrionidae, Aeshnidae, Gomphidae, Libellulidae, Corixidae, Pleidae, Veliidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Culicidae, Psychodidae, Simuliidae, Tabanidae, Lymnaeidae.

PES	Causes	Sources	Flow/Non flow related
D	Altered hydraulic habitat.	Road bridge.	Flow related.
	Deterioration in channel bed morphology, loss of instream and riparian habitat.	Cattle trampling, clearing, bank instability.	Non flow related.
	Deterioration in water quality.	Cattle, farming activities, sedimentation.	Non flow related.

Confidence: 2

5.4 Trend (previously trajectory of change) and reasons

PES	Trend	Resulting PES	Time	Reasons
D	Negative	D/E	5 years	Ongoing agriculture, cattle, upstream abstraction, land clearing, nutrient enrichment and bacterial contamination and abstraction.

Confidence: 2

5.5 Alternative ECs

No alternative ecological categories were considered.

6 EWR 6: SWART RIVER

6.1 Data availability

Historical data

No data available.

Project survey data

This site was surveyed by invertebrate specialists once in March 2003.

6.2 Reference condition

This site is not considered dramatically altered from natural. The expected reference fauna and SASS5 scores are similar to those recorded on site. However, the low flows (reportedly due to low summer rainfall) have led to a slight reduction in diversity and abundance of particular taxa. Taxa that would be expected at this site in a natural condition could include (at least) Heptageniidae Tricorythidae, a greater number of baetid mayfly species, chlorocyphid dragonflies, Veliidae, Pissulid caddisflies, Psephenidae, Dixidae and Tipulidae, Lymnaeidae and Physidae.

6.3 PES

The fauna at this site was considered to be close to a natural state. The habitat diversity was high, with areas of stones in flow, marginal vegetation, runs and small pools. The high water quality, close-to-natural hydrology, and plentiful, diverse habitat favour a community with a relatively high sensitivity (ASPT > 5.5) and with the majority of expected invertebrate families present at low abundances. The SASS scores of 170+ and number of taxa present (31) further illustrate its Good condition. In its present state, this site could be considered a reference site for the system.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	80.0	0.343	27.4	34.3	0.343	FT	1	100	0.435	1
HABITAT	80.0	0.311	24.9	31.1	0.311	VTA	3	60	0.261	0.6
WATER QUALITY	86.2	0.347	29.9	34.7	0.347	HQA	2	70	0.304	0.7
	246.2	1		100	1.000				0.435	
Invertebrate PES			82.1					230	1	
Category	49.23		B							

Taxa Collected: Turbellaria, Oligochaeta, Potamonautidae, Hydracarina, Perlidae, Baetidae 2sp., Caenidae, Leptophlebiidae, Chorocyphidae, Coenagrionidae, Aeshnidae, Gomphidae, Libellulidae, Corixidae, Gerridae, Hydrometridae, Veliidae, Hydropsychidae, Philopotamidae, Leptoceridae, Dytiscidae, Elmidea, Gyrinidae, Helodidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Psychodidae, Simuliidae, Tabanidae, Ancyliidae.

PES	Causes	Sources	Flow/Non flow related
B	Abstraction.	Small amount of pumping for farming activities.	Flow related.
	Low disturbance to water quality.	Farming activities.	Non flow related.

Confidence: 3

6.4 Trend and reasons

PES	Trend	Resulting PES	Time	Reasons
B	Stable	Same		Unless farming activities increase, or abstraction is increased, this site is likely to remain in good condition as it is fairly high in the catchment and is inaccessible.

Confidence: 3

6.5 Alternative ECs

The reduction in flows and the change in habitat abundances associated with a C are likely to affect the numbers (and possibly the presence) of the most flow-sensitive invertebrates in this community, e.g. Plecopterans and Philopotamids. Some of the invertebrates that are moderately sensitive to flow and water quality changes (Elmids, Hydropsychids, Simuliids) may also be affected by losses of critical life stages.

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	67.1	0.343	23.0	34.3	0.343	FT	1	100	0.435	1
HABITAT	68.8	0.311	21.4	31.1	0.311	VTA	3	60	0.261	0.6
WATER QUALITY	80.3	0.347	27.8	34.7	0.347	HQA	2	70	0.304	0.7
	216.2	1		100	1.000				0.435	
Invertebrate PES			72.2					230	1	
Category	43.25		C							

7 AQUATIC INVERTEBRATE PES INFORMATION

7.1 EWR 1

7.1.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	2	0.20	0.39	3	80	0.20
Abundance of taxa with a preference for very fast flowing water	FTA	3	0.17	0.51	4	70	0.17
Presence of taxa with a preference for moderately fast flowing water	MT	1	0.24	0.24	1	100	0.24
Abundance of taxa with a preference for moderately fast flowing water	MTA	3	0.22	0.66	2	90	0.22
Presence of taxa with a preference for slow flowing water	ST	2	0.10	0.20	5	40	0.10
Abundance of taxa with a preference for slow flowing water	STA	3	0.07	0.22	6	30	0.07
Proportional change in average flow dependence of the assemblage			1	44.39		410	1

7.1.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	1	0.18	0.18	1	100	0.18
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	1	0.11	0.11	5	60	0.11
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	2	0.17	0.33	2	95	0.17
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	1	0.11	0.11	5	60	0.11
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	1	0.15	0.15	3	85	0.15
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	1	0.09	0.09	6	50	0.09
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	2	0.12	0.25	4	70	0.12
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	2	0.09	0.18	6	50	0.09
			1			570	1.00
Overall change in habitat assemblages				27.54			

7.1.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	1	0.13	0.1250	2	80	0.13
Has the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	1	0.09	0.0938	4	60	0.09
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	2	0.16	0.3125	1	100	0.16
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	1	0.16	0.1563	1	100	0.16
Are any taxa with a low requirement for unmodified water quality present?	LQ	2	0.12	0.2344	3	75	0.12
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	3	0.12	0.3516	3	75	0.12
How does the total SASS score differ from expected?	SASS	2	0.12	0.2344	3	75	0.12
How does the total ASPT score differ from expected?	ASPT	1	0.12	0.1172	3	75	0.12
		1		640			
Overall change to indicators of modified water quality				32.50			

7.1.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	55.6	0.380	21.1	38.0	0.380	FT	1	100	0.476	1
HABITAT	72.5	0.264	19.1	26.4	0.264	VTA	3	50	0.238	0.5
WATER QUALITY	67.5	0.356	24.0	35.6	0.356	HQA	2	60	0.286	0.6
	195.6	1		100	1.000				0.476	
Invertebrate PES			64.3					210	1	
Category	39.11		C							

7.2 EWR 1: Alternative Category

7.2.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	3	0.20	0.59	3	80	0.20
Abundance of taxa with a preference for very fast flowing water	FTA	3	0.17	0.51	4	70	0.17
Presence of taxa with a preference for moderately fast flowing water	MT	2	0.24	0.49	1	100	0.24
Abundance of taxa with a preference for moderately fast flowing water	MTA	3	0.22	0.66	2	90	0.22
Presence of taxa with a preference for slow flowing water	ST	2	0.10	0.20	5	40	0.10
Abundance of taxa with a preference for slow flowing water	STA	3	0.07	0.22	6	30	0.07
Proportional change in average flow dependence of the assemblage			1	53.17		410	1

7.2.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	2	0.18	0.35	1	100	0.18
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	2	0.11	0.21	5	60	0.11
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	2	0.17	0.33	2	95	0.17
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	1	0.11	0.11	5	60	0.11
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	1	0.15	0.15	3	85	0.15
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	1	0.09	0.09	6	50	0.09
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	2	0.12	0.25	4	70	0.12
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	2	0.09	0.18	6	50	0.09
			1			570	1.00
Overall change in habitat assemblages				33.16			

7.2.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	3	0.13	0.3750	2	80	0.13
Has the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	2	0.09	0.1875	4	60	0.09
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	2	0.16	0.3125	1	100	0.16
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	1	0.16	0.1563	1	100	0.16
Are any taxa with a low requirement for unmodified water quality present?	LQ	2	0.12	0.2344	3	75	0.12
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	3	0.12	0.3516	3	75	0.12
How does the total SASS score differ from expected?	SASS	3	0.12	0.3516	3	75	0.12
How does the total ASPT score differ from expected?	ASPT	2	0.12	0.2344	3	75	0.12
		1			640		
Overall change to indicators of modified water quality				44.06			

7.2.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	46.8	0.380	17.8	38.0	0.380	FT	1	100	0.476	1
HABITAT	66.8	0.264	17.7	26.4	0.264	VTA	3	50	0.238	0.5
WATER QUALITY	55.9	0.356	19.9	35.6	0.356	HQA	2	60	0.286	0.6
	169.6	1		100	1.000				0.476	
Invertebrate PES			55.4					210	1	
Category	33.92		D							

7.3 EWR 2

7.3.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	2	0.19	0.37	1	100	0.19
Abundance of taxa with a preference for very fast flowing water	FTA	3	0.17	0.50	2	90	0.17
Presence of taxa with a preference for moderately fast flowing water	MT	2	0.19	0.37	1	100	0.19
Abundance of taxa with a preference for moderately fast flowing water	MTA	3	0.17	0.50	2	90	0.17
Presence of taxa with a preference for slow flowing water	ST	3	0.15	0.44	3	80	0.15
Abundance of taxa with a preference for slow flowing water	STA	3	0.15	0.44	3	80	0.15
Proportional change in average flow dependence of the assemblage			1	52.59		540	1

7.3.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT	1	0.11	0.11	2	90	0.11
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA	3	0.10	0.30	3	80	0.10
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	2	0.13	0.25	1	100	0.13
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	3	0.13	0.38	1	100	0.13
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	3	0.11	0.34	2	90	0.11
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	3	0.10	0.30	3	80	0.10
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	2	0.09	0.18	4	70	0.09
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	3	0.08	0.23	5	60	0.08
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	1	0.09	0.09	4	70	0.09
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	2	0.08	0.15	5	60	0.08
			1			800	1.00
Overall change in habitat assemblages				46.25			

7.3.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	2	0.15	0.2941	1	100	0.15
Has the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	3	0.12	0.3529	3	80	0.12
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	2	0.15	0.2941	1	100	0.15
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	3	0.13	0.3971	2	90	0.13
Are any taxa with a low requirement for unmodified water quality present?	LQ	3	0.12	0.3529	3	80	0.12
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	1	0.12	0.1176	3	80	0.12
How does the total SASS score differ from expected?	SASS	3	0.11	0.3309	4	75	0.11
How does the total ASPT score differ from expected?	ASPT	1	0.11	0.1103	4	75	0.11
		1			680		
Overall change to indicators of modified water quality				45.00			

7.3.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	47.4	0.401	19.0	40.1	0.401	FT	1	100	0.476	1
HABITAT	53.8	0.297	15.9	29.7	0.297	VTA	3	50	0.238	0.5
WATER QUALITY	55.0	0.303	16.6	30.3	0.303	HQA	2	60	0.286	0.6
	156.2	1		100	1.000				0.476	
Invertebrate PES			51.6					210	1	
Category	31.23		D							

7.4 EWR 3

7.4.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	3	0.18	0.55	2	90	0.18
Abundance of taxa with a preference for very fast flowing water	FTA	4	0.16	0.65	3	80	0.16
Presence of taxa with a preference for moderately fast flowing water	MT	3	0.20	0.61	1	100	0.20
Abundance of taxa with a preference for moderately fast flowing water	MTA	4	0.16	0.65	3	80	0.16
Presence of taxa with a preference for slow flowing water	ST	3	0.14	0.43	4	70	0.14
Abundance of taxa with a preference for slow flowing water	STA	4	0.14	0.57	4	70	0.14
Proportional change in average flow dependence of the assemblage			1	69.39		490	1

7.4.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT	4	0.08	0.32	6	60	0.08
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA	4	0.08	0.32	6	60	0.08
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	4	0.09	0.35	5	65	0.09
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	4	0.09	0.35	5	65	0.09
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	4	0.12	0.49	2	90	0.12
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	3	0.14	0.41	1	100	0.14
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	4	0.11	0.43	3	80	0.11
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	3	0.11	0.32	3	80	0.11
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	4	0.09	0.38	4	70	0.09
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	3	0.09	0.28	4	70	0.09
			1			740	1.00
Overall change in habitat assemblages				73.24			

7.4.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	4	0.15	0.5818	2	80	0.15
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	4	0.13	0.5091	3	70	0.13
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	4	0.18	0.7273	1	100	0.18
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	4	0.13	0.5091	3	70	0.13
Are any taxa with a low requirement for unmodified water quality present?	LQ	4	0.11	0.4364	4	60	0.11
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	4	0.11	0.4364	4	60	0.11
How does the total SASS score differ from expected?	SASS	3	0.10	0.3000	5	55	0.10
How does the total ASPT score differ from expected?	ASPT	2	0.10	0.2000	5	55	0.10
		1			550		
Overall change to indicators of modified water quality				74.00			

7.4.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	30.6	0.412	12.6	41.2	0.412	FT	1	100	0.476	1
HABITAT	26.8	0.311	8.3	31.1	0.311	VTA	3	50	0.238	0.5
WATER QUALITY	26.0	0.277	7.2	27.7	0.277	HQA	2	60	0.286	0.6
	83.4	1		100	1.000				0.476	
Invertebrate PES			28.1					210	1	
Category	16.67		E							

7.5 EWR 4

7.5.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	4	0.17	0.70	3	80	0.17
Abundance of taxa with a preference for very fast flowing water	FTA	4	0.15	0.61	4	70	0.15
Presence of taxa with a preference for moderately fast flowing water	MT	4	0.22	0.87	1	100	0.22
Abundance of taxa with a preference for moderately fast flowing water	MTA	4	0.20	0.78	2	90	0.20
Presence of taxa with a preference for slow flowing water	ST	3	0.13	0.39	5	60	0.13
Abundance of taxa with a preference for slow flowing water	STA	3	0.13	0.39	5	60	0.13
Proportional change in average flow dependence of the assemblage			1	74.78		460	1

7.5.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	2	0.10	0.20	5	60	0.10
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	2	0.10	0.20	5	60	0.10
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	1	0.15	0.15	2	90	0.15
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	1	0.16	0.16	1	100	0.16
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	3	0.13	0.39	3	80	0.13
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	3	0.13	0.39	3	80	0.13
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	3	0.11	0.34	4	70	0.11
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	3	0.11	0.34	4	70	0.11
			1			610	1.00
Overall change in habitat assemblages				43.61			

7.5.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	1	0.17	0.1667	2	90	0.17
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	3	0.15	0.4444	3	80	0.15
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	1	0.19	0.1852	1	100	0.19
Have the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	3	0.14	0.4167	4	75	0.14
Are any taxa with a low requirement for unmodified water quality present?	LQ	2	0.10	0.2037	5	55	0.10
Have the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	3	0.09	0.2778	6	50	0.09
How does the total SASS score differ from expected?	SASS	3	0.08	0.2500	7	45	0.08
How does the total ASPT score differ from expected?	ASPT	1	0.08	0.0833	7	45	0.08
		1		540			
Overall change to indicators of modified water quality				40.56			

7.5.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	25.2	0.380	9.6	38.0	0.380	FT	1	100	0.435	1
HABITAT	56.4	0.353	19.9	35.3	0.353	VTA	2	70	0.304	0.7
WATER QUALITY	59.4	0.268	15.9	26.8	0.268	HQA	3	60	0.261	0.6
	141.1	1		100	1.000				0.435	
Invertebrate PES			45.4					230	1	
Category	28.21		D							

7.6 EWR 5

7.6.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	2	0.19	0.37	1	100	0.19
Abundance of taxa with a preference for very fast flowing water	FTA	4	0.17	0.67	2	90	0.17
Presence of taxa with a preference for moderately fast flowing water	MT	2	0.19	0.37	1	100	0.19
Abundance of taxa with a preference for moderately fast flowing water	MTA	4	0.17	0.67	2	90	0.17
Presence of taxa with a preference for slow flowing water	ST	3	0.15	0.44	3	80	0.15
Abundance of taxa with a preference for slow flowing water	STA	4	0.15	0.59	3	80	0.15
Proportional change in average flow dependence of the assemblage			1	62.22		540	1

7.6.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	2	0.11	0.21	5	65	0.11
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	4	0.10	0.39	6	60	0.10
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	2	0.15	0.29	2	90	0.15
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	4	0.16	0.65	1	100	0.16
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	1	0.13	0.13	3	80	0.13
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	2	0.13	0.26	3	80	0.13
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	3	0.11	0.34	4	70	0.11
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	4	0.11	0.46	4	70	0.11
			1			615	1.00
Overall change in habitat assemblages				54.63			

7.6.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	0	0.17	0	2	90	0.17
Has the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	0	0.19	0	1	100	0.19
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	1	0.13	0.1321	4	70	0.13
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	1	0.14	0.1415	3	75	0.14
Are any taxa with a low requirement for unmodified water quality present?	LQ	3	0.09	0.2830	6	50	0.09
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	4	0.10	0.4151	5	55	0.10
How does the total SASS score differ from expected?	SASS	3	0.08	0.2547	7	45	0.08
How does the total ASPT score differ from expected?	ASPT	1	0.08	0.0849	7	45	0.08
		1			530		
Overall change to indicators of modified water quality				26.23			

7.6.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	37.8	0.419	15.8	41.9	0.419	FT	1	100	0.435	1
HABITAT	45.4	0.334	15.2	33.4	0.334	VTA	2	70	0.304	0.7
WATER QUALITY	73.8	0.247	18.2	24.7	0.247	HQA	3	60	0.261	0.6
	156.9	1		100	1.000				0.435	
Invertebrate PES			49.2					230	1	
Category	31.38		D							

7.7 EWR 6

7.7.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	1	0.18	0.18	3	80	0.18
Abundance of taxa with a preference for very fast flowing water	FTA	1	0.16	0.16	4	70	0.16
Presence of taxa with a preference for moderately fast flowing water	MT	1	0.22	0.22	1	100	0.22
Abundance of taxa with a preference for moderately fast flowing water	MTA	1	0.20	0.20	2	90	0.20
Presence of taxa with a preference for slow flowing water	ST	1	0.13	0.13	5	60	0.13
Abundance of taxa with a preference for slow flowing water	STA	1	0.11	0.11	6	50	0.11
Proportional change in average flow dependence of the assemblage			1	20.00		450	1

7.7.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	1	0.15	0.15	1	100	0.15
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	1	0.13	0.13	2	90	0.13
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	1	0.15	0.15	1	100	0.15
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	1	0.13	0.13	2	90	0.13
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	1	0.12	0.12	3	80	0.12
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	1	0.10	0.10	4	70	0.10
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	1	0.12	0.12	3	80	0.12
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	1	0.10	0.10	4	70	0.10
			1			680	1.00
Overall change in habitat assemblages				20.00			

7.7.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	1	0.15	0.1538	1	100	0.15
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	1	0.14	0.1385	2	90	0.14
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	1	0.15	0.1538	1	100	0.15
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	1	0.14	0.1385	2	90	0.14
Are any taxa with a low requirement for unmodified water quality present?	LQ	0	0.12	0.0000	3	80	0.12
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	1	0.11	0.1077	4	70	0.11
How does the total SASS score differ from expected?	SASS	0	0.09	0.0000	5	60	0.09
How does the total ASPT score differ from expected?	ASPT	0	0.09	0.0000	5	60	0.09
		1		650			
Overall change to indicators of modified water quality				13.85			

7.7.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	80.0	0.343	27.4	34.3	0.343	FT	1	100	0.435	1
HABITAT	80.0	0.311	24.9	31.1	0.311	VTA	3	60	0.261	0.6
WATER QUALITY	86.2	0.347	29.9	34.7	0.347	HQA	2	70	0.304	0.7
	246.2	1		100	1.000				0.435	
Invertebrate PES			82.1					230	1	
Category	49.23		B							

7.8 EWR 6: Alternative Category

7.8.1 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	2	0.18	0.36	3	80	0.18
Abundance of taxa with a preference for very fast flowing water	FTA	2	0.16	0.31	4	70	0.16
Presence of taxa with a preference for moderately fast flowing water	MT	1	0.22	0.22	1	100	0.22
Abundance of taxa with a preference for moderately fast flowing water	MTA	2	0.20	0.40	2	90	0.20
Presence of taxa with a preference for slow flowing water	ST	1	0.13	0.13	5	60	0.13
Abundance of taxa with a preference for slow flowing water	STA	2	0.11	0.22	6	50	0.11
Proportional change in average flow dependence of the assemblage			1	32.89		450	1

7.8.2 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	3	0.15	0.44	1	100	0.15
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	3	0.13	0.40	2	90	0.13
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	1	0.15	0.15	1	100	0.15
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	1	0.13	0.13	2	90	0.13
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	1	0.12	0.12	3	80	0.12
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	1	0.10	0.10	4	70	0.10
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	1	0.12	0.12	3	80	0.12
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	1	0.10	0.10	4	70	0.10
			1			680	1.00
Overall change in habitat assemblages				31.18			

7.8.3 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	2	0.15	0.3077	1	100	0.15
Has the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	2	0.14	0.2769	2	90	0.14
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	1	0.15	0.1538	1	100	0.15
Has the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	1	0.14	0.1385	2	90	0.14
Are any taxa with a low requirement for unmodified water quality present?	LQ	0	0.12	0.0000	3	80	0.12
Has the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	1	0.11	0.1077	4	70	0.11
How does the total SASS score differ from expected?	SASS	1	0.09	0.0923	5	60	0.09
How does the total ASPT score differ from expected?	ASPT	1	0.09	0.0923	5	60	0.09
		1			650		
Overall change to indicators of modified water quality				19.69			

7.8.4 PES

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	67.1	0.343	23.0	34.3	0.343	FT	1	100	0.435	1
HABITAT	68.8	0.311	21.4	31.1	0.311	VTA	3	60	0.261	0.6
WATER QUALITY	80.3	0.347	27.8	34.7	0.347	HQA	2	70	0.304	0.7
	216.2	1		100	1.000				0.435	
Invertebrate PES			72.2					230	1	
Category	43.25		C							

APPENDIX F

HYDRAULICS

Dr A.L. Birkhead, Streamflow Solutions

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1 DATA COLLECTION

The coordinates (Cape datum LO 25°) and elevation (above mean sea level) of the fixed stations at the EWR sites are given in Table F-1.

Table F-1 Coordinates of fixed survey stations at the EWR sites

River	Site no.	Station	Y-Coord (m)	X-Coord (m)	Eamsl (m)
Kromme	1	IPC1.1	68131.22	3756083.86	222.45
		IPC1.2	68260.96	3756064.69	223.80
	2	MRK2.1	46352.10	3765005.60	105.01
		MRK2.2	46345.18	3765013.46	104.66
Geelhoutboom	4	IPC4.1	23716.72	3773717.05	16.62
		IPC4.2	23719.87	3773715.08	17.16
Seekoei	5	IPC5.1	27531.81	3763274.56	207.21
		IPC5.2	27522.74	3763248.83	207.82

Eamsl: elevation above mean sea level

IPC: Iron Peg in Concrete

MRK: Mark (Painted)

The measured discharges and flow depths are provided in Table F-2, together with the dates when the data were collected.

Table F-2 Hydraulic data collected at EWR Sites

River	Site no.	Date	Discharge Q (m ³ /s)	Max. flow depth, y (m)	
				A ¹	B ¹
Kromme	1	11/11/2003	0.13	0.27	1.30
		29/03/2004	0.028	0.16	1.13
	2	11/11/2003	0.054	0.52	0.21
		31/03/2004	0.042	0.52	0.18
Geelhoutboom	4	12/11/2003	0.000086	0.014	
Seekoei	5	14/11/2003	0.016	0.20	
Swart	6	30/03/2004	0.0055	0.13	

¹cross-section number

1.1 Modelling

The observed rating data at the EWR sites have been extended using Manning=s resistance relationship. The surveyed water surface and regional (1:50 000 topographical) channel slopes are given in Tables F-2 and F-4, respectively, and these have been used in conjunction with estimates of Manning=s resistance coefficient (Table F-5) to synthesize rating data for discharges higher than those measured. Continuous rating functions of the form given by equation F.1 have been fitted to the measured and modelled data, and these are plotted in Figures F-8 - 10.

$$Q = ay^b + c \quad \text{equation F.1}$$

Where y is the flow depth (m), Q is the discharge (m³/s), and a , b and c are regression coefficients, listed in Table F-6.

Table F-3 Regional 1:50k channel slope

River	Site no.	Channel slope
Kromme	1	0.0050
	2	0.0085
Geelhoutboom	4	0.0045
Seekoei	5	0.0133
Swart	6	0.0083

Table F-4 Surveyed water surface slopes

River	Site no.	Discharge (m ³ /s)	Water surface slope
Kromme	1A	0.13	0.0079
		0.028	0.011
	2B	0.042, 0.054	0.044
Geelhoutboom	4	0.000086	0.030
Seekoei	5	0.016	0.040
Swart	6	0.0055	0.030

Table F-5 Hydraulic data used to extend the measured rating data

River	Site no.	Discharge (m ³ /s)	Manning's resistance, <i>n</i>	Max. flow depth, <i>y</i> (m)	Energy slope, <i>S</i>	Ave. velocity <i>v</i> (m/s)
Kromme	1A	0.028	0.23	0.16	0.011	0.08
		0.13	0.19	0.27	0.0079	0.11
		11.7	0.06	1.00	0.006	0.91
		83	0.04	2.50	0.003	1.72
	2B	0.042	0.50	0.18	0.044	0.09
		0.054	0.39	0.21	0.044	0.10
		9.1	0.06	0.75	0.020	1.3
		47.9	0.04	1.50	0.010	2.2
Geelhoutboom	4	0.000086	0.21	0.014	0.03	0.03
		0.19	0.04	0.20	0.0100	0.60
		1.4	0.04	0.50	0.0070	1.0
		10.5	0.035	1.50	0.0045	1.7
Seekoei	5	0.016	0.28	0.20	0.040	0.1
		2.0	0.06	0.50	0.030	1.1
		15.7	0.04	1.20	0.015	2.0
Swart	6	0.0055	0.32	0.13	0.030	0.07
		1.2	0.06	0.50	0.025	1.3
		21.0	0.04	1.50	0.016	1.8

Italic – modelled

Table F-6 Regression coefficients in equation F.1

River	Site no.	Discharge Q (m ³ /s)	Rating coefficients		
			<i>a</i>	<i>b</i>	<i>c</i>
Kromme	1A	Q < 3.00	0.470	0.280	0.000
		Q > 3.00	0.150	0.600	0.350
	1B	Q < 3.50	0.580	0.300	0.963
		Q > 3.50	0.145	0.600	1.500
	2A	Q < 0.35	0.280	0.200	0.370
		Q > 0.35	0.213	0.490	0.470
	2B	Q < 0.90	0.350	0.200	0.000
		Q > 0.90	0.213	0.480	0.140
Geelhoutboom	4	Q < 0.17	0.340	0.310	0.000
		Q > 0.17	0.350	0.600	0.075
Seekoei	5	Q < 0.05	0.300	0.100	0.000
		Q > 0.05	0.370	0.550	0.179
Swart	6	Q < 0.008	0.380	0.200	0.000
		Q > 0.008	0.370	0.440	0.100

2 RESULTS

2.1 Cross-sectional profiles

Cross-sectional profiles are shown in Figures F-1 to F-7.

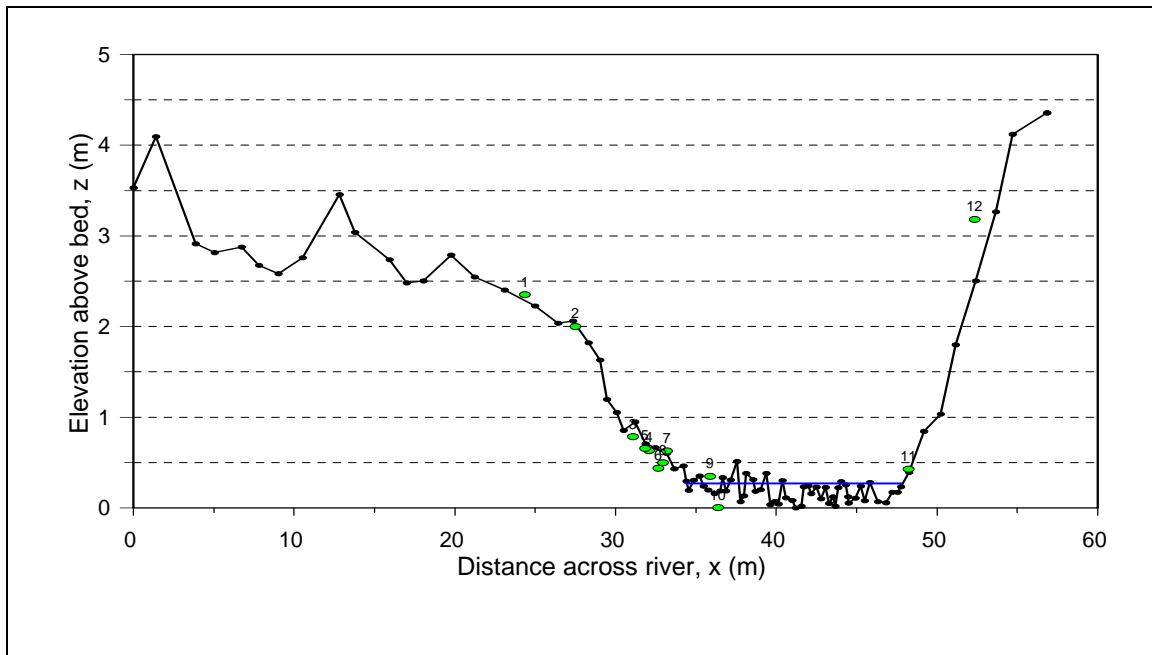


Figure F-1 Cross-sectional profile for EWR site 1A (Riffle) on the Kromme River. The vegetation markers are indicated by the green filled circles, and the water level (0.27 m, 0.13 m³/s) at the date of survey (11/11/2003) is indicated by the blue line

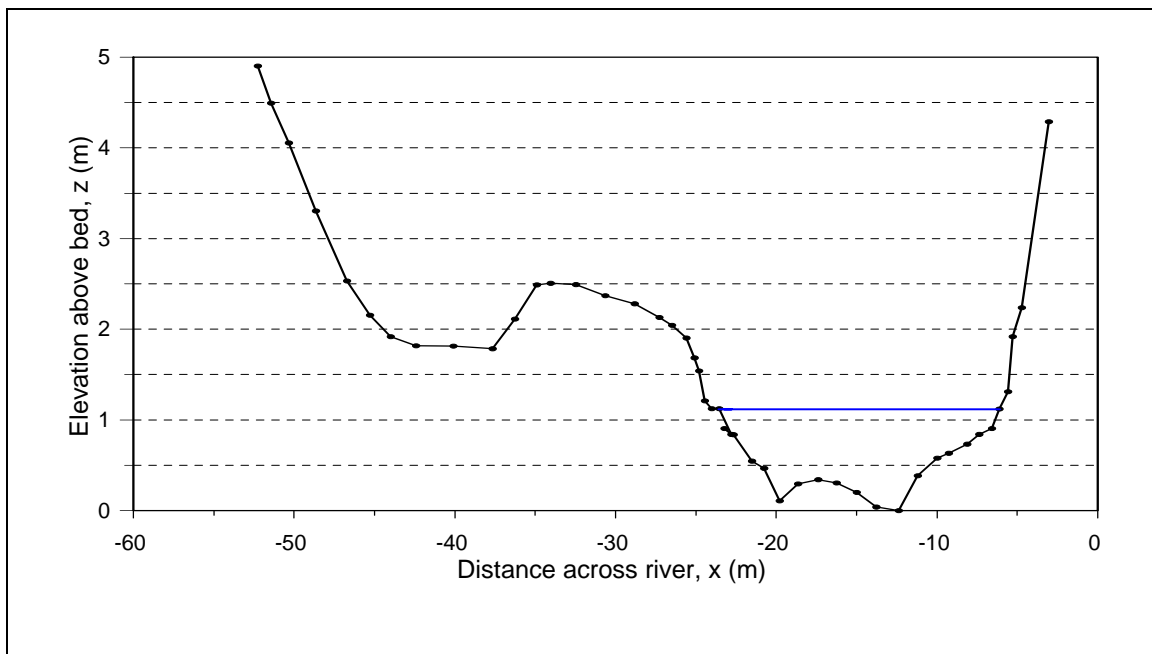


Figure F-2 Cross-sectional profile for EWR Site 1B (Pool) on the Kromme River. The water level (1.13 m, 0.028 m³/s) at the date of survey (29/03/2004) is indicated by the blue line

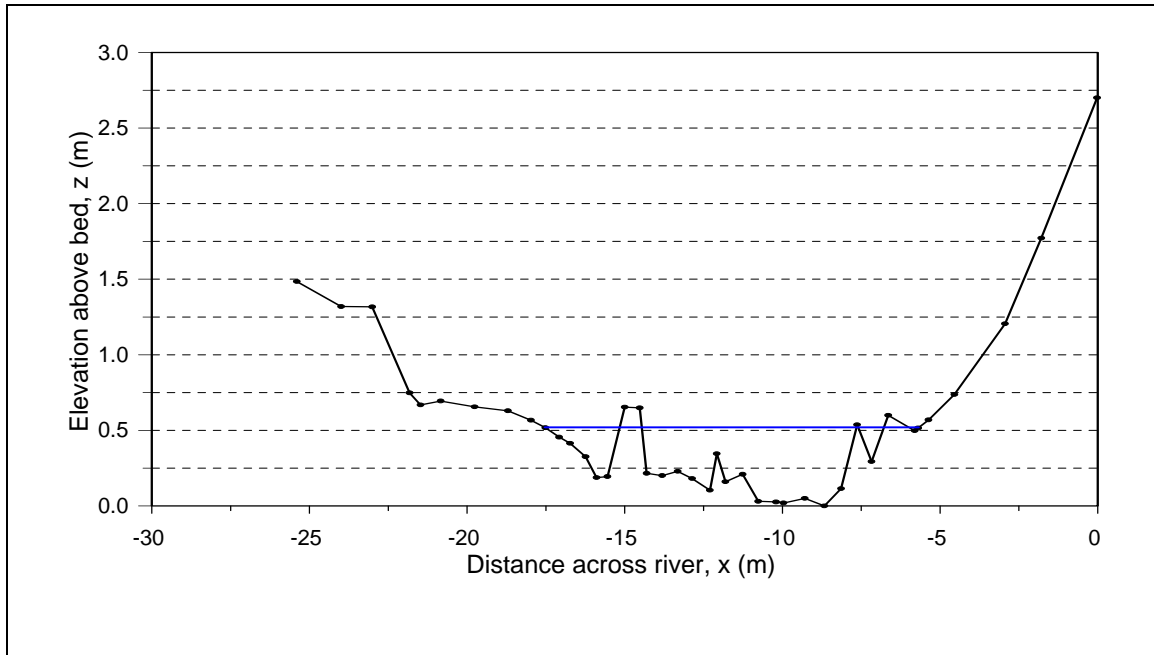


Figure F-3 Cross-sectional profile for EWR site 2A (Pool) on the Kromme River. The water level (0.52 m, 0.042 m³/s) at the date of survey (31/03/2004) is indicated by the blue line

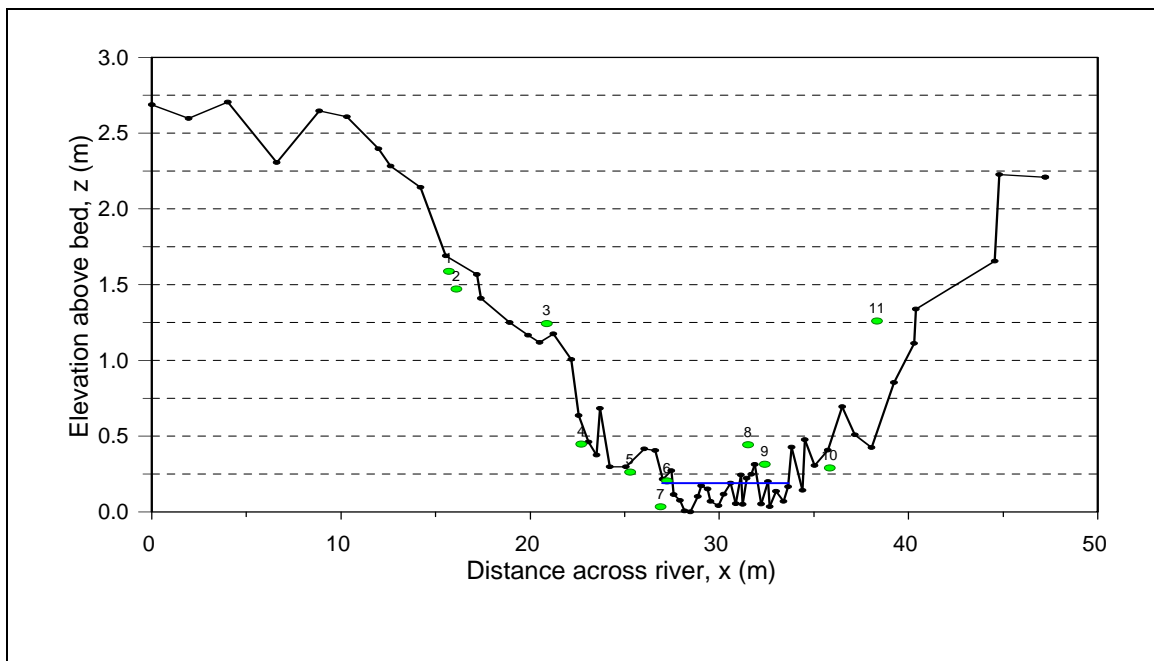


Figure F-4 Cross-sectional profile for EWR site 2B (Pool) on the Kromme River. The vegetation markers are indicated by the green filled circles, and the water level (0.21 m, 0.054 m³/s) at the date of survey (11/11/2003) is indicated by the blue line

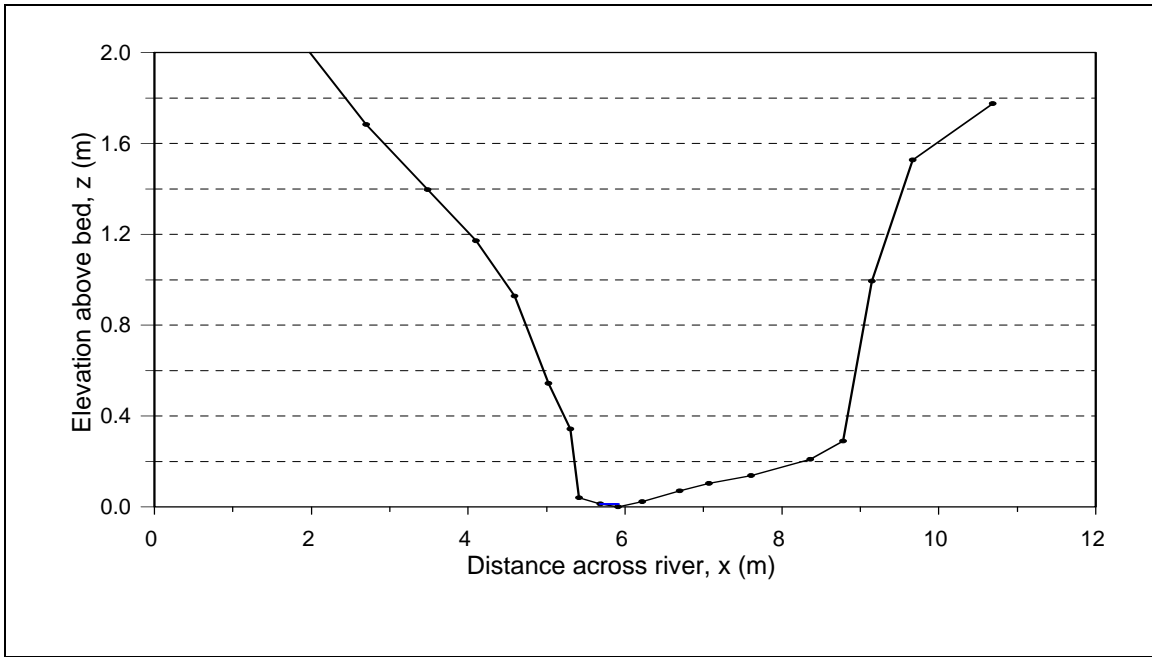


Figure F-5 Cross-sectional profile for EWR site 4 (Run) on the Geelhoutboom River

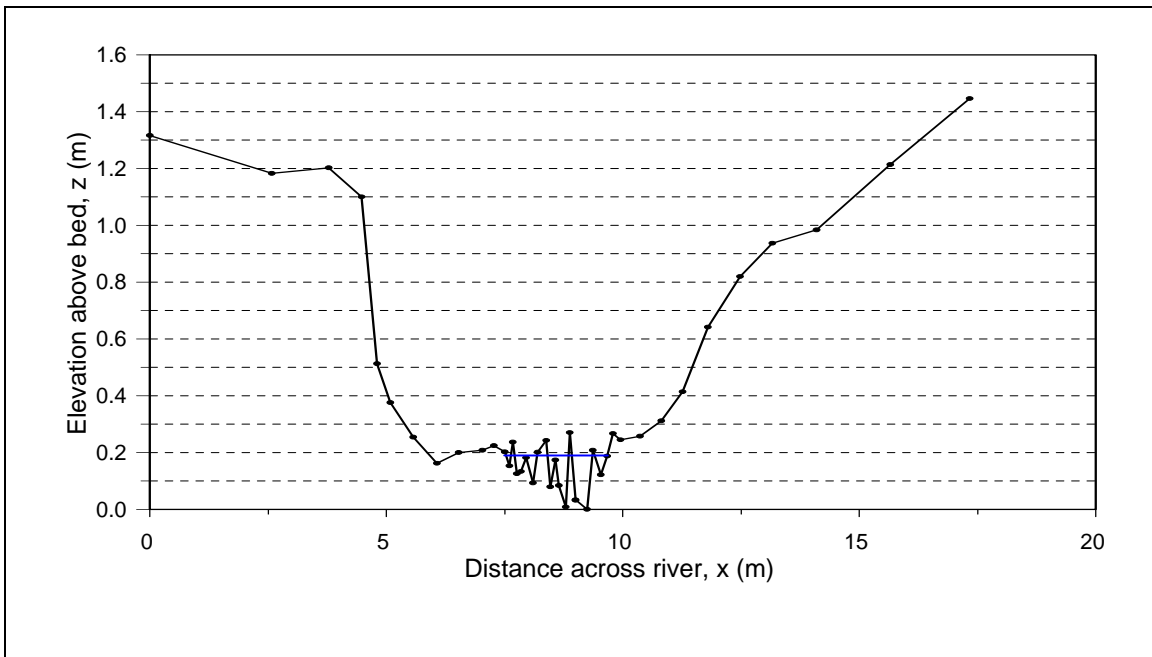


Figure F-6 Cross-sectional profile for EWR site 5 (Riffle) on the Seekoei River. The water level (0.20 m, 0.016 m³/s) at the date of survey (14/11/2003) is indicated by the blue line

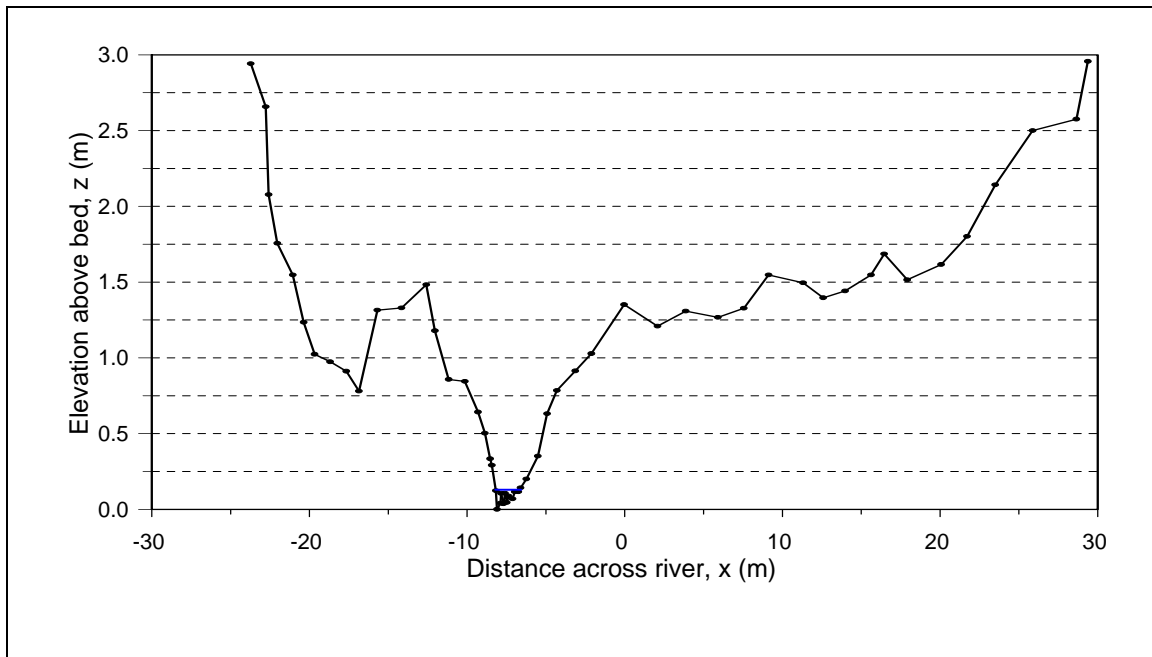


Figure F-7 Cross-sectional profile for EWR site 6 (Riffle) on the Swart River. The water level (0.13 m, 0.0055 m³/s) at the date of survey (30/03/2004) is indicated by the blue line

2.2 Rating data and functions

Results are shown in figures F-8 to F-10.

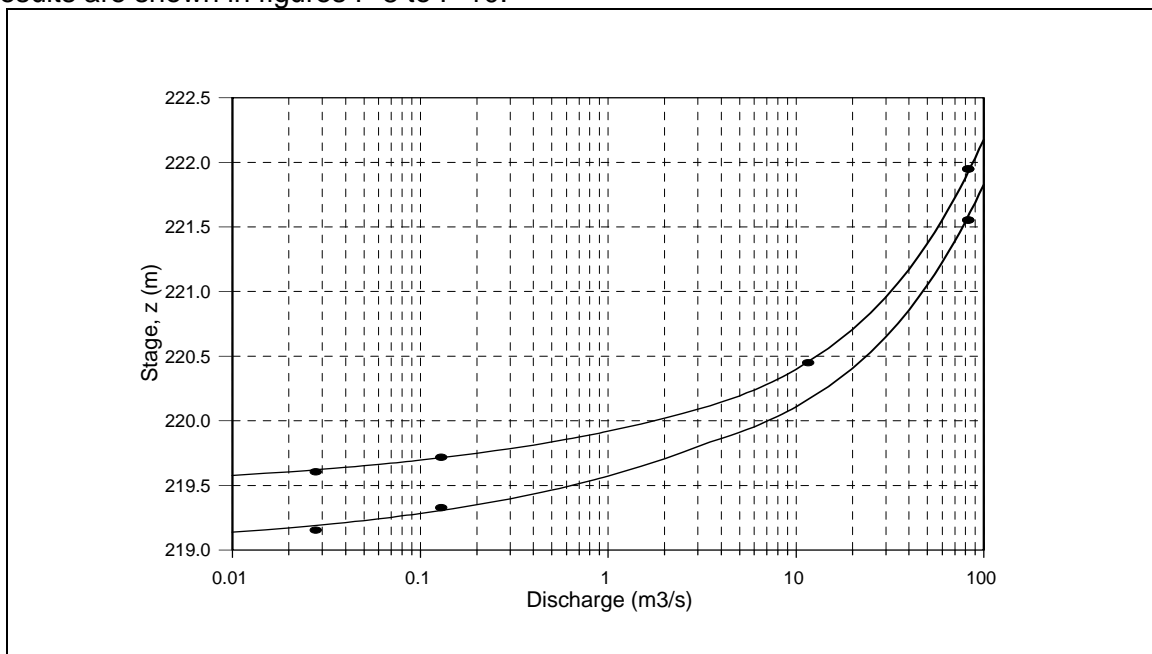


Figure F-8 Measured and modelled rating data and functions for the cross-sectional profiles at EWR Site 1 on the Kromme River. Cross-section A (upper curve) lies through the upstream riffle and cross-section B (lower curve) through the downstream pool

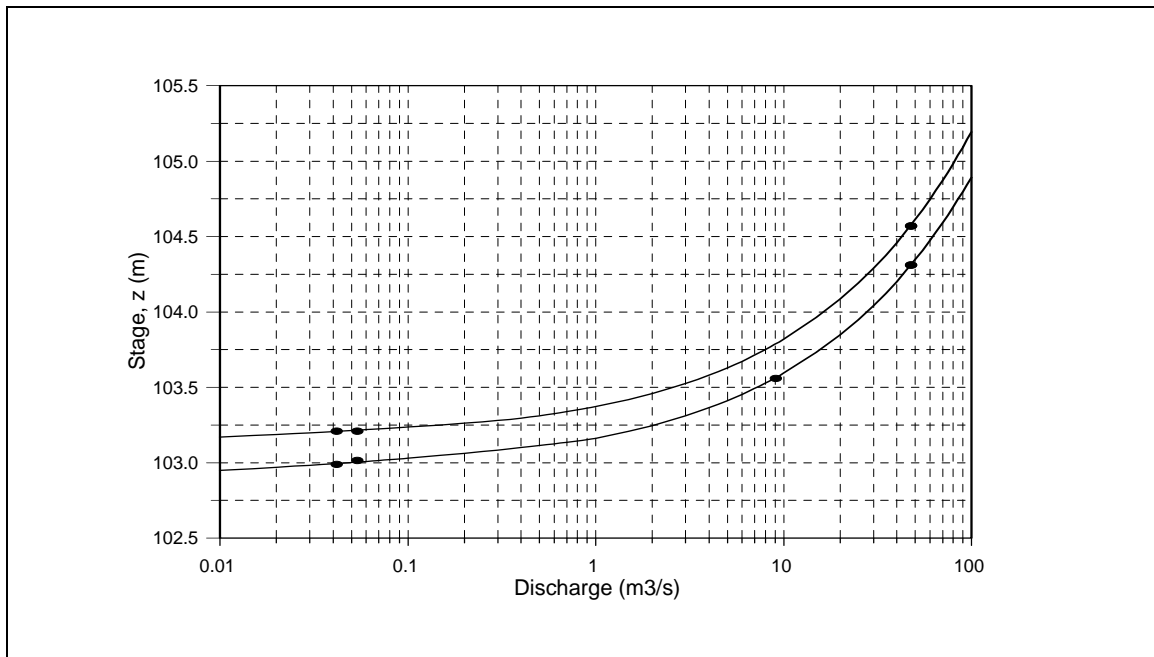


Figure F-9 Measured and modelled rating data and function for the cross-sectional profiles at EWR Site 2 on the Kromme River. Cross-section A (upper curve) lies through the upstream pool and cross-section B (lower curve) through the downstream rapid

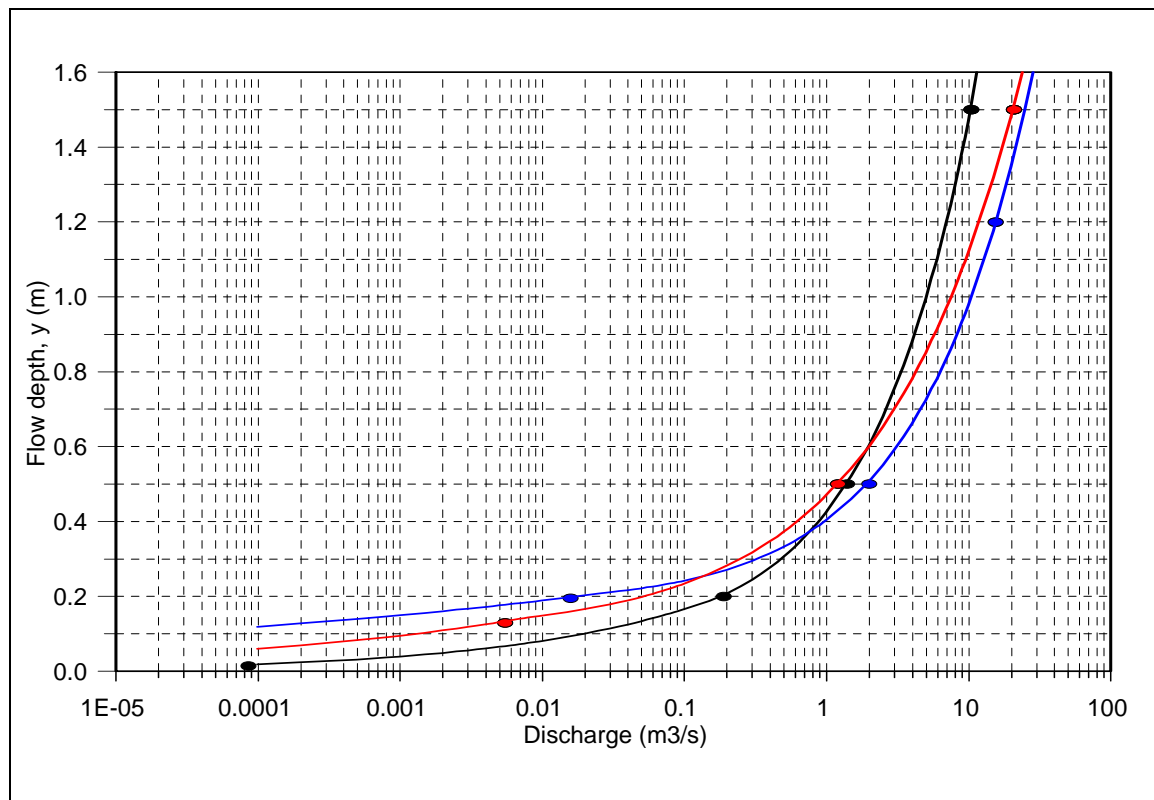


Figure F-10 Measured and modelled rating data and function for the cross-sectional profiles at EWR site 4 on the Geelhoutboom River (black), EWR site 5 on the Seekoei River (blue), and EWR site 6 on the Swart River (red)

2.3 Tabulated modelled hydraulic data

Results are shown in tables F-7 to F-13

Table F-7 Tabulated hydraulic data for EWR site 1A on the Kromme River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.00	0.01	0.00	0.41	0.41	0.00
0.04	0.00	0.02	0.01	0.55	0.58	0.01
0.06	0.00	0.03	0.03	1.13	1.22	0.02
0.08	0.00	0.03	0.07	2.33	2.51	0.03
0.10	0.00	0.04	0.12	3.16	3.44	0.03
0.12	0.01	0.05	0.19	3.96	4.36	0.04
0.14	0.01	0.06	0.28	4.49	5.00	0.05
0.16	0.02	0.07	0.37	5.01	5.64	0.06
0.18	0.03	0.08	0.48	6.35	7.10	0.07
0.20	0.05	0.08	0.62	7.58	8.48	0.08
0.22	0.07	0.09	0.79	8.64	9.69	0.08
0.24	0.09	0.10	0.97	9.66	10.87	0.09
0.26	0.12	0.11	1.17	10.47	11.80	0.10
0.28	0.16	0.12	1.39	11.20	12.64	0.11
0.30	0.20	0.14	1.62	11.75	13.30	0.12
0.32	0.25	0.15	1.86	12.24	13.87	0.14
0.34	0.31	0.16	2.11	12.81	14.51	0.15
0.36	0.39	0.18	2.37	13.26	15.02	0.16
0.38	0.47	0.19	2.64	13.57	15.39	0.18
0.40	0.56	0.21	2.91	13.72	15.57	0.19
0.42	0.67	0.23	3.19	13.83	15.71	0.21
0.44	0.79	0.25	3.46	14.07	15.98	0.23
0.46	0.93	0.26	3.75	14.60	16.55	0.25
0.48	1.08	0.27	4.04	14.83	16.80	0.27
0.50	1.25	0.29	4.34	14.97	16.97	0.29
0.52	1.43	0.31	4.64	15.10	17.12	0.31
0.54	1.64	0.33	4.95	15.20	17.23	0.33
0.56	1.87	0.34	5.25	15.30	17.34	0.36
0.58	2.12	0.36	5.56	15.40	17.44	0.38
0.60	2.39	0.38	5.87	15.50	17.55	0.41
0.62	2.69	0.39	6.18	15.75	17.81	0.44
0.64	3.00	0.41	6.50	16.01	18.07	0.46
0.66	3.35	0.42	6.82	16.27	18.34	0.49
0.68	3.72	0.43	7.15	16.57	18.64	0.52
0.70	4.10	0.44	7.48	16.88	18.96	0.55
0.72	4.50	0.46	7.82	17.08	19.17	0.58
0.74	4.92	0.48	8.17	17.18	19.27	0.60
0.76	5.34	0.49	8.51	17.27	19.37	0.63
0.78	5.78	0.51	8.86	17.36	19.47	0.65
0.80	6.24	0.53	9.21	17.46	19.58	0.68
0.82	6.71	0.54	9.56	17.55	19.68	0.70
0.84	7.19	0.56	9.91	17.65	19.78	0.73
0.86	7.69	0.58	10.26	17.82	19.96	0.75
0.88	8.20	0.58	10.62	18.19	20.34	0.77
0.90	8.72	0.59	10.99	18.55	20.72	0.79
0.92	9.25	0.60	11.36	18.92	21.10	0.81
0.94	9.80	0.61	11.75	19.29	21.47	0.83
0.96	10.36	0.62	12.13	19.54	21.73	0.85
0.98	10.93	0.64	12.53	19.69	21.89	0.87
1.00	11.52	0.65	12.92	19.84	22.05	0.89
1.02	12.11	0.67	13.32	20.00	22.21	0.91
1.04	12.72	0.68	13.72	20.13	22.35	0.93
1.06	13.34	0.70	14.13	20.21	22.44	0.94
1.08	13.98	0.71	14.53	20.32	22.56	0.96
1.10	14.62	0.73	14.94	20.43	22.68	0.98
1.12	15.28	0.75	15.35	20.54	22.80	1.00
1.14	15.94	0.76	15.76	20.66	22.92	1.01
1.16	16.62	0.78	16.17	20.77	23.04	1.03
1.18	17.31	0.79	16.59	20.88	23.16	1.04
1.20	18.01	0.81	17.01	20.98	23.28	1.06
1.22	18.72	0.83	17.43	21.02	23.34	1.07
1.24	19.45	0.85	17.85	21.07	23.40	1.09
1.26	20.18	0.87	18.27	21.11	23.46	1.10
1.28	20.92	0.88	18.69	21.16	23.52	1.12

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.30	21.68	0.90	19.12	21.20	23.58	1.13
1.32	22.45	0.92	19.54	21.25	23.64	1.15
1.34	23.22	0.94	19.97	21.29	23.70	1.16
1.36	24.01	0.96	20.39	21.34	23.76	1.18
1.38	24.81	0.97	20.82	21.38	23.82	1.19
1.40	25.62	0.99	21.25	21.43	23.88	1.21
1.42	26.43	1.01	21.68	21.47	23.94	1.22
1.44	27.26	1.03	22.11	21.51	24.00	1.23
1.46	28.10	1.05	22.54	21.56	24.06	1.25
1.48	28.95	1.06	22.97	21.60	24.12	1.26
1.50	29.81	1.08	23.40	21.65	24.18	1.27
1.52	30.68	1.10	23.84	21.69	24.24	1.29
1.54	31.56	1.12	24.27	21.74	24.30	1.30
1.56	32.45	1.13	24.71	21.78	24.36	1.31
1.58	33.34	1.15	25.14	21.83	24.42	1.33
1.60	34.25	1.17	25.58	21.87	24.48	1.34
1.62	35.17	1.19	26.02	21.91	24.54	1.35
1.64	36.10	1.20	26.46	21.98	24.61	1.36
1.66	37.04	1.22	26.90	22.08	24.72	1.38
1.68	37.98	1.23	27.34	22.18	24.83	1.39
1.70	38.94	1.25	27.78	22.28	24.94	1.40
1.72	39.91	1.26	28.23	22.37	25.05	1.41
1.74	40.88	1.28	28.68	22.47	25.15	1.43
1.76	41.87	1.29	29.13	22.57	25.26	1.44
1.78	42.86	1.30	29.58	22.67	25.37	1.45
1.80	43.87	1.32	30.04	22.77	25.48	1.46
1.82	44.88	1.33	30.49	22.88	25.60	1.47
1.84	45.90	1.35	30.95	22.99	25.72	1.48
1.86	46.93	1.36	31.41	23.11	25.84	1.49
1.88	47.97	1.37	31.88	23.22	25.97	1.51
1.90	49.02	1.39	32.34	23.34	26.09	1.52
1.92	50.08	1.40	32.81	23.45	26.21	1.53
1.94	51.15	1.41	33.28	23.57	26.34	1.54
1.96	52.23	1.42	33.75	23.69	26.46	1.55
1.98	53.31	1.44	34.23	23.80	26.58	1.56
2.00	54.41	1.45	34.70	23.92	26.71	1.57
2.02	55.51	1.46	35.18	24.04	26.83	1.58
2.04	56.62	1.48	35.67	24.15	26.96	1.59
2.06	57.74	1.43	36.16	25.26	28.07	1.60
2.08	58.87	1.44	36.67	25.54	28.36	1.61
2.10	60.01	1.44	37.18	25.73	28.56	1.61
2.12	61.16	1.45	37.70	25.92	28.75	1.62
2.14	62.32	1.46	38.22	26.11	28.95	1.63
2.16	63.48	1.47	38.74	26.30	29.14	1.64
2.18	64.65	1.48	39.27	26.49	29.34	1.65
2.20	65.84	1.49	39.80	26.68	29.54	1.65
2.22	67.03	1.50	40.34	26.86	29.73	1.66
2.24	68.23	1.51	40.88	27.09	29.96	1.67
2.26	69.43	1.52	41.42	27.34	30.22	1.68
2.28	70.65	1.52	41.97	27.59	30.47	1.68
2.30	71.87	1.53	42.52	27.84	30.73	1.69
2.32	73.11	1.53	43.08	28.09	30.99	1.70
2.34	74.35	1.54	43.65	28.34	31.25	1.70
2.36	75.60	1.55	44.22	28.59	31.50	1.71
2.38	76.86	1.55	44.79	28.84	31.76	1.72
2.40	78.12	1.56	45.37	29.09	32.02	1.72
2.42	79.40	1.56	45.96	29.38	32.31	1.73
2.44	80.68	1.57	46.55	29.68	32.61	1.73
2.46	81.97	1.57	47.14	29.98	32.92	1.74
2.48	83.27	1.58	47.75	30.27	33.22	1.74
2.50	84.58	1.54	48.36	31.32	34.28	1.75

Table F-8 Tabulated hydraulic data for EWR site 1B on the Kromme River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.96	0.00	0.56	9.25	16.65	17.82	0.00
0.98	0.00	0.57	9.58	16.75	17.93	0.00
1.00	0.00	0.59	9.92	16.85	18.04	0.00
1.02	0.00	0.61	10.26	16.95	18.14	0.00
1.04	0.00	0.62	10.60	17.05	18.25	0.00
1.06	0.00	0.64	10.94	17.15	18.36	0.00
1.08	0.01	0.65	11.28	17.25	18.47	0.00
1.10	0.01	0.67	11.63	17.35	18.57	0.00
1.12	0.01	0.69	11.98	17.45	18.68	0.00
1.14	0.02	0.68	12.33	18.04	19.28	0.00
1.16	0.03	0.70	12.70	18.20	19.44	0.00
1.18	0.04	0.71	13.06	18.35	19.60	0.00
1.20	0.05	0.73	13.43	18.50	19.76	0.00
1.22	0.07	0.74	13.80	18.62	19.88	0.00
1.24	0.09	0.76	14.18	18.69	19.97	0.01
1.26	0.11	0.78	14.55	18.77	20.06	0.01
1.28	0.14	0.79	14.93	18.85	20.14	0.01
1.30	0.17	0.81	15.30	18.92	20.23	0.01
1.32	0.20	0.83	15.68	18.98	20.30	0.01
1.34	0.24	0.85	16.06	19.01	20.35	0.02
1.36	0.29	0.86	16.44	19.04	20.40	0.02
1.38	0.34	0.88	16.82	19.07	20.46	0.02
1.40	0.40	0.90	17.21	19.10	20.51	0.02
1.42	0.46	0.92	17.59	19.13	20.56	0.03
1.44	0.53	0.94	17.97	19.16	20.61	0.03
1.46	0.61	0.96	18.35	19.19	20.66	0.03
1.48	0.69	0.97	18.74	19.22	20.71	0.04
1.50	0.79	0.99	19.12	19.26	20.76	0.04
1.52	0.89	1.01	19.51	19.29	20.82	0.05
1.54	1.00	1.03	19.90	19.32	20.87	0.05
1.56	1.12	1.05	20.28	19.37	20.93	0.06
1.58	1.25	1.06	20.67	19.42	21.00	0.06
1.60	1.39	1.08	21.06	19.47	21.07	0.07
1.62	1.54	1.10	21.45	19.52	21.14	0.07
1.64	1.70	1.12	21.84	19.57	21.21	0.08
1.66	1.87	1.13	22.23	19.62	21.27	0.08
1.68	2.06	1.15	22.62	19.67	21.34	0.09
1.70	2.25	1.17	23.02	19.72	21.41	0.10
1.72	2.46	1.18	23.41	19.78	21.49	0.11
1.74	2.68	1.20	23.81	19.84	21.56	0.11
1.76	2.92	1.22	24.21	19.89	21.63	0.12
1.78	3.17	1.23	24.61	19.95	21.71	0.13
1.80	3.44	1.17	25.02	21.42	23.19	0.14
1.82	3.80	1.02	25.47	25.03	26.82	0.15
1.84	4.20	1.02	25.98	25.49	27.30	0.16
1.86	4.62	1.02	26.49	25.95	27.78	0.17
1.88	5.05	1.02	27.02	26.41	28.26	0.19
1.90	5.49	1.03	27.55	26.86	28.74	0.20
1.92	5.96	1.03	28.09	27.37	29.26	0.21
1.94	6.43	1.03	28.64	27.72	29.63	0.22
1.96	6.92	1.04	29.20	28.08	29.99	0.24
1.98	7.43	1.05	29.77	28.44	30.36	0.25
2.00	7.95	1.05	30.34	28.80	30.73	0.26
2.02	8.48	1.06	30.92	29.15	31.10	0.27
2.04	9.03	1.07	31.50	29.51	31.47	0.29
2.06	9.59	1.07	32.10	29.92	31.88	0.30
2.08	10.17	1.08	32.70	30.33	32.31	0.31
2.10	10.75	1.08	33.31	30.75	32.74	0.32
2.12	11.36	1.09	33.93	31.16	33.16	0.33
2.14	11.97	1.09	34.56	31.58	33.59	0.35
2.16	12.60	1.10	35.19	31.99	34.01	0.36
2.18	13.24	1.11	35.84	32.38	34.41	0.37
2.20	13.89	1.11	36.49	32.76	34.81	0.38
2.22	14.55	1.12	37.15	33.15	35.21	0.39
2.24	15.23	1.13	37.82	33.54	35.60	0.40
2.26	15.92	1.14	38.49	33.91	35.99	0.41
2.28	16.62	1.14	39.17	34.29	36.39	0.42
2.30	17.33	1.14	39.86	34.85	36.97	0.43

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
2.32	18.06	1.15	40.57	35.41	37.54	0.45
2.34	18.80	1.15	41.28	35.97	38.12	0.46
2.36	19.55	1.15	42.00	36.53	38.69	0.47
2.38	20.31	1.15	42.74	37.04	39.21	0.48
2.40	21.08	1.16	43.49	37.50	39.69	0.48
2.42	21.86	1.17	44.24	37.96	40.17	0.49
2.44	22.66	1.17	45.00	38.43	40.65	0.50
2.46	23.47	1.18	45.78	38.89	41.13	0.51
2.48	24.28	1.18	46.56	39.35	41.60	0.52

Table F-9 Tabulated hydraulic data for EWR site 2A on the Kromme River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.37	0.00	0.21	1.70	7.96	8.50	0.00
0.39	0.00	0.23	1.86	8.20	8.78	0.00
0.41	0.00	0.24	2.03	8.44	9.06	0.00
0.43	0.00	0.25	2.20	8.72	9.38	0.00
0.45	0.00	0.26	2.38	9.02	9.72	0.00
0.47	0.01	0.28	2.56	9.30	10.04	0.00
0.49	0.01	0.29	2.75	9.57	10.35	0.01
0.51	0.03	0.29	2.95	10.01	10.82	0.01
0.53	0.06	0.30	3.15	10.60	11.45	0.02
0.55	0.11	0.30	3.37	11.17	12.06	0.03
0.57	0.19	0.31	3.60	11.73	12.64	0.05
0.59	0.30	0.31	3.84	12.29	13.23	0.08
0.61	0.42	0.32	4.09	12.74	13.71	0.10
0.63	0.56	0.33	4.35	13.09	14.09	0.13
0.65	0.71	0.33	4.62	14.11	15.12	0.15
0.67	0.88	0.32	4.92	15.29	16.31	0.18
0.69	1.07	0.32	5.24	16.53	17.56	0.20
0.71	1.28	0.33	5.57	16.98	18.01	0.23
0.73	1.50	0.34	5.91	17.17	18.20	0.25
0.75	1.75	0.36	6.26	17.33	18.37	0.28
0.77	2.01	0.38	6.61	17.44	18.49	0.30
0.79	2.29	0.40	6.96	17.55	18.61	0.33
0.81	2.60	0.41	7.31	17.66	18.72	0.36
0.83	2.92	0.43	7.66	17.77	18.84	0.38
0.85	3.26	0.45	8.02	17.88	18.96	0.41
0.87	3.62	0.47	8.38	18.00	19.08	0.43
0.89	4.00	0.48	8.74	18.11	19.19	0.46
0.91	4.40	0.50	9.10	18.22	19.31	0.48
0.93	4.81	0.52	9.47	18.33	19.43	0.51
0.95	5.25	0.53	9.84	18.44	19.55	0.53
0.97	5.71	0.55	10.21	18.55	19.67	0.56
0.99	6.18	0.57	10.58	18.66	19.78	0.58
1.01	6.68	0.58	10.95	18.77	19.90	0.61
1.03	7.19	0.60	11.33	18.88	20.02	0.63
1.05	7.72	0.62	11.71	18.99	20.14	0.66
1.07	8.28	0.63	12.09	19.10	20.26	0.68
1.09	8.85	0.65	12.47	19.21	20.37	0.71
1.11	9.44	0.67	12.86	19.32	20.49	0.73
1.13	10.05	0.68	13.24	19.43	20.61	0.76
1.15	10.69	0.70	13.63	19.54	20.73	0.78
1.17	11.34	0.71	14.03	19.65	20.84	0.81
1.19	12.01	0.73	14.42	19.76	20.96	0.83
1.21	12.70	0.75	14.82	19.87	21.08	0.86
1.23	13.41	0.76	15.21	19.95	21.17	0.88
1.25	14.14	0.78	15.61	20.03	21.26	0.91
1.27	14.89	0.80	16.02	20.11	21.35	0.93
1.29	15.66	0.81	16.42	20.20	21.44	0.95
1.31	16.45	0.83	16.82	20.28	21.53	0.98
1.33	17.26	0.81	17.24	21.41	22.67	1.00
1.35	18.09	0.82	17.67	21.62	22.88	1.02
1.37	18.94	0.83	18.11	21.83	23.10	1.05
1.39	19.80	0.84	18.54	22.04	23.31	1.07
1.41	20.69	0.85	18.99	22.25	23.53	1.09
1.43	21.60	0.87	19.43	22.46	23.75	1.11
1.45	22.53	0.88	19.89	22.67	23.96	1.13
1.47	23.48	0.89	20.34	22.87	24.18	1.15

Table F-10 Tabulated hydraulic data for EWR site 2B on the Kromme River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.00	0.01	0.01	0.43	0.44	0.00
0.04	0.00	0.03	0.02	0.60	0.61	0.00
0.06	0.00	0.03	0.03	1.24	1.29	0.00
0.08	0.00	0.03	0.07	2.01	2.13	0.01
0.10	0.00	0.04	0.11	2.77	2.97	0.02
0.12	0.00	0.05	0.18	3.48	3.76	0.03
0.14	0.01	0.06	0.25	4.07	4.43	0.04
0.16	0.02	0.07	0.34	4.66	5.12	0.06
0.18	0.04	0.08	0.44	5.27	5.83	0.08
0.20	0.06	0.10	0.55	5.57	6.21	0.11
0.22	0.10	0.11	0.66	5.76	6.48	0.15
0.24	0.15	0.12	0.78	6.27	7.07	0.19
0.26	0.23	0.14	0.91	6.72	7.57	0.25
0.28	0.33	0.15	1.05	7.02	7.93	0.31
0.30	0.46	0.15	1.19	8.06	9.01	0.39
0.32	0.64	0.16	1.36	8.53	9.53	0.47
0.34	0.87	0.17	1.53	9.03	10.07	0.56
0.36	1.07	0.18	1.72	9.53	10.62	0.62
0.38	1.28	0.19	1.91	10.04	11.18	0.67
0.40	1.51	0.20	2.12	10.65	11.85	0.71
0.42	1.77	0.20	2.35	11.71	12.97	0.75
0.44	2.04	0.21	2.58	12.19	13.49	0.79
0.46	2.33	0.22	2.83	12.70	14.05	0.82
0.48	2.65	0.23	3.09	13.17	14.57	0.86
0.50	2.98	0.25	3.36	13.59	15.01	0.89
0.52	3.34	0.26	3.63	13.94	15.40	0.92
0.54	3.72	0.28	3.92	14.22	15.71	0.95
0.56	4.11	0.29	4.20	14.51	16.03	0.98
0.58	4.53	0.30	4.50	14.79	16.34	1.01
0.60	4.97	0.32	4.80	15.07	16.65	1.04
0.62	5.43	0.33	5.10	15.36	16.97	1.07
0.64	5.92	0.35	5.41	15.63	17.27	1.09
0.66	6.42	0.36	5.72	15.88	17.55	1.12
0.68	6.95	0.37	6.04	16.12	17.83	1.15
0.70	7.49	0.39	6.37	16.30	18.03	1.18
0.72	8.06	0.41	6.70	16.37	18.12	1.20
0.74	8.65	0.43	7.02	16.45	18.20	1.23
0.76	9.26	0.45	7.35	16.52	18.29	1.26
0.78	9.90	0.46	7.69	16.60	18.38	1.29
0.80	10.55	0.48	8.02	16.68	18.47	1.32
0.82	11.23	0.50	8.35	16.75	18.56	1.34
0.84	11.93	0.52	8.69	16.83	18.64	1.37
0.86	12.65	0.53	9.03	16.91	18.74	1.40
0.88	13.39	0.55	9.36	17.02	18.85	1.43
0.90	14.15	0.57	9.71	17.12	18.97	1.46
0.92	14.94	0.58	10.05	17.23	19.08	1.49
0.94	15.75	0.60	10.40	17.33	19.20	1.52
0.96	16.58	0.62	10.74	17.43	19.31	1.54
0.98	17.44	0.63	11.09	17.54	19.42	1.57
1.00	18.31	0.65	11.44	17.64	19.54	1.60
1.02	19.21	0.66	11.80	17.80	19.70	1.63
1.04	20.13	0.68	12.16	18.00	19.91	1.66
1.06	21.07	0.69	12.52	18.19	20.11	1.68
1.08	22.04	0.70	12.88	18.39	20.31	1.71
1.10	23.03	0.71	13.25	18.59	20.51	1.74
1.12	24.04	0.73	13.63	18.79	20.71	1.76
1.14	25.07	0.72	14.01	19.40	21.35	1.79
1.16	26.13	0.72	14.40	20.02	21.98	1.81
1.18	27.21	0.72	14.81	20.58	22.56	1.84
1.20	28.31	0.73	15.22	20.82	22.81	1.86
1.22	29.43	0.74	15.64	21.07	23.07	1.88
1.24	30.58	0.75	16.07	21.31	23.33	1.90
1.26	31.75	0.77	16.50	21.53	23.57	1.92
1.28	32.94	0.78	16.93	21.73	23.78	1.95
1.30	34.16	0.79	17.36	21.93	23.99	1.97
1.32	35.40	0.80	17.81	22.12	24.20	1.99
1.34	36.66	0.82	18.25	22.33	24.42	2.01
1.36	37.94	0.82	18.70	22.78	24.87	2.03

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.38	39.25	0.82	19.16	23.23	25.32	2.05
1.40	40.58	0.83	19.63	23.68	25.77	2.07
1.42	41.93	0.84	20.11	24.06	26.16	2.09
1.44	43.31	0.85	20.59	24.35	26.46	2.10
1.46	44.71	0.86	21.08	24.64	26.75	2.12
1.48	46.13	0.87	21.58	24.93	27.05	2.14
1.50	47.58	0.88	22.08	25.22	27.35	2.15
1.52	49.05	0.89	22.59	25.51	27.64	2.17
1.54	50.54	0.90	23.10	25.80	27.94	2.19
1.56	52.06	0.91	23.62	26.09	28.24	2.20
1.58	53.60	0.91	24.14	26.52	28.67	2.22
1.60	55.16	0.91	24.68	27.05	29.21	2.23
1.62	56.74	0.91	25.23	27.58	29.74	2.25
1.64	58.35	0.92	25.78	28.11	30.27	2.26
1.66	59.99	0.92	26.35	28.59	30.75	2.28
1.68	61.64	0.93	26.92	28.87	31.04	2.29
1.70	63.32	0.95	27.50	29.04	31.23	2.30
1.72	65.02	0.96	28.09	29.11	31.32	2.32
1.74	66.75	0.98	28.67	29.18	31.40	2.33
1.76	68.50	1.00	29.25	29.25	31.48	2.34
1.78	70.27	1.02	29.84	29.31	31.57	2.36
1.80	72.07	1.04	30.43	29.38	31.65	2.37
1.82	73.89	1.05	31.01	29.45	31.74	2.38
1.84	75.74	1.07	31.60	29.52	31.82	2.40
1.86	77.61	1.09	32.19	29.59	31.91	2.41
1.88	79.50	1.11	32.79	29.65	31.99	2.42
1.90	81.41	1.12	33.38	29.72	32.07	2.44
1.92	83.35	1.14	33.98	29.79	32.16	2.45
1.94	85.32	1.16	34.57	29.86	32.24	2.47
1.96	87.30	1.18	35.17	29.93	32.33	2.48
1.98	89.31	1.19	35.77	29.99	32.41	2.50
2.00	91.35	1.21	36.37	30.06	32.50	2.51
2.02	93.41	1.23	36.97	30.13	32.58	2.53
2.04	95.49	1.24	37.58	30.20	32.66	2.54
2.06	97.59	1.26	38.18	30.27	32.75	2.56
2.08	99.72	1.28	38.79	30.33	32.83	2.57
2.10	101.88	1.30	39.39	30.40	32.92	2.59
2.12	104.05	1.31	40.00	30.47	33.00	2.60
2.14	106.26	1.33	40.61	30.54	33.09	2.62
2.16	108.48	1.34	41.22	30.76	33.32	2.63
2.18	110.73	1.35	41.84	30.99	33.57	2.65
2.20	113.01	1.36	42.46	31.23	33.82	2.66
2.22	115.30	1.66	43.11	25.93	36.55	2.67
2.24	117.62	1.38	43.72	31.69	34.31	2.69
2.26	119.97	1.39	44.35	31.92	34.56	2.70
2.28	122.34	1.40	44.99	32.15	34.81	2.72
2.30	124.73	1.41	45.63	32.27	34.96	2.73
2.32	127.15	1.52	42.70	28.09	31.36	2.98
2.34	129.60	1.52	43.26	28.46	31.76	3.00
2.36	132.06	1.52	43.83	28.83	32.15	3.01
2.38	134.55	1.52	44.41	29.21	32.55	3.03
2.40	137.07	1.52	45.00	29.58	32.95	3.05
2.42	139.61	1.52	45.60	30.01	33.40	3.06
2.44	142.17	1.52	46.20	30.43	33.85	3.08
2.46	144.76	1.52	46.81	30.85	34.29	3.09
2.48	147.37	1.52	47.44	31.27	34.74	3.11
2.50	150.01	1.52	48.06	31.69	35.18	3.12

Table F-11 Tabulated hydraulic data for EWR site 4 on the Geelhoutboom River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.00	0.01	0.01	0.54	0.55	0.02
0.04	0.00	0.02	0.02	0.96	0.96	0.05
0.06	0.00	0.04	0.04	1.19	1.20	0.09
0.08	0.01	0.05	0.07	1.41	1.44	0.14
0.10	0.02	0.06	0.10	1.64	1.68	0.20
0.12	0.03	0.07	0.13	1.93	1.99	0.26
0.14	0.06	0.08	0.18	2.24	2.31	0.32
0.16	0.09	0.09	0.22	2.46	2.55	0.39
0.18	0.13	0.10	0.27	2.68	2.79	0.47
0.20	0.18	0.11	0.33	2.90	3.02	0.54
0.22	0.23	0.13	0.39	3.07	3.20	0.59
0.24	0.29	0.14	0.45	3.18	3.33	0.63
0.26	0.35	0.16	0.52	3.29	3.46	0.67
0.28	0.41	0.17	0.58	3.40	3.58	0.70
0.30	0.48	0.19	0.65	3.46	3.67	0.73
0.32	0.55	0.21	0.72	3.48	3.71	0.76
0.34	0.63	0.23	0.79	3.50	3.76	0.79
0.36	0.71	0.24	0.86	3.54	3.81	0.82
0.38	0.80	0.26	0.93	3.57	3.87	0.85
0.40	0.88	0.28	1.01	3.61	3.93	0.88
0.42	0.98	0.30	1.08	3.65	3.98	0.91
0.44	1.07	0.31	1.15	3.69	4.04	0.93
0.46	1.17	0.33	1.23	3.73	4.10	0.96
0.48	1.28	0.35	1.30	3.76	4.15	0.98
0.50	1.38	0.36	1.38	3.80	4.21	1.00
0.52	1.49	0.38	1.45	3.84	4.27	1.03
0.54	1.61	0.39	1.53	3.88	4.32	1.05
0.56	1.72	0.41	1.61	3.91	4.38	1.07
0.58	1.84	0.43	1.69	3.95	4.43	1.09
0.60	1.97	0.44	1.77	3.98	4.48	1.11
0.62	2.09	0.46	1.85	4.01	4.53	1.13
0.64	2.22	0.48	1.93	4.05	4.59	1.15
0.66	2.35	0.49	2.01	4.08	4.64	1.17
0.68	2.49	0.51	2.09	4.11	4.69	1.19
0.70	2.63	0.52	2.17	4.15	4.75	1.21
0.72	2.77	0.54	2.26	4.18	4.80	1.23
0.74	2.91	0.56	2.34	4.21	4.85	1.25
0.76	3.06	0.57	2.42	4.25	4.90	1.26
0.78	3.21	0.59	2.51	4.28	4.96	1.28
0.80	3.37	0.60	2.59	4.31	5.01	1.30
0.82	3.52	0.62	2.68	4.34	5.06	1.31
0.84	3.68	0.63	2.77	4.38	5.12	1.33
0.86	3.84	0.65	2.86	4.41	5.17	1.35
0.88	4.01	0.66	2.95	4.44	5.22	1.36
0.90	4.17	0.68	3.03	4.48	5.27	1.38
0.92	4.34	0.69	3.12	4.51	5.33	1.39
0.94	4.52	0.71	3.21	4.55	5.39	1.41
0.96	4.69	0.72	3.31	4.61	5.46	1.42
0.98	4.87	0.73	3.40	4.66	5.52	1.43
1.00	5.05	0.74	3.49	4.71	5.59	1.45
1.02	5.24	0.75	3.59	4.77	5.67	1.46
1.04	5.42	0.76	3.68	4.83	5.74	1.47
1.06	5.61	0.77	3.78	4.89	5.81	1.48
1.08	5.80	0.78	3.88	4.95	5.88	1.50
1.10	5.99	0.79	3.98	5.01	5.96	1.51
1.12	6.19	0.81	4.08	5.07	6.03	1.52
1.14	6.39	0.82	4.18	5.13	6.10	1.53
1.16	6.59	0.83	4.28	5.19	6.17	1.54
1.18	6.79	0.84	4.39	5.25	6.25	1.55
1.20	7.00	0.84	4.49	5.32	6.34	1.56
1.22	7.21	0.85	4.60	5.40	6.42	1.57
1.24	7.42	0.86	4.71	5.47	6.51	1.58
1.26	7.63	0.87	4.82	5.55	6.60	1.58
1.28	7.85	0.88	4.93	5.62	6.68	1.59
1.30	8.07	0.89	5.05	5.69	6.77	1.60
1.32	8.29	0.89	5.16	5.77	6.85	1.61
1.34	8.51	0.90	5.28	5.84	6.94	1.61

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.36	8.74	0.91	5.39	5.92	7.03	1.62
1.38	8.97	0.92	5.51	5.99	7.11	1.63
1.40	9.20	0.93	5.63	6.06	7.20	1.63
1.42	9.43	0.94	5.76	6.14	7.28	1.64
1.44	9.66	0.95	5.88	6.21	7.37	1.64
1.46	9.90	0.95	6.00	6.29	7.46	1.65
1.48	10.14	0.96	6.13	6.36	7.54	1.65
1.50	10.38	0.97	6.26	6.44	7.63	1.66
1.52	10.63	0.98	6.39	6.51	7.72	1.66
1.54	10.87	0.98	6.52	6.63	7.84	1.67
1.56	11.12	0.98	6.65	6.77	7.99	1.67
1.58	11.37	0.98	6.79	6.90	8.13	1.67
1.60	11.62	0.98	6.93	7.04	8.27	1.68
1.62	11.88	0.98	7.07	7.18	8.42	1.68
1.64	12.14	0.99	7.22	7.32	8.56	1.68
1.66	12.40	0.99	7.36	7.46	8.70	1.68
1.68	12.66	0.99	7.51	7.59	8.85	1.68
1.70	12.92	0.99	7.67	7.72	8.98	1.69
1.72	13.19	1.00	7.82	7.85	9.12	1.69
1.74	13.46	1.00	7.98	7.98	9.25	1.69
1.76	13.73	1.00	8.14	8.11	9.39	1.69
1.78	14.00	1.02	8.30	8.15	9.44	1.69
1.80	14.27	1.03	8.45	8.20	9.50	1.69
1.82	14.55	1.04	8.60	8.24	9.55	1.69
1.84	14.83	1.06	8.76	8.29	9.61	1.69
1.86	15.11	1.07	8.92	8.33	9.66	1.69
1.88	15.39	1.08	9.07	8.38	9.72	1.70
1.90	15.68	1.10	9.23	8.42	9.77	1.70
1.92	15.97	1.11	9.39	8.47	9.83	1.70
1.94	16.26	1.12	9.55	8.51	9.89	1.70
1.96	16.55	1.13	9.71	8.56	9.95	1.70
1.98	16.84	1.15	9.87	8.60	10.00	1.71
2.00	17.14	1.16	10.04	8.65	10.06	1.71
2.02	17.43	1.17	10.20	8.69	10.12	1.71
2.04	17.73	1.19	10.37	8.74	10.18	1.71
2.06	18.04	1.20	10.53	8.78	10.24	1.71
2.08	18.34	1.21	10.70	8.83	10.30	1.71
2.10	18.65	1.22	10.87	8.87	10.36	1.72
2.12	18.95	1.24	11.03	8.90	10.40	1.72
2.14	19.26	1.25	11.20	8.93	10.45	1.72
2.16	19.58	1.27	11.37	8.96	10.50	1.72
2.18	19.89	1.28	11.54	8.99	10.54	1.72
2.20	20.21	1.30	11.71	9.03	10.59	1.73
2.22	20.52	1.31	11.88	9.06	10.64	1.73
2.24	20.84	1.33	12.06	9.09	10.69	1.73
2.26	21.17	1.34	12.23	9.12	10.74	1.73
2.28	21.49	1.36	12.40	9.15	10.78	1.73
2.30	21.82	1.37	12.57	9.18	10.83	1.73
2.32	22.14	1.38	12.75	9.21	10.88	1.74
2.34	22.47	1.40	12.92	9.24	10.93	1.74
2.36	22.80	1.41	13.10	9.27	10.98	1.74
2.38	23.14	1.43	13.28	9.30	11.03	1.74
2.40	23.47	1.44	13.45	9.33	11.08	1.75
2.42	23.81	1.46	13.63	9.36	11.13	1.75
2.44	24.15	1.47	13.81	9.39	11.18	1.75
2.46	24.49	1.48	13.99	9.42	11.23	1.75
2.48	24.84	1.50	14.16	9.45	11.28	1.75
2.50	25.18	1.51	14.34	9.48	11.33	1.76

Table F-12 Tabulated hydraulic data for EWR site 5 on the Seekoei River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.000	0.00	0.00	0.00	0.00	0.00
0.02	0.000	0.01	0.00	0.18	0.21	0.00
0.04	0.000	0.02	0.01	0.35	0.41	0.00
0.06	0.000	0.04	0.01	0.41	0.51	0.00
0.08	0.000	0.05	0.02	0.47	0.62	0.00
0.10	0.000	0.06	0.03	0.57	0.79	0.00
0.12	0.000	0.07	0.05	0.70	1.00	0.00
0.14	0.001	0.06	0.06	1.01	1.42	0.01
0.16	0.002	0.07	0.09	1.30	1.81	0.02
0.18	0.006	0.06	0.12	1.92	2.55	0.05
0.20	0.017	0.07	0.16	2.49	3.22	0.11
0.22	0.045	0.06	0.23	3.67	4.47	0.20
0.24	0.093	0.08	0.30	4.06	4.93	0.31
0.26	0.156	0.08	0.39	4.75	5.66	0.40
0.28	0.23	0.10	0.49	5.08	6.01	0.48
0.30	0.32	0.11	0.59	5.33	6.26	0.54
0.32	0.43	0.13	0.70	5.54	6.48	0.61
0.34	0.54	0.14	0.82	5.71	6.65	0.67
0.36	0.67	0.16	0.93	5.88	6.83	0.72
0.38	0.81	0.17	1.05	6.04	6.99	0.78
0.40	0.97	0.19	1.17	6.17	7.13	0.83
0.42	1.13	0.21	1.30	6.29	7.25	0.87
0.44	1.31	0.22	1.42	6.37	7.35	0.92
0.46	1.50	0.24	1.55	6.46	7.45	0.97
0.48	1.70	0.26	1.68	6.55	7.55	1.01
0.50	1.91	0.27	1.81	6.64	7.64	1.05
0.52	2.13	0.29	1.95	6.72	7.73	1.09
0.54	2.36	0.31	2.08	6.78	7.81	1.13
0.56	2.61	0.33	2.22	6.83	7.88	1.17
0.58	2.86	0.34	2.36	6.89	7.95	1.21
0.60	3.12	0.36	2.50	6.95	8.03	1.25
0.62	3.40	0.38	2.64	7.01	8.10	1.29
0.64	3.68	0.39	2.78	7.07	8.18	1.33
0.66	3.98	0.41	2.92	7.15	8.27	1.36
0.68	4.29	0.42	3.06	7.24	8.37	1.40
0.70	4.60	0.44	3.21	7.32	8.48	1.44
0.72	4.93	0.45	3.35	7.41	8.58	1.47
0.74	5.27	0.47	3.50	7.49	8.68	1.50
0.76	5.61	0.48	3.65	7.58	8.78	1.54
0.78	5.97	0.50	3.81	7.67	8.88	1.57
0.80	6.33	0.51	3.96	7.75	8.98	1.60
0.82	6.71	0.53	4.12	7.84	9.08	1.63
0.84	7.09	0.54	4.28	7.97	9.22	1.66
0.86	7.49	0.55	4.44	8.09	9.36	1.69
0.88	7.89	0.56	4.60	8.22	9.50	1.72
0.90	8.31	0.57	4.76	8.35	9.64	1.74
0.92	8.73	0.58	4.93	8.48	9.78	1.77
0.94	9.17	0.59	5.10	8.63	9.95	1.80
0.96	9.61	0.58	5.28	9.04	10.37	1.82
0.98	10.06	0.58	5.47	9.45	10.80	1.84
1.00	10.52	0.59	5.66	9.66	11.02	1.86
1.02	10.99	0.60	5.85	9.81	11.18	1.88
1.04	11.47	0.61	6.05	9.96	11.34	1.90
1.06	11.96	0.62	6.25	10.11	11.50	1.91
1.08	12.46	0.63	6.45	10.25	11.67	1.93
1.10	12.97	0.64	6.66	10.40	11.83	1.95
1.12	13.48	0.64	6.87	10.67	12.10	1.96
1.14	14.01	0.65	7.09	10.94	12.37	1.98
1.16	14.54	0.65	7.31	11.21	12.65	1.99
1.18	15.09	0.66	7.54	11.49	12.92	2.00
1.20	15.64	0.59	7.78	13.12	14.56	2.01
1.22	16.20	0.58	8.05	13.84	15.29	2.01
1.24	16.77	0.58	8.33	14.37	15.82	2.01
1.26	17.35	0.58	8.63	14.90	16.35	2.01
1.28	17.94	0.58	8.93	15.43	16.88	2.01
1.30	18.54	0.58	9.24	15.96	17.41	2.01

Table F-13 Tabulated hydraulic data for EWR site 6 on the Swart River

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.000	0.000	0.00	0.00	0.00	0.00
0.02	0.000	0.010	0.00	0.11	0.13	0.00
0.04	0.000	0.019	0.00	0.24	0.27	0.00
0.06	0.000	0.027	0.01	0.41	0.47	0.01
0.08	0.000	0.029	0.02	0.75	0.87	0.02
0.10	0.001	0.037	0.04	1.09	1.25	0.03
0.12	0.003	0.045	0.06	1.44	1.63	0.05
0.14	0.007	0.060	0.09	1.56	1.76	0.07
0.16	0.016	0.074	0.13	1.72	1.92	0.13
0.18	0.031	0.087	0.16	1.89	2.09	0.19
0.20	0.051	0.099	0.20	2.05	2.26	0.25
0.22	0.077	0.112	0.25	2.18	2.40	0.32
0.24	0.11	0.13	0.29	2.31	2.54	0.38
0.26	0.15	0.14	0.34	2.44	2.67	0.44
0.28	0.19	0.15	0.39	2.56	2.81	0.50
0.30	0.25	0.16	0.44	2.70	2.95	0.56
0.32	0.31	0.17	0.50	2.85	3.11	0.62
0.34	0.37	0.19	0.55	2.99	3.26	0.68
0.36	0.45	0.20	0.62	3.11	3.38	0.73
0.38	0.53	0.21	0.68	3.18	3.47	0.78
0.40	0.62	0.23	0.74	3.26	3.55	0.84
0.42	0.72	0.24	0.81	3.34	3.64	0.89
0.44	0.83	0.26	0.88	3.42	3.73	0.94
0.46	0.94	0.27	0.95	3.49	3.82	0.99
0.48	1.06	0.28	1.02	3.57	3.90	1.05
0.50	1.19	0.30	1.09	3.65	3.99	1.10
0.52	1.33	0.31	1.16	3.75	4.10	1.15
0.54	1.48	0.32	1.24	3.86	4.21	1.20
0.56	1.64	0.33	1.32	3.96	4.33	1.25
0.58	1.81	0.34	1.40	4.07	4.44	1.29
0.60	1.98	0.35	1.48	4.18	4.56	1.34
0.62	2.17	0.37	1.56	4.28	4.67	1.39
0.64	2.36	0.38	1.65	4.41	4.80	1.43
0.66	2.56	0.38	1.74	4.56	4.96	1.47
0.68	2.78	0.39	1.83	4.73	5.13	1.52
0.70	3.00	0.40	1.93	4.89	5.30	1.56
0.72	3.23	0.40	2.03	5.05	5.46	1.59
0.74	3.47	0.41	2.13	5.21	5.63	1.63
0.76	3.73	0.42	2.24	5.37	5.80	1.67
0.78	3.99	0.42	2.35	5.53	5.96	1.70
0.80	4.26	0.43	2.46	5.77	6.20	1.73
0.82	4.54	0.43	2.58	6.03	6.47	1.76
0.84	4.83	0.43	2.70	6.30	6.73	1.79
0.86	5.13	0.38	2.84	7.54	7.98	1.81
0.88	5.45	0.39	2.99	7.77	8.22	1.82
0.90	5.77	0.39	3.15	8.01	8.46	1.83
0.92	6.10	0.40	3.31	8.24	8.70	1.84
0.94	6.45	0.41	3.48	8.47	8.93	1.85
0.96	6.80	0.42	3.65	8.70	9.17	1.86
0.98	7.16	0.43	3.83	8.93	9.40	1.87
1.00	7.54	0.44	4.01	9.16	9.64	1.88
1.02	7.93	0.45	4.19	9.39	9.87	1.89
1.04	8.32	0.46	4.38	9.60	10.08	1.90
1.06	8.73	0.47	4.58	9.78	10.27	1.91
1.08	9.15	0.48	4.77	9.97	10.46	1.92
1.10	9.58	0.49	4.97	10.15	10.65	1.93
1.12	10.02	0.50	5.18	10.34	10.84	1.94
1.14	10.47	0.51	5.39	10.52	11.03	1.94
1.16	10.94	0.52	5.60	10.71	11.22	1.95
1.18	11.41	0.53	5.82	10.89	11.41	1.96
1.20	11.90	0.55	6.04	11.06	11.58	1.97
1.22	12.39	0.54	6.26	11.55	12.08	1.98
1.24	12.90	0.53	6.50	12.37	12.91	1.99
1.26	13.42	0.51	6.75	13.19	13.74	1.99
1.28	13.95	0.47	7.03	14.86	15.42	1.99
1.30	14.50	0.43	7.35	17.22	17.79	1.97
1.32	15.05	0.41	7.72	18.91	19.48	1.95
1.34	15.62	0.41	8.10	19.69	20.28	1.93

Flow depth (m)	Discharge (m ³ /s)	Av. flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.36	16.20	0.42	8.50	20.13	20.72	1.90
1.38	16.79	0.44	8.91	20.31	20.91	1.88
1.40	17.39	0.45	9.32	20.63	21.23	1.87
1.42	18.00	0.45	9.74	21.67	22.28	1.85
1.44	18.63	0.45	10.18	22.72	23.34	1.83
1.46	19.27	0.45	10.65	23.51	24.13	1.81
1.48	19.92	0.46	11.12	24.24	24.88	1.79
1.50	20.58	0.43	11.63	27.07	27.71	1.77
1.52	21.26	0.39	12.21	31.18	31.82	1.74
1.54	21.94	0.36	12.88	35.79	36.44	1.70
1.56	22.64	0.36	13.63	38.08	38.73	1.66
1.58	23.35	0.37	14.40	38.90	39.55	1.62
1.60	24.08	0.38	15.19	39.71	40.37	1.59
1.62	24.81	0.39	15.99	40.49	41.16	1.55
1.64	25.56	0.41	16.80	41.06	41.73	1.52
1.66	26.32	0.42	17.63	41.62	42.30	1.49
1.68	27.09	0.44	18.47	42.19	42.87	1.47
1.70	27.88	0.45	19.32	42.56	43.25	1.44
1.72	28.68	0.47	20.17	42.83	43.52	1.42
1.74	29.49	0.49	21.03	43.10	43.80	1.40
1.76	30.31	0.50	21.89	43.36	44.06	1.38
1.78	31.15	0.52	22.76	43.57	44.28	1.37
1.80	32.00	0.54	23.64	43.78	44.50	1.35
1.82	32.86	0.56	24.51	43.94	44.66	1.34
1.84	33.73	0.58	25.39	44.08	44.80	1.33
1.86	34.62	0.59	26.28	44.22	44.95	1.32
1.88	35.52	0.61	27.16	44.36	45.10	1.31
1.90	36.44	0.63	28.05	44.50	45.24	1.30
1.92	37.36	0.65	28.94	44.63	45.39	1.29
1.94	38.30	0.67	29.84	44.77	45.54	1.28
1.96	39.25	0.68	30.73	44.91	45.68	1.28
1.98	40.22	0.70	31.63	45.05	45.83	1.27
2.00	41.20	0.72	32.54	45.19	45.98	1.27
2.02	42.19	0.74	33.44	45.33	46.12	1.26
2.04	43.20	0.76	34.35	45.47	46.27	1.26
2.06	44.22	0.77	35.26	45.61	46.42	1.25
2.08	45.25	0.79	36.17	45.75	46.56	1.25
2.10	46.29	0.81	37.09	45.86	46.69	1.25
2.12	47.35	0.83	38.01	45.97	46.82	1.25
2.14	48.42	0.84	38.93	46.08	46.95	1.24
2.16	49.51	0.86	39.85	46.22	47.10	1.24
2.18	50.61	0.88	40.78	46.36	47.26	1.24
2.20	51.72	0.90	41.71	46.50	47.41	1.24
2.22	52.85	0.91	42.64	46.64	47.57	1.24
2.24	53.99	0.93	43.57	46.77	47.72	1.24
2.26	55.14	0.95	44.51	46.91	47.88	1.24
2.28	56.31	0.97	45.45	47.05	48.03	1.24
2.30	57.49	0.98	46.39	47.19	48.19	1.24
2.32	58.68	1.00	47.34	47.33	48.34	1.24
2.34	59.89	1.02	48.28	47.47	48.50	1.24
2.36	61.12	1.03	49.23	47.61	48.66	1.24
2.38	62.35	1.05	50.19	47.75	48.81	1.24
2.40	63.60	1.07	51.14	47.89	48.97	1.24
2.42	64.87	1.08	52.10	48.03	49.12	1.24
2.44	66.14	1.10	53.07	48.17	49.28	1.25
2.46	67.44	1.12	54.03	48.30	49.43	1.25
2.48	68.74	1.14	55.00	48.44	49.59	1.25
2.50	70.06	1.15	55.97	48.58	49.74	1.25

2.4 Habitat type abundance assessments and velocity distribution information

A method for using standard hydraulic information as the basis for quantifying habitat types for fish is described in the methodology (Section 3.3), and the results are provided in tables F-14 to F-18. The shaded rows denote ratings corresponding to measured flows. Velocity distribution information using the distribution model of Lamouroux et al., (1995) is provided in Tables F-19 to F-23.

Table F-14 Ratings of habitat type abundance for EWR site 1 on the Kromme River

Discharge (m ³ /s)	Ecologist assessment (on-site)				Hydraulic rating (calculated)				Final rating			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
0.01					5	5	0	0	3	3	0	0
0.028					5	4	0	0	5	4	1	0
0.13					5	4	0	0	5	4	2	0
0.5					5	5	2	2	4-5	5	3	2
1.0					4	5	2	3	4	5	5	3
1.5					3	5	2	3	3	5	5	4

Table F-15 Ratings of habitat type abundance for EWR site 2 on the Kromme River

Discharge (m ³ /s)	Ecologist assessment (on-site)				Hydraulic rating (calculated)				Final rating			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
0.01					5	4	1	0	5	4	1	0
0.042	5	2	3	0	5	4	1	0	5	4	1	0
0.054	4	4	2	0	5	4	1	0	5	4	1	0
0.2					4	5	3	0	4	5	3	0
0.5					4	5	3	1	4	5	3	1
1.0					4	5	4	2	3	5	4	2

Table F-16 Ratings of habitat type abundance for EWR site 4 on the Geelhoutboom River

Discharge (m ³ /s)	Ecologist assessment (on-site)				Hydraulic rating (calculated)				Final rating			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
0.000086	1	1	0	0	1		0	0	1	2	0	0
0.01					2		1	0	2	3	1	1
0.05					2		3	0	2	3	2	1
0.10					2		4	0	3	4	3	2
0.15					2		5	0	3	4	4	2

Table F-17 Ratings of habitat type abundance for EWR site 5 on the Seekoei River

Discharge (m ³ /s)	Ecologist assessment (on-site)				Hydraulic rating (calculated)				Final rating			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
0.001					2		1	0	2	1	1	0
0.016	4	1	2	0	4		2	0	4	1	2	0
0.05					5		2	0	5	2	2	0
0.10					4		3	0	5	2	3	0

Table F-18 Ratings of habitat type abundance for EWR site 6 on the Swart River

Discharge (m ³ /s)	Ecologist assessment (on-site)				Hydraulic rating (calculated)				Final rating			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
0.001					5		1	0	4	2	0	0
0.0055	5	3	2	0	5		1	0	5	3	1	0
0.05					4		3	0	4	4	2	0
0.10					3		4	0	4	4	3	0
0.20					2		5	0	3	4	4	1

Table F-19 Velocity distributions for EWR site 1A (Riffle)

Discharge (m ³ /s)	Average velocity (m/s)	Lamouroux et al. (1995)			
		Max. velocity (m/s)	Frequency (%) of velocity (m/s)		
			≤0.1	≤0.3	≤0.6
0.01	0.05	0.15	75	100	100
0.028	0.07	0.15	75	100	100
0.13	0.10	0.25	59	100	100
0.5	0.18	0.55	41	84	100
1.0	0.31	0.8	31	64	94
1.5	0.31	0.9	27	56	91

Table F-20 Velocity distributions for EWR site 2B (Rapid)

Discharge (m ³ /s)	Average velocity (m/s)	Lamouroux et al. (1995)			
		Max. velocity (m/s)	Frequency (%) of velocity (m/s)		
			≤0.1	≤0.3	≤0.6
0.01	0.04		100	100	100
0.04	0.08	0.25	57	100	100
0.05	0.11	0.35	61	100	100
0.2	0.25		39	70	96
0.5	0.39		26	49	80
1.0	0.62		14	30	53
2.0	0.79		9	20	39

Table F-21 Velocity distributions for EWR site 4 (Run)

Discharge (m ³ /s)	Average velocity (m/s)	Lamouroux et al. (1995)			
		Max. velocity (m/s)	Frequency (%) of velocity (m/s)		
			≤0.1	≤0.3	≤0.6
0.000086	0.02	0.05	100	100	100
0.01	0.14	0.4	34	96	100
0.05	0.30	0.8	10	48	95
0.10	0.47	1.2	2	21	65
0.15	0.54	1.3	1	15	53

Table F-22 Velocity distributions for EWR site 5 (Riffle)

Discharge (m ³ /s)	Average velocity (m/s)	Lamouroux et al. (1995)			
		Max. velocity (m/s)	Frequency (%) of velocity (m/s)		
			≤0.1	≤0.3	≤0.6
0.001	0.008		100	100	100
0.016	0.11	0.33	77	97	100
0.050	0.20	0.6	65	81	100
0.100	0.31	0.9	42	65	89

Table F-23 Velocity distributions for EWR site 6 (Riffle)

Discharge (m ³ /s)	Average velocity (m/s)	Lamouroux et al. (1995)			
		Max. velocity (m/s)	Frequency (%) of velocity (m/s)		
			≤0.1	≤0.3	≤0.6
0.001	0.031	0.1	100	100	100
0.0055	0.07	0.2	75	100	100
0.05	0.25	0.75	28	66	97
0.10	0.38	1.1	15	40	82
0.20	0.50	1.4	9	27	63

2.5 Confidence in the hydraulic characterisations

The confidence in the characterisations of the hydraulic relationships is provided in Table F-24.

Table F-24 Confidence in the hydraulic characterisations

Site no.	Site character	Available data	Reference to PES or recommended EC	
			Low flows	High flows
1	3	2	4	2
Measured flows of 0.028 and 0.13 m ³ /s. No measured medium and high flow data. Recommended low-flows are in the range 0.001 to 0.22 m ³ /s and high flows in the range 2-18 (within year) to 50 m ³ /s.				
2	3.5	3	4	3
Measured flows of 0.042 and 0.054 m ³ /s. No measured medium and high flow data. Recommended low-flows are in the range 0.001 to 0.082 m ³ /s and high flows in the range 3-23 (within year) to 60 m ³ /s.				
4	5	1	2	3
Measured flow of 0.000086 m ³ /s (86 ml/s). No measured low to medium and high flow data.. Recommended low-flows are in the range 0 to 0.01 m ³ /s and high flows in the range 0.3-1.4 m ³ /s (within year).				
5	4	1	3	2
Measured flow of 0.016 m ³ /s. Low-flow drought and maintenance flows in range of 0 to 0.01 m ³ /s. No measured medium and high flow data. Recommended low-flows are in the range 0 to 0.008 m ³ /s and high flows in the range 0.3-1.9 m ³ /s (within year).				
6	3	1	3	1
Measured flow of 0.0055 m ³ /s. No measured medium and high flow data. Recommended low-flows are in the range 0.001 to 0.22 m ³ /s and high flows in the range 0.3-1.3 (within year) to 27 m ³ /s.				

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

PES: Present Ecological State

EC: Ecological Category

APPENDIX G

SOCIO-CULTURAL IMPORTANCE OF THE KROMME AND SEEKOEI RIVERS

Mr G. Huggins, IWR Catchment Consultants

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1 OVERVIEW

Specific methods to determine the social importance have not yet been determined. However the basic assumption followed in this case is to assess the river with regard to the dependence of people on its healthy functioning. Also included is a consideration of the cultural and tourism potential. Specifically the methodology employed for the study incorporated:

- A desktop analysis of existing literature (Obtained from: Stats SA: Census Data 2001 Ward Profiles for the Kouga, Kou Kamma and Humansdorp Municipalities).
- An overview of the catchment from existing data sources.

The Kromme and Seekoei rivers flow through the largely rural areas of the Kouga and Kou Kamma municipalities. The major urban settlements within the catchments are Humansdorp, Jeffrey's Bay and allied coastal settlement as well as Kareedouw. More specifically, the upper parts of the Kromme River flows through Ward 2 of the Kou Kamma Municipality (including Kareedouw), while the lower parts flow through Ward 1 of the Kouga Municipality. The Seekoei River is located mostly within Ward 1 of the Kouga Municipality, although Humansdorp (Ward 8 of the Kouga Municipality) is also within the catchment. Total population figures drawn from the 2001 National Census, and as provided by Statistics SA, are provided in Figures G-1 to G-3. Figures in the purple columns represent the situation as it was in the 1996 Census, while the figures in the white columns represent the situation as it was for the 2001 Census.

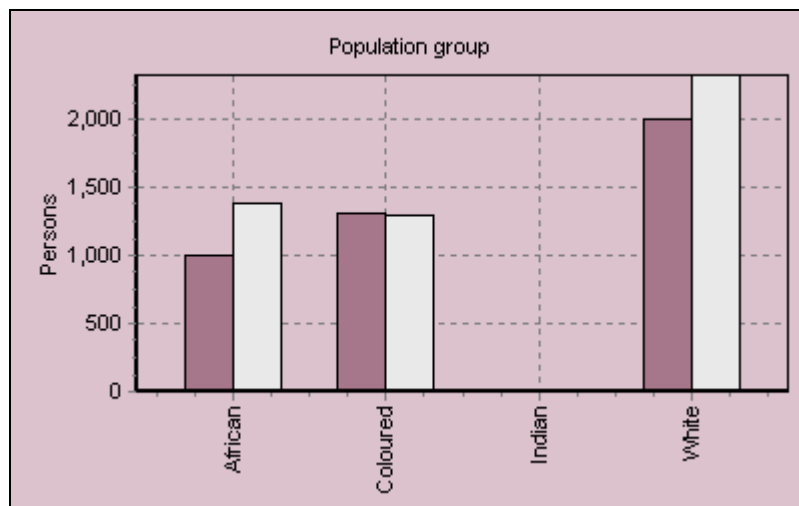


Figure G-1 Population of Ward 1 of the Kouga Municipality (Lower Kromme and Seekoei)

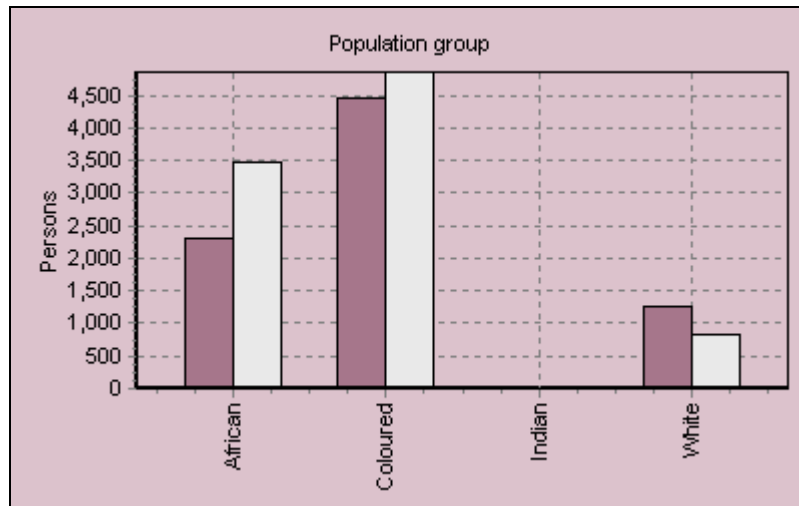


Figure G-2 Population of Ward 2 of the Kou Kamma Municipality (Upper Kromme)

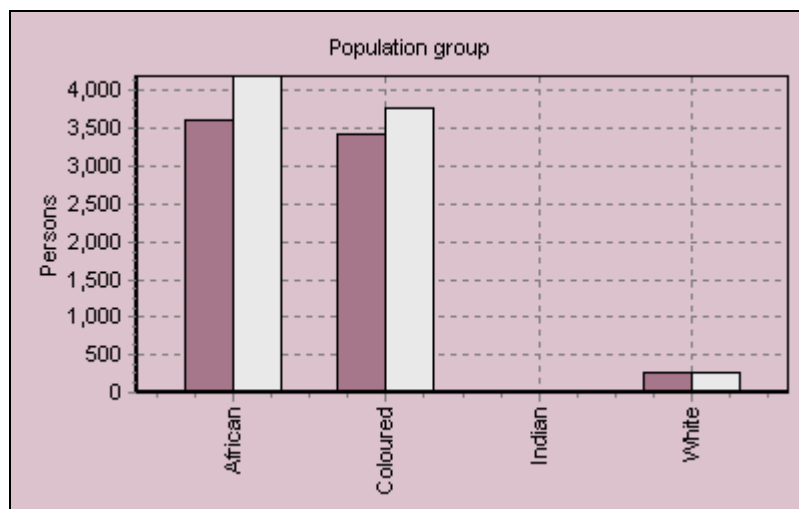


Figure G-3 Population of Humansdorp

The figures above indicate that there is a population mix typical of many of the rural areas of South Africa. For the most part people in Ward 2 of the Kou Kamma Municipality are engaged in agriculture and associated activities, while the larger “white” population indicated in Ward 1 of the Kouga Municipality are resident in the towns of St Francis Bay and other coastal nodes. Humansdorp has a population typical of a second order service town. Of importance to this study are Figures G-1 to G-6 that illustrate the sources of water supply for the people of the catchments.

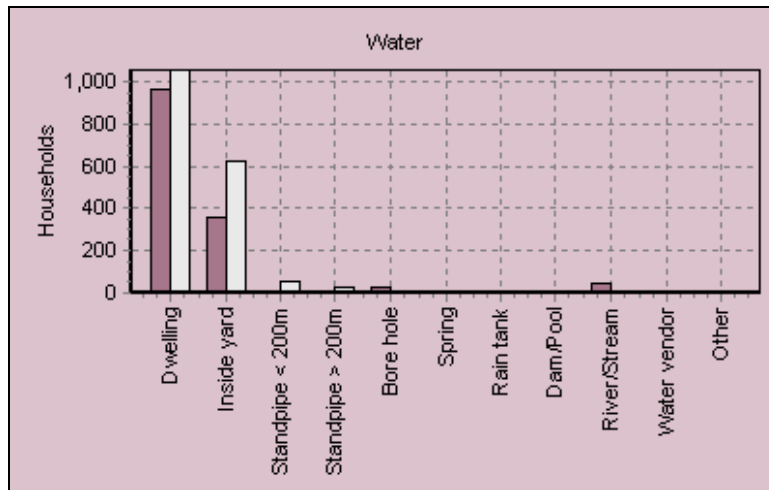


Figure G-4 Water supply for the households of Ward 1 of the Kouga Municipality (Lower Kromme and Seekoei)

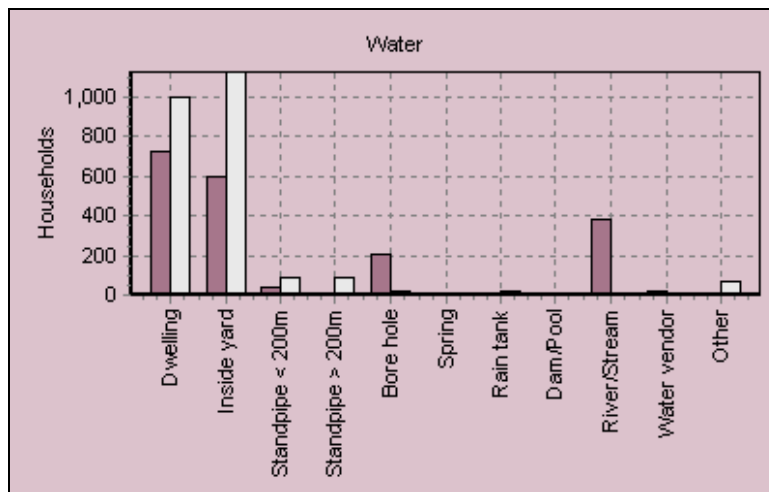


Figure G-5 Water supply for the households of Ward 2 of the Kou Kamma Municipality (Upper Kromme)

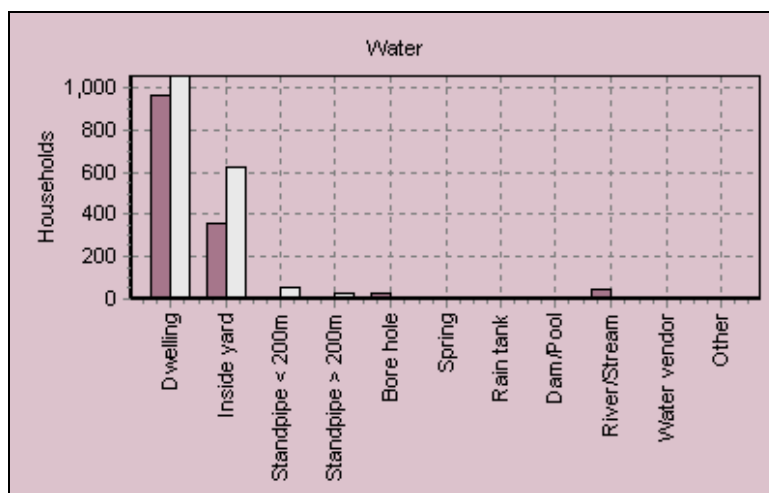


Figure G-6 Water supply for the households of Humansdorp

Figures G-4 to G-6 indicate that the water supply situation in terms of delivery of potable water to households has improved over the past few years. While the 1996 situation indicated that there were some households' dependant on the river for their water, by 2001

this situation had been eradicated and the vast majority of the population has access to water either in their dwelling or in their yard. Unlike many other areas of South Africa where rural areas are characterized by high levels of dependence on riverine systems for provision of goods and services, this does not appear to be the case in the Kromme and Seekoei catchments. The only exceptions to this appear to be the dependence of many of the households on the irrigated agricultural sector (excluded from consideration of socio-cultural importance) and the role that the estuaries play in providing a recreational resource.

2 ASSESSMENT

Unit	Importance	Reason	Confidence in assessment
Resource Unit A: Segment 4 - 11 (Kromme River above Churchill Dam): Land use is almost exclusively agricultural with the small town of Kareedouw also dependent on this sector for its existence.	Low	Formal Rural Settlements with limited dependence on the river with exception of direct economic exploitation.	Medium
Resource Unit B: Segment 14 - 15 (Between Churchill and Impofu dams): Land use is almost exclusively agricultural.	Low	Formal Rural Settlements with limited dependence on the river with exception of direct economic exploitation.	Medium
Resource Unit C: Segment 18 (Below Impofu Dam): Mostly dry land commercial farming. Some irrigation.	Low	Formal Rural Settlements with limited dependence on the river with exception of direct economic exploitation.	Medium
Resource Unit D: Estuary (Kromme River): Town of St Francis Bay and relatively large population who use the estuary for recreation.	High	Recreational use of the estuary is an important feature.	Medium
Resource Unit E: Segment 1 to 4 (at estuary) (Geelhoutboom River)	Moderate	Some estuarine utilisation for recreation purposes.	Medium
Resource Unit F: Segment 1 to 3 of the Seekoei River: Town of Humansdorp and irrigated agricultural lands.	Low	River is of importance to irrigated agriculture and to the town of Humansdorp but direct dependence as defined for the purposes of socio-cultural importance is limited.	Medium
Resource Unit G: Estuary (Seekoei River): Town of Paradys Strand.	High	Recreational use of the estuary is an important feature.	Medium
Resource Unit H: Segment 1 to 3 (Swart River)	Low	Formal Rural Settlements with limited dependence on the river.	Medium

APPENDIX H

ECOLOGICAL IMPORTANCE AND SENSITIVITY

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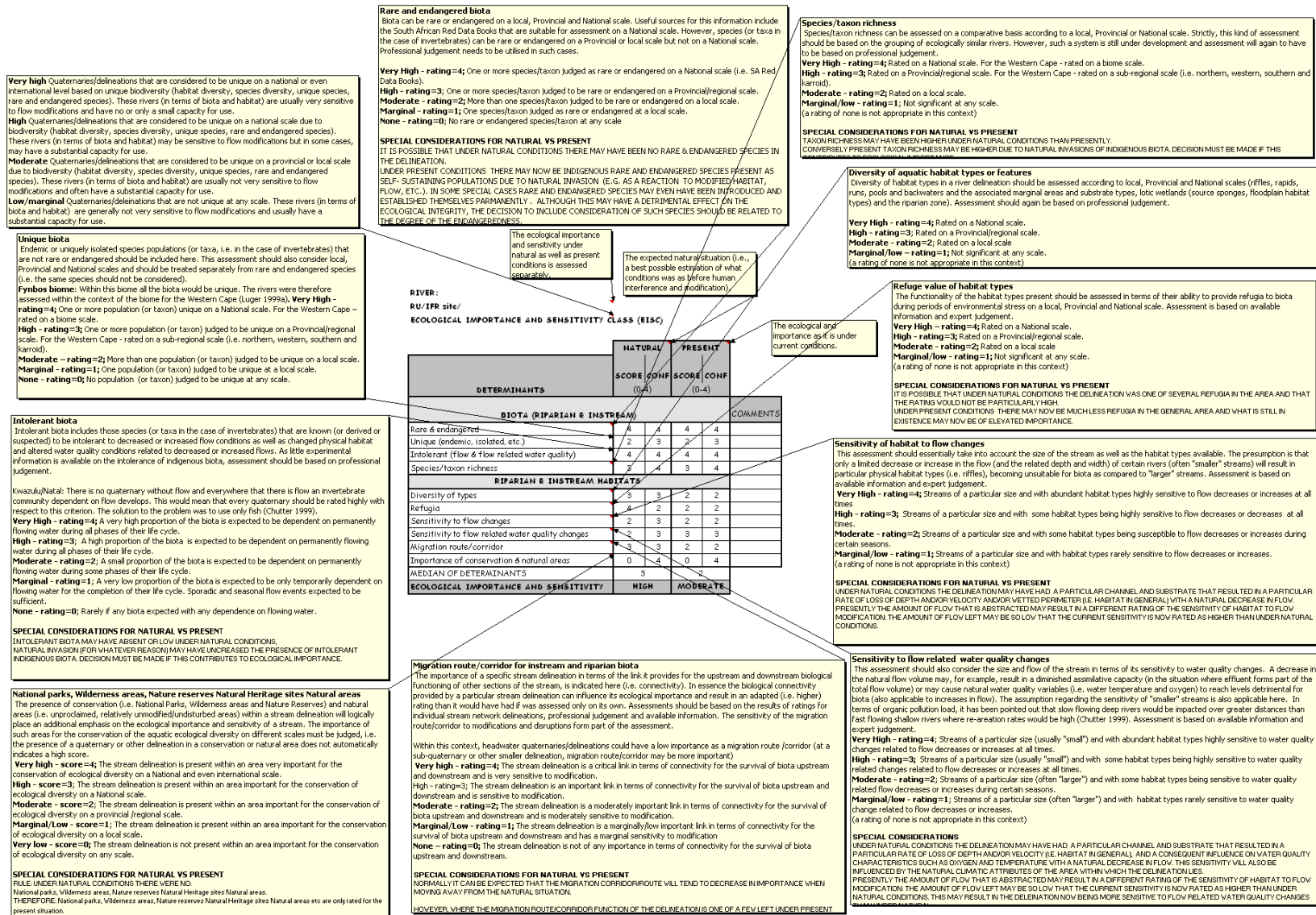


Figure H-1 EIS rule-based model and explanation

1 EWR 1: UPPER KROMME RIVER

DETERMINANTS	NATURAL		PRESENT		
	SCORE	CONF	SCORE	CONF	
	(0-4)		(0-4)		
BIOTA (RIPARIAN & INSTREAM)					COMMENTS
Rare & endangered (range: 4=very high - 0= none)	2	2	1	2	Presence of <i>Pseudobarbus afer</i> and Teloganodidae.
Unique (endemic, isolated, etc.) (range: 4=very high - 0= none)	1	1	0	3	Notonemouridae
Intolerant (flow & flow related water quality) (range: 4=very high - 0= none)	2	3	2	3	5 species (4 present) dependant on flow the whole year.
Species/taxon richness (range: 4=very high - 1=low/marginal)	3	3	2	2	Invertebrates
RIPARIAN & INSTREAM HABITATS					
Diversity of types (4=Very high - 1=marginal/low)	3	2	2	3	Pools, riffles, undercut banks, instream vegetation, backwaters.
Refugia (4=Very high - 1=marginal/low)	3	2	2	2	Loss of secondary channels under present conditions and marginal vegetation.
Sensitivity to flow changes (4=Very high - 1=marginal/low)	2	2	2	2	
Sensitivity to flow related water quality changes (4=Very high - 1=marginal/low)	2	2	2	2	
Migration route/corridor (instream & riparian, range: 4=very high - 0= none)	1	3	0	3	
Importance of conservation & natural areas (range, 4=very high - 0=very low)			0	4	
MEDIAN OF DETERMINANTS	2		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	MODERATE		MODERATE		

2 EWR 2: MIDDLE KROMME RIVER

DETERMINANTS	NATURAL		PRESENT		
	SCORE	CONF	SCORE	CONF	
	(0-4)		(0-4)		
BIOTA (RIPARIAN & INSTREAM)					COMMENTS
Rare & endangered (range: 4=very high - 0= none)	2	2	1	2	Presence of <i>Pseudobarbus afer</i> and Teloganodidae.
Unique (endemic, isolated, etc.) (range: 4=very high - 0= none)	1	1	0	3	Notonemouridae
Intolerant (flow & flow related water quality) (range: 4=very high - 0= none)	2	3	2	3	Simuliids, abundant Hydrosychids, Ceratopogonids
Species/taxon richness (range: 4=very high - 1=low/marginal)	3	3	2	2	Invertebrates
RIPARIAN & INSTREAM HABITATS					
Diversity of types (4=Very high - 1=marginal/low)	3	2	2	3	Pools, riffles, undercut banks, instream vegetation and backwaters.
Refugia (4=Very high - 1=marginal/low)	3	2	3	2	Large deep pools.
Sensitivity to flow changes (4=Very high - 1=marginal/low)	2	2	3	2	
Sensitivity to flow related water quality changes (4=Very high - 1=marginal/low)	2	2	2	2	
Migration route/corridor (instream & riparian, range: 4=very high - 0= none)	2	3	0	3	
Importance of conservation & natural areas (range, 4=very high - 0=very low)			1	4	
MEDIAN OF DETERMINANTS	2		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	MODERATE		MODERATE		

3 EWR 4: GEELHOUTBOOM RIVER

DETERMINANTS	NATURAL		PRESENT		COMMENTS
	SCORE	CONF	SCORE	CONF	
	(0-4)		(0-4)		
BIOTA (RIPARIAN & INSTREAM)					
Rare & endangered (range: 4=very high - 0= none)	4	4	4	4	Presence of <i>Podocarpus latifolius</i> .
Unique (endemic, isolated, etc.) (range: 4=very high - 0= none)	0	1	2	3	Closed canopy across the whole length of system.
Intolerant (flow & flow related water quality) (range: 4=very high - 0= none)	1	1	1	1	
Species/taxon richness (range: 4=very high - 1=low/marginal)	3	3	3	2	Vegetation.
RIPARIAN & INSTREAM HABITATS					
Diversity of types (4=Very high - 1=marginal/low)	1	2	1	3	
Refugia (4=Very high - 1=marginal/low)	2	1	2	1	Birds.
Sensitivity to flow changes (4=Very high - 1=marginal/low)	2	1	1	1	
Sensitivity to flow related water quality changes (4=Very high - 1=marginal/low)	2	2	2	2	Shaded habitats.
Migration route/corridor (instream & riparian, range: 4=very high - 0= none)	2	2	1	1	
Importance of conservation & natural areas (range, 4=very high - 0=very low)			1	4	
MEDIAN OF DETERMINANTS	2		1.5		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	MODERATE		MODERATE		

4 EWR 5: SEEKOEI RIVER

DETERMINANTS	NATURAL		PRESENT		COMMENTS
	SCORE	CONF	SCORE	CONF	
	(0-4)		(0-4)		
BIOTA (RIPARIAN & INSTREAM)					
Rare & endangered (range: 4=very high - 0= none)	3	3	2	4	Presence of <i>Pseudobarbus afer</i> and <i>Podocarpus latifolius</i> .
Unique (endemic, isolated, etc.) (range: 4=very high - 0= none)	0	3	0	3	
Intolerant (flow & flow related water quality) (range: 4=very high - 0= none)	3	2	2	2	Fish and invertebrates.
Species/taxon richness (range: 4=very high - 1=low/marginal)	3	3	2	2	
RIPARIAN & INSTREAM HABITATS					
Diversity of types (4=Very high - 1=marginal/low)	3	2	2	3	Pools, shoots, rapids, riffles, marginal vegetation, overhanging vegetation.
Refugia (4=Very high - 1=marginal/low)	3	1	2	1	Deep pools - filled up in present conditions, undercut banks.
Sensitivity to flow changes (4=Very high - 1=marginal/low)	2	1	2	1	
Sensitivity to flow related water quality changes (4=Very high - 1=marginal/low)	2	2	2	2	
Migration route/corridor (instream & riparian, range: 4=very high - 0= none)	1	2	1	1	
Importance of conservation & natural areas (range, 4=very high - 0=very low)			1	4	Upstream mountain stream.
MEDIAN OF DETERMINANTS	3		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	MODERATE		MODERATE		

5 EWR 6: SWART RIVER

DETERMINANTS	NATURAL		PRESENT		
	SCORE	CONF	SCORE	CONF	
	(0-4)		(0-4)		
BIOTA (RIPARIAN & INSTREAM)					COMMENTS
Rare & endangered (range: 4=very high - 0= none)	2	2	1	2	Presence of <i>Pseudobarbus afer</i> and Teloganodidae.
Unique (endemic, isolated, etc.) (range: 4=very high - 0= none)	1	1	0	3	Notonemouridae.
Intolerant (flow & flow related water quality) (range: 4=very high - 0= none)	2	3	2	3	Simuliids, abundant Hydrosychids, Ceratopogonids.
Species/taxon richness (range: 4=very high - 1=low/marginal)	3	3	2	2	Invertebrates.
RIPARIAN & INSTREAM HABITATS					
Diversity of types (4=Very high - 1=marginal/low)	3	2	2	3	Pools, riffles, undercut banks, instream vegetation and backwaters.
Refugia (4=Very high - 1=marginal/low)	3	2	3	2	Large deep pools.
Sensitivity to flow changes (4=Very high - 1=marginal/low)	2	2	3	2	
Sensitivity to flow related water quality changes (4=Very high - 1=marginal/low)	2	2	2	2	
Migration route/corridor (instream & riparian, range: 4=very high - 0= none)	2	3	0	3	
Importance of conservation & natural areas (range, 4=very high - 0=very low)			1	4	
MEDIAN OF DETERMINANTS	2		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	MODERATE		MODERATE		

APPENDIX I

HIGH FLOW REQUIREMENTS

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1 EWR 1: MELKHOUTBOSKRAAL

1.1 Class I

FLOOD CLASS I: 1 - 3 m ³ /s				RECOMMENDED EC C SCENARIO EVALUATION			ALTERNATIVE EC D SCENARIO EVALUATION		
				Fish C; Invertebrates C; Riparian vegetation E; Geomorph D			Fish D; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Fish	Flush out fines, create suitable habitat for spawning in terms of clean cobbles, depths and velocities. Also for migration of fish to suitable spawning habitat and allow eels (if present) to migrate.	Depth and velocity	Spring and summer	4	Every 1 - 2 months	Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.	2	Every 2 - 3 months	Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.
Invertebrates	Inundate vegetation.	Depth	Early summer	1	Yearly	To provide breeding habitat and cover for juveniles.	1	Yearly	
			Mid summer	2	Yearly		1	Yearly	
Riparian Vegetation	Flood marginal zone.	Depth (0.5 to 0.8 m)	Spring and summer	6	Yearly	Deposition of sediments and nutrients on marginal zone.			
						Inundation of marginal zone to supply and maintain marginal vegetation.			
Geo-morphology	Inundates low in-channel bench allowing sediment deposition in this area.	0.5 - 0.8 m	Spring to autumn	5	5 per year	To achieve sufficient variability within a year to maintain sediment accretion processes.			

1.2 Class II

FLOOD CLASS II: 3 - 8 m ³ /s				RECOMMENDED EC C SCENARIO EVALUATION			ALTERNATIVE EC D SCENARIO EVALUATION		
				Fish C; Invertebrates C; Riparian vegetation E; Geomorph D			Fish D; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Fish	Same as for class I, but better flushing of riffles, creating more and improved spawning habitat, easier passage for migrants over shallow riffles.	Depth and velocity	Spring and summer	2.0	Every 2-3 months	See class I.	1	In early summer	See class I.
Invertebrates	Scour mobile beds and clear algae.	Velocity	Early summer	1.0	Yearly	To clear SIC habitat and particularly upper and back sides of stones for sensitive rheophilic species requiring cover.	1	Yearly	
			Midsummer	1.0	Yearly				
Riparian Vegetation	Inundate the lower riparian zone	Depth (0.8 to 1.2 m)	Summer	1.0	Yearly	Provides sediments and nutrients to the lower riparian zone. Inundates and provides water to maintain vegetation.			
Geo-morphology	Effective flood for sediment transport.	Water level between 1.6 m and 2 m (within active channel).	Spring to autumn	N/A	Return period of 3 years	Frequent enough to maintain open substrate conditions but sufficient soaking between events to allow vegetation to stabilise low bench.			

1.3 Class III

FLOOD CLASS III: 6 – 18 m/s ³				RECOMMENDED EC C SCENARIO EVALUATION			ALTERNATIVE EC D SCENARIO EVALUATION		
				Fish C; Invertebrates C; Riparian vegetation E; Geomorph D			Fish D; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Fish	Will move sediment and cobbles in riffle areas and improve habitat for fish spawning as well as egg incubation.	Velocity	Summer			Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.			
Riparian Vegetation	Inundates the lower areas of the upper riparian zone.	Depth (1.2 to 2 m)	Summer	1	Every three years	Deposits nutrients and sediments and facilitates the recovery of habitat.			
Geomorphology	Sediment accretion on upper flood bench to repair damage due to major events.	Water level to 2.6 m to 3.0 m	Spring to autumn	N/A	Return period of 5 years				

1.4 Class IV

FLOOD CLASS IV: 33 – 55 m/s ³				RECOMMENDED EC C SCENARIO EVALUATION			ALTERNATIVE EC D SCENARIO EVALUATION		
				Fish C; Invertebrates C; Riparian vegetation E; Geomorph D			Fish D; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Geo-morphology	Negatively reset system through sediment	Water level exceeds 4 m	Any time		Return period exceeding				

	redistribution.				1: 12 years (1:20)				
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2 EWR 2: KROMMERIVIERS POORT

2.1 Class I

FLOOD CLASS I: 1 - 3 m ³ /s				RECOMMENDED EC D SCENARIO EVALUATION		
				Fish C; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Create suitable habitat for spawning in terms of clean cobbles, depths of 10 - 15cm and velocities of 0.3 - 0.05m/s. Also for migration of fish to move upstream to suitable spawning habitat and allow eels (if present) to migrate. Also flush out fines (not much present) in rifles.	Depth and velocity.	Spring and summer months	4	Every 1 to 2 months	Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.
Invertebrates	Inundate in-channel and marginal vegetation.	Depth, increase of wetted perimeter.	Early summer	1	Yearly	Marginal vegetation is a key biotope at this site. Need to provide breeding habitat for adults and shelter for juveniles.
			Midsummer	1	Yearly	
Riparian Vegetation	Flood marginal zone.	Depth (0.4 to 0.66 m)	Spring and summer	6	Yearly	Deposition of sediments and nutrients (if present) on marginal zone.
						Inundation of marginal zone to supply and maintain marginal vegetation.
Geomorphology	Accretion of fine sediment on to channel bars.			0	0	Lack of sediment limits accretion potential.

2.2 Class II

FLOOD CLASS II: 3 - 5 m ³ /s				RECOMMENDED EC D SCENARIO EVALUATION		
				Fish C; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Same as for Class I, but better flushing of riffles, creating more and improved spawning habitat, easier passage for migrants over shallow riffles abundance on sides in marginal vegetation.	Suitable clean and loose cobbles on sides of active channel to be inundated - this would be optimum habitat for spawning provided that suitable depths and velocities present. Also shallow slow habitat will be created for larval fish.	Spring and summer	2	Every 2-3 months	Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.
Invertebrates	Clear loose cobbles on channel edge and clear matrix of fines and detritus.	Flow width (up to 15 m).	Early summer	1	Yearly	Large cobbles and boulders in the SIC area at lower flows are imbricated (packed). This means there is no surface area beneath rocks, which is a preferred habitat for many invertebrates. This flood will clear fines and detritus from between the loose cobbles, thus clearing undersides of the cobbles and providing habitat for these invertebrates.
Riparian Vegetation	Inundate the lower riparian zone.	Depth (0.66 to 1.1 m).	Summer	1	Yearly	Provides sediments and nutrients (if present) to the lower riparian zone. Inundates and provides water to maintain vegetation.
Geomorphology	Effective flood for sediment transport.	Water level between 2 m and 2.5 m (within active channel) 90 - 150 m ³ /s.	Spring to autumn	N/A	Return period of 2.5 years	Frequent enough to destabilise bed and limit vegetation encroachment.

2.3 Class III

FLOOD CLASS III: 6 - 23 m ³ /s				RECOMMENDED EC D SCENARIO EVALUATION		
				Fish C; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Will move sediment and cobbles in riffle areas and improve habitat for fish spawning as well as egg incubation.	As for Class II - and new spawning habitat made available as clean cobbles on edge inundated by high water level.		1		Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.
Riparian Vegetation	Inundates the lower areas of the upper riparian zone	Depth (1.2 to 1.7 m).	Summer	1	Every three years	Deposits nutrients and sediments and facilitates the recovery of habitat. Provision of water to vegetation to maintain growth.
Geomorphology	Sediment accretion on upper flood bench to repair damage due to major events.		Spring to autumn	N/A	0 requirement	No sediment available.

2.4 Class IV

FLOOD CLASS IV: 28 - 63 m ³ /s				RECOMMENDED EC D SCENARIO EVALUATION		
				Fish C; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Geomorphology	Reset system through sediment redistribution and disturb vegetation to allow new recruitment	Discharge 200 to 450 m ³ /s	Any time		Return period exceeding 1: 12 years (1:20)	

3 EWR 4: GEELHOUTBOOM RIVER

3.1 Class I

FLOOD CLASS I: 0.1 - 0.3 m ³ /s				RECOMMENDED EC C/D SCENARIO EVALUATION		
				Fish D; Invertebrates D; Riparian vegetation A/B; Geomorph C		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Very little suitable spawning habitat but riffle habitat may be marginally suitable. Also for migration of fish to suitable spawning habitat and allow eels (if present) to migrate.	Velocity	Spring and summer	5	Every 1 to 2 months	Flushing out of system, migration facilitated.
Invertebrates	Establish connectivity.	Flow and depth	Early summer	1		Improve water quality, clear organic detritus and sediments from channel and pools, ensure invertebrate drift.
			Mid summer	2		Improve water quality.
			Late summer	1		
Riparian Vegetation	Flood marginal zone.	Depth (0.2 to 0.38 m)	Spring and summer	6	Yearly	Deposition of sediments and nutrients (if present) on marginal zone. Inundation of marginal zone to supply and maintain marginal vegetation.

3.2 Class II

FLOOD CLASS II: 0.3 - 0.8 m ³ /s				RECOMMENDED EC C/D SCENARIO EVALUATION		
				Fish D; Invertebrates D; Riparian vegetation A/B; Geomorph C		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Same as for class I, easier passage for migrants over shallow riffles.	Velocity	Spring and summer	3	Every 2-3 months	Flushing out of system, migration facilitated.
Invertebrates	Inundate marginal vegetation.	Width.	Early summer	1	Yearly	Provide breeding habitat for adults and cover for juveniles.
		Flow	Mid summer	1	Yearly	Improve water quality.
			Late summer	1	Yearly	
Riparian Vegetation	Flood marginal zone.	Depth (0.2 to 0.45 m)	Spring and summer	6	Yearly	Deposition of sediments and nutrients (if present) on marginal zone.
		Depth (0.38 to 0.44 m)				Move debris (small branches and leaves) within the system.

3.3 Class III

FLOOD CLASS III: 0.8 - 1.4 m ³ /s				RECOMMENDED EC C/D SCENARIO EVALUATION		
				Fish D; Invertebrates D; Riparian vegetation A/B; Geomorph C		
Comp	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Geom	Sediment sorting.	Depth range 0.4 to 0.5m, velocity range 0.8 to 1m/s. Flow = 0.8 - 1.4 m ³ /s	Wet season	1	1 per year	Effective discharge for sediment transport assumed to be annual flood.

4 EWR 5: SEEKOEI RIVER

4.1 Class I

FLOOD CLASS I: 0.1 - 0.3 m ³ /s				RECOMMENDED EC C SCENARIO EVALUATION		
				Fish C; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Create suitable depths over riffle to allow fish movement over riffle and allow spawning to take place.	Create depths over riffles and flood into vegetation to allow <i>Sandelia capensis</i> to breed in vegetated backwaters.	Spring into early summer	4	Every 1-2 months	Allow egg incubation and growth of larvae before next flood.
Invertebrates	Inundate Marginal vegetation.	Flow depth, Wetted Perimeter	Early summer	1	Yearly	Provide breeding habitat for adults and shelter for juvenile taxa.
			Late summer	1	Yearly	
Riparian Vegetation	Flood marginal zone.	Depth (0.02 to 0.16)	Spring and summer	6 to 8	Yearly	Deposition of sediments and nutrients on marginal zone. Inundation of marginal zone to supply and maintain marginal vegetation.
Geomorphology	Deposition of fine sediment on in-channel bench.	Depth between 0.25 – 3 m; Flow = 0.15 - 0.3 m ³ /s; Velocity = 0.4 - 0.54m ³ /s	Wet season	4	4 per year	To achieve sufficient variability within a year to maintain sediment accretion processes.

4.2 Class II

FLOOD CLASS I: 0.3 - 0.8 m ³ /s				RECOMMENDED EC C SCENARIO EVALUATION		
				Fish C; Invertebrates D; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning
Fish	Same reasons as Class I but more so- I.e. create suitable depths over riffle to allow fish movement over riffle and allow spawning to take place and flush out pools.	Create depths over riffles and flood into vegetation to allow <i>Sandelia capensis</i> to breed in vegetated backwaters	Spring	2	Every 2-3 months	Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.
Invertebrates	Clear fines from areas of mobile cobbles.	Velocity	Early summer	1	Yearly	Clear the interstices between cobbles and general surface area of cobbles.
Riparian Vegetation	Inundate the lower riparian zone.	Depth (0.26 to 0.5 m)	Summer	1	Yearly	Provides sediments and nutrients to the lower riparian zone. Inundates and provides water to maintain vegetation.
Geomorphology	Sorting of bed material.	Depth between 0.4 - 0.5 m; Flow = 1 - 1.9 m ³ /s; Velocity = 0.8 - 1.04 m/s	Wet season	1	Yearly	Effective discharge for sediment transport assumed to be annual flood.

5 EWR 6: SWART RIVER

5.1 Class I

FLOOD CLASS I: 0.2 - 0.3 m ³ /s				RECOMMENDED EC B SCENARIO EVALUATION			ALTERNATIVE EC C SCENARIO EVALUATION		
				Fish C; Invertebrates B; Riparian vegetation D; Geomorph C			Fish D; Invertebrates C; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Fish	Will need to create depth and velocity for spawning and migration for fish and eels.	Create depths over riffles and flood into vegetation to allow <i>Sandelia capensis</i> to breed in vegetated backwaters.	Spring/early summer	4	Every 1-2 months	Allow egg incubation and growth of larvae before next flood.	2.0	Every 2 months	Allow egg incubation and growth of larvae before next flood.
Invertebrates	Flushing and inundation of marginal vegetation.	Depth	Early summer	1	Yearly	Improve quality of breeding habitat for adults and shelter for juveniles.	1.0		Improve quality of breeding habitat for adults and shelter for juveniles.
			Mid summer	1			1.0		
			Early summer	1					
Riparian vegetation	Flood marginal zone.	Depth (0.2 to 0.4 m).	Spring and summer	6	Yearly	Deposition of sediments and nutrients (if present) on marginal zone.			
						Inundation of marginal zone to supply and maintain marginal vegetation.			
Geomorphology	Accretion of fine sediment on in-channel bench	Depth .26 - .35 m Velocity .44 - .7 m/s Flow = .15 - .4 m ³ /s	Wet season	5		Within year variability of intermediate flows.			

5.2 Class II

FLOOD CLASS II: 0.4 - 0.6 m ³ /s				RECOMMENDED EC B SCENARIO EVALUATION			ALTERNATIVE EC C SCENARIO EVALUATION		
				Fish C; Invertebrates B; Riparian vegetation D; Geomorph C			Fish D; Invertebrates C; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Fish	Same as for Class I but more optimum conditions. Also flush sediment out pools and riffles.	Create depths over riffles and flood into vegetation to allow <i>Sandelia capensis</i> to breed in vegetated backwaters.	Spring	2	Every 2-3 months	Allow incubation of eggs and growth of larvae before next high flow and prevent flushing out incubating eggs in crevices.			
Invertebrates	Flush fines and organics from channel.	Velocity	Early summer	1		Clear SIC and SOC habitat for adults, juveniles and eggs.			
			Mid summer	1					
Riparian vegetation	Inundate the lower riparian zone.	Depth (0.4 to 0.75m)	Summer	1	Yearly	Provides sediments and nutrients (if present) to the lower riparian zone.			
						Inundates and provides water to maintain vegetation.			
Geomorphology	Effective discharge for sediment transport.	Depth = 0.7 - 1 Velocity = 1.55 - 1.9 Flow = 3 - 7.5 m ³ /s	Wet season	1	1:2	Frequency of effective discharge reduced to prevent excessive scour.			

5.3 Class III

FLOOD CLASS III: 0.6 - 3.5 m ³ /s				RECOMMENDED EC B SCENARIO EVALUATION			ALTERNATIVE EC C SCENARIO EVALUATION		
				Fish C; Invertebrates B; Riparian vegetation D; Geomorph C			Fish D; Invertebrates C; Riparian vegetation D; Geomorph D		
Component	Function/s (What does it have to do)	Description (what is the flood characteristic that does that)	Season	No of events	Frequency	Reasoning	No of events	Frequency	Reasoning
Riparian vegetation	Inundates the lower areas of the upper riparian zone.	Depth (0.75 to 1.25 m)	Summer	1	Every three years	Deposits nutrients and sediments and facilitates the recovery of habitat.			
						Provision of water to vegetation to maintain growth.			
Geomorphology	Sediment accretion on flood zone.	Depth 1 - 1.7 m Velocity 1.9 -1.45 m/s Flow = 7.5 - 27.4 m ³ /s			1:2.5	Local knowledge of frequency of overbank flooding.			These floods will become destructive in a degraded system.

APPENDIX J

ALTERNATIVE ECs: RESULTS OF INTEGRATED MODELS

Ms S. Koekemoer, IWR Source-to-Sea

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1 EWR 1: MELKHOUTBOSKRAAL

1.1 Alternative EC: D

Only one alternative category, a D category was considered. A B category will not be considered, as it is highly unlikely that this can ever be achieved by improving flows. If non-flow related problems are addressed such as the rehabilitation of the wetland and addressing alien vegetation and fish, the river state will improve.

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios, the matrices that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

1.2 Habitat Driver PES

Table J-1 Habitat Driver Category for EWR 1

Components	Weighted driver score
GEOMORPHOLOGY	10.11 (D)
HYDROLOGY	25.05 (D)
WATER QUALITY	22.19 (C)
Weighted driver status (%)	57.36
HABITAT DRIVER CATEGORY	D

1.3 Instream PES (D)

Table J-2 Instream Present Ecological conditions for EWR 1

Criteria	Rating (0=low, 5=high)					
	Conf	Rating	Ave	Weight	PES	Category
Availability of high confidence fish information						
1 Diversity of fish species with different flow requirements		2				
2 Diversity of fish species with a preference for different cover types		2				
3 Diversity of fish species with a preference for different flow depth classes		1				
4 Diversity of fish species with various tolerances to modified water quality		2.5	1.875	0.413	48.5	D
Availability of high confidence invertebrate information						
5 Diversity of invertebrate biotopes		3				
6 Diversity of invertebrate taxa with different velocity requirements		3				
7 Diversity of invertebrate taxa with different tolerances to modified water quality		2	2.66667	0.587	55.4	D
			4.54167	1	52.5	D

1.4 PES Ecostatus (D)

Table J-3 Summary of the Ecostatus for EWR 1

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality		3		
Fish: What is the general level of trophic specialisation		2		
What is the general level of habitat specialisation		3		
What is the general level of flow intolerance		4	3	0.53
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3		
How sensitive are hydraulic habitats to flow change?		3		
How sensitive is water quality to flow change?		2	2.67	0.47
Total			5.67	1
PES	52.52	Category		
INSTREAM CATEGORY		D		
DRIVER CATEGORY	57.4	D		
ECOSTATUS	54.80	D		

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F
 This rating is applicable to low flows

2 EWR 6 – SWART RIVER:

2.1 Alternative EC: C

Only one alternative category, a C category was considered. The situation for a C category is described below.

Riparian vegetation has a negative trajectory and the geomorphological response will be a widening channel that has less depth and is incised. This will result in a decrease within the geomorphology category. No foreseen decrease in the hydrology category is expected unless a dam is built upstream, which would impact on the flood regime. The general assumption is that water quality will drop a category, mainly the components oxygen, temperature and turbidity (which is the most sensitive for the fish and invertebrates at this site).

2.2 Habitat Driver PES

Table J-4 Habitat Driver Category for EWR 6

Components	Weighted driver score
GEOMORPHOLOGY	14.48 (C)
HYDROLOGY	48.39 (B)
WATER QUALITY	17.87 (A/B)
Weighted driver status (%)	80.74
HABITAT DRIVER CATEGORY	B

2.3 Instream PES (C/D)

Table J-5 Instream Present Ecological conditions for EWR 1

Criteria	Rating (0=low, 5=high)					
	Conf	Rating	Ave	Weight	PES	Category
Availability of high confidence fish information		3				
1 Diversity of fish species with different flow requirements		2				
2 Diversity of fish species with a preference for different cover types		1				
3 Diversity of fish species with a preference for different flow depth classes		2				
4 Diversity of fish species with various tolerances to modified water quality		1	1.5	0.429	47.5	D
Availability of high confidence invertebrate information						
5 Diversity of invertebrate biotopes		2				
6 Diversity of invertebrate taxa with different velocity requirements		2				
7 Diversity of invertebrate taxa with different tolerances to modified water quality		2	2	0.571	72.2	C
			3.5	1	61.6	C

2.4 PES Ecostatus (C)

Table J-6 Summary of the Ecostatus for EWR 6

Separating out the proportions for Driver: Response	Rating (0=low, 5=high)			
	Response	Score	Ave	Weight
<i>Instream Response questions</i>				
What is the general level of sensitivity to modified water quality?		2		
Fish: What is the general level of trophic specialisation?		2		
What is the general level of habitat specialisation?		2		
What is the general level of flow intolerance?		2.5	2.13	0.43
<i>Habitat Driver Questions</i>				
How sensitive is channel type to change in geomorphological drivers?		3.5		
How sensitive are hydraulic habitats to flow change?		3		
How sensitive is water quality to flow change?		2	2.83	0.57
Total			4.96	1
PES	61.64	Category		
INSTREAM CATEGORY		C/D		
DRIVER CATEGORY	80.7	B		
ECOSTATUS	72.56	C		

(%): > 89 = A; 80 – 89 = B; 60 – 79 = C; 40 – 59 = D; 20 – 39 = E; < 20 = F
 This rating is applicable to low flows

APPENDIX K

RAPID ECOLOGICAL RESERVE METHODOLOGY (RERM) III

Ms D. Louw and Ms S. Koekemoer,
IWR Source-to-Sea

EXECUTIVE SUMMARY

INTRODUCTION

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

BACKGROUND

Rapid Ecological Reserve Methodology (RERM)

Broadly the RERM III comprises the following steps:

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

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

ECOLOGICAL CATEGORIES

The categories provided for EWR 7 are summarised below.

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

(1) Instream Habitat Integrity

(2) Riparian Habitat Integrity

SUMMARY OF RESULTS

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

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

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

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

1 INTRODUCTION

1.1 Background

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

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

1.2 Study area and level of Reserve required

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

1.3 Scope of the report

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

1.4 Study objectives

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

2 K90D: DIEP RIVER

2.1 River reach

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

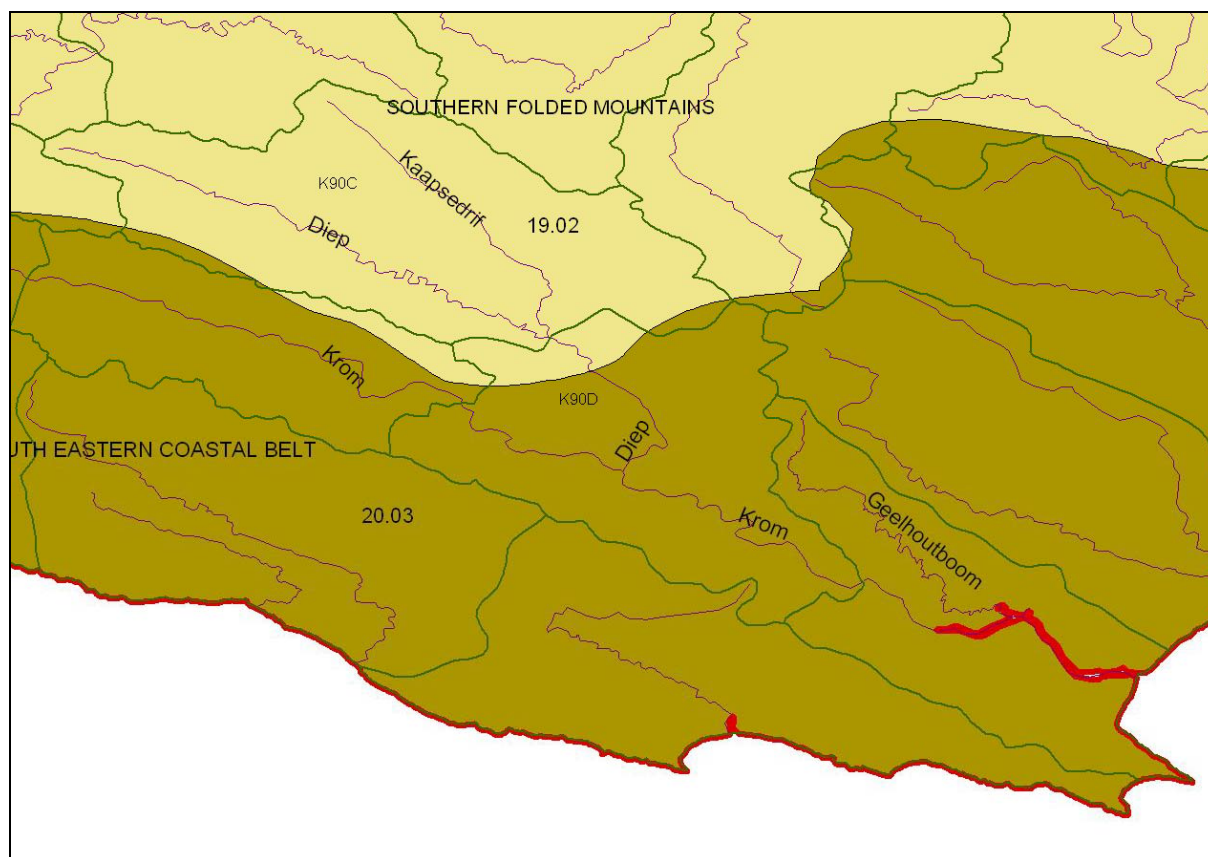


Figure K-1 Study area: Ecoregion South Eastern Coastal belt

2.2 EWR site

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

S 34° 01.322
E 24° 35.557

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

The site is illustrated in Figure K-2.



Figure K-2 Diep River (0.061 m³/s, 9/03/05)

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

Table K-1 EWR site evaluation table

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

2.3 Ecoclassification

2.3.1 Available information

Fish

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

Confidence: 2

Aquatic Invertebrates

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

Confidence: 2

Hydraulics

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

Confidence: 2

Hydrology

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

Confidence: 2

2.3.2 Reference conditions

Fish

The following indigenous fish species are expected under reference conditions:

<i>Pseudobarbus afer</i>	<i>Sandelia capensis</i>
<i>Gilchristella aestuaria</i>	<i>Anguilla mossambica</i>
<i>Anguilla marmorata</i>	<i>Anguilla bicolor bicolor</i>

Aquatic Invertebrates

The following taxa are expected under reference conditions.

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

SASS5 score: 200

ASPT: 6

Hydrology

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

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

2.3.3 PES

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

Table K-2 Water quality information

RIVER	Diep River	Water Quality Monitoring Points	
WQSU	6	RC	Default boundary tables
EWR SITE	7	PES	WQ6 (n=4)
Water Quality Constituents		Value	Category / Comment
Inorganic salts (mg/L)	MgSO ₄	-	An assessment of inorganic salts could not be undertaken as the data from the NMMM laboratories were not compatible with the salt model.
	Na ₂ SO ₄	-	
	MgCl ₂	-	
	CaCl ₂	-	
	NaCl	-	
	CaSO ₄	-	
Nutrients (mg/L)	SRP	0.245	E/F (Poor)
	TIN	0.01	A (Natural)
Physical variables	pH (5 th -95 th %)	6.8 - 7.2	A (Natural)
	Temperature	-	No data available, but not considered a problem water quality variable as the site is not downstream of a dam, and thermal and dissolved oxygen impacts are not expected.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	No data
	Electrical conductivity (mS/m)	40.7	A/B (Upper Good)
Response variable	Chl-a: periphyton	184.3	E/F (Poor)
	Chl-a: phytoplankton	0.913	A (Natural)
	Biotic community composition: macroinvertebrate (ASPT) score	6.13 (Oct 03)	B (Good)
	Fish community score	-	No data
Toxics	Fluoride (mg/L)	0.07	A (Natural)
OVERALL SITE CLASSIFICATION FOR WATER QUALITY		B/C	

2.3.4 Habitat integrity

Instream Habitat Integrity: Category C (Attachment D)

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

Riparian Habitat Integrity: Category E (Attachment D)

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

2.3.5 Fish (C) (Attachment B)

Species found during the survey were:

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

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

2.3.6 Aquatic Invertebrates (C) (Attachment C)

SASS5 score: 146

ASPT: 5.6

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

2.3.7 Ecostatus (C/D)

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

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

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

2.3.8 Ecological Importance and Sensitivity (EIS)

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

2.3.9 Range of Ecological Categories

Recommended Ecological Category (REC)

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

Alternative Ecological Categories

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

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

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

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

2.4 Flow requirement results

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

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

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

⁽¹⁾ MLF: Maintenance Low Flows

⁽²⁾ DLF: Drought Low Flows

⁽³⁾ HF: High flows

%: % of VMAR

The D Desktop category was determined following the same approach.

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

The Desktop C percentages of the virgin MAR at EWR 1 was as follows:

Drought low flows: 2.99% Maintenance low flows: 7.89% High flows: 11.3%

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

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

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

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

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

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

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

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

2.4.1 Fish

C/D category motivation

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

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

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

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

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

D category motivation

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

2.4.2 Aquatic Invertebrates

C/D category motivation

Maintenance wet season flow of 0.077 m³/s

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

At these flows the riffle will provide similar habitat to the present conditions (0.061 m³/s). Maximum flow depth increases by only 4 cm from current conditions, which will increase inundation of marginal vegetation, providing for additional surface area for colonisation. Marginal vegetation in current (MVIC) habitat will increase slightly. The average velocity is in the region of 0.19 m/s which is only marginally different from present conditions (0.18 m/s); the distribution of flow types therefore varies only marginally from present conditions. The aquatic invertebrate community is unlikely to alter.

Maintenance dry season flow of 0.035 m³/s

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

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

Drought flows of 0.025 m³/s

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

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

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

Drought flows of 0.001 m³/s

Discharge	0.001
Conditions	Trickle flow through riffle.

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

D motivation:

Maintenance flow of 0.055 m³/s

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

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

Maintenance flow of 0.018 m³/s

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

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

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

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

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

Desktop Version 2, Printed on 2005/03/10

Summary of IFR estimate for: Diep WRSM90 Flows

Determination based on defined BBM Table with site specific assurance rules.

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

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

REC = C/D

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

Monthly Distributions (cu.m./s)

Distribution Type : S.Karoo

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

Desktop Version 2, Printed on 2005/03/10

Summary of IFR rule curves for: Diep WRSM90 Flows

Determination based on defined BBM Table with site specific assurance rules.

REC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.278	0.249	0.223	0.196	0.151	0.126	0.093	0.060	0.036	0.029
Nov	0.204	0.201	0.194	0.182	0.162	0.133	0.097	0.060	0.033	0.025
Dec	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jan	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Feb	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Mar	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
Apr	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
May	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jun	0.258	0.228	0.201	0.175	0.131	0.107	0.078	0.048	0.026	0.019
Jul	0.267	0.238	0.212	0.186	0.142	0.117	0.086	0.054	0.031	0.024
Aug	0.847	0.728	0.564	0.486	0.369	0.304	0.223	0.141	0.080	0.062
Sep	0.635	0.548	0.473	0.404	0.286	0.236	0.175	0.112	0.066	0.052

Reserve flows without High Flows

Oct	0.109	0.107	0.104	0.098	0.088	0.074	0.056	0.038	0.024	0.021
Nov	0.098	0.096	0.093	0.088	0.078	0.065	0.048	0.032	0.019	0.016
Dec	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jan	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Feb	0.054	0.053	0.051	0.048	0.042	0.033	0.023	0.012	0.004	0.001
Mar	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
Apr	0.059	0.058	0.056	0.052	0.046	0.036	0.025	0.013	0.005	0.002
May	0.065	0.064	0.062	0.058	0.051	0.041	0.029	0.017	0.008	0.005
Jun	0.082	0.081	0.078	0.073	0.065	0.054	0.039	0.025	0.014	0.010
Jul	0.098	0.096	0.093	0.088	0.078	0.065	0.048	0.032	0.019	0.016
Aug	0.119	0.118	0.114	0.108	0.097	0.082	0.063	0.044	0.030	0.026
Sep	0.109	0.107	0.104	0.098	0.089	0.076	0.059	0.042	0.029	0.026

Natural Duration curves

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

2.4.4 IFR table and assurance rules for a D REC

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

Desktop Version 2, Printed on 2005/03/10

Summary of IFR estimate for: Diep WRSM90 Flows

Determination based on defined BBM Table with site specific assurance rules.

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

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

ERC = D

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

Monthly Distributions (cu.m./s)

Distribution Type : S.Karoo

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

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

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.281	0.249	0.220	0.193	0.146	0.121	0.091	0.060	0.037	0.030
Nov	0.214	0.211	0.204	0.191	0.170	0.140	0.101	0.063	0.034	0.026
Dec	0.042	0.042	0.040	0.038	0.034	0.028	0.020	0.012	0.007	0.005
Jan	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Feb	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Mar	0.033	0.032	0.031	0.029	0.026	0.021	0.015	0.008	0.004	0.002
Apr	0.037	0.036	0.035	0.032	0.029	0.023	0.016	0.009	0.004	0.002
May	0.046	0.045	0.044	0.041	0.036	0.030	0.022	0.013	0.007	0.005
Jun	0.250	0.218	0.189	0.163	0.117	0.097	0.071	0.045	0.026	0.020
Jul	0.262	0.231	0.203	0.176	0.130	0.108	0.080	0.052	0.031	0.025
Aug	0.910	0.777	0.564	0.486	0.386	0.318	0.234	0.148	0.085	0.066
Sep	0.686	0.590	0.507	0.432	0.302	0.250	0.184	0.118	0.069	0.055

Reserve flows without High Flows

Oct	0.092	0.091	0.088	0.083	0.075	0.064	0.049	0.034	0.024	0.020
Nov	0.083	0.081	0.079	0.074	0.067	0.056	0.042	0.029	0.018	0.015
Dec	0.042	0.042	0.040	0.038	0.034	0.028	0.020	0.012	0.007	0.005
Jan	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Feb	0.033	0.032	0.031	0.029	0.026	0.020	0.014	0.007	0.003	0.001
Mar	0.033	0.032	0.031	0.029	0.026	0.021	0.015	0.008	0.004	0.002
Apr	0.037	0.036	0.035	0.032	0.029	0.023	0.016	0.009	0.004	0.002
May	0.046	0.045	0.044	0.041	0.036	0.030	0.022	0.013	0.007	0.005
Jun	0.055	0.054	0.053	0.050	0.045	0.037	0.028	0.019	0.012	0.010
Jul	0.074	0.072	0.070	0.066	0.060	0.050	0.039	0.027	0.018	0.015
Aug	0.101	0.100	0.097	0.092	0.083	0.071	0.056	0.040	0.029	0.025
Sep	0.101	0.100	0.097	0.092	0.083	0.071	0.056	0.040	0.029	0.025

Natural Duration curves

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

3 REFERENCES

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ATTACHMENT A^K

RIVER HYDRAULICS

**Dr A.L. Birkhead
Streamflow Solutions CC
Paradise Valley, Gonubie, East London**

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1 INTRODUCTION AND AIMS OF THIS REPORT

The role of hydraulics and procedure for generating hydraulic information for Ecological Reserve studies have been documented for the Comprehensive and Intermediate levels of determination (DWAF, 1999), with subsequent periodic updates (Birkhead, 2002; Jordanova *et al.*, in press). This report provides the hydraulic information (data collection, modelling and results) for a site on the Diep River (tributary of the Kromme River) for a Rapid level III determination.

1.1 Methodology

The application of holistic methods for ecological flow determination (refer to Tharme, 1996) requires water requirements to be expressed as discharge rates (including its temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling of sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants (which have been found over the course of numerous flow assessments, to be the most useful): depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (refer to Rowston *et al.*, 2000; Birkhead, 2002 for descriptions of procedures for deriving hydraulic information for use in ecological flow requirements (or Reserves). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (see Section A4.3).

The cross-sectional profile plots and look-up tables comprise the “standard hydraulic data” used in Reserve determinations in South Africa at the Rapid III, Intermediate and Comprehensive levels. Ecologists use these standard hydraulic data with the aid of site assessments, photographs and video exposure, to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat (eg. hydraulic, substrate and cover attributes for fish)). For this reason, a procedure has been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Jordanova *et al.* (in press) for an explanation of the method). The method allows the assessment of abundance of different habitat types to be applied more consistently in Ecological Reserve determinations, and has been applied in the Rapid Level III determinations in this study.

1.2 Data collection

Fixed stations were installed at the EWR site using a local datum (Table 1).

Table 1 Fixed survey stations at EWR site 7 on the Diep River

River	Site no.	Station	Hz (decimal degrees) rel. to cross-section (0°)	Eald (m)
Diep	7	7.1 (IPC)	Setup	100.00
		7.2 (MRK)	303.41	98.44
		7.3 (MRK)	0.80	98.02

(1) Eald: Elevation above local datum

(2) IPC: Iron Peg in Concrete

(3) MRK: Mark (painted)

The measured discharge and flow depth are provided in Table A 2, together with the date when the data were collected.

Table 2 Hydraulic data collected at EWR Site 7 on the Diep River

River	Site no.	Date	Discharge Q (m ³ /s)	Stage amsl z (m)	Max. flow depth y (m)
				Cross-section A	
Diep	7	09/03/2005	0.061	97.65	0.24

1.3 Modelling

The observed rating data at the EWR sites have been extended using Manning's resistance relationship. The surveyed water surface and regional (1:50 000 topographical) channel slopes are given in Tables 3 and 4, and these have been used in conjunction with estimates of Manning's resistance coefficient (Table 5) to synthesize rating data for discharges higher than those measured. Continuous rating functions of the form given by equation 1 have been fitted to the measured and modelled data, and these are plotted in Figure 1 for the EWR site.

$$Q = ayb + c \quad \text{equation 1}$$

where y is the flow depth (m), Q is the discharge (m³/s), and a , b and c are regression coefficients, listed in Table A 6.

Table 3 Regional 1:50 000 channel slope

River	Site no.	Channel slope
Diep	7	0.0063

Table 4 Surveyed water surface slopes

River	Site no.	Discharge (m ³ /s)	Water surface slope
Diep	7	0.061	0.024 (7.5), 0.0075 (29)

(x) Distance over which slope surveyed (m)

Table 5 Hydraulic data used to extend the measured rating data

River	Site no.	Discharge Q(m ³ /s)	Manning's resistance, <i>n</i>	Max. flow depth, <i>y</i> (m) ¹	Stage amsl, <i>z</i> (m)	Energy slope, <i>S</i>	Ave. velocity <i>v</i> (m/s)
Diep	7	6.5	0.06	1.00	98.41	0.008	0.99

Italic modelled

Table 6 Regression coefficients in equation A1

River	Site no.	Discharge Q (m ³ /s)	Cross-section	Rating coefficients			
				<i>a</i>	<i>b</i>	<i>c</i> relative to	
						bed	local datum
Diep	7	All	A	0.564	0.306	0.000	97.41

1.4 Results

The results of the hydraulic survey are shown in Figures 1 and 2, and Tables 7, 8 and 9.

1.4.1 Cross-sectional profile

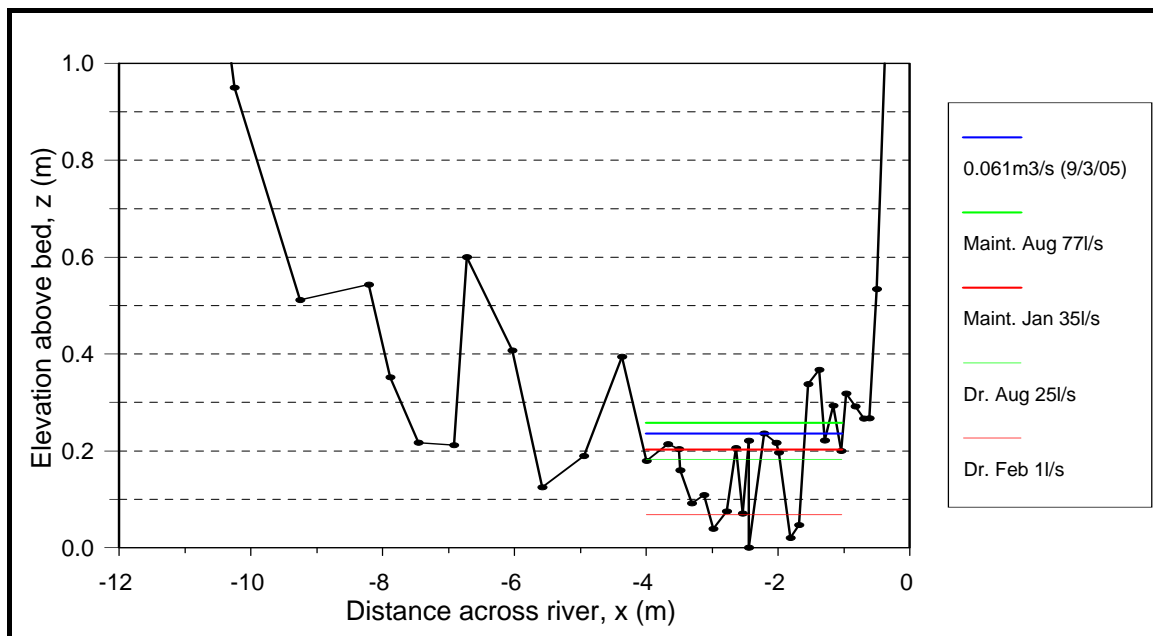


Figure 1 Cross-sectional profile for the Diep River EWR Site 7 (riffle), showing the water level surveyed on 09/03/2005 and the maintenance and drought flows generated using the desktop model for a C/D category.

1.4.2 Rating functions

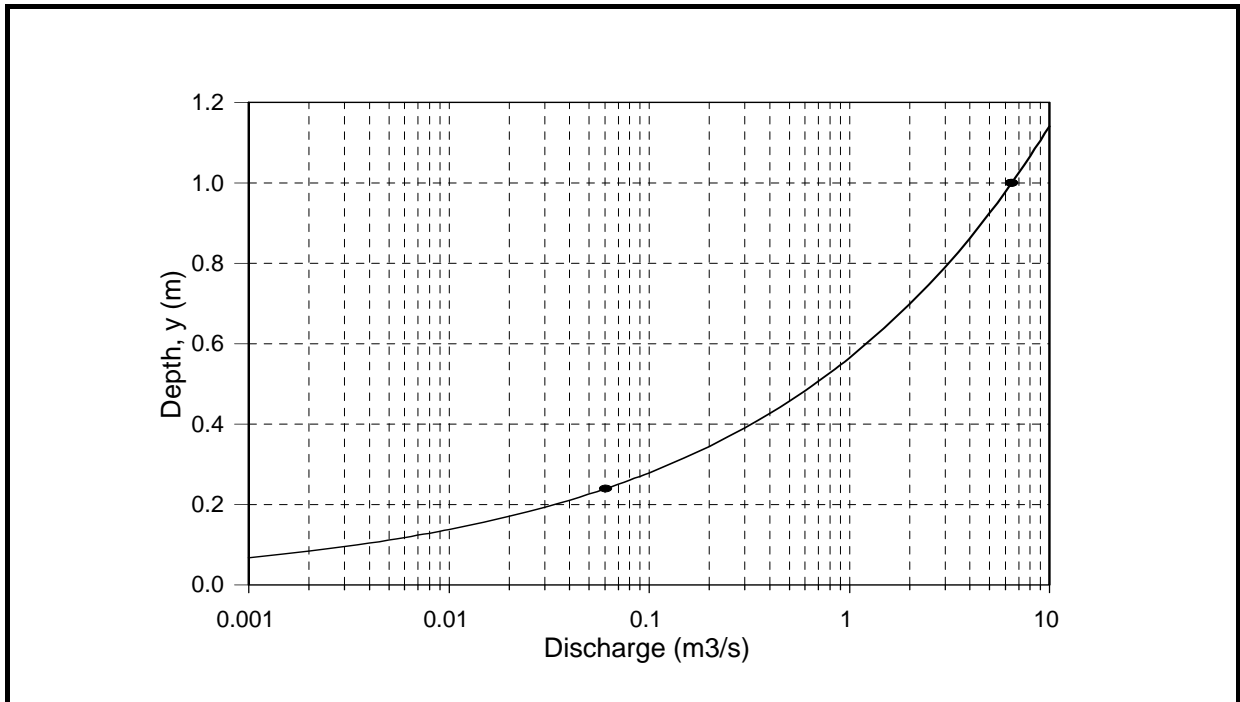


Figure 2 Measured and modelled rating data points and function for the cross-sectional profile at EWR Site 7 on the Diep River. The cross-section lies through a riffle.

Tabulated modelled hydraulic data

Table 7 Tabulated hydraulic data for EWR Site 7 on the Diep River

Flow depth (m)	Discharge (m ³ /s)	Average flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Average velocity (m/s)
0.00	0.000	0.00	0.00	0.00	0.00	0.00
0.02	0.000	0.01	0.00	0.02	0.05	0.09
0.04	0.000	0.01	0.00	0.17	0.23	0.09
0.06	0.001	0.02	0.01	0.40	0.52	0.08
0.08	0.002	0.03	0.02	0.60	0.78	0.09
0.10	0.004	0.04	0.03	0.84	1.11	0.11
0.12	0.006	0.05	0.05	1.11	1.46	0.12
0.14	0.011	0.05	0.08	1.43	1.87	0.14
0.16	0.016	0.06	0.11	1.81	2.34	0.15
0.18	0.024	0.07	0.15	2.16	2.79	0.16
0.20	0.034	0.07	0.20	2.64	3.38	0.17
0.22	0.046	0.07	0.26	3.78	4.61	0.18
0.24	0.061	0.08	0.34	4.23	5.15	0.18
0.26	0.080	0.09	0.43	4.52	5.52	0.19
0.28	0.10	0.10	0.52	4.98	6.06	0.19
0.30	0.13	0.12	0.63	5.37	6.54	0.20
0.32	0.16	0.13	0.74	5.70	6.96	0.21
0.34	0.19	0.14	0.85	5.94	7.26	0.22
0.36	0.23	0.16	0.97	6.25	7.63	0.24
0.38	0.28	0.17	1.10	6.47	7.90	0.25
0.40	0.33	0.19	1.23	6.62	8.10	0.26
0.42	0.38	0.20	1.37	6.73	8.24	0.28
0.44	0.44	0.22	1.50	6.86	8.40	0.30
0.46	0.51	0.24	1.64	6.98	8.56	0.31
0.48	0.59	0.25	1.78	7.10	8.71	0.33
0.50	0.68	0.27	1.93	7.23	8.87	0.35
0.52	0.77	0.27	2.07	7.67	9.35	0.37
0.54	0.87	0.26	2.23	8.51	10.23	0.39
0.56	0.98	0.28	2.41	8.71	10.47	0.41
0.58	1.10	0.29	2.58	8.85	10.63	0.42
0.60	1.22	0.31	2.76	8.98	10.80	0.44
0.62	1.36	0.33	2.94	9.03	10.87	0.46
0.64	1.51	0.34	3.12	9.08	10.94	0.48
0.66	1.67	0.36	3.30	9.13	11.01	0.51
0.68	1.84	0.38	3.49	9.18	11.08	0.53
0.70	2.03	0.40	3.67	9.23	11.15	0.55
0.72	2.22	0.42	3.86	9.28	11.22	0.58
0.74	2.43	0.43	4.04	9.33	11.29	0.60
0.76	2.65	0.45	4.23	9.38	11.36	0.63

Flow depth (m)	Discharge (m ³ /s)	Average flow depth (m)	Area (m ²)	Width (m)	Perimeter (m)	Average velocity (m/s)
0.78	2.89	0.47	4.42	9.43	11.43	0.65
0.80	3.13	0.49	4.61	9.48	11.50	0.68
0.82	3.40	0.50	4.80	9.53	11.57	0.71
0.84	3.68	0.52	4.99	9.58	11.64	0.74
0.86	3.97	0.54	5.18	9.63	11.71	0.77
0.88	4.28	0.56	5.37	9.68	11.78	0.80
0.90	4.61	0.57	5.57	9.73	11.85	0.83
0.92	4.95	0.59	5.76	9.78	11.92	0.86
0.94	5.31	0.61	5.96	9.83	11.99	0.89
0.96	5.69	0.62	6.16	9.87	12.05	0.92
0.98	6.08	0.64	6.35	9.89	12.10	0.96
1.00	6.50	0.66	6.55	9.91	12.15	0.99

1.4.3 Habitat type abundance and velocity distribution analyses

Kleynhans (1999) suggested that the hydraulic information necessary to characterize habitat for fish is depth-averaged velocity (V) and flow depth (D). Together with substrate and vegetation cover information, these are sufficient to broadly describe fish habitat. Further, he suggests that velocity and depth need only be specified coarsely, and has proposed the following four velocity-depth classes (hydraulic habitat types), as adapted from Oswald and Barber (1982):

- Slow (<0.3 m/s) and shallow (<0.5m) (SS): This includes shallow pools and backwaters.
- Slow (<0.3 m/s) and deep (>0.5m) (SD): This includes deep pools and backwaters.
- Fast (>0.3 m/s) and shallow (<0.3m) (FS): Shallow runs, rapids and riffles fall in this class
- Fast (>0.3 m/s) and deep (>0.3m) (FD): Deep runs, rapids and riffles fall under this class.

The results of the habitat-type abundance assessments (fish) are provided in Table 8 for the riffle feature. The rows of data in bold font denote scorings corresponding to measured flows observed at the site on 9 March 2005. Velocity distribution information using the distribution model of Lamouroux *et al.*, (1995) is provided in Table 9.

Table 8 Ratings of habitat type abundance for EWR Site 7 (Diep River)

Discharge (m ³ /s)	Ecological assessment (on-site) ¹				Hydraulic assessment (calculated)							
					Rating (0-5)				Metres of perimeter			
	SS	SD	FS	FD	SS	SD	FS	FD	SS	SD	FS	FD
0.016					3	0	1	0	2.2	0.0	0.2	0.0
0.034					3	0	1	0	2.9	0.0	0.4	0.0
0.061	4	4	1	0	4	0	2	0	4.3	0.0	0.8	0.0
0.10					5	0	2	0	5.0	0.0	1.1	0.0

¹ Rating for site, whereas hydraulic assessment is for riffle:

0=none, 1=rare, 2=sparse, 3=moderate, 4=abundant, 5=very abundant

Table 9 Velocity distributions for EWR Site 7 (Diep River)

Discharge (m ³ /s)	Average velocity (m/s)	Lamouroux <i>et al.</i> , 1995				
		Maximum velocity (m/s)	Frequency (%) of velocity (m/s)			
			0-0.1	0.1-0.3	0.3-0.6	>0.6
0.016	0.15	0.45	41	51	8	0
0.034	0.17	0.50	38	49	13	0
0.061	0.18	0.55(0.85)	36	48	16	0
0.10	0.19	0.55	36	46	18	0

(x) = measured value

1.5 Confidence in the hydraulic characterisations

The confidence in the characterisations of the hydraulic relationships are provided in Table 10. “Site character” refers to the suitability of the site for hydraulic modelling, “available data” refers to the range of measured rating data, and the final column refers to the confidence in the hydraulic characterisations with reference to the ecological low and high flow recommendations.

Table 10 Confidence in the hydraulic characterisations

Site no.	Site character	Available data	Reference to PES or recommended EC	
			Low flows	High flows ¹
7 (Diep)	2	2	3	N/a
<p>Site characterised by a short (7.5m long) riffle composed predominantly of large cobbles and small boulders. Pools occur upstream and downstream of the riffle, with the depth in the upstream pool in excess of 1m at the time of the site visit. A mid-channel bar vegetated with Palmiet exists immediately upstream of the riffle, with divided flows at medium to high discharges.</p> <p><i>"Site character" rating =2</i></p> <p><u>Advantages</u> Measurement of discharge using manual gauging.</p> <p><u>Disadvantages</u> Non-uniform flow over short riffle 'step' feature. Riffle will drown-out at medium to high flows (approximately 0.3 m³/s), but additional riffle-type hydraulic habitat on bed (chainages between -4 to -8m) may become active. Difficult to determine reduction in flow resistance from site calibrated value as influence of control becomes drowned out at higher discharges. Influence of channel blockages, channel form, and pool/riffle/rapid sequences on flow resistance.</p> <p>Single measured discharge of 0.061 m³/s.</p> <p><i>"Available data" rating = 2.</i></p> <p>The measured discharge is within the range (0.035 to 0.077 m³/s) of desktop-generated maintenance flows (C/D category), and drought flows are in the range 0 to 0.025 m³/s.</p>				

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

⁽¹⁾ Not Applicable since high flows are not considered as part of Rapid Level III assessment.

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ATTACHMENT B^K

Fish

Dr A. Bok, Anton Bok and Associates

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	1.3.2 Flow modification	B ^K -6
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1 FISH EC

1.1 Diep River (K90D): Fish PES (C)

1.1.1 Flow depth

FLOW-DEPTH CLASS METRICS: With reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	0.00	0.00	0.00	3.00	0.00	0.00
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	0.00	0.00	0.00	3.00	0.00	0.00
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-1.00	0.53	-2.11	1.00	100.00	0.53
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	-1.00	0.47	-1.89	2.00	90.00	0.47
Absolute sum			1.00	4.00	4.00	190.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				20.00			

1.1.2 Flow modification

FLOW MODIFICATION METRICS: With reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependence metric scores	Weight of flow metrics	Flow dependence: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.00	0.00	4.0	0.00	0.00
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-2.00	0.50	-4.00	1.0	100.0	0.50
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-2.00	0.40	-3.20	2.0	80.0	0.40
Frequency of occurrence of species tolerant of no flow conditions	FT	-1.00	0.10	-0.40	3.0	20.0	0.10
			1.00	7.6	4.0	200.0	1.0
Absolute overall % change in flow dependence of assemblage				38.00			

1.1.3 Migration

<u>MIGRATION METRICS</u>		Flow dependence metric scores	Weight of flow metrics	Flow dependence: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of spp with catchment scale movements	CAT	-4.00	0.50	-10.00	1.0	100.0	0.50
Frequency of occurrence of spp with requirement for movement between reaches or fish habitat segments	BR	-2.00	0.250	-2.50	2.0	50.0	0.25
Frequency of occurrence of spp with requirement for movement within reach or fish habitat segment	IR	-2.00	0.250	-2.50	2.0	50.0	0.25
			1.00	15.0	5.0	200.0	1.0
Absolute overall % change in population longitudinal continuity				60.00			

1.1.4 Cover

<u>COVER METRICS: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?</u>		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-2.0	0.27	-2.7	2	80.0	0.27
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-2.0	0.10	-1.0	3	30.0	0.10
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-3.0	0.33	-5.0	1	100.0	0.33
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-2.0	0.27	-2.7	2	80.0	0.27
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.03	0.0	4	10.0	0.03
			1.0	11.3	5.0	300.0	1.0
Absolute overall % change in habitat assemblages				45.33			

1.1.5 Health condition

HEALTH/CONDITION OF SPECIES (Introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighted abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	0.00	0.00	0.00	0.00	0.00	0.00
Health of species moderately intolerant of modified water quality	MIH	-2.00	0.59	-3.53	1.00	100.00	0.59
Health of species moderately tolerant of modified water quality	MTH	-1.00	0.35	-1.06	2.00	60.00	0.35
Health of species tolerant of modified water quality	HT	0.00	0.06	0.00	3.00	10.00	0.06
Sum			1.00	4.59	4.00	170.00	1.00
Overall % change to indicators of modified water quality				30.59			

1.1.6 Introduced species

INTRODUCED SPECIES METRICS: With reference to the types of introduced species, the characteristics of the habitat and the native species, what is the following observed or expected to be?		Introduced spp score	Introduced spp weight	Weighted introduced species score	Ranking of metrics	%Weight	Standardize sum to = 1
The potential impact of introduced predaceous spp?	IP	5.0	0.43	8.57	1.0	90.0	0.429
How widespread (frequency of occurrence) are introduced predaceous spp?	FP	5.0	0.48	9.52	2.0	100.0	0.476
The potential impact of introduced habitat modifying spp?	IH	-1.0	0.05	-0.19	3.0	10.0	0.048
How widespread (frequency of occurrence) are habitat modifying spp?	FH	-1.0	0.05	-0.19	3.0	10.0	0.048
Sum			1.0	17.71	4.0	210.0	
Overall % potential impact of introduced spp				88.57			

1.2 PES: C

Fish PES Metric group		Metric group: Calculated score	Fish PES: Based on weights of metric groups			
			Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	80.00	0.34	27.12	1.00	100.00
FLOW MODIFICATION METRICS	FM	62.00	0.27	16.81	2.00	80.00
MIGRATION METRICS	CM	40.00	0.03	1.36	3.00	10.00
COVER METRICS	HM	54.67	0.34	18.53	1.00	100.00
HEALTH/CONDITION METRICS	IS	69.41	0.02	1.18	4.00	5.00
IMPACT OF INTRODUCED SPP (NEGATIVE)		88.57	0.00	0.00	5.00	0.00
Fish PES				65.00		
Fish PES Category				C		

1.3 Diep River (K90D): Fish Alternative EC (D)

1.3.1 Flow depth

FLOW-DEPTH CLASS METRICS: With reference to flow modifications and changes in sediment movement, what are the changes to the following observed or expected to be?		Flow-depth preference scores (observed or expected under present conditions)	Weight of flow, depth preference metric	Flow-depth preferences: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with very high and high preference for FAST-DEEP conditions	FFD	0.00	0.00	0.00	3.00	0.00	0.00
Frequency of occurrence of species with very high and high preference for FAST-SHALLOW conditions	FFS	0.00	0.00	0.00	3.00	0.00	0.00
Frequency of occurrence of species with very high and high preference for SLOW-DEEP conditions	FSD	-1.00	0.53	-2.11	1.00	100.00	0.53
Frequency of occurrence of species with very high and high preference for SLOW-SHALLOW conditions	FSS	-2.00	0.47	-3.79	2.00	90.00	0.47
Absolute sum			1.00	5.89	4.00	190.00	1.00
Absolute overall % change in flow-depth classes composition of assemblage				29.47			

1.3.2 Flow modification

FLOW MODIFICATION METRICS: With reference to flow modifications, what are the changes to the following observed or expected to be?		Flow dependence metric scores	Weight of flow metrics	Flow dependence: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species intolerant of no-flow conditions	FI	0.00	0.00	0.00	4.0	0.00	0.00
Frequency of occurrence of species moderately intolerant of no-flow conditions	FMI	-3.00	0.50	-6.00	1.0	100.0	0.50
Frequency of occurrence of species moderately tolerant of no flow conditions	FMT	-3.00	0.40	-4.80	2.0	80.0	0.40
Frequency of occurrence of species tolerant of no flow conditions	FT	-1.00	0.10	-0.40	3.0	20.0	0.10
			1.00	11.2	4.0	200.0	1.0
Absolute overall % change in flow dependence of assemblage				56.00			

1.3.3 Migration

<u>MIGRATION METRICS</u>		Flow dependence metric scores	Weight of flow metrics	Flow dependence: weighted score per metric (out of 5)	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of spp with catchment scale movements	CAT	-4.00	0.50	-10.00	1.0	100.0	0.50
Frequency of occurrence of spp with requirement for movement between reaches or fish habitat segments	BR	-2.00	0.250	-2.50	2.0	50.0	0.25
Frequency of occurrence of spp with requirement for movement within reach or fish habitat segment	IR	-2.00	0.250	-2.50	2.0	50.0	0.25
			1.00	15.0	5.0	200.0	1.0
Absolute overall % change in population longitudinal continuity				60.00			

1.3.4 Cover

COVER METRICS: With reference to changes in fish cover features, what are the changes to the following observed or expected to be?		Cover metric score	Weight of cover metric	Weighed cover preference score	Ranking of metrics	% Weight	Standardize sum to = 1
Frequency of occurrence of species with a very high to high preference for overhanging vegetation	OV	-2.0	0.27	-2.7	2	80.0	0.27
Frequency of occurrence of species with a very high to high preference for undercut banks and root wads	UB	-2.0	0.10	-1.0	3	30.0	0.10
Frequency of occurrence of species with a high to very high preference for a particular substrate type	SUB	-3.0	0.33	-5.0	1	100.0	0.33
Frequency of occurrence of species with a high to very high preference for aquatic macrophytes	AMAC	-3.0	0.27	-4.0	2	80.0	0.27
Frequency of occurrence of species with a very high to high preference for the water column	WC	0.0	0.03	0.0	4	10.0	0.03
			1.0	12.7	5.0	300.0	1.0
Absolute overall % change in habitat assemblages				50.67			

1.3.5 Health condition

HEALTH/CONDITION OF SPECIES (Introduced and native): With reference to changes in water quality conditions, what are the changes to the following observed or expected to be?		Abundance, health, condition scoring	Abundance, health, condition weights	Weighted abundance, health and condition score	Ranking of metrics	% Weight	Standardize sum to = 1
Health of species intolerant of modified water quality	ITH	0.00	0.00	0.00	0.00	0.00	0.00
Health of species moderately intolerant of modified water quality	MIH	-3.00	0.59	-5.29	1.00	100.00	0.59
Health of species moderately tolerant of modified water quality	MTH	-2.00	0.35	-2.12	2.00	60.00	0.35
Health of species tolerant of modified water quality	HT	0.00	0.06	0.00	3.00	10.00	0.06
Sum			1.00	7.41	3.00	170.00	1.00
Overall % change to indicators of modified water quality				49.41			

1.4 Alternative EC: D

Fish PES Metric group		Metric group: Calculated score	Fish PES: Based on weights of metric groups			
			Calculated weight	Weighted score for group	Rank of metric group	% Weight for metric group
FLOW-DEPTH METRICS	FD	70.53	0.34	23.91	1.00	100.00
FLOW MODIFICATION METRICS	FM	44.00	0.27	11.93	2.00	80.00
MIGRATION METRICS	CM	40.00	0.03	1.36	3.00	10.00
COVER METRICS	HM	49.33	0.34	16.72	1.00	100.00
HEALTH/CONDITION METRICS	IS	50.59	0.02	0.86	4.00	5.00
IMPACT OF INTRODUCED SPP (NEGATIVE)		88.57	0.00	0.00	5.00	0.00
Fish PES				54.78		
Fish PES Category				D		

ATTACHMENT C^K

Aquatic Invertebrates

Dr A.C. Uys, Lauging Waters

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1 AQUATIC INVERTEBRATES EC

1.1 Diep River (K90D): Aquatic Invertebrate PES (C)

1.1.0 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	1	0.26	0.26	1	100	0.26
Abundance of taxa with a preference for very fast flowing water	FTA	2	0.11	0.21	3	40	0.11
Presence of taxa with a preference for moderately fast flowing water	MT	1	0.26	0.26	1	100	0.26
Abundance of taxa with a preference for moderately fast flowing water	MTA	2	0.11	0.21	3	40	0.11
Presence of taxa with a preference for slow flowing water	ST	2	0.16	0.32	2	60	0.16
Abundance of taxa with a preference for slow flowing water	STA	2	0.11	0.21	3	40	0.11
Proportional change in average flow dependence of the assemblage			1	29.47		380	1

1.1.0 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	0	0.17	0.00	1	100	0.17
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	2	0.13	0.25	3	75	0.13
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	3	0.15	0.46	2	90	0.15
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	3	0.13	0.38	3	75	0.13
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	2	0.11	0.22	4	65	0.11
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	2	0.10	0.20	5	60	0.10
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	2	0.11	0.22	4	65	0.11
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	3	0.10	0.31	5	60	0.10
			1			590	1.00
Overall change in habitat assemblages				40.85			

1.1.0 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	0	0.15	0.0000	1	100	0.15
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	2	0.10	0.2090	4	70	0.10
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	2	0.15	0.2985	1	100	0.15
Have the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	3	0.12	0.3582	3	80	0.12
Are any taxa with a low requirement for unmodified water quality present?	LQ	3	0.10	0.3134	4	70	0.10
Have the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	0	0.10	0.0000	4	70	0.10
How does the total SASS score differ from expected?	SASS	2	0.13	0.2687	2	90	0.13
How does the total ASPT score differ from expected?	ASPT	2	0.13	0.2687	2	90	0.13
		1			670		
Overall change to indicators of modified water quality				34.33			

1.1.0 PES: C

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	70.5	0.263	18.5	26.3	0.263	FT	1	100	0.370	1
HABITAT	59.2	0.367	21.7	36.7	0.367	CT	2	90	0.333	0.9
WATER QUALITY	65.7	0.370	24.3	37.0	0.370	HQ	3	80	0.296	0.8
	195.4	1		100	1.000				0.370	
Invertebrate PES			64.6					270	1	
Category	39.07		C							

1.1 Diep River (K90D): Aquatic Invertebrates Alternative EC (D)

1.1.0 Flow modification

INDICATORS OF FLOW MODIFICATION		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1
Presence of taxa with a preference for very fast flowing water	FT	2	0.26	0.53	1	100	0.26
Abundance of taxa with a preference for very fast flowing water	FTA	2	0.11	0.21	3	40	0.11
Presence of taxa with a preference for moderately fast flowing water	MT	2	0.26	0.53	1	100	0.26
Abundance of taxa with a preference for moderately fast flowing water	MTA	2	0.11	0.21	3	40	0.11
Presence of taxa with a preference for slow flowing water	ST	2	0.16	0.32	2	60	0.16
Abundance of taxa with a preference for slow flowing water	STA	2	0.11	0.21	3	40	0.11
Proportional change in average flow dependence of the assemblage			1	40.00		380	1

1.1.0 Habitat preference

INDICATORS OF HABITAT PREFERENCE		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT		0.00	0.00			0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA		0.00	0.00			0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	2	0.17	0.34	1	100	0.17
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	2	0.13	0.25	3	75	0.13
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	3	0.15	0.46	2	90	0.15
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	3	0.13	0.38	3	75	0.13
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	2	0.11	0.22	4	65	0.11
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	2	0.10	0.20	5	60	0.10
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	2	0.11	0.22	4	65	0.11
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	3	0.10	0.31	5	60	0.10
			1			590	1.00
Overall change in habitat assemblages				40.85			

1.1.0 Water quality

INDICATORS OF WATER QUALITY		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1
Are any taxa with a high requirement for unmodified water quality absent?	HQ	2	0.15	0.2985	1	100	0.15
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	2	0.10	0.2090	4	70	0.10
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	3	0.15	0.4478	1	100	0.15
Have the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	3	0.12	0.3582	3	80	0.12
Are any taxa with a low requirement for unmodified water quality present?	LQ	3	0.10	0.3134	4	70	0.10
Have the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	1	0.10	0.1045	4	70	0.10
How does the total SASS score differ from expected?	SASS	3	0.13	0.4030	2	90	0.13
How does the total ASPT score differ from expected?	ASPT	3	0.13	0.4030	2	90	0.13
			1	670			
Overall change to indicators of modified water quality				50.75			

1.1.0 Alternative EC: D

PES metrics	Estimated indicator score	Weight	Weighted score	Expected Natural Reference Weighted Score	Calc weight	READ	Rank	%Weight	Std to sum to 1	Weight relative to 1
FLOW MODIFICATION	60.0	0.263	15.8	26.3	0.263	FT	1	100	0.370	1
HABITAT	52.4	0.367	19.2	36.7	0.367	CT	2	90	0.333	0.9
WATER QUALITY	49.3	0.370	18.2	37.0	0.370	HQ	3	80	0.296	0.8
	161.6	1		100	1.000				0.370	
Invertebrate PES			53.2					270	1	
Category	32.33		D							

ATTACHMENT D^K

Habitat Integrity Assessment and PES Ecostatus

Assessed during the specialist meeting

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2	RIPARIAN HABITAT INTEGRITY EVALUATION	D ^K -4

1 INSTREAM HABITAT INTEGRITY EVALUATION

Instream Habitat Integrity Evaluation	None	Small	Moderate	Large	Serious
	(0)	(1-5)	(6-10)	(11-15)	(16-20)
Delineation	Diep River				
PRIMARY					
Water abstraction			10		
Flow modification			10		
Bed modification			8		
Channel modification			11		
Water quality			6		
Inundation			4		
SECONDARY					
Exotic macrophytes			0		
Exotic fauna			0		
Solid waste disposal			0		
INSTREAM HABITAT INTEGRITY SCORE	70.6				
CATEGORY	C				

2 RIPARIAN HABITAT INTEGRITY EVALUATION

Riparian zone Habitat Integrity Evaluation	None	Small	Moderate	Large	Serious
	(0)	(1-5)	(6-10)	(11-15)	(16-20)
Delineation	Diep River				
Vegetation decrease	13.0				
Exotic vegetation	21.0				
Bank erosion	14.0				
Channel modification	11.0				
Water abstraction	2.0				
Inundation	2.0				
Flow modification	2.0				
Water quality	0.0				
Total (Out of 200)	65.0				
Riparian zone Habitat Integrity score	30.2				
CATEGORY	E				
RIPARIAN VEGETATION INTEGRITY SCORE	37.4				
RIPARIAN VEGETATION INTEGRITY CLASS	E				

3 ECOSTATUS

The table below shows the Ecological Categories per component, and the integrated Ecostatus for this river site.

Components	Diep River
FRAI	65.0
BRAI	64.6
INSTREAM BIOTIC INTEGRITY	64.8
INSTREAM HABITAT INTEGRITY	70.6
RIPARIAN ZONE INTEGRITY	30.2
RIPARIAN VEGETATION INTEGRITY (Derived from Riparian Zone Integrity)	37.4
ECOSTATUS (RIVER HEALTH) (Instream = 50% of weight, Riparian zone = 50% of weight)	50.8
	D

Due to the importance of the instream component in this section of the Diep River, the instream weighting was changed to 80% and the Ecostatus reassessed. The Ecostatus category (see table below) shows an improvement to a C/D category.

ECOSTATUS (RIVER HEALTH) (Instream = 80% of weight, Riparian zone = 20% of weight)	57.9
	C/D

ATTACHMENT E^K

Ecological Importance and Sensitivity

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1 ECOLOGICAL IMPORTANCE AND SENSITIVITY E^K-3

1 ECOLOGICAL IMPORTANCE AND SENSITIVITY

Delineation	Diep River IFR 7	Comments
DETERMINANTS	PRESENT SCORE	SCORE
BIOTA (RIPARIAN & INSTREAM)	(0-4)	(0-4)
Rare & endangered (range: 4 = very high - 0 = none)	4	<i>Myxus capensis, Pseudobarbus afer</i>
Unique (endemic, isolated, etc.) (range: 4 = very high - 0 = none)	1	Possibly some caddis flies and ghost or sand frogs?
Intolerant (flow & flow related water quality) (range: 4 = very high - 0 = none)	2	Invertebrates
Species/taxon richness (range: 4 = very high - 1 = low/marginal)	2.5	
RIPARIAN & INSTREAM HABITATS	(0-4)	(0-4)
Diversity of types (4=Very high - 1 = marginal/low)	0	
Refugia (4 = Very high - 1 = marginal/low)	2	Local Refuge
Sensitivity to flow changes (4 = Very high - 1 = marginal/low)	2.5	
Sensitivity to flow related water quality changes (4 = Very high - 1 = marginal/low)	1	
Migration route/corridor (instream & riparian, range: 4 = very high - 0 = none)	1	
Importance of conservation & natural areas (range, 4 = very high - 0 = very low)	0	
MEDIAN OF DETERMINANTS	2	
ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY (EIS)	MODERATE	