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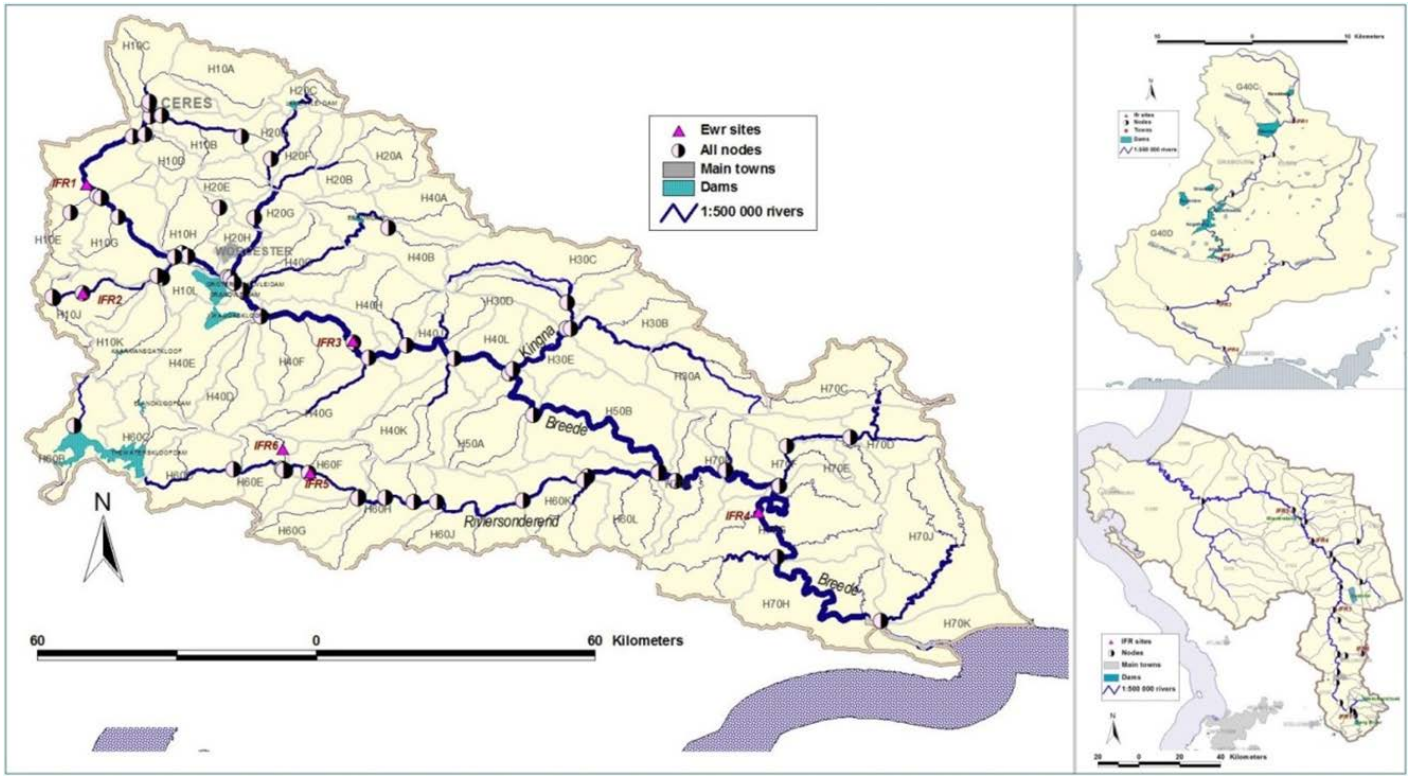
Department of Water Affairs
Directorate: Options Analysis

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

REPORT No.1 – VOLUME 1
Riverine Environmental Water Requirements

APPENDIX No.4

Rapid Reserve Assessments (Quantity) for the Steenbras, Pombers and Kromme Rivers



June 2012

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		Vol 2	PWMA19 G10/00/2413/2	**Rapid Determination of the Environmental Water Requirements of the Palmiet River Estuary**
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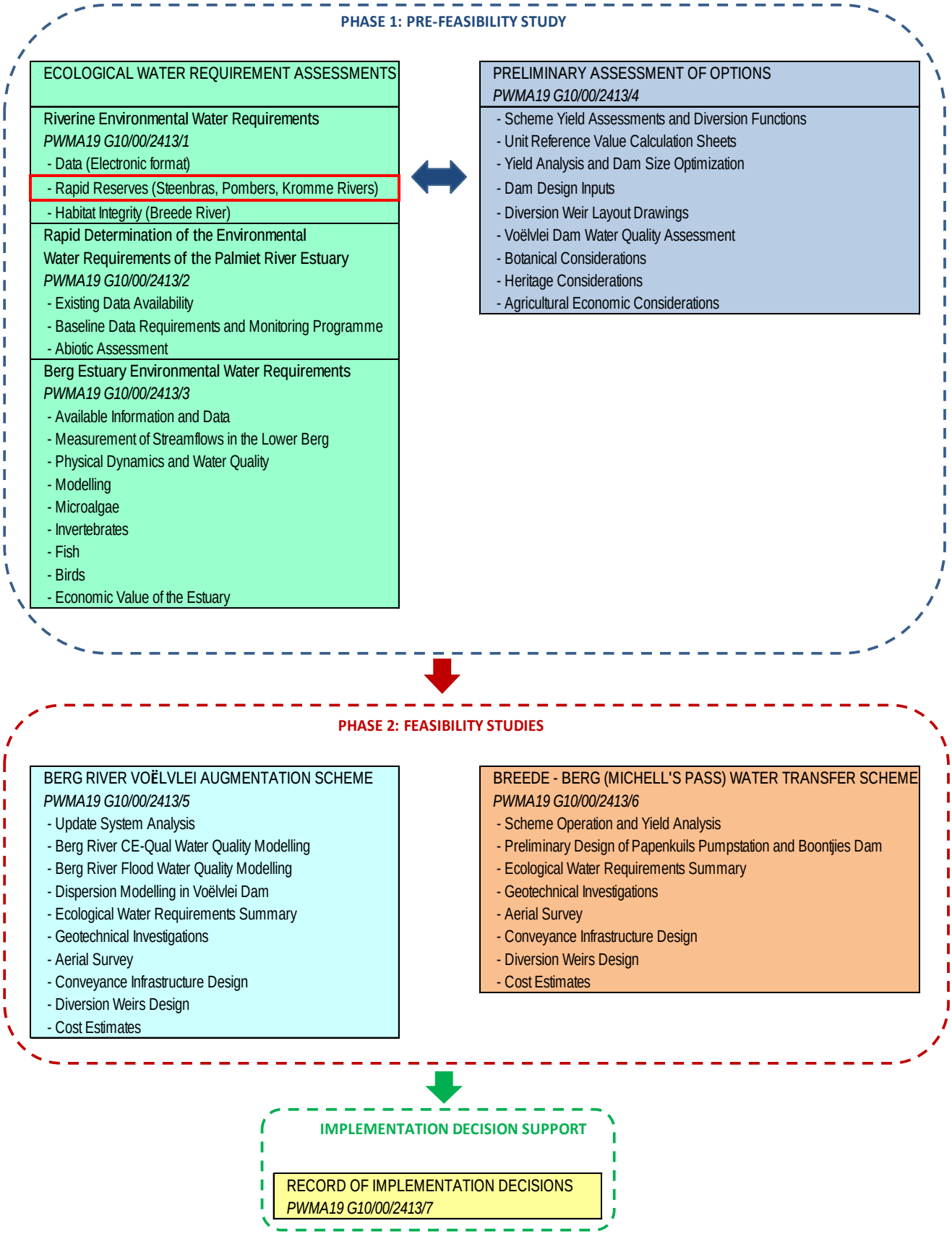

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GLOSSARY AND ABBREVIATIONS

%MAR	Percentage Mean Annual Run-off
a^{-1}	Per annum
AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
DWA	Department of Water Affairs
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirement
GAI	Geomorphology Driver Assessment Index
m^3s^{-1}	Cubic meters per second
MAR	Mean Annual Run-off
masl	meters above sea level
MCM	Million cubic meters
MIRAI	Macroinvertebrate Response Assessment Index
nMAR	Natural Mean Annual Run-off
nMean Q	Natural mean discharge
PES	Present Ecological Status
REC	Recommended Ecological Category
SASS5	South African Scoring System version 5
VEGRAI	Riparian Vegetation Response Assessment Index

1 INTRODUCTION

This study is part of the Western Cape Feasibility and Pre-feasibility Studies for the options to augment the Western Cape Water Supply Scheme being undertaken by Western Cape Water Consultants on behalf of the Department of Water Affairs (DWA). These options include schemes on the Steenbras, Pombers and Kromme Rivers.

Rapid II level Ecological Water Requirement (EWR) determinations were recommended for the three rivers in order to provide input to the catchment-wide assessment of EWRs (as per the technical requirements of the Water Resource Classification System; Dollar *et al*. 2006) that will be done as part of the Western Cape Feasibility and Pre-feasibility Studies.

These Rapid II assessments comprise one task, Task 1.3, of a suite of Reserve-related tasks in the Western Cape Feasibility and Pre-feasibility Studies and were approved under Variation Order 1.

Task 1.3 comprised the following sub-tasks:

Sub-Task 1.3.1 Literature Review.

Sub-Task 1.3.2 Field visit. Team members visited the Steenbras, Pombers and Kromme Rivers on 6th July 2009 to familiarize themselves with the rivers, and to assess the Present Ecological Status (PES) of the rivers.

The data collected in the field were used to:

- complete the Ecoclassification datasheets for each discipline;
- compare the discharge with those recommended by the Desktop Model for the same month (July).

Sub-Task 1.3.3 Generation of naturalised hydrology.

Sub-Task 1.3.4 Specialist meeting – Ecological Water Requirements (EWRs) determination. A one-day workshop was held at Southern Waters Offices on the 9th July 2009 to determine the EWRs.

Sub-Task 1.3.5 Report writing. The results are presented in this report.

1.1 Study team

The study team comprised:

- Rembu Magoba: Task leader and macroinvertebrate specialist
- Mark Rountree: Geomorphologist
- Karl Reinecke: Riparian vegetation
- Cate Brown: Reserve team leader.
- Anton Sparks: Hydrology.

2 STUDY AREA AND EWR SITES

2.1 Steenbras River

Steenbras River is a perennial river that rises in the Hottentots Holland Mountains near Cape Town, and enters the sea near Gordon's Bay (Figure 2.1). The river is impounded by the upper and lower Steenbras dams, which form part of the Western Cape Water Supply System. The Lower Steenbras Dam was constructed in 1921. It was raised for the first time in 1928 and for the second time in 1954. The Upper Steenbras Dam was constructed in 1977. No EWRs are currently released from the dams, and flows in the downstream river have been severely reduced for over half a century.

There is a proposal to raise the wall of Lower Steenbras Dam for a third time, by 24 m to the same full supply level as that of the Upper Steenbras Dam (370 masl), thereby creating a single Greater Steenbras Dam.

2.2 Pombers and Kromme Rivers

The Pombers River has its source in the Hawequas Mountain Catchment Area and is a tributary of the Kromme River, which itself is a tributary of the Berg River. The Kromme River joins the Berg River just west of the town of Wellington. Both are naturally seasonal rivers, although the Pombers River receives water from the Wit River during the summer via Gawie se Water. Gawie se Water was constructed in 1900 and has been in use ever since. It currently diverts 5 MCM a^{-1} into the Pombers River, and thus into the Kromme River downstream of its confluence with the Pombers River (Figure 2.2).

There is a proposal to replace the Gawie-se-Water diversion with a diversion of 10 MCM a^{-1} of winter water from the Wit River via the Pombers River to new dam on Doolhof Farm. An alternative proposal is to divert the water into a dam on Oaklands Farm, upstream of Doolhof Farm (Figure 2.2).

2.3 EWR sites

The location of the EWR sites selected on the Steenbras, Pombers and Kromme rivers are shown in Figure 2.1 and Figure 2.2, respectively. These are discussed in more detail in Section 4.

Figure 2.1 Google image showing Steenbras EWR Site (S: 34.19379°, E: 18.82467°) situated near the mouth downstream of the Steenbras dams.

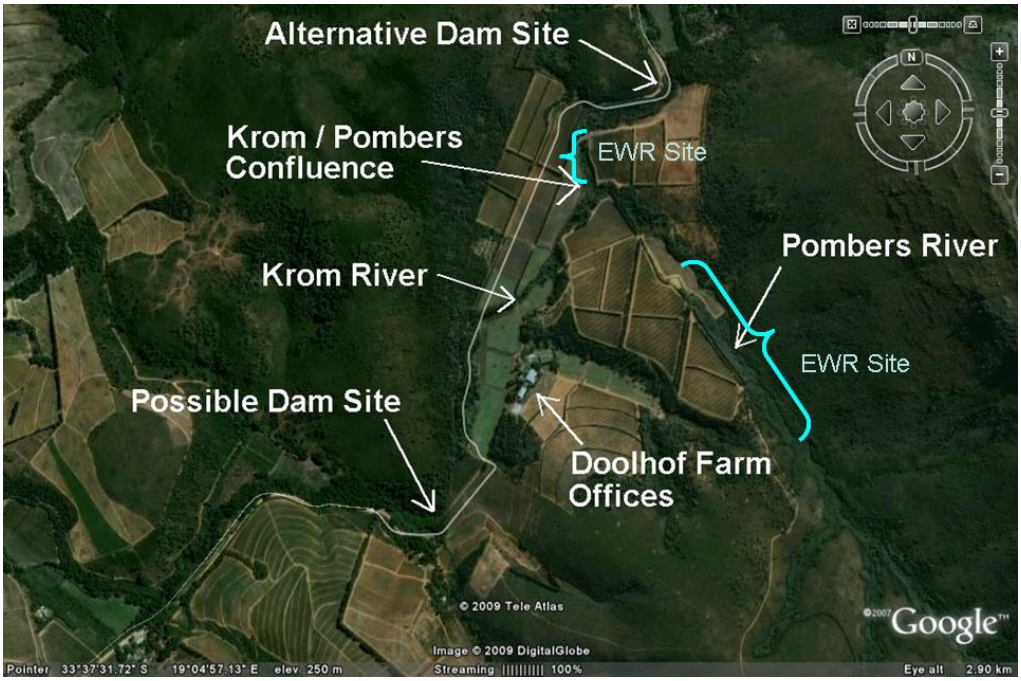

Figure 2.2 Google image showing EWR Sites for the Pombers (S: 33.62554°, E: 19.08985°) and Kromme Rivers (S: 33.62577°, E: 19.08166°)

3 APPROACH ADOPTED

The river Rapid II EWR determination procedure was followed (DWAF 1999). In summary, the procedure is as follows:

- Site visit and EWR assessment done by a team of 2-3 people.
- Consideration of readily-available information on the river, to set PES.
- Flow measurement during the site visit so that at least one point can be compared with the values generated by the Desktop.
- No hydraulic information.

The Desktop Model (Hughes and Hannart 2003) was used to determine EWRs for the Steenbras, Pombers and Kromme Rivers. The Desktop Model is a rule-based model calibrated using trends emerging from the previous Comprehensive Reserve determinations for rivers with similar hydrological characteristics (Hughes and Hannart 2003). All summary hydrology and rule tables were produced using the Desktop Version 2[1] and IFR Edit.

4 ECOCLASSIFICATION

Ecoclassification assessments for the Steenbras, Pombers and Kromme Rivers were done using:

Geomorphology:	GAI (Level IV) (Rowntree and Du Preez, in prep).
Vegetation:	VEGRAI (Kleynhans *et al.* 2008).
Macroinvertebrates:	MIRAI (Thirion 2008).

Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS), Recommended Ecological Category (REC) were determined for each site.

[1] Refer to Hughes and Hannart (2003) for the details of the model and its use.

PES is the current ecological condition (i.e., the extent to which it differs from its Reference or natural condition), whereas the REC considers the regional and national importance (EIS) of the system in a regional and national context, as well as other factors, such as protected-area status, and restorability (DWAF 2004).

Importance is assessed on a local and a national scale. Sensitivity refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. The combined EIS is used as a guideline for deciding on the REC (DWAF 1999) in that if the EIS is high then the REC may be higher than PES. The REC can be the same or higher than PES, but never lower (DWAF 1999).

The ecological categories used to characterise the different components at each site are (after Kleynhans 1999):

A = Unmodified, natural.
B = Largely natural with few modifications.
C = Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
D = Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E = The loss of natural habitat, biota and basic ecosystem functions are extensive.
F = Critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat.

4.1 Steenbras River

4.1.1 *River reach assessed*

The Steenbras EWR site (Figure 2.1) was used to represent the river between the lower Steenbras Dam and the estuary. In addition to the detailed PES assessment at the EWR site, the study team visited the river immediately downstream of the dam to estimate PES.

4.1.2 *Overall Present Ecological Status*

The PES of the Steenbras River was scored as 78.6%, which puts it into a B/C ecological category. The river is largely natural in terms of the species present but these occur at a reduced extent. The marginal zone was reduced in width and would have covered a greater portion of the channel bed in the absence of flow regulation. There were also more terrestrial species in the river corridor than expected under natural conditions. If there are no major disturbances in the catchment, the condition of the vegetation will probably remain stable. However, it is likely that the reduced protection offered to the river system means that both the resistance and resilience of the system has been compromised and that it is more vulnerable to perturbations such as fire or flooding than it would have been in its natural state.

The PES, EIS (DWAF 1999) and REC for the Steenbras River are summarised in Table 4.1.

Table 4.1 Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) for the Steenbras River

Component of the riverine ecosystem	PES		**EIS**	REC*
	Category	**Trajectory**		
Hydrology	E/F	Stable		
Geomorphology	B	Stable		
Riparian vegetation	B/C	Stable	*Moderate/high*.	**B/C**
Macroinvertebrates	A	Stable		
PRESENT ECOSTATUS	**B/C**	4.1.3 ***Stable***		

The PES of the Steenbras River increased from immediately downstream of the lower Steenbras Dam, where water quality problems were noticed but not quantified (Figure 4.1), to the EWR site. The average ecological category for the reach was a B/C.

The major factors contributing to the PES of the Steenbras River were:

- low water levels associated with the presence of the Steenbras dams;
- geomorphology that is highly resistant to flow changes;
- poor water quality immediately downstream of the dam;
- largely natural riparian and instream vegetation, which is reduced in extent;
- a largely natural macroinvertebrate community.

Additional detail is provided below.

Figure 4.1 A pool in the Steenbras River *c*. 40 m downstream of the lower Steenbras Dam, showing the poor water quality.

4.1.4 ***Hydrology***

The discharge at Steenbras EWR Site at the time of the site visit (i.e. 06.07.2009) was 0.076 m^3s^{-1} (i.e., considerably less than the average July discharge of 4.18 m^3s^{-1} expected under natural conditions and 0.15 m^3s^{-1} predicted for present day conditions) (Table 4.2).

4.1.5 ***Geomorphology***

The predominance of bedrock on the riverbed and banks means that the geomorphology is highly resistant to flow-driven change. Thus, despite the changes in hydrology, the Geomorphology PES is a B/C Category (Table 4.3). The reduction from natural is mostly related to the influence of the dams on sediment movement, both in terms of system connectivity (sediment movement downstream) and transport capacity.

Table 4.2 Simulated naturalised and present day monthly hydrological data for the Steenbras River

Period: 1928 - 2004					
Month	**Mean (MCM)**		**% Natural**	**nMean Q (m^3s^{-1})**	**PD Mean Q (m^3s^{-1})**
	Natural MAR	**Present Day MAR**			
October	4.0	0.1	2.5	1.49	0.04
November	2.1	0.0	0.0	0.81	0.00
December	1.5	0.0	0.0	0.56	0.00
January	1.0	0.0	0.0	0.37	0.00
February	0.8	0.0	0.0	0.33	0.00
March	0.9	0.0	0.0	0.34	0.00
April	2.0	0.0	0.0	0.77	0.00
May	4.4	0.0	0.0	1.64	0.00
June	8.5	0.2	2.4	3.28	0.08
July	11.2	0.4	3.6	4.18	0.15
August	11.7	0.5	4.3	4.37	0.19
September	6.9	0.2	2.9	2.66	0.08

Table 4.3 Results from the GAI Level IV assessment for the Steenbras River

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	Weighed score
System Connectivity	3.00	60.00	1.80	0.17	0.31
Sediment supply	2.00	70.00	0.72	0.20	0.14
Transport capacity (hydrology)	1.00	100.00	1.00	0.29	0.29
Perimeter resistance	4.00	50.00	0.61	0.14	0.09
Morphological change	3.00	70.00	0.70	0.20	0.14
TOTALS		350.00		1.00	0.96
System Driver status:					**0.96**
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					**80.71**
HABITAT DRIVER CATEGORY					**B**

4.1.6 ***Riparian vegetation***

The reach of the Steenbras River represented by the EWR site was historically dominated by Palmiet vegetation (Figure 4.2). Palmiet is an ecosystem engineer – it binds the sediment on the floor (valley bottoms and banks) of river channels. The base flows in the system have been severely curtailed by the upstream Steenbras Dam, since no lowflow releases are made from this structure, and it only overtops when high rainfall events occur when the reservoir is already full. The reduction in lowflows has resulted in reduced areas of Palmiet (the marginal vegetation) and allowed for more upland vegetation to encroach into the riparian and marginal areas along the channel. The encroaching vegetation may also shade the Palmiet, further reducing its vigor.

Figure 4.2 Riparian vegetation at the Steenbras River EWR Site

There was also some evidence of an accumulation of fines in the channel probably linked to the reduced flooding, but this probably ameliorated by: 1) trapping of sediments in the dam, and 2) flows from the two small tributaries downstream of the dam.

The riparian vegetation of the Steenbras River has a diversity of species but a vastly reduced aerial cover and abundance. *Prionium serratum* (palmiet) was the most prominent marginal zone species and occurred with the graminoids *Pennisetum macrourum, Juncus effusus* and *J. lomatophyllus;* the shrub *Erica caffra* (water heath); the restios *Calopsis paniculata* and *Elegia capensis;* and the forbs *Blechnum capense* and *Todea barbara.* *Metrosideros angustifolia* (Cape myrtle) was the most prominent non-marginal zone species and occurred with *Brabejum stellatifolium* (wild almond), *Brachylaena neriifolia* (water white alder), *Morella serrata* (lance-leaf waxberry), *Berzelia lanuginosa* (vleiknopbos) and *Diospyros glabra* (Fynbos star-apple). There was encroachment of some terrestrial Fynbos species, prominently *Cliffortia* spp., *Rhus gluaca* (blue kuni-bush) and *Pelargonium cucullatum* (wildemalva).

4.1.7 ***Invertebrates***

South African Scoring System version 5 (SASS5) protocols were followed for sampling aquatic macroinvertebrates (Dickens and Graham, 2002). The overall macroinvertebrate ecological category (EC) at the EWR site was an A. The Ephemeroptera, Trichoptera and Odonata group, the presence of which is indicative of good conditions, was well represented at the site. The sampled taxa were abundant, with an exception of Oligochaeta; Trichorythidae and Psephenidae, which were low in numbers (Table 4.4). The macroinvertebrate ecological category was, however, expected to decline significantly in summer months when flows are very low, water temperatures are higher (Saltveit *et al.* 1994), and there is increased utilisation of the river by the public.

Table 4.4 Macroinvertebrates sampled at Steenbras River

Taxon	Sensitivity score	Estimated abundance
ANNELIDA		
Oligochaeta (Earthworms)	1	A
EPHEMEROPTERA (Mayflies)		
Baetidae > 2 species	12	B
Tricorythidae	9	A
ODONATA (Dragonflies & Damselflies)		
Coenagrionidae	4	B
Gomphidae	6	B
Libellulidae	4	B
HEMIPTERA (Bugs)		
Corixidae*	3	B
TRICHOPTERA (Caddisflies)		
Hydropsychidae > 2 species	12	B
Barbarochthonidae	13	B
COLEOPTERA (Beetles)		
Psephenidae	10	A
SASS score		**74**
No. of taxa		**10**
Average Score Per Taxon (ASPT)		**7.4**
Estimated abundance: 1=1; A=2-10; B=10-100. * Air breathers		

4.2 Pombers River

4.2.1 *River reach assessed*

The Pombers River EWR site (Figure 2.1) was used to represent the river from about 300 m upstream of the agricultural activities associated with Doolhof Farm to the confluence with the Kromme River. The study team also visited the river at Gawie se Water on Bainskloof Pass.

The EWR reach was divided into two sub-reaches (1 and 2), based on the differences in agricultural activities on the banks (Figure 4.3).

Figure 4.3 The two sub-reaches of the Pombers River assessed in this study

4.2.2 ***Overall Present Ecological Status***

The overall PES of the Pombers River as represented by the EWR site was a D category. The upper sub-reach (sub-reach 1) was in a C category, while the lower sub-reach (sub-reach 2) was a D category (Figure 4.3; Table 4.5The difference was a result of agricultural activity on the banks.

Both sub-reaches were characterised by incised active channels; with sub-reach 2 (Figure 4.3) also impacted through infilling to create agricultural lands and introduced spoils in the active channel. Cobbles and gravels within the active channel were mobile and non-embedded in most places. There was extensive loss/removal of indigenous riparian flora. Some marginal vegetation was present but this was dominated by disturbance-triggered alien graminoids. There were some indigenous herbaceous species in the marginal zone but there were no indigenous woody species present in either the marginal and non-marginal zones. There were signs of recent clearing of *Acacia mearnsii* in the upper part of sub-reach 2, but the upper parts of sub-reach 1 (Figure 4.3) were still heavily infested. Nevertheless, it is likely that this was intermingled with indigenous species and thus the ecological condition was probably slightly better in sub-reach 2 than in sub-reach 2 where many of the natural features of the river had been destroyed.

The PES, EIS and REC for the Pombers River are summarised in Table 4.5.

Table 4.5 Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) for the Pombers River

Component of the riverine ecosystem	PES		EIS	REC*
	Category	Trajectory		
Hydrology	E/F	Stable	*Moderate*	**C**
Geomorphology	B	Negative		
Riparian vegetation	E	Negative		
Macroinvertebrates	B	Stable		
PRESENT ECOSTATUS	**D**	**Negative**		

The major factors contributing to the PES of the Pombers River were:

- incision of the river channel (flow related);
- bank erosion;
- infilling to create agricultural lands;
- invasion by alien plants;
- largely natural macroinvertebrates community.

Additional detail is provided below.

Hydrology

The present day flows in the Pombers River are considerably higher than they would have been naturally (Table 4.6).

Geomorphology

The lower sub-reach (sub-reach 2) had a GAI EC of a D (Table 4.7); whilst the reach upstream (sub-reach 1 in Figure 4.3) was estimated as a C. The elevated baseflows associated with the Gawie-se-Water diversion have incised the active channel (Table 4.8) and destabilized the banks, although poor management of the riparian zone has exacerbated the effects. So much so that re-establishment of indigenous riparian vegetation in this river would require extensive channel re-modification.

Table 4.6 Simulated naturalised and present day monthly hydrological data for the Pombers River

Period: 1928 - 2004					
Month	**Mean (MCM)**		**% Natural**	**nMean Q (m^3s^{-1})**	**PD Mean Q (m^3s^{-1})**
	Natural MAR	**Present Day MAR**			
October	0.1	0.5	500	0.04	0.19
November	0.1	0.5	500	0.04	0.19
December	0.0	0.4	-	0.00	0.15
January	0.0	0.4	-	0.00	0.15
February	0.0	0.4	-	0.00	0.17
March	0.0	0.4	-	0.00	0.15
April	0.0	0.5	-	0.00	0.19
May	0.1	0.5	500	0.04	0.19
June	0.2	0.6	300	0.08	0.23
July	0.3	0.7	233	0.11	0.26
August	0.3	0.8	267	0.11	0.30
September	0.2	0.6	300	0.08	0.23

Table 4.7 Results from the GAI Level IV assessment for the Pombers River

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	Weighed score
System Connectivity	3.00	80.00	3.04	0.21	0.64
Sediment supply	2.00	90.00	2.37	0.24	0.56
Transport capacity (hydrology)	1.00	100.00	2.29	0.26	0.60
Perimeter resistance	4.00	60.00	1.30	0.16	0.21
Morphological change	5.00	50.00	5.01	0.13	0.66
TOTALS		380.00		1.00	2.67
System Driver status:					**2.67**
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					**46.63**
HABITAT DRIVER CATEGORY					**D**

Table 4.8 The downstream (sub-reach 2) of the Pombers River assessed in this study showing incision of the channel and some infilling from agricultural fields. The inset shows the mobile cobbles on the bed.

Riparian vegetation

The area upstream of the site (sub-reach 1) was highly infested with *Acacia mearnsii*. The flora in sub-reach 2 (Figure 4.4) was typical of recently cleared areas with predominantly disturbance-triggered alien graminoids and shrubs. The graminoids *Avena* spp., *Bromus* spp., *Erharta* spp., *Pentashistis* spp., *Briza* spp., *Cynodon dactylon* and *Paspalum urvillei* were prominent in the marginal zone along with *Phytolacca*

americana (American pokeweed) and *Rubus fruticosus* (blackberry). There were a number of indigenous marginal zones species including the sedges *Juncus lomatophyllus* and *J. capensis* and the graminoids *Ehrharta ramosa* and *E., setacea*. The non-marginal zone was disturbed and dominated by the same graminoids, and *Pennisetum clandestinum* (kikuyu), *Conyza* spp., *Solanum nigrum* (European black nightshade)*, Rubus fruticosus* and *Acacia mearnsii* seedlings.

Macroinvertebrates

The macroinvertebrates were not sampled in the Pombers River EWR site, but based on the results from the Kromme River EWR site (Table 4.9) and an assessment of available habitats (Brooks *et al*. 2005) in the Pombers (sub-reach 2), they are expected to be in a B category, i.e., good.

Figure 4.4 Riparian vegetation on the Pombers River (sub-reach 2)

4.3 Kromme (Krom) River

4.3.1 *River reach assessed*

The EWR site on the Kromme River was *c*. 250 m below the confluence with the Pombers River on the Doolhof Farm (Figure 2.2). The site has been subjected to the same elevated baseflows as the Pombers site, and was characterised by a deeply-incised active channel; eroding banks; encroachment and infilling from agriculture; and introduced spoils. Cobbles and gravels within the active channel were embedded or smothered by fines sediments (Figure 4.5).

4.3.2 *Overall Present Ecological Status*

The overall PES of the Kromme River was a D/E category (Table 4.9). The channel was deeply incised and heavily invaded with *Populus* X *canesccens* (grey poplar), *A. mearnsii, Arundo donax* (Spanish reed) and *Qeurcus robur* (English oak), many herbaceous garden escapees and some citrus trees. There were no marginal zone species present, partly due to shading by the closed alien canopy. There were some *Ilex mitis* (Cape Holly) individuals scattered through the marginal zone, these being the only remnants of the indigenous riparian flora.

Figure 4.5 The reach of the Kromme River assessed in this study showing incision of the channel. The inset shows the embedded cobbles on the bed, which have been smothered by the fines introduced from the eroding banks.

Table 4.9 Present Ecological Category (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) for the Kromme River

Component of the riverine ecosystem	PES		EIS	REC*
	Category	Trajectory		
Hydrology	E/F	Negative	*Moderate*	**D**
Geomorphology	D/E	Negative		
Riparian vegetation	F	Negative		
Macroinvertebrates	B/C	Negative		
PRESENT ECOSTATUS	**D/E**	**Negative**		

The major factors contributing to the Present Ecological Category of the Kromme River were:

- incision of the river channel (flow related);
- bank erosion;
- infilling to create agricultural lands;
- invasion by alien plant species;
- largely natural macroinvertebrates community.

Additional detail is provided below.

Hydrology

The discharge at Kromme River EWR Site at the time of the site visit (i.e. 06.07.2009) was 0.42 m^3s^{-1} (i.e., similar to the average July discharge of 0.41 m^3s^{-1} expected under present day conditions but almost double the 0.26 m^3s^{-1} expected under natural conditions) (Table 4.10).

Table 4.10 Simulated naturalised and present day monthly hydrological data for the Kromme River

Period: 1928 – 2004					
Month	**Mean (MCM)**		**% Natural**	**nMean Q (m^3s^{-1})**	**PD Mean Q (m^3s^{-1})**
	Natural MAR	**Present Day MAR**			
October	0.3	0.7	233.3	0.11	0.26
November	0.2	0.6	300.0	0.08	0.23
December	0.1	0.5	500.0	0.04	0.19
January	0.0	0.4	-	0.00	0.15
February	0.0	0.4	-	0.00	0.17
March	0.0	0.4	-	0.00	0.15
April	0.1	0.4	400.0	0.04	0.15
May	0.3	0.5	166.7	0.11	0.19
June	0.5	1.0	200.0	0.19	0.39
July	0.7	1.1	157.1	0.26	0.41
August	0.8	1.2	150.0	0.30	0.45
September	0.5	0.9	180.0	0.19	0.35

Geomorphology

The geomorphological PES at Kromme River EWR site was a D/E category (Table 4.11). The deeply incised channel prevented most floods from overtopping on to the old floodplain areas; and the eroding banks had completely changed the bed sediment characteristics.

Table 4.11 Results from the GAI Level IV assessment for the Kromme River

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	Weighed score
System Connectivity	3.00	80.00	3.61	0.21	0.76
Sediment supply	2.00	90.00	2.71	0.24	0.64
Transport capacity (hydrology)	1.00	100.00	2.29	0.26	0.60
Perimeter resistance	4.00	60.00	2.26	0.16	0.36
Morphological change	5.00	50.00	5.48	0.13	0.72
TOTALS		380.00		1.00	3.08
System Driver status:					**3.08**
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					**38.37**
HABITAT DRIVER CATEGORY					**E**

Riparian vegetation

The Kromme VEGRAI score is 10.0, an indication of critically modified system condition and hence ecological category F. There was almost a complete loss of indigenous riparian flora except for some isolated and stunted *Ilex mitis* (Cape holly) trees. There were no marginal zone species present. Downstream of the EWR site, and the proposed Doolhof Dam, the riparian zone was infested with various woody and non-woody alien species.

Macroinvertebrates

The overall macroinvertebrate ecological category (EC) was a B/C. All the taxa were in low abundances, with some such as Crustacea, Plecoptera and Megaloptera represented by only a single individual (Table 4.12).

Table 4.12 Macroinvertebrates sampled at Kromme River.

Taxon	Sensitivity score	Estimated abundance
CRUSTACEA		
Potamonautidae*	3	1
PLECOPTERA (Stoneflies)		
Notonemouridae	14	1
EPHEMEROPTERA (Mayflies)		
Baetidae 2 species	6	A
ODONATA (Dragonflies & Damselflies)		
Gomphidae	6	A
Libellulidae	4	A
HEMIPTERA (Bugs)		
Naucoridae*	7	A
Notonectidae*	3	A
MEGALOPTERA (Dobsonflies)		
Corydalidae	8	1
TRICHOPTERA (Caddisflies)		
Barbarochthonidae	13	A
DIPTERA (Flies)		
Simulidae	5	A
SASS score		**69**
No. of taxa		**10**
Average Score Per Taxon (ASPT)		**6.9**
Estimated abundance: 1=1; A=2-10; B=10-100. * Air breathers		

4.4 Summary of Ecological Conditions

The estimated ecological conditions of the different components of the rivers at each EWR site are provided in Table 4.13.

Table 4.13 Ecological Categories (ECs) of the different components of the river at each EWR site

River	Hydrology	Geomorphology /Floodplain (GAI)	Riparian vegetation (VEGRAI)	Macroinvertebrates (MIRAI)	Overall		Recommended EC for Ecological Reserve	Alternative EC
Steenbras River	E/F	B/C	B/C	A	B/C		B/C	None
Pombers River (Sub-reach 1)	*E/F	*C	*D	*B	*C	D	C	None
Pombers River (Sub-reach 2)	E/F	D	E	*B	D			
Kromme River	E/F	D/E	F	B/C	D/E		D	None

*Visited by specialists but no detailed data collected, ECs were estimated based on specialists' observation.

Explanation for Alternative Ecological Categories (AEC)

Steenbras River: No AEC assessed because the present condition can probably be maintained with fairly low EWRs.

Pombers River: No AEC because the releases from the Wit River are likely to prevent a higher ecological category from being attained.

Kromme River: No AEC because the releases from the Wit River are likely to prevent a higher ecological category from being attained.

5 EWR RESULTS

Mr Anton Sparks of Aurecon provided the monthly hydrological data (i.e. natural and present day hydrology) used in this report. The length of the simulated records was 76 years, 1928 to 2004. A summary of natural and present day volumes at the proposed development sites is given in Table 5.1.

Table 5.1 Summary hydrology at proposed development sites

River	Natural (MCM)	Present Day (MCM)	% Natural	Comment
Steenbras River				
Below lower Steenbras dam wall	54.9	1.7	3.1	Seepage through left flank may provide some baseflow
Pombers River				
Upstream of the Kromme and Pombers Confluence	1.5	6.4	426.7	Flow from Gawie se water may have a more seasonal distribution than the 0.41 Mm^3/month assumed
Kromme River				
Downstream of the Kromme and Pombers Confluence	3.6	8.5	236.1	-

5.1 Streenbras River

Reserve to be met at Steenbras (lower) Dam Wall.

An EWR was determined for a B/C Ecological Category. The summary hydrology, rule tables and flood requirements for the Steenbras River are provided in Table 5.2 – Table 5.4 respectively.

Recommended Ecological Category (REC): B/C.

Table 5.2 Summary hydrology table for B/C category EWRs for the Steenbras River EWR Site

Desktop Version 2, Generated on 2009/07/09
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area:
Total Runoff : R002.NATG4R00

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

MAR	=	54.876
S.Dev.	=	18.443
CV	=	0.336
Q75	=	0.930
Q75/MMF	=	0.203
BFI Index	=	0.397
CV(JJA+JFM) Index	=	1.527

Ecological Category = B/C

Total IFR	=	7.404 (13.49 %MAR)
Maint. Lowflow	=	6.073 (11.07 %MAR)
Drought Lowflow	=	4.095 (7.46 %MAR)
Maint. Highflow	=	1.331 (2.42 %MAR)

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

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	4.030	3.196	0.793	0.673	0.440	0.000	0.673
Nov	2.136	1.330	0.623	0.509	0.345	0.000	0.509
Dec	1.488	1.203	0.809	0.370	0.253	0.000	0.370
Jan	1.018	1.032	1.013	0.284	0.196	0.000	0.284
Feb	0.773	0.448	0.579	0.235	0.164	0.000	0.235
Mar	0.864	0.813	0.941	0.227	0.150	0.000	0.227
Apr	1.972	2.103	1.066	0.273	0.189	0.000	0.273
May	4.352	4.180	0.960	0.390	0.266	0.121	0.511
Jun	8.480	7.360	0.868	0.605	0.408	0.121	0.726
Jul	11.189	6.818	0.609	0.798	0.535	0.484	1.281
Aug	11.715	6.676	0.570	0.918	0.615	0.484	1.402
Sep	6.861	4.713	0.687	0.792	0.532	0.121	0.913

Table 5.3 Rule tables for B/C category EWRs for the Steenbras River EWR Site

Desktop Version 2, Generated on 28/01/2010
Summary of IFR rule curves (Desktop Version 2) for:
Total Runoff: R002.NATG4R00
Regional Type: W.Cape(wet)
Ecological Category = B/C
Data are given in m^3 * 10^6 monthly flow volume

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.839	0.839	0.836	0.828	0.811	0.777	0.717	0.625	0.514	0.442
Nov	0.634	0.634	0.632	0.626	0.614	0.589	0.546	0.479	0.399	0.347
Dec	0.458	0.458	0.455	0.450	0.437	0.412	0.373	0.322	0.276	0.255
Jan	0.351	0.351	0.349	0.345	0.335	0.316	0.287	0.248	0.213	0.197
Feb	0.290	0.290	0.289	0.285	0.277	0.262	0.238	0.207	0.178	0.165
Mar	0.282	0.282	0.281	0.279	0.273	0.262	0.242	0.211	0.175	0.151
Apr	0.340	0.340	0.339	0.336	0.329	0.317	0.294	0.259	0.217	0.190
May	0.621	0.621	0.618	0.611	0.597	0.568	0.516	0.437	0.342	0.281
Jun	0.896	0.896	0.893	0.887	0.874	0.849	0.800	0.713	0.570	0.424
Jul	1.863	1.773	1.691	1.615	1.539	1.393	1.302	1.137	0.867	0.589
Aug	2.015	1.925	1.842	1.765	1.688	1.538	1.439	1.260	0.969	0.670
Sep	1.222	1.192	1.162	1.131	1.092	1.020	0.935	0.805	0.649	0.548

Reserve Flows without High Flows										
Oct	0.839	0.839	0.836	0.828	0.811	0.777	0.717	0.625	0.514	0.442
Nov	0.634	0.634	0.632	0.626	0.614	0.589	0.546	0.479	0.399	0.347
Dec	0.458	0.458	0.455	0.450	0.437	0.412	0.373	0.322	0.276	0.255
Jan	0.351	0.351	0.349	0.345	0.335	0.316	0.287	0.248	0.213	0.197
Feb	0.290	0.290	0.289	0.285	0.277	0.262	0.238	0.207	0.178	0.165
Mar	0.282	0.282	0.281	0.279	0.273	0.262	0.242	0.211	0.175	0.151
Apr	0.340	0.340	0.339	0.336	0.329	0.317	0.294	0.259	0.217	0.190
May	0.486	0.486	0.484	0.479	0.470	0.452	0.419	0.368	0.307	0.268
Jun	0.760	0.760	0.758	0.753	0.744	0.725	0.689	0.625	0.519	0.411
Jul	1.002	1.002	0.999	0.993	0.980	0.955	0.908	0.822	0.682	0.538
Aug	1.154	1.154	1.150	1.143	1.128	1.100	1.045	0.946	0.784	0.618
Sep	0.987	0.987	0.983	0.974	0.955	0.916	0.848	0.743	0.616	0.535
Natural Duration curves										
Oct	9.140	6.550	4.550	2.730	2.510	2.300	2.200	2.110	1.960	0.840
Nov	3.400	2.450	2.030	1.930	1.760	1.710	1.620	1.470	1.330	0.740
Dec	2.400	1.490	1.310	1.210	1.160	1.070	1.010	0.960	0.910	0.640
Jan	1.890	1.130	0.900	0.830	0.770	0.740	0.700	0.630	0.570	0.530
Feb	1.090	0.990	0.850	0.710	0.620	0.580	0.540	0.510	0.460	0.380
Mar	1.550	0.960	0.820	0.690	0.640	0.590	0.510	0.440	0.430	0.340
Apr	4.420	3.620	2.200	1.550	1.150	0.990	0.770	0.630	0.480	0.380
May	9.310	6.750	4.360	3.590	3.130	2.170	1.810	1.420	1.020	0.670
Jun	19.100	14.200	10.300	9.270	6.390	4.300	2.780	2.140	1.670	0.850
Jul	20.690	15.340	14.400	12.190	10.850	8.570	7.280	5.420	2.780	1.750
Aug	19.970	16.750	13.970	12.490	10.820	9.970	7.840	5.970	4.630	2.430
Sep	13.220	11.640	9.040	6.990	5.500	4.560	3.120	2.470	2.310	1.410

Table 5.4 Flood requirements (Steenbras River)

Month	Peak daily Q (m^3s^{-1})	Duration (Days)	Volume (MCM)	%MAR
October	0.000	0	0.000	0.000
November	0.000	0	0.000	0.000
December	0.000	0	0.000	0.000
January	0.000	0	0.000	0.000
February	0.000	0	0.000	0.000
March	0.000	0	0.000	0.000
April	0.000	0	0.000	0.000
May	1.000	2	0.121	0.220
June	1.000	2	0.121	0.220
July	4.000	2	0.484	0.880
August	4.000	2	0.484	0.880
September	1.000	2	0.121	0.220

5.1.1 *Motivation for the Steenbras EWR and suggestions for improved management of the river ecosystem*

The changes that have occurred in the Steenbras River are a result of the presence of the dam and resultant changes to the flow regime. Although the system is in fairly good ecological condition, implementing EWR releases can reduce the risk of a further and possibly dramatic drop in condition.

The site currently receives about 2.5% of the MAR, with no summer base flows and dampened winter floods (1.4 MCM of an estimated natural MAR of 55 MCM). The recommended EWR is 13.49% of MAR. In recognition of the resilient morphology of the Steenbras River downstream of the dam, no channel forming or maintenance floods have been requested, although five small intra-annual floods have been requested to maintain and improve the low bars and lower flood zone of the channel, and improve the vegetation and bank stability of the active channel. The summer base flows and Class 1 and 2 floods will also stimulate the reestablishment of the marginal vegetation in parts of the channel.

There is an urgency to investigate and remedy the water quality immediately downstream of the lower Steenbras dam wall (See Figure 4.1).

Benefits of improved flows:

- Protect riparian vegetation from desiccation and thus also from future fire damage.
- Very high socio-economic (tourism) use in summer – the baseflows will improve recreation options and ensure adequate water quality in the river.

5.2 Pombers EWR Site

Reserve to be met at: Doolhof Farm above the confluence with the Kromme River.

EWRs were determined for a C Ecological Category. The summary hydrology, rule tables and flood requirements for the Pombers River are provided in Table **5.5** – Table 5.7, respectively.

Recommended Ecological Category: C

Table 5.5 Summary hydrology table for C -category EWRs for the Pombers River EWR Site

Desktop Version 2, Generated on 2009/07/09
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area:
Total Runoff: Pombers

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

MAR	=	1.518
S.Dev.	=	0.682
CV	=	0.449
Q75	=	0.010
Q75/MMF	=	0.079
BFI Index	=	0.355
CV(JJA+JFM) Index	=	1.927

Ecological Category = C

Total IFR	=	0.331 (21.82 %MAR)
Maint. Lowflow	=	0.188 (12.40 %MAR)
Drought Lowflow	=	0.185 (12.18 %MAR)
Maint. Highflow	=	0.143 (9.42 %MAR)

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

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.118	0.033	0.280	0.024	0.024	0.008	0.032
Nov	0.065	0.021	0.322	0.019	0.018	0.002	0.020
Dec	0.030	0.016	0.515	0.010	0.011	0.000	0.010
Jan	0.013	0.010	0.739	0.005	0.005	0.000	0.005
Feb	0.010	0.014	1.413	0.004	0.002	0.000	0.004
Mar	0.016	0.016	1.043	0.004	0.003	0.000	0.004
Apr	0.043	0.058	1.355	0.006	0.005	0.000	0.006
May	0.136	0.169	1.246	0.012	0.011	0.018	0.030
Jun	0.230	0.228	0.992	0.019	0.018	0.031	0.050
Jul	0.312	0.260	0.833	0.027	0.027	0.015	0.042
Aug	0.342	0.260	0.761	0.032	0.032	0.054	0.086
Sep	0.204	0.124	0.610	0.028	0.029	0.015	0.043

Table 5.6 Rule tables for C-category EWRs for the Pombers River EWR Site

Desktop Version 2, Generated on 28/01/2010
Summary of IFR rule curves (Desktop Version 2) for:
Total Runoff: Pombe
Regional Type: W.Cape(wet)
Ecological Category = C
Data are given in m^3 * 10^6 monthly flow volume

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.044	0.044	0.043	0.043	0.042	0.041	0.038	0.034	0.028	0.025
Nov	0.028	0.028	0.028	0.028	0.027	0.027	0.025	0.023	0.020	0.018
Dec	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.012	0.011	0.010
Jan	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.005
Feb	0.005	0.005	0.005	0.005	0.005	0.004	0.000	0.000	0.000	0.000
Mar	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.003	0.000
Apr	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.006	0.006	0.005
May	0.038	0.038	0.038	0.037	0.036	0.034	0.030	0.024	0.017	0.010
Jun	0.065	0.065	0.064	0.064	0.063	0.060	0.056	0.048	0.035	0.020
Jul	0.065	0.063	0.060	0.058	0.055	0.051	0.048	0.044	0.036	0.028
Aug	0.142	0.132	0.123	0.116	0.108	0.094	0.088	0.076	0.057	0.038
Sep	0.069	0.065	0.061	0.059	0.056	0.050	0.047	0.041	0.035	0.030
Reserve Flows without High Flows										
Oct	0.034	0.034	0.034	0.033	0.033	0.032	0.031	0.029	0.026	0.024
Nov	0.026	0.026	0.026	0.026	0.026	0.025	0.024	0.022	0.020	0.018
Dec	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.012	0.011	0.010
Jan	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.005
Feb	0.005	0.005	0.005	0.005	0.005	0.004	0.000	0.000	0.000	0.000
Mar	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.003	0.000
Apr	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.006	0.006	0.005
May	0.016	0.016	0.016	0.016	0.016	0.015	0.014	0.013	0.012	0.010
Jun	0.027	0.027	0.027	0.027	0.027	0.026	0.025	0.024	0.021	0.018
Jul	0.038	0.038	0.038	0.038	0.038	0.037	0.036	0.034	0.030	0.027
Aug	0.047	0.047	0.046	0.046	0.046	0.045	0.044	0.041	0.037	0.032
Sep	0.039	0.039	0.039	0.039	0.038	0.038	0.036	0.033	0.030	0.029
Natural Duration curves										
Oct	0.160	0.140	0.130	0.120	0.120	0.110	0.100	0.090	0.080	0.050
Nov	0.090	0.080	0.070	0.070	0.060	0.060	0.050	0.050	0.040	0.030
Dec	0.050	0.040	0.030	0.030	0.030	0.030	0.020	0.020	0.020	0.010
Jan	0.020	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Feb	0.020	0.010	0.010	0.010	0.010	0.010	0.000	0.000	0.000	0.000
Mar	0.030	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.000
Apr	0.100	0.070	0.040	0.030	0.020	0.010	0.010	0.010	0.010	0.010
May	0.340	0.200	0.150	0.120	0.080	0.070	0.040	0.030	0.020	0.010
Jun	0.640	0.380	0.250	0.190	0.160	0.140	0.090	0.060	0.050	0.020
Jul	0.730	0.480	0.390	0.280	0.230	0.160	0.130	0.110	0.090	0.040
Aug	0.720	0.520	0.400	0.310	0.260	0.220	0.170	0.150	0.130	0.100
Sep	0.400	0.240	0.180	0.160	0.160	0.150	0.140	0.140	0.130	0.080

Table 5.7 Flood requirements for the Pombers River

Month	Peak daily Q (m^3s^{-1})	Duration (Days)	Volume (MCM)	%MAR
October	0.069	2	0.008	0.550
November	0.013	2	0.002	0.100
December	0.000	0	0.000	0.000
January	0.000	0	0.000	0.000
February	0.000	0	0.000	0.000
March	0.000	0	0.000	0.000
April	0.000	0	0.000	0.000
May	0.150	2	0.018	1.200
June	0.254	2	0.031	2.030
July	0.125	2	0.015	1.000
August	0.445	2	0.054	3.550
September	0.125	2	0.015	1.000

5.2.1 *Motivation for the Pombers EWR and suggestions for improved management of the river ecosystem*

The proposed increased flows (10 MCM) during winter months would cause further incision of the channel within sub-reach 1 while sub-reach 2 is likely to be flooded significantly by the proposed reservoir. It should be noted that it was assumed that the winter months are May – October. Since the stream is not strongly perennial, floods were not considered in this option although 800% more water will be added to the river. Also, floods were not considered because there is no plan to place any dam on the Pombers River, so the floods will still come through anyway.

As far as the recommendations for ecological water requirements are concerned, no big floods are required to maintain this river reach, since any floods would only serve to further accelerate the erosion of the active channel currently happening as a result of the highly elevated base flows. The planned releases are going to increase flows higher than would have been motivated for EWRs. Therefore, from ecological point of view, there is no compelling reason to motivate for such a proposed reserve.

5.3 Kromme EWR Site

Reserve to be met at: Doolhof Farm below the confluence with the Pombers River.

EWRs have been determined (using the calibrated desktop), for a D Ecological Category. The summary hydrology, rule tables and flood requirements for the Kromme River are provided in Table 5.8 – Table 5.10 respectively.

Recommended Ecological Category (REC): D.

Table 5.8 Summary hydrology table for D-category EWR for the Kromme River EWR Site

Desktop Version 2, Generated on 2009/07/09
Summary of Desktop (Version 2) estimate for Quaternary Catchment Area:
Total Runoff: KromP

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

MAR	=	3.557
S.Dev.	=	1.602
CV	=	0.450
Q75	=	0.030
Q75/MMF	=	0.101
BFI Index	=	0.354
CV(JJA+JFM) Index	=	1.977

Ecological Category = D

Total IFR	=	0.505 (14.19 %MAR)
Maint. Lowflow	=	0.216 (6.07 %MAR)
Drought Lowflow	=	0.216 (6.06 %MAR)
Maint. Highflow	=	0.289 (8.12 %MAR)

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

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.277	0.076	0.275	0.028	0.028	0.017	0.044
Nov	0.152	0.048	0.319	0.021	0.021	0.003	0.025
Dec	0.070	0.037	0.530	0.012	0.012	0.000	0.012
Jan	0.030	0.024	0.784	0.006	0.006	0.000	0.006
Feb	0.023	0.030	1.323	0.004	0.005	0.000	0.004
Mar	0.032	0.039	1.240	0.005	0.005	0.000	0.005
Apr	0.100	0.136	1.365	0.007	0.007	0.000	0.007
May	0.320	0.398	1.244	0.013	0.013	0.037	0.050
Jun	0.541	0.535	0.990	0.022	0.020	0.062	0.084
Jul	0.734	0.611	0.833	0.030	0.030	0.031	0.061
Aug	0.802	0.612	0.762	0.036	0.036	0.109	0.145
Sep	0.478	0.292	0.612	0.032	0.032	0.031	0.062

Table 5.9 Rule tables for D -category EWRs for the Kromme River EWR Site

Desktop Version 2, Generated on 28/01/2010
Summary of IFR rule curves (Desktop Version 2) for:
Total Runoff: KromP
Regional Type: W.Cape(wet)
Ecological Category = D
Data are given in m^3 * 10^6 monthly flow volume

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.080	0.080	0.079	0.078	0.076	0.072	0.064	0.053	0.039	0.030
Nov	0.047	0.047	0.047	0.047	0.046	0.043	0.040	0.034	0.027	0.022
Dec	0.022	0.022	0.022	0.022	0.021	0.020	0.018	0.015	0.013	0.012
Jan	0.011	0.011	0.011	0.011	0.011	0.010	0.009	0.008	0.007	0.006
Feb	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.006	0.005	0.000
Mar	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.007	0.006	0.005
Apr	0.013	0.013	0.013	0.013	0.013	0.012	0.011	0.010	0.008	0.007
May	0.082	0.082	0.081	0.080	0.077	0.072	0.062	0.047	0.029	0.017
Jun	0.146	0.146	0.146	0.144	0.141	0.134	0.122	0.100	0.064	0.027
Jul	0.121	0.115	0.110	0.105	0.100	0.090	0.084	0.072	0.053	0.034
Aug	0.273	0.253	0.235	0.219	0.204	0.174	0.160	0.134	0.092	0.048
Sep	0.123	0.115	0.108	0.102	0.096	0.085	0.076	0.062	0.046	0.035

Reserve Flows without High Flows										
Oct	0.055	0.055	0.055	0.054	0.053	0.051	0.047	0.040	0.033	0.028
Nov	0.043	0.043	0.043	0.042	0.041	0.039	0.036	0.031	0.025	0.022
Dec	0.022	0.022	0.022	0.022	0.021	0.020	0.018	0.015	0.013	0.012
Jan	0.011	0.011	0.011	0.011	0.011	0.010	0.009	0.008	0.007	0.006
Feb	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.006	0.005	0.000
Mar	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.007	0.006	0.005
Apr	0.013	0.013	0.013	0.013	0.013	0.012	0.011	0.010	0.008	0.007
May	0.027	0.027	0.026	0.026	0.026	0.025	0.023	0.019	0.016	0.013
Jun	0.047	0.047	0.047	0.047	0.046	0.044	0.042	0.037	0.029	0.020
Jul	0.066	0.066	0.066	0.066	0.065	0.063	0.059	0.052	0.042	0.030
Aug	0.080	0.080	0.080	0.079	0.078	0.076	0.071	0.063	0.050	0.037
Sep	0.063	0.063	0.063	0.063	0.061	0.058	0.054	0.046	0.038	0.032
Natural Duration curves										
Oct	0.380	0.330	0.300	0.280	0.270	0.250	0.240	0.210	0.200	0.120
Nov	0.220	0.200	0.170	0.160	0.150	0.140	0.120	0.110	0.100	0.080
Dec	0.110	0.080	0.080	0.070	0.060	0.060	0.050	0.040	0.040	0.030
Jan	0.050	0.030	0.030	0.030	0.030	0.020	0.020	0.020	0.010	0.010
Feb	0.050	0.030	0.020	0.010	0.010	0.010	0.010	0.010	0.010	0.000
Mar	0.060	0.030	0.030	0.020	0.020	0.020	0.010	0.010	0.010	0.010
Apr	0.230	0.160	0.090	0.060	0.040	0.030	0.030	0.020	0.020	0.010
May	0.800	0.460	0.350	0.280	0.200	0.160	0.080	0.070	0.040	0.020
Jun	1.490	0.900	0.590	0.450	0.380	0.320	0.200	0.150	0.110	0.050
Jul	1.730	1.120	0.920	0.670	0.550	0.370	0.310	0.270	0.220	0.090
Aug	1.690	1.230	0.930	0.730	0.610	0.510	0.410	0.360	0.300	0.240
Sep	0.950	0.560	0.420	0.390	0.370	0.350	0.330	0.320	0.290	0.200

Table 5.10 Flood requirements for the Kromme River

Month	Peak daily Q (m^3s^{-1})	Duration (Days)	Volume (MCM)	%MAR
October	0.138	2	0.017	0.470
November	0.026	2	0.003	0.090
December	0.000	0	0.000	0.000
January	0.000	0	0.000	0.000
February	0.000	0	0.000	0.000
March	0.000	0	0.000	0.000
April	0.000	0	0.000	0.000
May	0.305	2	0.037	1.040
June	0.515	2	0.062	1.750
July	0.253	2	0.031	0.860
August	0.898	2	0.109	3.060
September	0.253	2	0.031	0.860

5.3.1 *Motivation for the Kromme EWR and suggestions for improved management of the river ecosystem*

The Kromme River has been channelised for many kilometres and it is unlikely that this could be remedied by simply changing the flow patterns in the river. Restoration would require extensive re-engineering of the banks and reclamation of adjacent farmlands (and riparian re-vegetation), combined with flow restoration. The cost and scale of which was not considered to be feasible.

5.4 Summary results

The EWR results are summarised in Table 5.11.

Table 5.11 EWR summary results for the Steenbras, Pombers and Kromme Rivers

River	REC	nMAR/a (MCM)	Total EWR (MCM)
Steenbras	B/C	54.876	7.404 (13.49 %nMAR)
Pombers	C	1.518	0.331 (21.82 %nMAR)

Kromme	D	3.557	0.505 (14.19 %nMAR)

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7 ADDENDA

Addendum 1 Plant species identified at each River EWR site

RIVER	Marginal zone	Non-marginal zone
Steenbras	*Prionium serratum*	*Metrosideros angustifolia*
	Pennisetum macrourum	*Brabejum stellatifolium*
	Calopsis paniculata	*Brachylaena neriifolia*
	Erica caffra	*Erica caffra*
	Elegia capensis	*Prionium serratum*
	Zantedeschia aethiopica	*Dispyros glabra*
	Pelargonium cucullatum	*Dodonea viscosa*
	Metrosideros angustifolia (sapling)	*Berzelia lanuginosa*
	Blechnum capense	*Cliffortia species*
	Todea Barbara	*Oftia africana*
	Juncus effuses	*Rhus glauca*
	Juncus lomatophyllus	*Morella serrata*
	Ischyrolepis subverticillata	
Pombers	*Phytolacca Americana*	*Conyza bonariensis*
	Erharta spp.	*Conyza canadensis*
	Paspalum urvillei	*Pennisetum clandestinum*
	Juncus lomatophyllus	*Rubus fruticosus*
	Pentashistis spp.	*Acacia mearnsii* (sapling)
	Avena spp.	*Acacia mearnsii*
	Briza spp.	*Pentashistis* spp.
	Bromus spp.	*Avena* spp.
	Cynodon dactylon	*Briza* spp.
	Rubus fruticosus	*Bromus* spp.
	Ehrharta setacea	*Cynodon dactylon*
	Ehrharta ramose	*Solanum nigrum*
	Juncus capensis	
Kromme	Garden escapees	*Populus X canescens*
	Arundo donax	*Acacia mearnsii*
	Zantedeschia aethiopica	*Arundo donax*
	Paspalum urvillei	*Solanum mauritianum*
	Acacia mearnsii (sapling)	*Quercus robur*
		Ilex mitis

Addendum 2 Steenbras River: GAI Model

FINAL DRIVER STATUS GEOMORPHOLOGY								
SCORING GUIDELINES								
GEOMORPHOLOGY DRIVERS								
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	Weighed score	flow related (event hydrology; high flows, floods)	CONFIDENCE	
System Connectivity	3.00	60.00	1.80	0.17	0.31	0.00	3.00	
Sediment supply	2.00	70.00	0.72	0.20	0.14	0.00	3.00	
Transport capacity (hydrology)	1.00	100.00	1.00	0.29	0.29	100.00	4.00	
Perimeter resistance	4.00	50.00	0.61	0.14	0.09	0.00	3.53	
Morphological change	3.00	70.00	0.70	0.20	0.14	0.00	3.00	
TOTALS		350.00		1.00	0.96			
System Driver status:					0.96			
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					80.71			
HABITAT DRIVER CATEGORY					B			3.36
		FLOW RELATED (%)			29.62			

This model (GAI level IV) is designed for specialist use by trained, experienced geomorphologists, for the purposes of determining the PES and geomorphic drivers of monitoring sites. Although the data/information driving this model will assist in Reserve studies, additional ESSENTIAL data are required for flow determinations.

Addendum 3 Pombers River: GAI Model

FINAL DRIVER STATUS GEOMORPHOLOGY								
SCORING GUIDELINES								
GEOMORPHOLOGY DRIVERS								
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	Weighed score	flow related (event hydrology; high flows, floods)	CONFIDENCE	
System Connectivity	3.00	80.00	3.04	0.21	0.64	0.00	3.00	
Sediment supply	2.00	90.00	2.37	0.24	0.56	0.00	3.00	
Transport capacity (hydrology)	1.00	100.00	2.29	0.26	0.60	100.00	4.00	
Perimeter resistance	4.00	60.00	1.30	0.16	0.21	0.00	3.42	
Morphological change	5.00	50.00	5.01	0.13	0.66	0.00	3.00	
TOTALS		380.00		1.00	2.67			
System Driver status:					2.67			
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					46.63			
HABITAT DRIVER CATEGORY					D		3.33	
		FLOW RELATED (%)			22.58			

This model (GAI level IV) is designed for specialist use by trained, experienced geomorphologists, for the purposes of determining the PES and geomorphic drivers of monitoring sites. Although the data/information driving this model will assist in Reserve studies, additional ESSENTIAL data are required for flow determinations.

Addendum 4 Kromme River: GAI Model

FINAL DRIVER STATUS GEOMORPHOLOGY								***This model (GAI level IV) is designed for specialist use by trained, experienced geomorphologists, for the purposes of determining the PES and geomorphic drivers of monitoring sites. Although the data/information driving this model will assist in Reserve studies, additional ESSENTIAL data are required for flow determinations.***
SCORING GUIDELINES								
GEOMORPHOLOGY DRIVERS								
COMPONENTS	**RANK**	**RELATIVE WEIGHTING (%)**	**RATING**	**WEIGHT**	**Weighed score**	**flow related (event hydrology; high flows, floods)**	**CONFIDENCE**	
System Connectivity	3.00	80.00	3.61	0.21	0.76	0.00	4.00	
Sediment supply	2.00	90.00	2.71	0.24	0.64	0.00	4.00	
Transport capacity (hydrology)	1.00	100.00	2.29	0.26	0.60	100.00	4.00	
Perimeter resistance	4.00	60.00	2.26	0.16	0.36	0.00	4.30	
Morphological change	5.00	50.00	5.48	0.13	0.72	0.00	3.00	
TOTALS		380.00		1.00	3.08			
System Driver status:					**3.08**			
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					**38.37**			
HABITAT DRIVER CATEGORY					**E**		**3.92**	
		FLOW RELATED (%)			**19.55**			

Addendum 5 Steenbras River: VEGRAI Model

Marginal zone

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	INTENSITY	EXTENT	CONFIDENCE	NOTES: (give reasons for each assessment)
REMOVAL	0.5	0.5	4.0	
EXOTIC INVASION	0.5		4.0	
WATER QUANTITY	3.0	3.0	4.0	
WATER QUALITY	2.0	1.0	3.0	
AVERAGE			3.8	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	RESPONSE METRIC	CONSIDER? (Y/N)	RATING	CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	COVER	Y	2.5	4.0	
	ABUNDANCE	Y	2.5	4.0	
	SPECIES COMPOSITION	Y	0.5	4.0	
			1.8	4.0	
NON-WOODY	COVER	Y	2.5	4.0	mainly a reduction in the availability of WET habitat = reduced Palmiet presence and associated graminoids
	ABUNDANCE	Y	2.5	4.0	
	SPECIES COMPOSITION	Y	0.5	4.0	
			1.8	2.7	

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	2.0	50.0	1.8	0.92	4.0	
NON-WOODY	Y	1.0	100.0	1.8	1.83	2.7	
					2.75	3.3	
CHANGE (%) IN MARGINAL ZONE CONDITION			36.7				

Non marginal zone

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	INTENSITY	EXTENT	CONFIDENCE	NOTES: (give reasons for each assessment)
REMOVAL	0.5	0.5	3.0	
EXOTIC INVASION	0.5		3.0	
WATER QUANTITY	1.0	2.0	4.0	
WATER QUALITY	1.0	1.0	3.0	
AVERAGE			3.3	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	RESPONSE METRIC	CONSIDER? (Y/N)	RATING	CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	COVER	Y	0.5	4.0	
	ABUNDANCE	Y	0.5	4.0	
	SPECIES COMPOSITION	Y	0.5	4.0	
			0.5	4.0	
NON-WOODY	COVER	Y	0.5	4.0	
	ABUNDANCE	Y	0.5	4.0	
	SPECIES COMPOSITION	Y	0.5	4.0	
			0.5	2.7	

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	1.0	100.0	0.5	0.50	4.0	
NON-WOODY	Y	2.0	75.0	0.5	0.38	2.7	
					0.88	3.3	
CHANGE (%) IN MARGINAL ZONE CONDITION			10.0				

Riparian zone EC

LEVEL 3 ASSESSMENT						
METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	% WEIGHT	NOTES: (give reasons for each assessment)
MARGINAL	63.3	27.1	3.3	2.0	75.0	
NON MARGINAL	90.0	51.4	3.3	1.0	100.0	
	2.0				175.0	
LEVEL 3 VEGRAI (%)				78.6		
VEGRAI EC				B/C		
AVERAGE CONFIDENCE				3.3		

Addendum 6 Pombers River: VEGRAI Model

Marginal zone

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	INTENSITY	EXTENT	CONFIDENCE	NOTES: (give reasons for each assessment)
REMOVAL	4.0	4.0	4.0	
EXOTIC INVASION	4.0		4.0	
WATER QUANTITY	2.0	2.0	4.0	
WATER QUALITY	1.0	1.0	4.0	
AVERAGE			4.0	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	RESPONSE METRIC	CONSIDER? (Y/N)	RATING	CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	COVER	Y	5.0	4.0	
	ABUNDANCE	Y	5.0	4.0	
	SPECIES COMPOSITION	Y	5.0	4.0	
			5.0	4.0	
NON-WOODY	COVER	Y	3.0	4.0	
	ABUNDANCE	Y	3.0	4.0	
	SPECIES COMPOSITION	Y	3.0	4.0	
			3.0	2.7	

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	2.0	50.0	5.0	2.50	4.0	
NON-WOODY	Y	1.0	100.0	3.0	3.00	2.7	
					5.50	3.3	
CHANGE (%) IN MARGINAL ZONE CONDITION			73.3				

Non marginal zone

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	INTENSITY	EXTENT	CONFIDENCE	NOTES: (give reasons for each assessment)
REMOVAL	5.0	5.0	4.0	
EXOTIC INVASION	5.0		4.0	
WATER QUANTITY	2.0	3.0	4.0	
WATER QUALITY	1.0	2.0	4.0	
AVERAGE			4.0	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	RESPONSE METRIC	CONSIDER? (Y/N)	RATING	CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	COVER	Y	4.0	4.0	
	ABUNDANCE	Y	4.0	4.0	
	SPECIES COMPOSITION	Y	4.0	4.0	
			4.0	4.0	
NON-WOODY	COVER	Y	4.0	4.0	
	ABUNDANCE	Y	4.0	4.0	
	SPECIES COMPOSITION	Y	4.0	4.0	
			4.0	2.7	

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	1.0	100.0	4.0	4.00	4.0	
NON-WOODY	Y	2.0	75.0	4.0	3.00	2.7	
					7.00	3.3	
CHANGE (%) IN MARGINAL ZONE CONDITION			80.0				

Riparian zone EC

LEVEL 3 ASSESSMENT						
METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	% WEIGHT	NOTES: (give reasons for each assessment)
MARGINAL	26.7	10.7	3.3	2.0	50.0	
NON MARGINAL	20.0	12.0	3.3	1.0	75.0	
	2.0				125.0	
LEVEL 3 VEGRAI (%)				22.7		
VEGRAI EC				**E**		
AVERAGE CONFIDENCE				3.3		

Addendum 7 Kromme River: VEGRAI Model

Marginal zone

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	INTENSITY	EXTENT	CONFIDENCE	NOTES: (give reasons for each assessment)
REMOVAL	4.0	4.0	4.0	
EXOTIC INVASION	4.0		4.0	
WATER QUANTITY	4.0	4.0	4.0	
WATER QUALITY	0.5	0.5	4.0	
AVERAGE			4.0	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	RESPONSE METRIC	CONSIDER? (Y/N)	RATING	CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	COVER	Y	4.5	4.0	
	ABUNDANCE	Y	4.5	4.0	
	SPECIES COMPOSITION	Y	4.5	4.0	
			4.5	4.0	
NON-WOODY	COVER	Y	4.5	4.0	
	ABUNDANCE	Y	4.5	4.0	
	SPECIES COMPOSITION	Y	4.5	4.0	
			4.5	2.7	

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	2.0	50.0	4.5	2.25	4.0	
NON-WOODY	Y	1.0	100.0	4.5	4.50	2.7	
					6.75	3.3	
CHANGE (%) IN MARGINAL ZONE CONDITION			90.0				

Non marginal zone

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	INTENSITY	EXTENT	CONFIDENCE	NOTES: (give reasons for each assessment)
REMOVAL	4.5	4.5	4.0	
EXOTIC INVASION	4.5		4.0	
WATER QUANTITY	1.0	1.0	4.0	
WATER QUALITY	0.5	0.5	4.0	
AVERAGE			4.0	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	RESPONSE METRIC	CONSIDER? (Y/N)	RATING	CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	COVER	Y	4.5	4.0	
	ABUNDANCE	Y	4.5	4.0	
	SPECIES COMPOSITION	Y	4.5	4.0	
			4.5	4.0	
NON-WOODY	COVER	Y	4.5	4.0	
	ABUNDANCE	Y	4.5	4.0	
	SPECIES COMPOSITION	Y	4.5	4.0	
			4.5	2.7	

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	1.0	100.0	4.5	4.50	4.0	
NON-WOODY	Y	2.0	75.0	4.5	3.38	2.7	
					7.88	3.3	
CHANGE (%) IN MARGINAL ZONE CONDITION			90.0				

Riparian zone EC

LEVEL 3 ASSESSMENT					
METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	% WEIGHT
MARGINAL	10.0	4.0	3.3	2.0	50.0
NON MARGINAL	10.0	6.0	3.3	1.0	75.0
	2.0				125.0
LEVEL 3 VEGRAI (%)				10.0	
VEGRAI EC				**F**	
AVERAGE CONFIDENCE				3.3	

Addendum 8 Steenbras River: MIRAI Model

FLOW MODIFICATION METRICS. WITH REFERENCE TO VELOCITY PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% Weight	COMMENTS
Presence of taxa with a preference for very fast flowing water	0.5	1	100	Number of taxa with a preference for very fast flowing water were present & are important in determining the present EC
Abundance and/or frequency of occurrence of taxa with a preference for very fast flowing water	0.5	1	100	Most taxa were recorded in relatively higher abundance
Presence of taxa with a preference for moderately fast flowing water	0	2	95	Number of taxa with a preference for Moderately fast flowing water were present
Abundance and/or frequency of occurrence of taxa with a preference for moderately fast flowing water	0.5	2	95	There were recorded in good abundance
Presence of taxa with a preference for slow flowing water	0	3	70	Number of taxa with a preference for Slow flowing water were present
Abundance and/or frequency of occurrence of taxa with a preference for slow flowing water	0	3	70	They were in large abundance
Presence of taxa with a preference for standing water	1.5	4	65	Relatively fewer taxa were recorded as the site lacks more standing water
Abundance and/or frequency of occurrence of taxa with a preference for standing water	2	4	65	Their abundance was relatively lower
Overall % change in flow dependance of assemblage			11	

Velocity Preference Scores: **GENERIC GUIDELINES FOR SCORING (0-5)** 0=No change from reference 1= Small change from reference 2=Moderate changefrom reference 3=Large change from reference 4=Serious change from reference 5=Extreme change from reference (completely dominant or absent)	**Velocity Categories:** Very Fast flowing water >0.6 m/s; Moderately fast flowing water 0.3-0.6 m/s; Slow flowing water 0.1-0.3 m/s; Standing water <0.1 m/s
Ranking of metrics: Rank order in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of velocity categories. Do not rank metrics that are not relevant (leave them blank)	**%Weight:** Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).

HABITAT MODIFICATION METRICS. WITH REFERENCE TO INVERTEBRATE HABITAT PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	%WEIGHT	COMMENTS
Has the occurrence of invertebrates with a preference for bedrock/boulders changed relative to expected?	0	3	80	More taxa were recorded from bedrock/boulders
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for bedrock/boulders changed?	0.5	3	80	Most of them were in good abunndance
Has the occurrence of invertebrates with a preference for loose cobbles changed relative to expected?	0.5	1	100	Almost all the expected inverts were recorded
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for loose cobbles changed?	0	1	100	Recorded abundance was expected
Has the occurrence of invertebrates with a preference for vegetation changed relative to expected?	0.5	2	95	A number of taxa with preference for Veg. were recorded
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for vegetation changed?	0	2	95	Abundance was not different from expected
Has the occurrence of invertebrates with a preference for sand, gravel or mud changed relative to expected?	1	5	40	very few taxa with preference for sand and mud were missing
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	1	5	40	Abundance was very comparable with the expected one, however some taxa were in lesser abundance
Has the occurrence of invertebrates with a preference for the water column or water surface changed relative to expected?	0	4	70	Very large number of taxa were recorded from water column
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for the water column/water surface changed?	0	4	7	The abundance was relatively natural
Overall % change in flow dependanceof assemblage			6	

WATER QUALITY METRICS. WITH REFERENCE TO WATER QUALITY REQUIREMENTS, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% WEIGHT	COMMENTS
Has the number of taxa with a high requirement for unmodified physico-chemical conditions changed?	0.5	1	100	Most of taxa were present
Has the abundance and/or frequency of occurrence of the taxa with a high requirement for unmodified physico-chemical	0	1	100	No major change in abundance
Has the number of taxa with a moderate requirement for unmodified physico-chemical conditions changed?	0.5	1	100	Most of taxa were present
Hasthe abundance and/or fequency of occurrence of the taxa with a moderate requirement for modified physico-chemical	1	1	100	very slight change in abundance
Has the number of taxa with a low requirement for unmodified physico-chemical conditions changed?	0.5	1	100	Most of taxa were present
Has the abundance and/or frequency of occurrence of the taxa with a low requirement for unmodified physico-chemical	0	1	100	No measurable change in abundance
Has the number of taxa with a very low requirement for unmodified physico-chemical conditions changed?	0.5	2	95	May be very small change which may be a result os seasonality
Has the abundance and/or frequency of occurrence of the taxa with a very low requirement for unmodified physico-chemical	0	2	95	No measurable change in abundance
How does the total SASS score differ from expected?	0	2	95	Was higher than expected
How does the total ASPT score differ from expected?	0	1	100	Was comparable to the expected
Overall change to indicators of modified water quality			6	

WHAT IS THE EXTENT OF THE FOLLOWING	RATINGS	COMMENTS
Weirs and causeways	0.00	No Weirs closer to the
Impoundments	0.00	No impoundments obs
Changes in seasonality	1.00	Fewer taxa were missi

Based on observed and derived data, with reference to migration and seasonality, how did the following change?	RATING	RANKING OF METRICS	% Weight	COMMENTS
Impact on distribution of migratory taxa	0	3	20	Inverts can move freely along the river stretch
Impact on abundance and/or frequency of occurrence of migratory taxa	0	3	20	No detected impact on abundance
Impact on occurrence of taxa with seasonal distribution	1	1	100	Few taxa were not present although expected during other seasons
Impact on abundance and/or frequency of occurrence of taxa with seasonal distribution	1	2	95	Some taxa were in very low abundance as they were in emerging stage during sampling
Overall % change in flow dependance of assemblage			**17**	

Which of these measures will best indicate the response of invertebrates (*in this system at this site*)							
			INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS				
INVERTEBRATE EC METRIC GROUP		**METRIC GROUP CALCULATED SCORE**	**CALCULATED WEIGHT**	**WEIGHTED SCORE OF GROUP**	**RANK OF METRIC GROUP**	**%WEIGHT FOR METRIC GROUP**	**COMMENTS**
FLOW MODIFICATION	**FM**	88.6	*0.270*	23.9558	1	100	Flow is very important for Inverts survival
HABITAT	**H**	93.8	*0.270*	25.3641	1	100	Habitats are important to support large number of taxa
WATER QUALITY	**WQ**	94.0	*0.243*	22.855	2	90	Good water quality is essential to inverts
CONNECTIVITY & SEASONALITY	**CS**	83.4	*0.216*	18.0334	3	80	Some taxa are only active during a specific season
						370	
INVERTEBRATE EC				90.2082			
INVERTEBRATE EC CATEGORY				**A**			
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F							

Addendum 9 Kromme River: MIRAI Model

FLOW MODIFICATION METRICS. WITH REFERENCE TO VELOCITY PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% Weight	COMMENTS
Presence of taxa with a preference for very fast flowing water	1	1	100	Some taxa with a preference for Very fast flowing water were absent, they are very important in determining the present EC
Abundance and/or frequency of occurrence of taxa with a preference for very fast flowing water	1	1	100	Most taxa were recorded in relatively lower abundance
Presence of taxa with a preference for moderately fast flowing water	1	2	90	Number of taxa with a preference for Moderately fast flowing water were present
Abundance and/or frequency of occurrence of taxa with a preference for moderately fast flowing water	2	2	90	They were recorded in good abundance
Presence of taxa with a preference for slow flowing water	2	3	70	Number of taxa with a preference for Slow flowing water were present
Abundance and/or frequency of occurrence of taxa with a preference for slow flowing water	1.5	3	70	They were in low abundance
Presence of taxa with a preference for standing water	1.5	4	60	Relatively fewer taxa were recorded
Abundance and/or frequency of occurrence of taxa with a preference for standing water	1	4	60	Abundance was lesser than expected
Overall % change in flow dependance of assemblage			27	

HABITAT MODIFICATION METRICS. WITH REFERENCE TO INVERTEBRATE HABITAT PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	%WEIGHT	COMMENTS
Has the occurrence of invertebrates with a preference for bedrock/boulders changed relative to expected?	1	3	70	More taxa were recorded from bedrock/boulders
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for bedrock/boulders changed?	1	3	70	Most of the taxa with a preference of boulders were in relatively lower abundance
Has the occurrence of invertebrates with a preference for loose cobbles changed relative to expected?	0.5	1	100	A number of expected inverts were recorded
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for loose cobbles changed?	1	1	100	The recorded abundance was slightly lower
Has the occurrence of invertebrates with a preference for vegetation changed relative to expected?	0	2	90	Vegetation in this site supported very high number of sensitive taxa
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for vegetation changed?	1.5	2	90	Abundance was relatively lower in vegetation
Has the occurrence of invertebrates with a preference for sand, gravel or mud changed relative to expected?	1	5	40	Very few taxa with preference for sand and mud were missing
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	1	5	40	Abundance was very comparable with the expected one, however some taxa were in lesser abundance
Has the occurrence of invertebrates with a preference for the water column or water surface changed relative to expected?	0	4	60	Very large number of taxa were recorded from the water surface
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for the water column/water surface changed?	0.5	4	60	The abundance was relatively natural, however Gyrinidae was not recorded in large abundace
Overall % change in flow dependanceof assemblage			15	
Habitat Preference Scores: **GENERIC GUIDELINES FOR SCORING (0-5)** 0=No change from reference 1= Small change from reference 2=Moderate changefrom reference 3=Large change from reference 4=Serious change from reference 5=Extreme change from reference (completely dominant or absent)				
Ranking of metrics: Rank order in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of habitat types. Do not rank metrics that are not relevant (leave them blank)	**%Weight:** Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).			

WATER QUALITY METRICS. WITH REFERENCE TO WATER QUALITY REQUIREMENTS, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	**RATING**	**RANKING OF METRICS**	**% WEIGHT**	**COMMENTS**
Has the number of taxa with a high requirement for unmodified physico-chemical conditions changed?	1	1	100	Most of taxa were present
Has the abundance and/or frequency of occurrence of the taxa with a high requirement for unmodified physico-chemical	2	1	100	Significant change in abundance
Has the number of taxa with a moderate requirement for unmodified physico-chemical conditions changed?	1	1	100	Most of taxa were present
Hasthe abundance and/or fequency of occurrence of the taxa with a moderate requirement for modified physico-chemical	2	1	100	Vissible change in abundance
Has the number of taxa with a low requirement for unmodified physico-chemical conditions changed?	0.5	1	100	Most of taxa were present
Has the abundance and/or frequency of occurrence of the taxa with a low requirement for unmodified physico-chemical	1	1	100	vissible change in abundance
Has the number of taxa with a very low requirement for unmodified physico-chemical conditions changed?	0	2	95	No vissible change in occurance
Has the abundance and/or frequency of occurrence of the taxa with a very low requirement for unmodified physico-chemical	0.5	2	95	No vissible change in abundance
How does the total SASS score differ from expected?	0	2	95	Was comparable to the expected
How does the total ASPT score differ from expected?	1	1	100	Very small change from the expected ASPT score
Overall change to indicators of modified water quality			18	

Water Qaulity delineations (Based on SASS5 weights) High Water Quality Preference: (SASS weights 12-15) Moderate Water Quality Preference: (SASS weights 7-11) Low Water Quality Preference: (SASS weights 4-6) Very low Water Quality Preference: (SASS weights 1-3)	**SASS Scores:** **GUIDELINES FOR SCORING (% of reference)** >90% = 0 80-90% = 1 60-80% = 2 40-60% = 3 20-40% = 4	
Water Quality Preference Scores: **GENERIC GUIDELINES FOR SCORING (0-5)** 0=No change from reference 1= Small change from reference 2=Moderate change from reference 3=Large change from reference 4=Serious change from reference 5=Extreme change from reference (completely dominant or absent)	**ASPT Values:** **GUIDELINES FOR SCORING (% of reference)** >95% = 0 90-95% = 1 85-90% = 2 80-85% = 3 75-80% = 4	
Ranking of metrics: Rank order in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of water quality requirements. Do not rank metrics that are not relevant (leave them blank)	**%Weight:** Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).	

WHAT IS THE EXTENT OF THE FOLLOWING	RATINGS	COMMENTS
Weirs and causeways	0.00	A bridge is located dov
Impoundments	0.00	No impoundments obs
Changes in seasonality	2.00	A number of seasonal

Based on observed and derived data, with reference to migration and seasonality, how did the following change?	RATING	RANKING OF METRICS	% Weight	COMMENTS
Impact on distribution of migratory taxa	0	3	80	Inverts can easily move along the river
Impact on abundance and/or frequency of occurrence of migratory taxa	0	3	80	No detected impact on abundance
Impact on occurrence of taxa with seasonal distribution	2	1	100	Few taxa were not present although expected during other seasons
Impact on abundance and/or frequency of occurrence of taxa with seasonal distribution	2	2	95	Some taxa were in very low abundance as they were in emerging stage during sampling
Overall % change in flow dependance of assemblage			**22**	

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	**FM**	73.0	*0.263*	19.2023	1	100
HABITAT	**H**	85.1	*0.263*	22.405	1	100
WATER QUALITY	**WQ**	81.8	*0.250*	20.4442	2	95
CONNECTIVITY & SEASONALITY	**CS**	78.0	*0.224*	17.4537	3	85
						380
INVERTEBRATE EC				79.5051		
INVERTEBRATE EC CATEGORY				**B/C**		

>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F