Appendix X

Aquatic Invertebrates

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ABBREVIATIONS

DWAF	Department of Water Affairs and Forestry, South Africa
EC	Ecological Category
EWR	Ecological Water Requirement
MIRAI	Macro Invertebrate Response Assessment Index
PES	Present Ecological State
REC	Recommended Ecological Category
SASS	South African Scoring System

GLOSSARY

ECOLOGICAL WATER REQUIREMENT	This term refers to both quality and quantity (i.e., once the water quality component is incorporated into the flow recommendation). Ecological Water Requirements are used as input into Scenario Modelling.
FRESHET	Small flow pulse.
LOW FLOW	The component(s) of the daily hydrograph between high flows, determined graphically from daily time series of flows. The low flow component of the flow regime and has a similar meaning to base flows, i.e., it excludes events (floods) (see high flows).

1. INTRODUCTION

Aquatic invertebrates are an important consideration in water resource management because many species are sensitive to changes in flow and water quality and may therefore be used as indicators of river condition or "health". Invertebrates are also able to transform polluted water into clean water, an ecological process of considerable economic value. Invertebrates form the bulk of biomass in most rivers and are important in ecological processes because they provide food for fishes, frogs, birds and other higher forms of life. Furthermore, burrowing invertebrates are sometimes important in aerating sediments and releasing nutrients.

On the negative side, certain invertebrates are of social and economic importance because of their pest status and role as vectors or hosts of various human and animal diseases. Water resource developments usually cause major shifts in the species composition, distribution and abundance of aquatic invertebrates and this often leads to increased numbers of undesirable species. Water resource developments also change human activities and this may lead to an increase in exposure to waterborne diseases.

Management for or against specific target species is straightforward because the species may be identified and their abundance monitored. This requires an understanding of the ecological requirements of the target species. Although this information is available for some species, particularly disease vectors and hosts, detailed information on the biophysical requirements for most aquatic invertebrate species is lacking. However, even if such information were available, it is unlikely to provide clear answers on how rivers should be managed because of the diversity and complexity of natural systems. The habitat requirements of many species differ as they age and this complicates the relation between habitat requirements and species. Furthermore, deciding which species to select as target species is not always straightforward.

Invertebrates have evolved to withstand the natural cycle of droughts and floods and the maintenance of a diverse and healthy invertebrate assemblage requires the main components of the natural flow regime. High flows or freshets are important for mobilising sediments and flushing accumulated debris, particularly decaying organic matter, as well as various forms of pollution. Freshets are also important reproductive cues. It is generally accepted that the timing of freshets should coincide with the natural seasonal pattern.

The overall composition of the invertebrate assemblage provides a useful integrated measure of river conditions or river "health". One advantage of using an integrated measure of river conditions, such as SASS, is that the problem of bias inherent when selecting and using target species is overcome.

The requirements of target species and the requirements of the species that make up an assemblage of invertebrates (i.e. total composition), may include critical habitats, preferred

water quality conditions, specific conditions, or range of conditions, at a particular time of the year. Some of these requirements may be translated into preferred current speeds, water depths or substrate types. These relationships allow invertebrate requirements to be incorporated into the management and operational rules of a river.

1.1 AIMS OF THIS REPORT

The aims of this report were to:

- ***Reference Conditions:*** To describe the natural (reference) species composition, distribution and abundance for aquatic invertebrates at two sites selected in the Elefantes River.

- ***Present Ecological State:*** To describe the Present Ecological State (PES) of aquatic invertebrates at each site.

- ***Trends:*** To describe trends (or changes) in aquatic invertebrate composition and abundance, under current development conditions;

- ***Alternative Categories:*** To assess how the invertebrates would respond to potential changes in flow management;

- ***Recommended Flows:*** To recommend the flows that would maintain aquatic invertebrates in a particular ecological category.

2. STUDY AREA

The study area for this report was the Elefantes River between Massingir Dam and Chokwe, a distance of 130 km (Figure 2-1). This area comprises two ecological zones, upstream and downstream of the confluence with the Limpopo River. One site was chosen in each zone. Details of the two sites chosen are included in Table 2-1. The sites were situated 10 and 98 km downstream of Massingir Dam. There was no historical information available on aquatic invertebrates downstream of Massingir Dam, but data were available for a number of sites upstream of the dam (Figure 2-1).

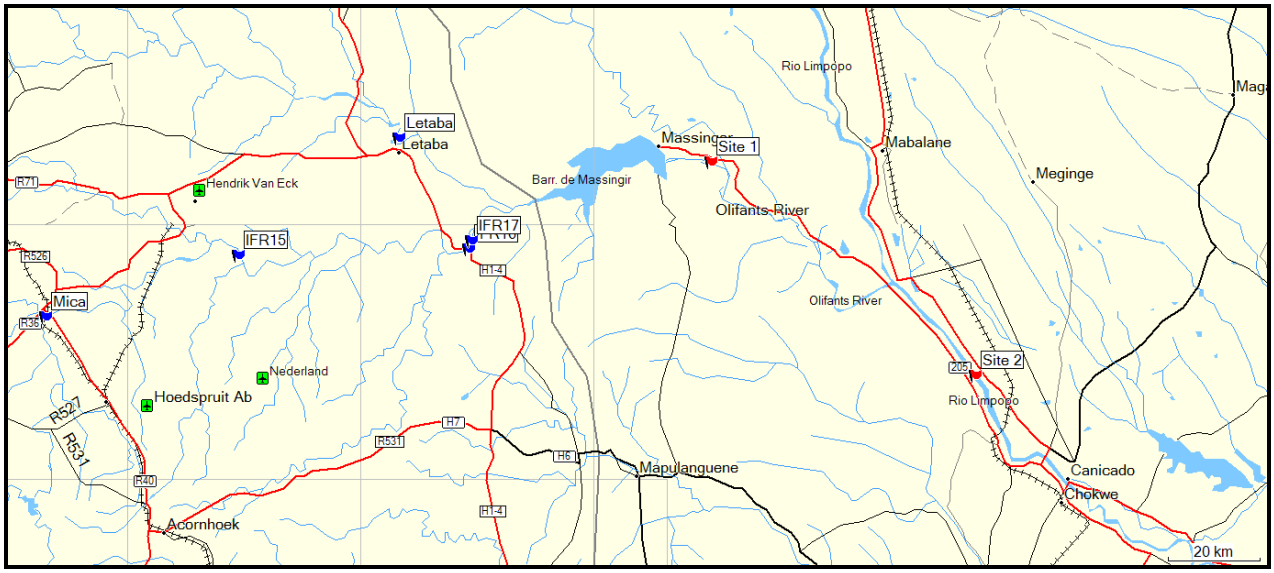

Figure 2-1. Map showing the position of Massingir Dam and two sites used for assessing ecological flow requirements for this study (Red Flags), and sites were historical data on aquatic invertebrates wre available (Blue Flags).

Table 2-1. Details of aquatic invertebrate monitoring sites in the vicinity of Massingir Dam.

Site number	Name	Grid (dd.mm.ss) (WGS84)	Description	Bankfull Width (m)
This Study				
Site 1	-	S23 52 48.2 E32 15 11.9	Elefantes River, 10 km downstream of Massingir Dam	260
Site 2	-	S24 17 53.7 E32 49 07.0	Limpopo River, 98 km downstream of Massingir Dam, and 28 km downstream of Elefantes River confluence	1000
Previous Studies				
-	Mica	S24 11 04.2 E30 49 34.4	Olifants River near Mica town	
IFR13	Tulani	S24 07 36.0 E30 01 01.2	Olifants River, about 30km downstream of the Olifants and Blyde River confluence.	75
IFR15	Mamba	S24 03 45.0 E31 14 21.0	Directly downstream of the Mamba Weir.	60
IFR16	Balule Bridge	S24 03 04.2 E31 43 56.4	Directly downstream of the Balule Bridge.	140
IFR17	Balule Downstream	S24 02 06.0 E31 44 16.8	About 500m downstream of IFR16, and about 10km upstream of the confluence with the Letaba River.	150

Figure 2-2. Satellite images of the two sites selected downstream of Massingir Dam, showing the position of the cross-sectional profiles. The images are not at the same school. [Images from www.googleearth.com.]

Site 1	Site 2
	
August 2005 (Flow: 22 m^3/s)	August 2005 (Flow: 17 m^3/s)
	
May 2006 (Flow: 8.5 m^3/s)	May 2006 (Flow: about 60 m^3/s)

Figure 2-3. Photographs of the two EWR sites downstream of Massingir Dam. Photographs were taken during site visits in August 2005 and May 2006.

3. METHODS

3.1 REFERENCE CONDITIONS

An assessment of the likely reference conditions for aquatic invertebrates provided the baseline against which the present ecological state was quantified. The composition of invertebrates in the Elefantes River Catchment prior to disturbance will never be known for certain. For this reason, reference conditions were based on professional judgement and inferred from available data. The two sites were treated as one, as it is unlikely that the composition or abundance of aquatic invertebrates at the two sites would differ significantly from each other under natural conditions.

The first published records of the aquatic invertebrate fauna found in the lower Elefantes River were from a once-off sample from the stones-in-current and marginal vegetation biotopes in the vicinity of Mica, in July 1956 (Agnew and Harrison 1959). The data provide a useful reference of the fauna that was present at the time.

In 1985 and 1986, aquatic invertebrates were collected on seven occasions as part of a baseline survey of the aquatic invertebrates in the Kruger National Park (Moore and Chutter 1988, Moore 1991). Samples were taken from various biotopes at the western and eastern borders of the park (Mamba and upstream of the Letaba River confluence).

In 1992, biomonitoring data using the SASS2 method were collected by the Institute for Water Quality Studies, Department of Water Affairs and Forestry, from a number of sites in the lower Elefantes River (IWQS unpublished data). In 1994 the sampling method was changed to SASS3, and three samples were collected. Later in the same year, the SASS method was changed to SASS4, and sampling continued until 1999. In August1999 additional biomonitoring data were collected by AfriDev Consultants and the Institute for Water Research (Palmer 2000). Biomonitoring data that were collected using the SASS4 or earlier methods were converted to SASS5 equivalent scores, where this was possible, to allow comparison of like with like.

Other information on aquatic invertebrates in the lower Elefantes River included:

- A record of freshwater prawns (*Macrobrachium* sp.) from the Olifants River within the Kruger National Park in 1958/1958 (Pienaar 1961).
- A detailed study of the freshwater prawns in the Kruger National Park (Taylor 1990).
- A survey of river crabs in Mpumalanga and the Northern Province (Cook 1997).
- Scattered publications on dragonflies (Balinsky 1965, Pinhey 1984, Samways 1999).
- Surveys of leeches (Annelida: Hirudinea) in the Kruger National Park, but with no records from the main stem of the Olifants River (Oosthuizen 1979, 1991).
- Surveys of snails in the Kruger National Park (Oberholzer and van Eeden 1967).

No data on aquatic invertebrates are available from the lower Elefantes River prior to the construction of Massingir Dam. However, the available data immediately upstream of the dam spans a period of over 40 years, and provides a fairly reliable indication of invertebrates that could be expected in the area under natural conditions.

3.2 PRESENT ECOLOGICAL STATE

The Present Ecological State of aquatic invertebrates was based on the application of the Macro Invertebrate Response Assessment Index (MIRAI) (Thirion 2005). The results were classified into one of six Present Ecological States (PES) categories, ranging from *Excellent* (Category A), to *Very Poor* (Category F) (Table 3-1). The assessment was based on information collected at the two sites during two field surveys conducted in:

- Winter (02 August 2005)
- Autumn (19 May 2006)

Aquatic invertebrates were collected using a standard SASS net and identified to at least family level according to the SASS5[1] sampling technique (Dickens and Graham 2002). A record was also made of species that are easily identified. Results for each biotope were kept separate to enable comparison of results from similar habitats. The abundance of each SASS taxon was scored on a 5-point scale (1=1; A=2-10; 3=11-100; 4=101-1000; 5=>1000). The suitability of each biotope to invertebrates was assessed on a 5-point scale (1=poor, 5=excellent).

A plot of the SASS scores against the Average Score per Taxon (ASPT) for the Olifants River Catchment as a whole was used to provide an alternative delineation of the results. The delineation was not always clear, and where scores bordered two or more classes, preference was given to the Average Score per Taxon (ASPT) rather than the total score.

1 SASS5, or South African Scoring System (version 5), is a rapid method of quantifying the condition or health of a river, based on the presence of major invertebrate groups (mostly families), each of which have been allocated a "sensitivity" value (Dickens and Graham 2002). The values are summed to provide a Total Score, and divided by the total number of taxa to provide an Average Score Per Taxon (ASPT).

Table 3-1. Delineation of Present State Categories in terms of invertebrate composition.

Category	Description
A	Unimpaired. High diversity of taxa with numerous sensitive taxa.
B	Slightly impaired. High diversity of taxa, but with fewer sensitive taxa.
C	Moderately impaired. Moderate diversity of taxa.
D	Considerably impaired. Mostly tolerant taxa present.
E	Severely impaired. Only tolerant taxa present.
F	Very severely impaired. Very few tolerant taxa present.

3.3 TRENDS

Trends refer to the anticipated directional change in the PES assessment under current development conditions. Trends were categorised as:

- 0 = no trend (ie stable)
- Negative (ie moving away from reference conditions)
- Positive (ie moving towards reference conditions)

3.4 ALTERNATIVE CATEGORIES

Alternative categories for aquatic invertebrates were determined by predicting how the invertebrates assemblages would respond an improvement and/or deterioration in flow management, and re-running the MIRAI.

3.5 LOW FLOW RECOMMENDATIONS

Recommendations for low flows were determined for each site using the Habitat Flow Stressor Response (HFSR) method (IWR Source-to-Sea 2004). The basis of the method is the application of a Stress Index, ranging from 0 (no stress) to 10 (complete stress), that describes the consequences of flow reduction to flow-dependent biota (Table 3-2). The stressors, flow hydraulics and associated habitat changes, are related to biotic responses in terms of abundance, life stages and persistence. The definitions apply to instream fauna and were calibrated for organisms that would comprise flowing water for optimal habitat. Separate stress indices were determined for invertebrates and selected target fish species, and an Integrated Stress Curve was determined based on the most sensitive components. The stress indices were generated by examining the relationships between flows, habitat availability and biomonitoring survey results.

Table 3-2. Stress Index, ranging from 0 (no stress) to 10 (complete stress), that describes the consequences of flow reduction to flow-dependent biota

Stress	Flow	Survival	Abundance	Life stage	Habitats	Habitat Response	Biotic Response
0	Very Fast, very deep	All species	All very abundant	All healthy	All very abundant	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	All very abundant, all healthy, all species persist
1	Fast, deep	All species	All abundant	All healthy	All abundant	All plentifull, high quality; fast, wide wetted perimeter	All abundant, all healthy, all species persist
2	Fast, deep, but slightly reduced	All species	Slight reduction in rheophilic spp	All healthy in some areas	Critical habitats not abundant	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist
3	Moderate, fairly deep	All species	Reduction in rheophilic spp	All healthy in remnant areas	Reduced critical habitat	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter	Reduction for all rheophilic species; all healthy in limited areas; all species persist
4	Moderate, some deep areas	All species	Further reduction in rheophilic spp	Critical life-stages of sensitive species at risk	Critical habitats limited	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist
5	Moderate, slow, some deep areas	All species	Remnant pops of all rheophilic spp	Critical life-stages of sensitive species non-viable	Critical habitats very reduced	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist
6	Moderate, slow, no deep areas	All species in the short-term	Sensitive rheophilic spp rare	Critical life-stages of many species non-viable	Critical habitats residual	Critical habitat residual. Low quality; Moderate/slow velocity.	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term
7	Slow, shallow	Sensitive species disappear	All rheophilic species rare	All life-stages of sensitive species non-viable	No critical habitat	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear
8	Slow trickle	All rheophilic spp disappear	Only remnant populations of hardy rheophilic species		Flowing water habitats residual	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear
9	No flow		Only pool dwellers		Stagnant habitats only	Standing water habitats only, very low quality, no flow	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear
10	No surface water		Only specialist survivors		Subriverbed refugia only	Only hyporheic refugia, no surface water	Only specialists persist, virtually no development.

The relation between flows and stress for aquatic invertebrates at each site was based on an assessment of the available hydraulic data, photographs of habitat availability at different flows, and expert knowledge of invertebrate fauna expected at each site. The most useful information in defining this relationship were photographs taken at different flows. Three sets of photographs and flows were available for each site. Additional information used to define this relationship were the hydraulic characteristics that were measured at different flows. The assessment focused on identifying key flow-dependent species and critical habitats, such as runs and marginal vegetation.

The first step in the process was to determine the flows at each site at which the stress would be zero. Higher stresses were determined by anticipating the depths and velocities and associated flows at which remnants of the key species, or required habitats, would be present. Stresses would be caused by reductions in velocity, with corresponding increases in water temperature, sedimentation, diatom growth, exposure to predators, and possibilities of decreased oxygen concentrations, especially at night. The suitability of various habitats to aquatic invertebrates at various stress levels was then rated on a five-point scale, where 0=no habitat and 5=highly suitable. Particular attention was given to inflection points in graphs that plotted the relations between flow

and key hydraulic parameters. The key hydraulic parameters (depth, velocity, wetted perimeter etc) associated with each stress were then specified.

3.6 HIGH FLOWS RECOMMENDATIONS

Recommendations for high flows were determined using the Downstream Response to Imposed Flow Transformation (DRIFT) method (Brown and King 2000). Statistical analysis of the flood peaks was done to determine the relationship between flood peak discharge and catchment area for a range of return periods that could be used to estimate return period floods at each of the EWR sites under natural conditions. These values, in particular the 1:2 year return period flood, were used as a reference point for the floods at each of the sites. Four classes of intra-annual flood events calculated as:

- Class IV = (1:2 annual peak –10%) to (1:2 annual peak –10%)/2;
- Class III = (1:2 annual peak –10%)/2 to (1:2 annual peak –10%)/4
- Class II = (1:2 annual peak –10%)/4 to (1:2 annual peak –10%)/8
- Class I = (1:2 annual peak –10%)/8 to (1:2 annual peak –10%)/16.

3.7 CONFIDENCE

Confidence in each assessment was rated on a six-point scale as follows:

0 = zero confidence
1 = very low
2 = low
3 = medium
4 = high
5 = very high

3.8 ASSUMPTIONS AND LIMITATIONS

3.8.1 Low Flow Recommendations

The relation between stress and flow at both sites was difficult to define because the available habitat cues were very limited. The sand beds are highly mobile and the channels and associated habitats are highly dynamic. This highlights one of the difficulties of setting environmental flows in sand-bed rivers such as this, and highlights the importance of implementing a monitoring programme and adapting the recommendations as new information becomes available. Interpretation at Site 1 was further complicated because the habitats and overall invertebrate composition was better during the second field visit, when flow was 8.5 m^3/s, than during the first field visit, when flow as 22 m^3/s. The reason for this apparent contradiction was because the flow had been high (around 80 m^3/s), for some time prior to the second field visit, and dropped suddenly a few days before the field visit. The

high biomonitoring scores recorded during the second visit therefore reflected historical flow conditions, and not the flows recorded on the day of sampling. This highlights the need to interpret biomonitoring results in relation to the recent flow history.

3.8.2 Hydro-Power

The implications of hydro-power generation were not considered, but are likely to be highly detrimental to aquatic invertebrates.

4. RESULTS

A summary of the available data on aquatic invertebrates is shown in Table 4-1. Detailed biomonitoring results collected during this study area shown in Annexure A. The taxa that were observed and expected at each site are listed in Annexure B, while the results of the MIRAI for the PES and alternative categories are presented in Annexure C.

Table 4-1. Summary of available aquatic invertebrate biomonitoring data from the lower Elefantes River.

Ref	Site	Method	Date	SASS Score	ASPT	Notes
Moore and Chutter 1991	Lower Letaba	CBI	05.85	± 147	± 7.4	*C. thomasseti* abundant. *Ellasoneuria* common. (Clean)
		CBI	06.85	± 166	± 6.9	Simuliidae abundant. (Slightly enriched)
		CBI	09.85	± 105	± 5.8	Tanytarsini abundant. (Enriched)
		CBI	05.86	± 113	± 6.6	Tricorythidae very abundant. *Ellasoneuria* present. (Clean)
		CBI	06.86	± 116	± 6.1	Simuliidae abundant. (Slightly enriched)
		CBI	08.86	± 75	± 6.3	*C. thomasseti* common. (Slightly enriched)
		CBI	10.86	± 73	± 6.6	*C. thomasseti* common. (Slightly enriched)
IWQS (unpubl)	IFR16	SASS2	06.06.93	75	5.0	Chironomidae abundant.
		SASS2	29.07.93	88	5.2	Chironomidae abundant.
		SASS4	20.07.94	102	5.1	-
		SASS4	01.08.95	100	5.5	Simuliidae abundant.
		SASS4	08.10.98	62	4.4	-
Palmer 2000	IFR17	SASS4	26.08.99	171	5.9	Caenidae, Corixidae & Veliidae abundant.
This study	Site 1	SASS5	02.08.05 19.05.06	110 101	4.8 5.6	Baetidae common. Simuliidae abundant (mainly *S. adersi*)
This study	Site 2	SASS5	02.08.05 19.05.06	165 81	5.5 5.8	Baetidae common. Simuliidae present (mainly *S. bovis*)

CBI=Chutter's Biomonitoring Index; IWQS=Institute for Water Quality Studies

The following section discusses the Present Ecological State of aquatic invertebrates at the two sites.

4.1 SITE 1

4.1.1 Reference Conditions

Based on available data it is likely that SASS5 scores under natural conditions are likely to have been >180, and ASPT >7.0. Notable taxa expected under natural conditions include:

- Freshwater shrimps (Atyidae)
- Freshwater prawns (*Macrobrachium* spp.)
- Flat-headed mayflies (Heptageniidae)
- Prongills (Leptophlebiidae)
- Brushlegged mayflies (Oligoneuridae)
- Stout Crawlers (Tricorythidae)
- Freshwater limpets (Ancylidae)
- Freshwater clams (Corbiculidae)
- Perly mussels (Unionidae)

4.1.2 Present Ecological State

PES Category: D Confidence: 4

The Present Ecological State of aquatic invertebrates at Site 1 during the first field visit, in August 2005, was rated as *Considerably Impaired* (Category D). The vegetation-in-current was dominated by blackfly larvae *Simulium adersi*, a species that is tolerant of polluted water, and is found in slow-flowing water, and is typical of impoundment outlets. Other taxa typical impoundment of outlets that were recorded, although in low numbers only, were the caddisflies *Amphipsyche scottae* and *Hydropsyche longifurca.* Abundant taxa were baetid mayflies (Baetidae), Coenagronidae damselflies and ripple bugs (Veliidae). Overall, there were 15 SASS5 taxa that were expected but not recorded. Taxa that were notably absent included flat-headed mayflies (Heptageniidae), Prongills (Leptophlebiidae), brushlegged mayflies (Oligoneuridae), freshwater limpets (Ancylidae) and freshwater clams (Corbiculiidae).

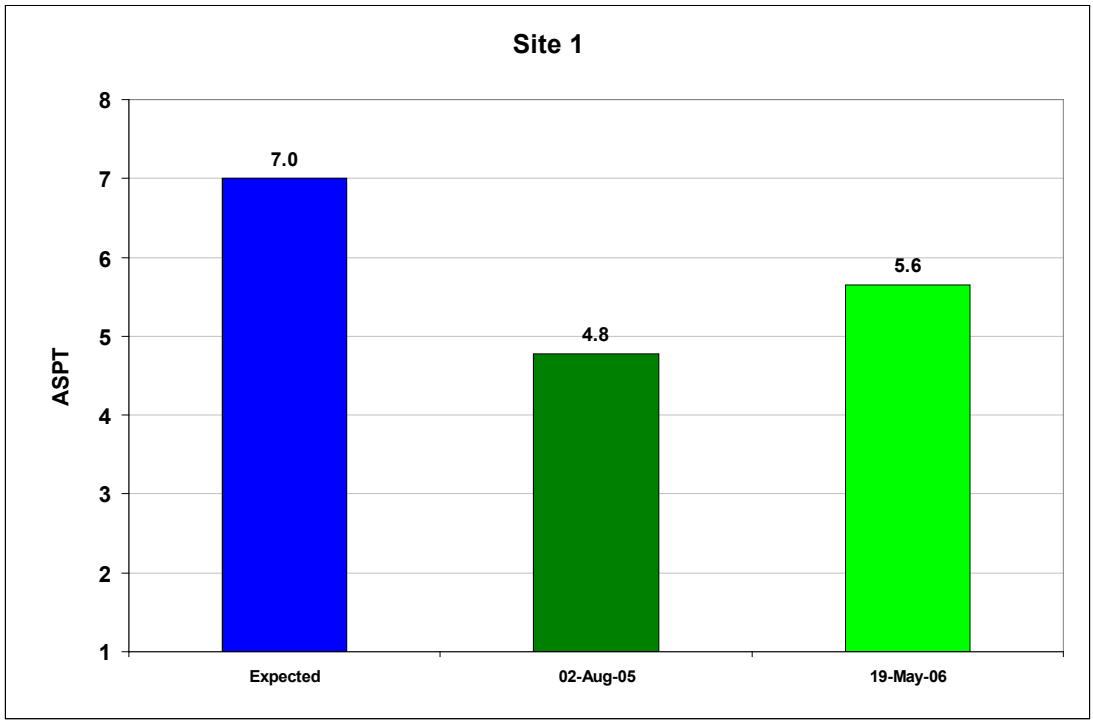

Figure 3-1. Summary biomonitoring results at Site 1, showing the expected and observed SAS5 Average Score per Taxon (ASPT) during two site visits. The colours of the bars indicate the category.

During the second field visit, in May 2006, when flow was higher, the fauna was classified as *Moderately Impaired* (Category C). The total number of taxa recorded was lower (17) compared to the first visit (23), but the presence of tricorythid mayflies indicated improved conditions. No single taxon dominated the fauna, and this also indicated improved conditions. Overall, there were 11 SASS5 taxa that were expected but not recorded.

Winter water temperatures at this site are likely to be significantly warmer than before the dam was built, and this is likely to have had a significant impact on aquatic invertebrates. In particular, the warmer temperatures are likely to have extended the seasonal transmission of bilharzia.

The degraded condition at Site 1 is partly attributed to Masssingir Dam, but there are other factors that are likely to play a role. The main non-flow related pressures is related to nutrient enrichment from cattle.

The main change in the composition and abundance of aquatic invertebrates at Site 1 compared to reference conditions is the elevated numbers of filter-feeders, such as the blackfly *Simulium adersi* and the cassisfly *Amphipsyche scottae.* Overall, the available information indicates that the site is within what is typically regarded as a Category D.

4.1.3 Trends

Trends: Positive Confidence: 2

The composition of aquatic invertebrates is predicted to improve under current development conditions. The reason for this is that the raised dam is predicted to cause the channel downstream of the dam to incise over time, and this is likely to expose bedrock which will improve the diversity of habitats for aquatic invertebrates. Although the instream conditions at this site is predicted to improve for aquatic invertebrates, the changes will be detrimental to the overall ecological state of the river and associated floodplains, because river banks will become destabilised, and floodplains will become terrestrialised as the frequency of floodplain inundation is reduced.

4.1.4 Alternative Categories

a) Up Alternative

Low-flow releases from Massingir Dam could easily be improved to provide perennial flows and an increase in low flows. The changes would improve conditions for flow-dependent invertebrate species, particularly taxa that have a preference for moderate current speeds. The changes would be expected to improve water quality, so some of the taxa that are sensitive to water quality deterioration would be expected to appear. Improved low flows would also be unfavourable to the high populations of *Simulium adersi*, a species that is commonly found in slow-flowing, organically enriched impoundment tailwaters. Improved low-flows are also expected to improve overall SASS scores to similar values as recorded at Site 2. The MIRAI model was rerun with these changes, and the results indicated a Category C. The recommended category for invertebrates at this site is Category C. This may be easily achievable.

b) Down Alternative

Increased releases from Massingir Dam, for whatever reason, are certain to increase the rate of channel incision. This will have detrimental environmental implications, such as unstable banks, a lowered water table and reduced incidence of floodplain inundation. These changes are typical downstream of all dams, particularly where the stream substrate is unconsolidated, a condition referred to as bed armouring. Bed armouring is likely to provide more diverse instream habitat and this is likely to improve the diversity of aquatic invertebrates. The down alternative for aquatic invertebrates is therefore expected to be no different to the up alternative (ie: Category C).

4.2 SITE 2

4.2.1 Reference Conditions

The reference conditions for aquatic invertebrates at Site 2 are unlikely to be significantly different from those expected at Site 1. Possible differences could include more frequent occurrence at Site 2 of certain snails (Unionidae and *Lanistes ovum),* and the blackfly *Simulium bovis.*

4.2.2 Present Ecological State

PES Category: C Confidence: 3

The overall Present Ecological Status at Site 2 was considered, with high confidence, to be a *Moderately Impaired* (Category C) (Figure 3-2). During the first visit in August 2005, when flow was very low, a total of 30 SASS5 taxa was recorded, mostly in vegetation out-of-current (*Ludwigia* and *Phragmites*). The high number of taxa was despite very poor habitat availability. There were no stones available at the site, and the sands were highly mobile. The fauna included sensitive taxa, such as brushlegged mayflies (Oligoneuridae) and stout crawlers (Tricorythidae). Five families of snails were recorded, including freshwater limpets (Ancylidae).

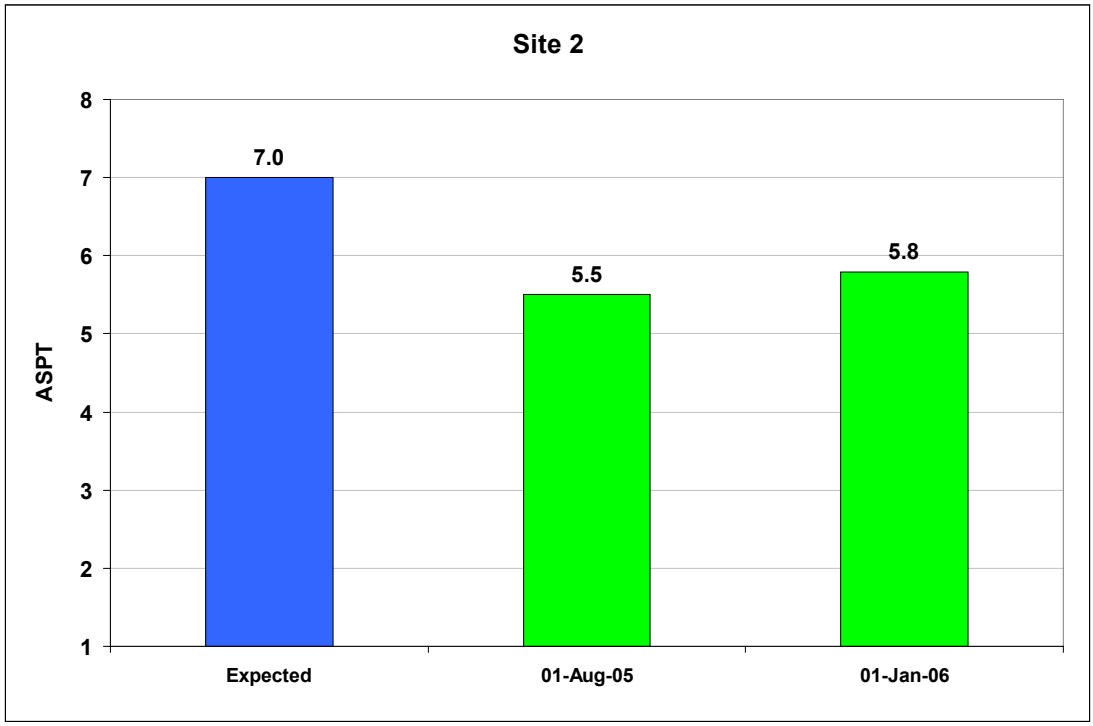

Figure 3-2. Summary biomonitoring results at Site 2, showing the expected and observed SAS5 Average Score per Taxon during two site visits. The colours of the bars indicate the category.

During the second visit in May 2006, conditions at Site 2 were not suitable for biomonitoring because the river was recovering from a recent flood. The right bank was inaccessible because of the deposition of large quantities of mud, so sampling was conducted on the left bank. The results were interpreted with caution because of the limited habitats available. The total SASS5 scores were significantly lower than the previous site visit, which is to be expected after floods. However, the ASPT was very similar to the previous survey, and the overall category was considered to be *Moderately Modified (*Category C).

4.2.3 Trends

Trends: 0 Confidence: 4

The conditions for aquatic invertebrates at Site 2 are considered stable under current development conditions. Changes in bed structure following operation of the raised Massingir Dam, as anticipated at Site 1, is not expected to extend as far as Site 2 because of the lower gradients at Site 2, and because of the distance involved.

4.2.4 Alternative Categories

a) Up Alternative

The up alternative for aquatic invertebrates was not considered for Site 2 because the site is presently in a Category C, and it is highly unlikely that improved releases from Massingir Dam could change this to a Category B.

b) Down Alternative

The down alternative at Site 2 for aquatic invertebrates was considered to be the same as the present state at Site 1 (ie, Category D).

4.3 LOW FLOWS

4.3.1 Site 1

Photographs and hydraulic characteristics suggested that the aquatic invertebrates at Site 1 would not be stressed when flows exceed 40 m^3/s (Table 4-2). Habitat conditions during the first field visit, when flows were 22 m^3/s, suggested a stress of 3 (ie, slight reduction in critical habitats). Habitat conditions during the second field visit, when flows were 8.5 m^3/s, suggested a stress of 5 (ie, critical habitats very reduced). Sandbanks were largely exposed, although there was still marginal vegetation available. Very low flows were measured in November 2005, and photographs indicated clearly that aquatic invertebrates were highly stressed (Stress 8).

Table 4-2. Relation between habitat, flow and stress for aquatic invertebrates at two sites downstream of Massingir Dam.

	Site 1							Site 2						
Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW
	SIC	SOC	VIC	VOC	GSM			SIC	SOC	VIC	VOC	GSM		
0	0	0	5	5	5	15	40	0	0	5	5	5	15	60
1	0	0	0	0	0	0	-	0	0	0	0	0	0	-
2	0	0	0	0	0	0	-	0	0	0	0	0	0	-
3	0	0	4	4	4	12	22	0	0	0	0	0	0	-
4	0	0	0	0	0	0	-	0	0	4	4	2	10	17
5	0	0	1	4	4	9	8.5	0	0	0	0	0	0	-
6	0	0	0	0	0	0	-	0	0	0	0	0	0	-
7	0	0	0	0	0	0	-	0	0	0	0	0	0	-
8	0	0	1	3	3	7	0.43	0	0	1	3	2	6	0.94
9	0	0	0	0	0	0	-	0	0	0	0	0	0	-
10	0	0	0	0	0	0	-	0	0	0	0	0	0	-

[SIC=Stones-in-current; SOC=stones-out-of-current; VIC=Vegetation-in-current; VOC=Vegetation-out-of-current; GSM=Gravel, sand and mud.]

The stress-durations that were recommended for aquatic invertebrates are detailed below. Confidence in the motivations was low, as the available habitat cues were limited to marginal vegetation. The hydraulic data provided little insight, as current speeds remained relatively high, irrespective of flows. The recommendations provided should therefore be considered as a first estimate, and should be re-evaluated as more information becomes available. This highlights the importance of implementing a monitoring programme to test the recommendations made, and to modify the recommended ecological flows, if necessary.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: Tricorythidae, Heptageniidae, Leptophlebiidae, Atyidae **Invertebrates:** The indicators are rheophilic species.
STRESS REQUIREMENTS FOR RECOMENDED EC (C)
DRY SEASON (October)
DROUGHT: +/-10%. Stress 7.5: Critical habitat residual. Ensure refuge habitats for taxa such as *Ampiphsyche scottae* and *Hydropsyche longifurca* on the few gravel bars that occur, and maintain marginal vegetation refugia.
MAINTENANCE: 30%. Stress 6: Require marginal vegetation for the dry season. Ensure sufficient current velocity for flow-dependent taxa such as Tricorythidae. Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*), mosquitoes (Culicidae) and excessive numbers of *S. adersi* which are associated with slow-flowing water. Provide sufficient flows for maintenance of freshwater shrimps (Atyidae).
WET SEASON (February)
DROUGHT: +/- 10%. Stress 6: Require sufficient current velocity for flow-dependent taxa such as Tricorythidae, which would be expected for a Category C.
MAINTENANCE: 30%. Stress 5: Ensure sufficient current velocity for flow-dependent taxa such as *Simulium bovis* and *Amphipsyche scottae* which would be expected for a Category C. Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*) and mosquitoes (Culicidae) and excessive numbers of *Simulium adersi.*

STRESS REQUIREMENTS FOR RECOMENDED EC (D)
Indicator: As above, but excluding Tricorythidae, Heptageniidae and Leptophlebiidae Invertebrates: As above
DRY SEASON (September)
DROUGHT: +/-10%. Stress 8:
MAINTENANCE: 30%. Stress 7:
WET SEASON (February)

DROUGHT: +/- **10%.** Stress 7:
MAINTENANCE: 30%. Stress 6:

4.3.2 Site 2

Habitat conditions during the first field visit, when flows were 17 m^3/s, suggested an invertebrate stress of 4 (ie, critical habitats limited) (Table 4-2). Flows during the second field visit were about 60 m^3/s, and no stress at these flows was observed. Very low flows were measured in November 2005, and photographs indicated clearly that aquatic invertebrates were highly stressed (Stress 8).

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: Tricorythidae, Heptageniidae, Leptophlebiidae, Atyidae **Invertebrates:** The indicators are rheophilic species.
STRESS REQUIREMENTS FOR RECOMENDED EC (C)
DRY SEASON (October)
DROUGHT: +/-**10%.** Stress 7:
MAINTENANCE: 30%. Stress 6:
WET SEASON (February)
DROUGHT: +/- **10%.** Stress 5
MAINTENANCE: 30%. Stress 4

STRESS REQUIREMENTS FOR RECOMENDED EC (D)
DRY SEASON (October)
DROUGHT: +/-**10%.** Stress 8:
MAINTENANCE: 30%. Stress 7:
WET SEASON (February)
DROUGHT: +/- **10%.** Stress 6
MAINTENANCE: 30%. Stress 5

4.4 HIGH FLOW RECOMMENDATIONS

The recommendations for high flows are shown in Table 4-3. The same high-flow recommendations were made for both sites, as the motivations were identical. Periodic high flows are important for mobilising sediments and flushing accumulated debris, particularly decaying organic matter, as well as various forms of pollution. Freshets are also important reproductive cues. It is generally accepted that the timing of freshets should coincide with the natural seasonal pattern.

Periodic high flows are also recommended to reduce the populations of certain undesirable species. The most undesirable aquatic invertebrate taxa in the lower Elefantes River are the snails *Biomphalaria pfeifferi* and *Bulinus africanus*, both intermediate hosts of the parasite *Schistosoma spp.,* which causes bilharzia in man. Neither species can tolerate current speeds exceeding 0.3 m/s, and can be effectively controlled with periodic spates (Brown 1994). Another undesirable species in the lower Elefantes River whose numbers could be reduced by periodic freshets is the blackfly *Simulium adersi,* whose adult females feed on blood. Their larvae are found exclusively in slow-flowing water. High populations of the Thiaridae snails, often associated with warm, enriched, slow-flowing waters, could also be reduced by periodic flushes.

Periodic high flows are also probably important cues for the upstream migration of freshwater prawns (M*acrobrachium* spp.), although very little is known about the life history requirements of these animals. These prawns are thought to breed in saline conditions found in estuaries. They then migrate upstream where they mature, but they return to estuaries breed. They are restricted to riffle habitats, and are therefore susceptible to low flow periods. These prawns are expected in the lower Elefantes River, but the construction of the Chokwe barrage creates a major barriers to the upstream migration of these prawns. No weirs or dams have been designed or built to include a passageway specifically for prawns (Taylor pers. comm. 1999). Fishways are likely to be unsuitable for prawn migration because of their steep gradient. However, it would be feasible to design a passageway specifically for prawns, providing the gradient is not too steep (Taylor pers. comm. 1999).

Table 4-3. High flow recommendations for aquatic invertebrates at two sites downstream of Massingir Dam.

FLOOD CLASS I:			Recommended EC: C			Alternative EC: D		
Function/s (what does it have to do)	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Freq**	**Reasoning**	**No of events**	**Freq**	**Reasoning**
• Flush out benthic algae and fines and provide cue for breeding or emergence of flow dependent taxa, such as Tricorythidae • Provide sufficient current speed to discourage dominance of *S. adersi*, as well as bilharzia and Thiaridae snail populations. • To maintain species diversity by ensuring temporal diversity of flows.	Velocity: a discharge of 12m^3/s has an average current speed of 1.04m/s. This is sufficient to mobilise fines and discourage bilharzia snails.	Autumn, Spring Summer	4	n/a	• Four flushes during the wet season is predicted to provide sufficient cues for emergence and breeding of invertebrates • Marginal vegetation should be inundated periodically	2	n/a	As for EC C, but with reduced frequency.
FLOOD CLASS II:			**Recommended EC: C**			**Alternative EC: D**		
Function/s (what does it have to do)	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Freq**	**Reasoning**	**No of events**	**Freq**	**Reasoning**
• To provide cue for breeding and upstream migration of freshwater prawns (*Macrobrachium* spp.)	Unknown.	Summer	1	n/a	• At least one freshet per year is recommended to ensure upstream migration of prawns	0	n/a	n/a

4.5 CONFIDENCE

The confidence was evaluated according to a score of 0 to 5, with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 4-4).

Table 4-4. Confidence ratings for aquatic invertebrates for various criteria at Site 1 and 2.

Site 1				
SITE	**AVAILABLE DATA**	**ECOLOGICAL CLASSIF.**	**OUTPUT LOW FL**	**OUTPUT HIGH FL**
2	2	4	3	3
Confidence in the site is low, as the diversity of habitats at this site is low, although the site is reprehensive of the reach. The habitats are limited to highly mobile sands and riparian vegetation, in and out of current. Absent biotopes include bedrock, stones-in-and out of current, gravel and mud. Confidence in the available data was low, as there is information from two field visits only. The results were significantly different, indicating variable conditions. Confidence in the ecological classification was high as two independent methods of assessment came to similar conclusions. However, information on referenced conditions was based on information collected further upstream, where habitats are different, with more bedrock and rocks. Confidence in the low flow recommendations was moderate, as ecological cues were very limited, but requirements were lower than for fish, which were the critical component. The influence of water quality reduced the confidence in the predictions, as periodic blooms of blue-green algae *Microcystis* in Massingir Dam are expected to affect downstream aquatic invertebrate composition and abundance. The confidence in the high flows was moderate, as invertebrate requirements for high flows are being met by the requirements of fish, but the limited availability of natural daily flows reduce the confidence in the values floods that were recommended.				
Site 2				
SITE	**AVAILABLE DATA**	**ECOLOGICAL CLASSIF.**	**OUTPUT LOW FL**	**OUTPUT HIGH FL**
1	2	3	3	3
As for Site 1, except that the availability of habitats is lower, which makes the site less suitable for assessing ecological flow requirements, and because the second field visit was undertaken in the wake of a flood, so the available data was more limited.				

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6. ANNEXURES

ANNEX A: Detailed SASS5 Biomonitoring Data

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd:mm:yr):	02-Aug-05		(dd.ddddd)	**Biotopes Sampled (tick & rate)**	Rating (1 - 5)	Time (min)
RHP Site Code:		Grid reference (dd mm ss.s) Lat: S	23 52 48.4 / 23.88011d	Stones In Current (SIC)	0	
Collector/Sampler:	Rob Palmer	Long: E	32 15 13.7 / 32.2538d	Stones Out Of Current (SOOC)	0	
River:	Elefantes	Datum (WGS84/Cape):	WGS84	Bedrock	0	
Level 1 Ecoregion:	3: LOWVELD	Altitude (m):		Aquatic Veg	0	
Quaternary Catchment:		Zonation:	Lowland River	MargVeg In Current	4	
	Temp (°C):	Routine or Project? (circle one)	Flow: Medium	MargVeg Out Of Current	4	
Site Description:	pH: 7.9	Project Name: Elefantes River EWR	Clarity (cm):	Gravel	1	
	DO (mg/L):	Massingir Dam	Turbidity: Low	Sand	4	
	Cond (mS/m): 45.4		Colour: Normal Transparent	Mud	0	
	Riparian Disturbance:			Hand picking/Visual observation	y	
	Instream Disturbance:					

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		B		B
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6			C	
Baetidae > 2 sp	12		C		C
Caenidae (Squaregills/Cainfles)	6		A	B	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4			C	C
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6			B	B
Libellulidae (Darters/Skimmers)	4		A	1	A
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		A		A
Corixidae* (Water boatmen)	3		A	B	B
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3		1		1
Notonectidae* (Backswimmers)	3		A		A
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		C		C
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6		A		A
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6		1		1
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6			A	A
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5		1		1
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1	1	A
Chironomidae (Midges)	2		B	B	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		D		D
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5			1	1
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3		A		A
Physidae* (Pouch snails)	3		B		B
Planorbinae* (Orb snails)	3		1		1
Thiaridae* (=Melanidae)	3		1		1
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					110
No. of Taxa					23
ASPT					4.8

Other biota:

S. adersi abundant; *S. bovis* present; *S. impukane* present
Hydropsyche longifurca; Amphipsyche scottae

Comments/Observations:

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd:mm:yr):	19-May-06						(dd.ddddd)		**Biotopes Sampled (tick & rate)**	**Rating (1 - 5)**	**Time (min)**
RHP Site Code:		Grid reference (dd mm ss.s) Lat:	S	23 52 48.4	23.88011d				**Stones In Current (SIC)**	0	
Collector/Sampler:	Rob Palmer	Long:	E	32 15 13.7	32.2538d				**Stones Out Of Current (SOOC)**	0	
River:	Elefantes	Datum (WGS84/Cape):		WGS84					**Bedrock**	0	
Level 1 Ecoregion:	3: LOWVELD	Altitude (m):							**Aquatic Veg**	0	
Quaternary Catchment:		Zonation:		Lowland River					**MargVeg In Current**	4	
	Temp (°C):	Routine or Project? (circle one)		Flow:	Low				**MargVeg Out Of Current**	4	
Site Description:	pH: 8.1	Project Name: Elefantes River EWR		Clarity (cm):					**Gravel**	1	
	DO (mg/L):	Massingir Dam		Turbidity:	V Low				**Sand**	4	
	Cond (mS/m): 73.8			Colour:	Normal Transparent				**Mud**	0	
	Riparian Disturbance:								**Hand picking/Visual observation**	y	
	Instream Disturbance:										

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3		A		A	Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3					Corixidae* (Water boatmen)	3					Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5		A		A	Ceratopogonidae (Biting midges)	5				
Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2		1	A	A
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7					Culicidae* (Mosquitoes)	1				
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3					Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8		A		A	Veliidae/M...veliidae* (Ripple bugs)	5					Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5		B		B
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5				
Perlidae	12					Dipseudopsidae	10					Tipulidae (Crane flies)	5				
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Baetidae 1sp	4					Hydropsychidae 1 sp	4			1		Ancylidae (Limpets)	6				
Baetidae 2 sp	6			A		Hydropsychidae 2 sp	6		A		A	Bulininae*	3				
Baetidae > 2 sp	12		C		C	Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainfles)	6		1	1	A	Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9					**Cased caddis:**						Thiaridae* (=Melanidae)	3			B	B
Oligoneuridae (Brushlegged mayflies)	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalvles)**					
Prosopistomatidae (Water specs)	15					Glossosomatidae SWC	11					Corbiculidae (Clams)	5			A	A
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6		1		1	Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9		A	1	A	Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6			A	A
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**					101
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6		1		1	**No. of Taxa**					18
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					**ASPT**					5.6
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4		B		B	Sericostomatidae SWC	13					*S. bovis* present; *S. ?alcocki*					
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**						Hydrophilidae very large - sent to Albany Museum					
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8										
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5					**Comments/Observations:**					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6		1	A	A	Helodidae (Marsh beetles)	12										
Libellulidae (Darters/Skimmers)	4		A		A	Hydraenidae* (Minute moss beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5		1		1						
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10										

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd:mm:yr):	01-Aug-05				(dd.ddddd)	
RHP Site Code:		**Grid reference (dd mm ss.s) Lat:**	**S**	23 18 00.00	23.3d	
Collector/Sampler:	Rob Palmer	**Long:**	**E**	32 49 16.7	32.8213d	
River:	Limpopo	**Datum (WGS84/Cape):**		WGS84		
Level 1 Ecoregion:	3: LOWVELD	**Altitude (m):**				
Quaternary Catchment:		**Zonation:**		Lowland River		
	Temp (°C):	**Routine or Project? (circle one)**	**Flow:**	Medium		
Site Description:	**pH:** 7.9	**Project Name: Elefantes River EWR**	**Clarity (cm):**			
	DO (mg/L):	**Massingir Dam**	**Turbidity:**	Low		
	Cond (mS/m): 45.4		**Colour:**	Normal Transparent		
	Riparian Disturbance:					
	Instream Disturbance:					

Biotopes Sampled (tick & rate)	**Rating (1 - 5)**	**Time (min)**
Stones In Current (SIC)	0	
Stones Out Of Current (SOOC)	0	
Bedrock	0	
Aquatic Veg	1	
MargVeg In Current	1	
MargVeg Out Of Current	4	
Gravel	1	
Sand	4	
Mud	0	
Hand picking/Visual observation	y	

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		A		A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12		C		C
Caenidae (Squaregills/Cainfles)	6		B		B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15		1		1
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9		A		A
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		B		B
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8		A		A
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6		1	A	A
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		A		A
Corixidae* (Water boatmen)	3			A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6		1		1
Naucoridae* (Creeping water bugs)	7			1	1
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4		B		B
Veliidae/M...veliidae* (Ripple bugs)	5		B		B
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4		1		1
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6		1		1
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6		1		1
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5		B		B
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5		A		A
Haliplidae* (Crawling water beetles)	5		A		A
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5		A		A
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1		1
Chironomidae (Midges)	2		A		A
Culicidae* (Mosquitoes)	1		1		1
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		A		A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6		1		1
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3		B		B
Planorbinae* (Orb snails)	3		1		1
Thiaridae* (=Melanidae)	3		B		B
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5			A	A
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					165
No. of Taxa					30
ASPT					5.5

Other biota:

S. bovis ; *S. adersi*

Hydrophilidae very large - sent to Albany Museum

Elassoneura; Biomphalaria

Baetis glaucus

Comments/Observations:

Results indicate benefecial influence of Limpopop

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd:mm:yr):	18-May-06				(dd.ddddd)	
RHP Site Code:		Grid reference (dd mm ss.s) Lat:	S	23 18 00.00	23.3d	
Collector/Sampler:	Rob Palmer	Long:	E	32 49 16.7	32.8213d	
River:	Limpopo	Datum (WGS84/Cape):		WGS84		
Level 1 Ecoregion:	3: LOWVELD	Altitude (m):				
Quaternary Catchment:		Zonation:		Lowland River		
	Temp (°C):	Routine or Project? (circle one)	Flow:	Medium		
Site Description:	pH: 8.5	Project Name: Elefantes River EWR	Clarity (cm):			
	DO (mg/L):	Massingir Dam	Turbidity:	Low		
	Cond (mS/m): 47.9		Colour:	Normal Transparent		
	Riparian Disturbance:					
	Instream Disturbance:					

Biotopes Sampled (tick & rate)	Rating (1 - 5)	Time (min)
Stones In Current (SIC)	0	
Stones Out Of Current (SOOC)	0	
Bedrock	0	
Aquatic Veg	0	
MargVeg In Current	4	
MargVeg Out Of Current	0	
Gravel	3	
Sand	0	
Mud	0	
Hand picking/Visual observation	y	

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		1		1
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12		C		C
Caenidae (Squaregills/Cainfles)	6		A		A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13		A		A
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6			A	A
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		A		A
Corixidae* (Water boatmen)	3		A		A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3		1		1
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6		A		A
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1		1
Chironomidae (Midges)	2		A		A
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		1		1
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5			A	A
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					81
No. of Taxa					14
ASPT					5.8

Other biota:

Empty shells of *Lanistes ovum* and *Unio ?caffer*

Comments/Observations:

Post flood conditions, therefore total scores not representative

ANNEX B: List of expected and observed invertebrates in the lower Elefantes River, and associated habitat preferences

List of aquatic invertebrates lower Elefantes River

	Flow				Substrate						Water Quality				Previous Studies						This Study			
	Standing (<0.1)	Slow (0.1-0.3)	Mod (0.3-0.6)	Fast (>0.6)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	Water Colum & Surface	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)	None (SASS <3)	IFR 11: Lissithaba	MICA	IFR 13: Grietjie	IFR 15: Mamba	IFR 17: Balule lower	nr Letaba confl	EWR1-Winter	EWR1-Summer	EWR2-Winter	EWR2-Summer
Porifera (Sponges)	1	1	1		1	1	1						1						1					
Coelenterata (C		1			1	1	1							1										
Hydra sp.	1	1					1	1										1		1				
Platyhelminthes (Flatworms)																								
Turbellaria (flatworms)	1	1					2	1	1					1				1						
Annelida																								
Oligochaeta (Earthworms)	1	1	1				1		2					1	1			1	2	1				
Hirudinea (Leeches)	1	1	1	1	1	1	2	1						1				2	1	1				
Arthropoda																								
Crustacea																								
Atyidae (freshwater shrimps)		1						2				1												
Caridina africana																		1			B	A	A	1
Palaemonidae (freshwater prawns)			1	2		2	1					1												
Macrobrachium lepidactylus																								
Macrobrachium ?equidens																								
Ch																								
Arachnida																								
Acarina (Mites & Ticks)																								
Hydrachnellidae (Water Mites)	1	1	1				1	2	1			1						1	1					
Insecta																								
Plecoptera (Stoneflies)																								
Perlidae			1	2		1	2				1													
Neoperla spio complex			1	2	1	2	2											1						
Ephemeroptera (Mayflies)																								
Leptophlebiidae (Prongills)	1	2	1		1	1	2	1	2			1			1		2	1	1					
Castanophlebia sp.																		1		1				
Choroterpes																		1		1				
Euthraulus elegans	1	1	1										1		1	1	1	1	1					
Caenidae (Squaregills)	1	2				1	2	1	1				1		1	1	1	1	3		B	A	B	A
Tricorythidae (Stout crawlers)			1	2	1	2	2	1				1			1	1	1	1				A	A	
Prosopistomatidae (Water specs)			2	1	1	1	1				1					1								
Oligoneuriidae (Brushlegged mayflies)			1	1		1	1		2		1												1	
Elassoneuria			1	2					2		1							1		1			1	

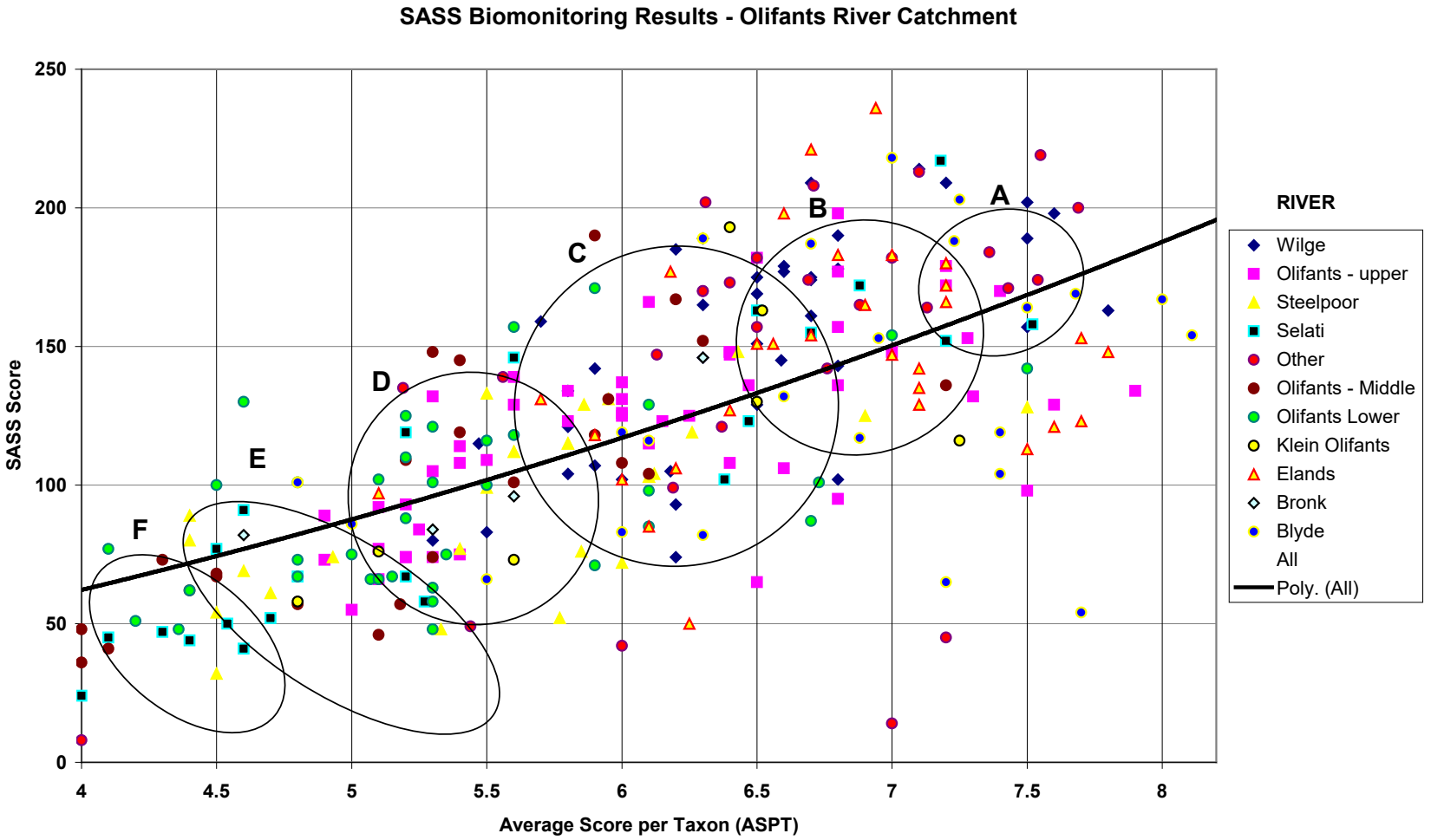
	Flow				Substrate						Water Quality				Previous Studies						This Study			
	Standing (<0.1)	Slow (0.1-0.3)	Mod (0.3-0.6)	Fast (>0.6)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	Water Colum & Surface	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)	None (SASS <3)	**IFR 11: Lissithaba**	**MICA**	**IFR 13: Grietjie**	**IFR 15: Mamba**	**IFR 17: Balule lower**	**nr Letaba confl**	**EWR1-Winter**	**EWR1-Summer**	**EWR2-Winter**	**EWR2-Summer**
Heptageniidae (Flathead mayflies)		1	1	1		1	2	1			1				1		1		1					A
Afronurus sp.		1	1	1		2	2					1				1		1		1				
Afronurus harrisoni						1	1					1						1						
Baetidae (Small minnow mayflies)															3		3	3	3		C	C	C	C
Baetis harrisoni	1	1	1	2		1	1						1		1									
Centroptiloides bifasciata				2		1	1				1						1							
Cheleocloeon excisum	2	1	1	1				1	2				1					1		1				
Cloeon																		1						
Crassabwa flava	1	2	1	1												1		1		1				
Dabulamanzia media	1	2	1	1			2											1		1				
Procloeon africanum	2							1	1									1		1				
Pseudocloeon bellus	2	1	1	1				1								1		1						
Pseudocloeon glaucum		1	1	2		2	2	1					1			1	1	1		1				
Pseudocloeon vinosum		1	1	1		1	1	1					1			1								
Psuedopannata maculosa			1	2		1	1				1						1	1						
Odonata																								
Zygoptera (Damselflies)																		1						
Chlorolestidae	1	1						2				1			1									
Lestidae	1	1						2				1												
Lestes pallidus																								
Coenagrionidae	1	2						2					1		1		1	2	2		C	B	B	B
Pseudagrion spp.																		1		1				
Pseudagrion massaicum																		1						
Chlorocyphidae	1	1					2	1				1			1			1						
Aeshnidae	1							2				1						1	1				A	
Aeshna																		1		1				
Corduliidae	1							2				1			2		1	1	1					
Gomphidae	1	1							2				1		2		1	1	1	1	B	A	A	A
Libelluliidae	1	1	1			1	1	1					1		1		1	1	1	1	A	A		
Zygonyx sp.																		1		1				
Notonectidae (Back swimmers	2									2				1			1	1	1		A			1
Pleidae (Pigmy back swmmers	2							2					1										B	
Naucoridae (Creeping water bugs)								2		1		1			1		1	1	2	1			1	
Nepidae (Water scorpions)	2							2						1	1				1		1			
Belostomatidae (Giant water b	2									2				1	1		1		1		A	A	A	A

	Flow				Substrate						Water Quality				Previous Studies						This Study			
	Standing (<0.1)	Slow (0.1-0.3)	Mod (0.3-0.6)	Fast (>0.6)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	Water Colum & Surface	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)	None (SASS <3)	IFR 11: Lissithaba	MICA	IFR 13: Grietjie	IFR 15: Mamba	IFR 17: Balule lower	nr Letaba confl	EWR1-Winter	EWR1-Summer	EWR2-Winter	EWR2-Summer
Corixidae (Water boatmen)	2	1						1	2	1				1			1	1	2		B		A	A
Micronecta																		1		1				
Gerridae (Water striders)	1	1								2			1					1	1	1		A		
Hydrometridae (Water measure	2									2			1						1				1	
Veliidae (Broad-shouldered wa	1	1								2			1		1		1	1	1		C		B	
Trichoptera (Caddisflies)																								
Dipseudopsidae		1	1						2			1												
Ecnomidae			1	1		1	2		2			1						1	1					
Ecnomus sp.																		1		1				
Hydropsychidae			1	2	1	2	1					1												
Aethaloptera maxima															1		2	1	1					
Amphipsyche scottae		1	1	2														1		1	A	A	1	
Cheumatopsyche thomasseti		1	1	2											1		1	1	1	1				
Cheumatopsyche zuluensis																1								
Hydropsyche longifurca				2																	A	A		
Hydroptilidae		1	1		1	1	1	1					1		1		1	1	1		1	1	1	
Catoxythira sp.																		1		1				
Hydroptila capensis																		1		1				
Hydroptila sp.																		1		1				
Orthotrichia sp.				1														1		1				
Leptoceridae		1	1		1	1	1	2	1				1		1		1	1	1	1	A	1	1	A
Athripsodes sp.																1		1						
Leptocerus inflatus																				1				
Leptocerus ?schoenebates																		1		1				
Oecetis sp.																		1		1				
Trichosetodes sp.				1														1		1				
Philopotamidae		1					2		1			1						1						
Chimarra sp.																1				1				
Lepidoptera (Moths)																								
Pyralidae	1	1	1	2	1	2	1	1			1							1						
Coleoptera (Beetles)																								
Dytiscidae (Diving Beetles)	2	1						2					1				1	1	1	1	1		B	
Elmidae (Riffle Beetles)			1	2		2	1	1				1			1	1		1	1	1				
Stenelmis sp.																		1		1				

	Flow				Substrate						Water Quality				Previous Studies						This Study			
	Standing (<0.1)	Slow (0.1-0.3)	Mod (0.3-0.6)	Fast (>0.6)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	Water Colum & Surface	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)	None (SASS <3)	IFR 11: Lissithaba	MICA	IFR 13: Grietjie	IFR 15: Mamba	IFR 17: Balule lower	nr Letaba confl	EWR1-Winter	EWR1-Summer	EWR2-Winter	EWR2-Summer
Gyrinidae (Whirligig Beetles)	1	2	2							2			1		1		1	1	1				A	
Hydraenidae (Minute Moss Beetles)																		1	1	1				
Haliplidae (Crawling Water Bee	2							2					1					1	1				A	
Hydrophilidae (Water Scaveng	2							2					1					1	1	1			A	
Psephenidae (Water Pennies)			1	2		2	1					1			1			1						
Diptera (Flies)																								
Nematocera																								
Tipulidae (Crane Flies)	1	1	1	1	1		1		2				1					1	1					
Culicidae (Mosquitoes)	2							2						1	1			1	1	1				
Ceratopogonidae (Biting Midge	1	1	1				1	2	1				1		1		1	1	1					
Bezzia sp.				1														1		1	1		1	1
Chironomidae (Midges)	2	1	1	1	1	1	1	1	1				1	2	1		1	1	2		B	A	A	A
Tanypodinae																		1		1				
Orthocladiinae																		1		1				
Chironominae																		1		1				
Simuliidae (Blackflies)		1	2	2	2	2	2	2				1	2	1	1		1	1	2	1	D	B	A	1
Simulium adersi	1	1					2	2	1			1	2	1					1		D		A	
Simulium alcocki							1	2				1										A		
Simulium bovis				1	2	2	1					1							1		A	A	A	
Simulium damnosum			1	1	1	1	1	2			2				1		1		1					
Simulium impukane		1					1	2			1	1	1								A			
Brachycera																								
Tabanidae (Horse Flies)	2	1					1	1	2				1		1		1	1	1	1	1			
Athericidae/Rhagionidae		1					1	1				1				1								
Empididae (Dance Flies)	1						1	1					1							1				
Cyclorrhapha																								
Ephydridae (Shore Flies)	2	1						1	1					1				1						
Muscidae	1	1						1	2					1				1						
Limnophora sp.																		1		1				
Mollusca																								
Gastropoda (Snails & limpets)																								
Prosobranchia																								
Ampullariidae (Pilidae)																								
Lanistes ovum																								Empt

	Flow				Substrate						Water Quality				Previous Studies						This Study			
	Standing (<0.1)	Slow (0.1-0.3)	Mod (0.3-0.6)	Fast (>0.6)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	Water Colum & Surface	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)	None (SASS <3)	**IFR 11: Lissithaba**	**MICA**	**IFR 13: Grietjie**	**IFR 15: Mamba**	**IFR 17: Balule lower**	**nr Letaba confl**	**EWR1-Winter**	**EWR1-Summer**	**EWR2-Winter**	**EWR2-Summer**
Thiaridae	1	2			1	1	1	1	2					1				1		1	1	B	B	
Cleopatra ferruginea																								
Pulmonata																								
Lymnaeidae	2	1			1		1	2						1				1			A			
Lymnaea columella	1	2	2	1				1					1											
Lymnaea natalensis	1	2	2	1																				
Lymnaea truncatula																								
Ancylidae	1	1	1	1	1	1	1	1					1										1	
Burnupia sp.	1	1	1	2													1	1	1	1				
Ferrissia sp.	1	1	1	1																				
Basommatophora																								
Planorbidae	2	1			1		1	2						1							1		1	
Biomphalaria pfeifferi	2	1						2										1					1	
Bulininae	2	1			1		1	2						1										
Bulinis spp	2	1																1						
Physidae	2	1			1		1	2						1							B		B	
Physa acuta																								
Bivalvia (Mussels)																								
Unionidae	1	1					1		2				1									A		
Unio caffer																								Empt
Corbiculidae	1	2	1				1		2				1		1		1	1	1			A	B	
Corbicula fluminalis																		1		1				
Spaeriidae		2					1		2					1										
Eupera sp.																				1				

ANNEX C: Summary SASS Biomonitoring Results – Olifants River Catchment



ANNEX D: Detailed Results of Benthic Invertebrate Response Assessment Index (MIRAI)

Site 1: PES (D)

INDICATORS OF *FLOW MODIFICATION*		Velocity preference scores	Weight	Weighted score	Rank	% Weight	Std to sum to 1	Taxa expected but not found
Presence of taxa with a preference for very fast flowing water	FT	3.5	0.07	0.25	5	30	0.07	Centroptiloides; Elmidae; Heptageniidae; Oligoneuridae;
Abundance of taxa with a preference for very fast flowing water	FTA	3	0.06	0.18	6	25	0.06	
Presence of taxa with a preference for moderately fast flowing water	MT	3	0.21	0.64	3	90	0.21	Dipseudopsidae; Gyrinidae; Leptophlebiidae
Abundance of taxa with a preference for moderately fast flowing water	MTA	3	0.20	0.60	4	85	0.20	
Presence of taxa with a preference for slow flowing water	ST	2	0.24	0.47	1	100	0.24	Bulininae; Chlorocyphidae; Hirudinae; Aeshnidae; Ceratopogonidae; Culicidae
Abundance of taxa with a preference for slow flowing water	STA	2	0.22	0.45	2	95	0.22	
Proportional change in average flow dependence of the assemblage			1	**51.53**		**425**	**1**	

INDICATORS OF *HABITAT PREFERENCE*		Habitat preference scores	Weight	Weighted score	Rank	%Weight	Std to sum to 1	Taxa expected but not found
Has the proportion of invertebrates with a preference for bedrock changed relative to expected?	BT	2.5	0.00	0.00	9	0	0.00	
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	BTA	2.5	0.00	0.00	10	0	0.00	
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	CT	2.5	0.08	0.20	7	50	0.08	Ecnomidae; Leptophlebiidae; Oligoneuridae
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	CTA	2.5	0.06	0.16	8	40	0.06	
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	VT	2	0.16	0.32	1	100	0.16	Aeshnidae; Bulininae; Ceratopogonidae; Culicidae; Elmidae;
Has the abundance of any of the taxa with a preference for vegetation changed?	VTA	2	0.15	0.31	2	95	0.15	
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	GT	1	0.14	0.14	3	90	0.14	Dipseudopsidae; Ecnomidae; Oligochaeta; Tipulidae
Have the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	GTA	1	0.14	0.14	4	85	0.14	
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	WT	2	0.13	0.26	5	82	0.13	Gyrinidae;
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	WTA	2	0.13	0.26	6	80	0.13	
			1			622	1.00	

INDICATORS OF *WATER QUALITY*		Water quality requirement score	Weight	Weighted score	Rank	%Weight	Std to sum to 1	Taxa expected but not foun
Are any taxa with a high requirement for unmodified water quality absent?	HQ	4	0.05	0.2116	7	30	0.05	Centroptiloides; Heptagenidae; Neoperla; Oligoneuridae
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	HQA	4	0.05	0.1975	8	28	0.05	
Are any taxa with a moderate requirement for unmodified water quality absent?	MQ	3	0.18	0.5291	1	100	0.18	Aeshnidae; Chlorocyphidae; Cordulidae; Elmidae; Ecnomidae; Naucoridae;
Have the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	MQA	3	0.17	0.5238	2	99	0.17	
Are any taxa with a low requirement for unmodified water quality present?	LQ	1	0.17	0.1675	3	95	0.17	Gyrinidae; Hydrophilidae; Pleidae
Have the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	LQA	0	0.16	0.0000	4	90	0.16	
How does the total SASS score differ from expected?	SASS	3	0.07	0.2116	5	40	0.07	
How does the total ASPT score differ from expected?	ASPT	3	0.15	0.4497	6	85	0.15	
			1			567		
Overall change to indicators of modified water quality				**45.82**				

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	48.5	0.419	20.3	41.9	*0.419*	MTA	1	100	0.500	1
HABITAT	64.2	0.245	15.7	24.5	*0.245*	CTA	3	40	0.200	0.4
WATER QUALITY	54.2	0.336	18.2	33.6	*0.336*	HQA	2	60	0.300	0.6
	166.8	1		100	1.000				0.500	
Invert PES			**54.2**					200	1	
Category	33.37		**D**							

Site 1: Alternative Category Up (C)

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**	2.5	0.07	0.18	5	30	0.07
Abundance of taxa with a preference for very fast flowing water	**FTA**	2.5	0.06	0.15	6	25	0.06
Presence of taxa with a preference for moderately fast flowing water	**MT**	2	0.21	0.42	3	90	0.21
Abundance of taxa with a preference for moderately fast flowing water	**MTA**	2	0.20	0.40	4	85	0.20
Presence of taxa with a preference for slow flowing water	**ST**	2	0.24	0.47	1	100	0.24
Abundance of taxa with a preference for slow flowing water	**STA**	2	0.22	0.45	2	95	0.22
Proportional change in average flow dependence of the assemblage			1	**41.29**		**425**	**1**

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**	2.5	0.00	0.00	9	0	0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	**BTA**	2.5	0.00	0.00	10	0	0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	**CT**	2.5	0.08	0.20	7	50	0.08
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	**CTA**	2.5	0.06	0.16	8	40	0.06
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	**VT**	2	0.16	0.32	1	100	0.16
Has the abundance of any of the taxa with a preference for vegetation changed?	**VTA**	2	0.15	0.31	2	95	0.15
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	**GT**	1	0.14	0.14	3	90	0.14
Have the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	**GTA**	1	0.14	0.14	4	85	0.14
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	**WT**	2	0.13	0.26	5	82	0.13
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	**WTA**	2	0.13	0.26	6	80	0.13
			1			622	1.00

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	0.05	0.1587	7	30	0.05
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	**HQA**	3	0.05	0.1481	8	28	0.05
Are any taxa with a moderate requirement for unmodified water quality absent?	**MQ**	2	0.18	0.3527	1	100	0.18
Have the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	**MQA**	2	0.17	0.3492	2	99	0.17
Are any taxa with a low requirement for unmodified water quality present?	**LQ**	1	0.17	0.1675	3	95	0.17
Have the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	**LQA**	0	0.16	0.0000	4	90	0.16
How does the total SASS score differ from expected?	**SASS**	2	0.07	0.1411	5	40	0.07
How does the total ASPT score differ from expected?	**ASPT**	2	0.15	0.2998	6	85	0.15
			1			567	
Overall change to indicators of modified water quality				**32.35**			

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	58.7	0.419	24.6	41.9	*0.419*	MTA	1	100	0.500	1
HABITAT	64.2	0.245	15.7	24.5	*0.245*	CTA	3	40	0.200	0.4
WATER QUALITY	67.7	0.336	22.7	33.6	*0.336*	HQA	2	60	0.300	0.6
	190.5	1		100	1.000				0.500	
Invert PES			**63.1**					200	1	
Category	38.11		**C**							

Site 2: PES (C)

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**	3.5	0.07	0.25	5	30	0.07
Abundance of taxa with a preference for very fast flowing water	**FTA**	3	0.06	0.18	6	25	0.06
Presence of taxa with a preference for moderately fast flowing water	**MT**	2	0.21	0.42	3	90	0.21
Abundance of taxa with a preference for moderately fast flowing water	**MTA**	2	0.20	0.40	4	85	0.20
Presence of taxa with a preference for slow flowing water	**ST**	1.5	0.24	0.35	1	100	0.24
Abundance of taxa with a preference for slow flowing water	**STA**	2	0.22	0.45	2	95	0.22
Proportional change in average flow dependence of the assemblage			1	**40.94**		**425**	**1**

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**	2.5	0.00	0.00	9	0	0.00
Has the abundance of any of the taxa with a preference for bedrock/boulders changed?	**BTA**	2.5	0.00	0.00	10	0	0.00
Has the proportion of invertebrates with a preference for mobile cobbles changed relative to expected?	**CT**	2.5	0.08	0.20	7	50	0.08
Has the abundance of any of the taxa with a preference for mobile cobbles changed?	**CTA**	2.5	0.06	0.16	8	40	0.06
Has the proportion of invertebrates with a preference for vegetation changed relative to expected?	**VT**	2	0.16	0.32	1	100	0.16
Has the abundance of any of the taxa with a preference for vegetation changed?	**VTA**	2	0.15	0.31	2	95	0.15
Has the proportion of invertebrates with a preference for sand, gravel or mud changed relative to expected?	**GT**	0.5	0.14	0.07	3	90	0.14
Have the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	**GTA**	0.5	0.14	0.07	4	85	0.14
Has the proportion of invertebrates with a preference for the water column or water surface changed relative to expected?	**WT**	0.5	0.13	0.07	5	82	0.13
Has the abundance of any of the taxa with a preference for the water column/water surface changed?	**WTA**	0.5	0.13	0.06	6	80	0.13
			1			622	1.00

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	0.05	0.2116	7	30	0.05
Have the abundance of any of the taxa with a high requirement for unmodified water quality been decreased?	**HQA**	4	0.05	0.1975	8	28	0.05
Are any taxa with a moderate requirement for unmodified water quality absent?	**MQ**	2	0.18	0.3527	1	100	0.18
Have the abundance of any of the taxa with a moderate requirement for unmodified water quality been decreased?	**MQA**	2	0.17	0.3492	2	99	0.17
Are any taxa with a low requirement for unmodified water quality present?	**LQ**	0.5	0.17	0.0838	3	95	0.17
Have the abundance of any of the taxa with a low requirement for unmodified water quality been increased?	**LQA**	0	0.16	0.0000	4	90	0.16
How does the total SASS score differ from expected?	**SASS**	0.5	0.07	0.0353	5	40	0.07
How does the total ASPT score differ from expected?	**ASPT**	2	0.15	0.2998	6	85	0.15
			1			567	
Overall change to indicators of modified water quality				**30.60**			

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	59.1	0.419	24.8	41.9	*0.419*	MTA	1	100	0.500	1
HABITAT	74.8	0.245	18.4	24.5	*0.245*	CTA	3	40	0.200	0.4
WATER QUALITY	69.4	0.336	23.3	33.6	*0.336*	HQA	2	60	0.300	0.6
	203.3	1		100	1.000				0.500	
Invert PES			**66.4**					200	1	
Category	40.65		**C**							