DETERMINING THE INSTREAM FLOW REQUIREMENT MONITORING PROTOCOL

Report submitted to the Water Research Commission by

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EXECUTIVE SUMMARY

The headings correspond with headings in the document, but the numbering does not.

1. Introduction

Over the last few years groups of different aquatic specialists have been involved in a process developing the Instream flow requirements (IFR's) of rivers across the country. A methodology known as "The building Block Methodology" (BBM) has been developed to assess the Instream flow requirements for any river. It can be used in any river situation and the emphasis is on identifying a complex of different magnitude flows for the maintenance of entire river ecosystems. The Department of Water Affairs (DWAF) uses the information obtained through the BBM workshops, in the planning phases of the proposed water resource developments.

Rivers that have impoundments or related developments planned in near future have been prioritised in the assigning of the recommended flows. According to the new Water Act, there is a need to monitor the effects of water development schemes. To determine the ecological effect of such developments, it is necessary to obtain pre-development data, which will provide baseline information, to which future effects and ecological findings can be compared.

This project is particularly aimed at Luvuvhu and the Sabie/Marite Rivers because both systems already have impoundments planned. Developments have already begun on these two rivers. The Injaka Dam development on the Marite tributary of the Sabie River originally aimed to be completed by the end of 2001, but this has since been postponed to the first quarter of 2002. The Nandoni (formerly known as the Mutoti) Dam on the Luvuvhu aims to be completed by September 2001, but it is also likely that this date will move forward.

IFR sites have been identified and established for both the Marite / Sabie and Luvuvhu Rivers, and the BBM workshops were held in August 1996 and July 1994 respectively. Various refinements to the IFR workshop documents have subsequently been presented, with the most recent for the Sabie being in 1997 and for the Luvuvhu in December 1998. Preliminary monitoring protocol, guidelines and objectives have also been compiled for the Luvuvhu River in December 1998 and the Sabie River in August 1997.

To date there has been considerable amount of monitoring on the Sabie River by different organisations. And some monitoring on the Luvuvhu River. Different sites along the rivers have had varying numbers of surveys completed and to different degrees. For example monitoring sites in the Kruger Park will have had more work done on them, than sites outside the protected area. On the Sabie River there have been quite comprehensive fish studies completed, and more recently macro invertebrate surveys using the SASS:4 method. Most of the monitoring that has taken place to date has been using the rapid assessment, River Health bio-monitoring techniques.

This report concentrates on the geomorphology, riparian vegetation, fish, and aquatic invertebrates.

The project started in September 1999 and was originally expected to be a two-year study. However it has since been extended to December 2001. Most of the fieldwork was completed by May / June 2001. Heavy rains in the 1999/ 2000 season resulted in flood conditions on both the Luvuvhu and Sabie Rivers. While it proved to be a fascinating occurrence, it did hinder the field trips and sampling in the rivers, and to date there are still gauging weirs that have not been re-established. Even by May 2001 the flows were still three to four times the magnitude of those recorded at the start of the project, and at the end of the 1999 dry season the flows were still considered to be above the required daily flow rates.

2.Aims and Objectives:

The main aims of the project and whether they were achieved:

a) Base line monitoring of the Luvuvhu and Marite / Sabie Rivers. *Two sites on the Luvuvhu and four sites on the Sabie / Marite Rivers were monitored. The geomorphology, riparian vegetation, fish and invertebrates were the components monitored. Under the conditions valuable baseline information was obtained.*

b) Develop and test monitoring methods that will check that the recommended ecological flows are being delivered to the different reaches of the Sabie and Luvuvhu rivers. *Different monitoring / sampling techniques were tried for the riparian vegetation and fish in particular. Standard methods for the geomorphology and invertebrates were used. A first draft and proposed invertebrate flow scoring system was developed, and an idea for IFR habitat assessment.*

c) Assess whether the recommended flows are achieving the objectives for which they were designed. *This objective was not possible to achieve because most of the flows for the project were higher than the recommended flows.*

d) Training / capacity building of 2 technicians. *Two technicians were trained in geomorphology, riparian vegetation, fish and invertebrate sampling / monitoring methods.*

All of the following components should be considered against the flow rates at the time (obtain nearest gauging weir reading and / or DWAF records), the specific habitats created at that flow rate, and the depths of the different habitats created at that particular flow.

Geomorphology

- Complete data sheet (as prescribed by Wadeson and Rowntree) at each of the six sites to be monitored.
- Obtain aerial photographs for each of the sites – preferably a set of say three in the last 20 – 30 years.
- Take photographs of different aspects of the geomorphological components at each of the sites.

Riparian Vegetation

- Create a photographic record of each of the sites at each visit – preferably using a fixed point.
- Try out/test different methods to monitor and/or determine the following aspects of the riparian vegetation
  : Species composition
  : Terrestrial, reeds and exotic species invasion / increase / decrease.
  : Recruitment and mortality of riparian species
  : Diameter and height classes
  : If there are any key species
- Develop an appropriate data sheet/s

Invertebrates

- Desk top study of past research done (if any)
- Apply SASS 4 at each site (Important for the water quality aspect)
- Separate all biotopes when sampling (record the flows and depths at each)
- Obtain a list of taxa for each site
- Develop an applicable and appropriate data sheet
- Diagram of site and where sampling took place (possible link with habitat modelling project at a later stage)
- Start to develop a flow related scoring system using data obtained to species / family level
- Develop a holistic IFR habitat assessment sheet

Fish

- Desk top study of past work done
- Sampling at each site using a combination of methods as appropriate to the site and habitats created.
- Separate all biotopes when sampling (record the flows and depths at each)
- Record the species, age class and health of each fish caught
- Develop an applicable and appropriate data sheet
- Obtain a list of species for each site
- Diagram of site and where sampling took place (possible link with habitat modelling project at a later stage)
- Start to develop a flow related scoring system using data obtained to species level

3. Methods used

The geomorphology was monitored with only one method, the Wadeson, Rowntree geomorphological index. It involves a desktop analysis and a site visit. It is a method designed for any monitoring programme. It is fairly quick to use (the tally of bed material size and distribution taking a little time extra), and requires minimal training. Parts of it are a little subjective.

Four different methods were used for the riparian vegetation. These were a line transect, a general survey, a belt transect and a belt transect with quadrants and indicator species. The belt transect involves recording every woody species, its height, substrate and damage rating (if any). The general survey and belt transect give valuable information for baseline purposes and an idea of the species composition in the riparian community. The line transect is a quick method and gives a summary view of species composition, but many line transects would be required to get an idea of the whole site. The belt and quadrant transect method makes use of riparian indicators, and terrestrial / riparian ecotone. It is less time consuming than a normal belt transect, and doesn't give enough information on the whole of the site, but does provide information on terrestrial encroachment to certain extent as well as information on indicator species. The way to go for long term monitoring is definitely with indicators specific to different sites across the country.
Five different techniques were used for sampling the fish. They were electro shocking, a large seine net, a small seine net, a mosquito net and a cast net. The electro shocker was most broadly used and generally gives a high CPUE. It can be tiresome to use (and carry) if the channel is very wide. It is not very effective in very fast deep water, frequently kills fish fry, and if the conductivity of the water is low it is less effective. It can be used in most habitats. The large seine net can also have a large CPUE, but requires more than two people to operate it. It is not effective in medium to fast flows, and has a tendency to snag on rocks and logs in the

substratum. The cast net can be very effective for catching unsuspecting adult fish (of the larger species), but it has a low CPUE, and it takes time to master the technique. The small seine is very easy to use with two people, its CPUE is variable, and is fine for shallower pools of slow or no flow. The mosquito net is very useful in a vegetated habitat of slow or no flow and not too deep, its CPUE is variable depending on the circumstances, but is usually high.

The invertebrates were sampled using the kicking method. Should any different invertebrate be caught during a fish sampling method for example shocking, then it was recorded as well. A more in depth SASS version 4 survey was used.

Sometimes it was necessary to make use of a two man inflatable boat, especially with the flows higher than average.

4. Results

Under 'normal' conditions geomorphology would not have changed much in a two year survey, but when an extreme event like the February floods takes place there are definitely geomorphological changes. Some of the (observed) sites changed less than others some changed only in terms of vegetation cover. The Luvuvhu IFR 1 site changed quite considerably in that the large downstream island changed from being mainly sand to a smaller cobble / boulder island. The Sabie IFR 4 site had the left hand channel opened up. IFR 2 on the Sabie became quite sedimented, large diagonal bedrock bars that were formerly visible are no longer exposed. The channel 1 at the Sabie IFR 5 site changed from a fairly wide slow to medium flow, and fairly deep channel to a narrow channel that has different flow velocities, but is not likely to remain perennial.

With the riparian vegetation monitoring, each site had at least one method used at the site, but it was generally two methods, and some sites had three different methods applied. There were fourty six species recorded at the Luvuvhu IFR 1 site. Luvuvhu IFR 2 site had 20 species recorded, 2 were exotic (woody) species and 2 were definite terrestrial species, the rest a combination of unknown and riparian species. Marite IFR 1 site had 41 species recorded at it, of which 6 were exotic species and 5 terrestrial species. The Sabie IFR 2 site had 31 species, of which 3 were exotics and 12 were terrestrial species. The Sabie IFR 4 site had 32 species, 7 were terrestrial and 2 exotics.

During the high flow conditions a total of eighteen fish were added to all the historic species lists, some being the same species at different sites, and some being debatable as to whether they are actually additional species, and have been recorded at the site or in the vicinity, but are not on the list. Whatever the case it is definite that additional species were recorded at some sites and it can be attributed to the different habitat conditions that have been created as a result of the floods. But then there are species that were not caught at any stage in the survey, that were caught fairly regularly in the past and are on the historic species list. This can also be attributed to a few reasons (sampling method, chance of capture, capture avoidance, and loss of habitat), but at least some of the species were not caught because of the flood conditions. Whether the species composition will stabilise or gradually change to the former, remains to be seen, much of which depends on whether previous habitats re-establish themselves. This refers particularly to the vegetation component of habitats.

The monitoring of invertebrates involved separating biotopes more specifically than a normal SASS survey, for example the stones in current biotope was separated from the stones out of current. Flows were also more refined, and were catogorised into no flow, slow flow, medium, fast and very fast flows. By distinguishing the biotopes and flows more specifically some interesting information was obtained on the biotopes that different taxa prefer, and as a result a preliminary flow scoring system was put together. SASS also applies in terms of water quality, and generally the scores were acceptable and good considering that the invertebrates were re-establishing themselves after the floods.

5. IFR Monitoring Protocol Workshop

A workshop held in August 2001, proved to be successful in most respects. Participants were experts from different aquatic fields. The main aims of the workshop were: to assist Department of Water Affairs in defining a monitoring policy for the Ecological Reserve; to design a monitoring system which will feedback into management, to review IFR monitoring methods and suggest further priorities, and to design a monitoring system which can be implemented and effective within available resources. Alison Howman of DWAF presented the Monitoring and Assessment Information System (MAIS) that DWAF are in the process of implementing. Dirk Roux presented the model of Strategic Adaptive Management (SAM), and assessment criteria, which contribute to the success of the design and implementation of an environmental monitoring programme, using the River Health Programme as a case study. It was agreed that TPC's (Thresholds of probable concern) were appropriate, but the TPC's for each component of the monitoring programme need to be defined and refined. A process diagram was devised to represent the processes involved in IFR monitoring and the proposed steps to be taken if a TPC is exceeded. The workshop participants then divided into different speciality groups: geomorphology; riparian vegetation; invertebrates and fish. Each group produced a proposed monitoring programme with different levels of detail.

6. Conclusion

While the February 2000 floods may have burdened the project to a certain degree (loss of cross sections, loss of gauging weirs and continued high flow conditions for most of the project), there has certainly been interesting and valuable information to be gained as well. With both the Injaka and Nandoni dams to be closed soon, there has now been some additional baseline monitoring at some sites. While it was not the objective of the project to monitor the responses of biota to high flow conditions, nor were sufficient sites monitored to gain a broader spectrum of information, the information collected is valuable under the circumstances. Initially it was thought that perhaps a fish scoring system needs to be developed, something similar to SASS for example, but flow related. But after the IFR Monitoring Protocol Workshop it was evident from discussions that the current RHP method FAII (Fish assemblage integrity index) is more than sufficient. A great deal of previous research on macro-invertebrate communities in the Sabie River in particular, identified the organisms to species level. At the out start of the project it was considered an option to do the same. However it was decided that for the present, that to the existing taxon level (mainly families) was sufficient. Perhaps certain indicator species could be identified at a site rating for a river and specific site, that could be used in the future long term IFR monitoring.

7. Recommendations

- That the proposed IFR Monitoring Programme be absorbed into DWAF's MAIS programme, and be implemented as soon as possible. It is imperative that rivers like the Luvuvhu and Sabie Rivers (Luvuvhu in particular) are monitored appropriately before the dams are completed.
- That a group of aquatic invertebrate specialists meet to discuss and further develop (or throw out) the proposed macro-invertebrate flow scoring system.
- Because habitat creation is a significant section of IFR's it is necessary to decide whether a habitat assessment is needed, and if so, is the proposed type appropriate. Secondly it is important that IFR monitoring link up with / adopt or adapt any current habitat modelling methods and any work that has due to be published.
- That the hydraulic cross sections and ratings take place as soon as possible at the IFR sites that were effected by the floods, as well as the new Botsoleni site.

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ACKNOWLEDGMENTS

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A SUMMARY OF ACRONYMS AND ABBREVIATIONS

- AEMC Attainable ecological management class
- ASPT Average score per a taxon
- BBM Building Block Methodology
- CPUE Catch per unit effort
- DEMC Desired ecological management class
- DESC Desired ecological status class
- DFS Desired Future State
- DWAF Department of Water Affairs
- EE Extended estimate
- EISC Ecological importance and sensitivity class
- EMC Ecological Management Class
- FAII Fish assemblage integrity index
- HAM Habitat Assessment Matrix
- HQI Habitat Quality Index
- IFR Instream Flow Requirements
- IHAS Integrated Habitat Assessment System
- IWQS Institute for Water Quality Studies
- IWR Institute for Water Research
- KNP Kruger National Park
- KNPRRP KNP Rivers Research Programme
- LHB Left hand bank
- MAIS Monitoring and Assessment Information System
- MAR Mean annual runoff
- MPB Mpumalanga Parks Board
- NWBM National water balance model
- PEMC Present ecological management class
- PERM Preliminary ecological reserve methodology
- PESC Present ecological status class
- RHB Right hand bank
- ROIP Relevant environmental (omgewing) impact prognosis
- SAM Strategic Adaptive Management
- SASS 4 South African Scoring System version 4
- SIC Stones in current
- SOOC Stones out of current
- TPC Thresholds of probable concern
- WBPE Water balance planning estimate
- WRC Water Research Commission

1. INTRODUCTION

Over the last few years groups of different aquatic specialists have been involved in a process developing the Instream flow requirements (IFR's) of rivers across the country. A methodology known as "The building Block Methodology" (BBM) has been developed to assess the Instream flow requirements for any river. It can be used in any river situation and the emphasis is on identifying a complex of different magnitude flows for the maintenance of entire river ecosystems. The Department of Water Affairs (DWAF) uses the information obtained through the BBM workshops, in the planning phases of the proposed water resource developments.

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To date there has been considerable amount of monitoring on the Sabie River by different organisations. And some monitoring on the Luvuvhu River. Different sites along the rivers have had varying numbers of surveys completed and to different degrees. For example monitoring sites in the Kruger Park will have had more work done on them, than sites outside the protected area. On the Sabie River there has been quite comprehensive fish studies completed, and more recently macro invertebrate surveys using the SASS:4 method. Most of the monitoring that has taken place to date has been using the rapid assessment, River Health bio-monitoring techniques.

The IFR workshops have identified eight important components to be considered and addressed in the IFR monitoring program. They are:

- Hydrology
- Hydraulics
- Geomorphology and Geohydrology
- Riparian vegetation
- Fish
- Aquatic invertebrates
- Water quality
- Co-ordination and Data Management

This report concentrates on the geomorphology, riparian vegetation, fish, and aquatic invertebrates.

The project started in September 1999 and was originally expected to be a two-year study. However it has since been extended to December 2001. Most of the fieldwork was completed by May / June 2001. Heavy rains in the 1999/ 2000 season resulted in flood conditions on both the Luvuvhu and Sabie Rivers. While it proved to be a fascinating occurrence, it did hinder the field trips and sampling in the rivers, and to date there are still gauging weirs that have not been re-established. Even by May 2001 the flows were still three to four times the magnitude of those recorded at the start of the project, and at the end of the 1999 dry season the flows were still considered to be above the required daily flow rates.

2. AIMS AND OBJECTIVES

The main aims of the project include:

- Base line monitoring of the Luvuvhu and Marite / Sabie Rivers
- Develop and test monitoring methods that will check that the recommended ecological flows are being delivered to the different reaches of the Sabie and Luvuvhu rivers
- Assess whether the recommended flows are achieving the objectives for which they were designed
- Training / capacity building of 2 technicians

2.1 OBJECTIVES

When monitoring the following components, the different flow rates at the time of monitoring (obtain nearest gauging weir reading and / or DWAF records) need to be considered, as well as the specific habitats created at that flow rate, and the depths of the different habitats created at that particular flow.

2.1.1 Geomorphology

- Complete data sheet (as prescribed by Wadeson and Rowntree) at each of the six sites to be monitored.
- Obtain aerial photographs for each of the sites – preferably a set of say three in the last 20 – 30 years.
- Take photographs of different aspects of the geomorphological components at each of the sites.

2.1.2 Riparian Vegetation

- Create a photographic record of each of the sites at each visit – preferably using a fixed point.
- Try out/test different methods to monitor and/or determine the following aspects of the riparian vegetation
  : Species composition
  : Terrestrial, reeds and exotic species invasion / increase / decrease.
  : Recruitment and mortality of riparian species
  : Diameter and height classes
  : If there are any key species
- Develop an appropriate data sheet/s

2.1.3 Invertebrates

- Desk top study of past research done (if any)
- Apply SASS 4 at each site (Important for the water quality aspect)
- Separate all biotopes when sampling (record the flows and depths at each)
- Obtain a list of taxa for each site
- Develop an applicable and appropriate data sheet
- Diagram of site and where sampling took place (possible link with habitat modelling project at a later stage)
- Start to develop a flow related scoring system using data obtained to species / family level
- Develop a holistic IFR habitat assessment sheet

2.1.4 Fish

- Desk top study of past work done
- Sampling at each site using a combination of methods as appropriate to the site and habitats created.
- Separate all biotopes when sampling (record the flows and depths at each)

- Record the species, age class and health of each fish caught
- Develop an applicable and appropriate data sheet
- Obtain a list of species for each site
- Diagram of site and where sampling took place (possible link with habitat modelling project at a later stage)
- Start to develop a flow related scoring system using data obtained to species level

3. STUDY AREAS

Two sites on the Luvuvhu River and four sites on the Marite / Sabie Rivers were worked on. With the construction of the Nandoni dam, the first IFR site on the Luvuvhu River was lost. This meant that a new site needed to be established. With the assistance of Mick Angliss who had the experience of participating in the IFR workshops and who has been monitoring the fish on the Luvuvhu for a period of time, a site at Botsoleni was created.

The Luvuvhu River originates in the Northern Uplands Bioregion, eventually flowing into the Limpopo River on the KNP boundary.

- **Luvuvhu River IFR Site 1 (Botsoleni - out KNP**). S 22° 47.25 E 30 ° 50.91. This site is part of the Bioregion 1: Limpopo (Brown, Eekhout, & King, 1996). The site is located in the Acocks Veld type 9, known as Lowveld Sour Bushveld (Acocks, 1988). It falls within a rural community where there is a degree of riparian vegetation clearance, assorted fishing taking place and a fair amount of human and livestock activity on the banks. The nearest gauging weir is: Mhinga (A9H012-A01).

> From Giyani travel north on the R81 till the road ends in a T' junction (left to Louis Trichardt and right to Punda Maria KNP). Turn right at the T' junction (road 524) and continue straight until the sign indicating Botsoleni. Turn left at sign and continue straight on dirt road till reach another T 'junction with a tower on left hand side. Turn left at tower and make a way across the village (roughly 1st right, 2nd left, 3rd right). Follow the rough dirt track below the soccer field to the waters edge. The site is right there where track ends –(a popular washing site on the exposed bedrock).

- **Luvuvhu River IFR Site 2 (Shidzivane - in KNP).** S 22 ° 38 08 E 30 ° 57 25. The site is located in the Acocks Veld type 9, known as Lowveld Sour Bushveld (Acocks, 1988). This site is part of the Bioregion 1: Limpopo (Brown, Eekhout, & King, 1996). It is a key Luvuvhu IFR site. The nearest gauging weir is: Mhinga (A9H012-A01).

> As you leave the Punda Maria camp take the left turn onto the 'Mahonie Loop'. Continue along the dirt road for c. 8 km and turn right at the 2nd No Entry road (Management road) continue straight with this road until it meets the river c. 6km (just below the Shidzivana hill). The site is on the bend at the riffle and the cobble side bar.

The Sabie River originates on the eastern slopes of the Mauchs Berg in the Transvaal Drakensberg and meets the Nkomatie River in Mozambique; it has a catchment of over 7000km2, and is of ecological importance because it is the only perennial river that flows through KNP (Brown, Eekhout, & King, 1996). The two major tributaries of the Sabie River are the Marite and Sand Rivers (Brown, Eekhout, & King, 1996; Anonymous, 2001).

- **Marite River IFR Site 1 (farm site - out KNP).** S 25 ° 01.3 E 31 ° 07.9 . Brown et al. (1996) includes the Marite into Bioregion 3: Northern Uplands. The site is located in the Acocks Veld type 9, known as Lowveld Sour Bushveld (Acocks, 1988). The State of the Rivers Report (Anon., 2001) has put the Marite into ecoregion 5.05 (a section of the Lowveld ecoregion), and notes that the ecological state of the Marite is classed as good. The instream habitats and fish are classed as good to fair, the riparian vegetation as fair to poor, and the macro-invertebrates as good to unacceptable (Anon., 2001).

The impacts on the river are from the construction of the Injaka dam upstream, which results in disturbance and erosion which influences sedimentation levels, which result in the loss of habitats downstream, sedimentation can also increase flood impacts (Anon., 2001). The desired ecological state for the river is to remain as good, and a management aim is remove alien invasive vegetation (Anon., 2001). The nearest gauging weir is Injaka (X30H11-A01).

> From Hazyview travel on the R40 towards Bushbuckridge. Soon after (c.0.3km) the first left hand turn to Graskop there is the Durr's Farm on the right hand side. Turn into the farm gate and continue straight past the farm house (on left). Keep left as the road goes around large shed buildings and continue straight. Just after the road crosses a small stream turn left and follow the road at the edge of the lemon orchards (orchards on right) for c.250m. there is an opening in the fence. The site is on the right hand back of the Marite alongside a long island. (This may be slightly upstream of the original IFR site).

- **Sabie River IFR Site 2 (The Bridge – out KNP).** S25^{o} 01.1 E 31^{o} 13.1 . Sabie River IFR 2 appears to fall within the interface of the Bioregions 3 & 6 (Northern Uplands and Lowveld). The site is located in the Acocks veld type 10 (Lowveld) (Acocks, 1988). This site falls within a rural community and is exposed to a variety of impacts, which include clearance of riparian vegetation and gill net fish right across the stream. It falls within the ecoregion 5.06 category, which is classed as mainly natural because the majority of the river falls within private conservation land or the KNP. The desired ecological state is for the upper sections to attain a classification of good. The nearest gauging weir is: KNP Skukuza (X3H021-A01).

> Take the 536 road from Hazyview to Paul Kruger Gate. Travel for c. 11 km to the bridge crossing the Sabie River, on the left (upstream of bridge) there is also a causeway / low level bridge. The site that has sometimes been used extends from causeway to about 300m downstream of the bridge.

- **Sabie River IFR Site 4 (Skukuza / Wardens House – in KNP**). S 24^{o} 59.2 E 31^{o} 35.27 . The Skukuza site falls within Bioregion 6: Lowveld (Brown et al., 1996). The site is located in the Acocks veld type 10 (Lowveld) (Acocks, 1988). The State of the Rivers report includes this site in the ecoregion 5.06, which is classed as mainly natural. The desired ecological state is to be natural in the lower sections of the river, which includes this site (Anon., 2001). The nearest gauging weir is: KNP Skukuza (X3H021-A01).

> Turn right out of the scientific services office block towards the Skukuza staff village. Cross the N'waswitshaka Bridge and keep right. Keep straight past the tennis courts and swimming pool, after crossing the little stream at the end of the village (before the road turns sharp left into Grysbok street) – park on the curb on the left. The site is located between the guesthouse (upstream) and the warden's house (down stream), around the protruding bedrock.

- **Sabie River IFR Site 5 (N'watimhiri – in KNP).** S 25^{o} 03.2 E 31^{o} 49.2. The site is located in the Acocks veld type 10 (Lowveld) (Acocks, 1988) and the Bioregion 6: Lowveld (Brown et al., 1996). The State of the Rivers Report (Anon., 2001) includes this site in ecoregion 5.07 (the low plains zone). This section of the Sabie River is classed as mainly natural with the desire to attain or maintain the classification of natural. The main activities are conservation and ecotourism, which results in limited impacts; the only possible impacts are clearing of vegetation for tourist roads (Anon., 2001).

The nearest gauging weirs are: KNP Skukuza (X3H021-A01) / KNP Lower Sabie (X3H015-A02).

Take the H4-1 road from Skukuza to Lower Sabie. Then take the S79 N'watimhiri dirt road, cross the causeway over the N'watimhiri stream, and c.1.3km after the causeway the site is situated.

4. METHODS USED IN BASE LINE MONITORING

IFR sites have been identified and established for both the Marite / Sabie and Luvuhu Rivers, and the BBM workshops were held in August 1996 and July 1994 respectively. Various refinements to the IFR workshop documents have subsequently been presented, with the most recent for the Sabie being in 1997 and for the Luvuvhu in December 1998. Preliminary monitoring protocol, guidelines and objectives have also been compiled for the Luvuvhu River in December 1998 and the Sabie River in August 1997.

4.1 GEOMORPHOLOGY METHODS

a) Rowntree/Wadeson: An Index of Stream Geomorphology for the Assessment of River Health

Equipment used / required:

- Topographical maps
- Data sheet
- Fairly solid stick similar to broom stick for bed material size and distribution survey.
- Camera – preferably a digital type

Rowntree and Wadeson have developed a method applicable to all the different types of biomonitoring programs. It consists of a desktop reach and site analysis and the field survey with 20 components. Refer to appendix 6.1 for an example of the data sheet. **1**. **Type of survey** (for what purpose *e.g.* IFR). **2**. **Background map based information**. **3. Photographic record**. **4**. **The flow regime** (historic). **5. Conditions at the time of flow** – water level at time of sampling, and the turbidity. **6. Channel plan** – a diagram of the site and different geomorphological features. **7. Channel cross section** - for the left and right hand banks. Indicating the different types of morphological characteristics present at the site *e.*g. terraces, bars, islands, benches and flood plains etc. **8. Channel dimensions for the macro and active channel**. **9. Reach Channel type** (describes the material in which the channel is formed: bedrock/ alluvial/ mixed/ fixed boulder bed). **10**. **Morphological units** - the dominant channel form features *e.g*. Waterfall, pools and riffle. **11. Reach types** – the characteristic pattern of morphological units as classified according to the predominant morphological units and the different channel types. **12. Bed material** description. **13**. **Bank material** – where left and right hand banks are considered separately. **14. Riparian and in-channel vegetation** is where an assessment of the type and amount of vegetation on the banks and in the channel/s is conducted**. 15. Channel modifications and bank impacts**. A description of the human induced impacts, as visible at the study site. **16**. **Bank stability** – an assessment of the potential stability of the active channel banks as based on five factors: bank height vs. bankfull depth; bank angle; stratification; particle size; and vegetation. **17. Bank erosion** is assessed according to erosion caused by the river and erosion caused by other impacts such as anthropogenic causes. **18. Bar types** – noting the different types occurring at the survey site. **19. Bed material and size distribution**. A tally of a 100 randomly selected clasts for each morphological unit in both the hydraulic control/s and bar/s. The bed packing and embeddedness is also assessed. **20. Habitat survey** where the habitat diversity and the habitat cover are both considered.

<u>Advantages</u>:

- Minimum training required.
- National database can be built upon irrespective of the reason for the survey ie. Limited duplication.
- Includes many components and therefore a good a good basis to which the different biota can be compared assessed.

<u>Disadvantages:</u>

- The 'mini' survey of bed material and distribution may be quite subjective.

4.2 RIPARIAN VEGETATION MONITORING METHODS

a) Line Transect

Equipment used / required:

- Dumpy level (preferably)
- 100m tape measure
- 1m tape measure
- Steel pegs
- Spray paint
- Plant press and sample book
- Tree books (indigenous and exotic species)
- Aerial photo graphs
- Topographic map of area
- Camera

A line transect was set out through the survey site. The site for the line transect is chosen according to the presence of key riparian species where possible – for example *Breonadia salicina* and *Syzygium* sp. A 100m tape measure was set out from the water's edge, along the line transect, for both the left hand and right hand banks, with the 0m mark being right at the water's edge (this enables one to determine the woody species' distance from the water edge, and how it differs from one flow to the next). The tape measure is extended along the transect from the edge of the water to the end of the riparian zone (approximately the ecotone between the riparian and terrestrial vegetation zones). At each 1m mark (starting at 0m) the strike is recorded. Refer to appendix 6.2 for an example of the data sheet. If the strike is bare ground it is recorded as such. Then the nearest plant, within a 50cm radius of the point, is recorded. The plant may be classified as one of the following: grass, herb, reed, sedge or a woody species and once again noted as such (irrespective of whether it is exotic / indigenous or riparian / terrestrial). However if the nearest plant is something other than a woody species, the nearest woody must also be recorded provided that it is within the 50cm radius, here the actual species (once again irrespective of whether it is exotic / indigenous) is recorded e.g. *Lantanna camara* or *Diospyros mespiliformes.* Then the distance of the woody to the center point is recorded, as well as the height / height class and circumference of the woody species' stem. Any damage to the woody species is recorded (e.g. bent over, no leaves or leaves eaten) as well as the known or suspected reason for the damage (e.g. flood / high flow, drought or animals). The substrate at the strike is also noted. Finally the status of the woody plant is also recorded – is it considered to be an exotic, a riparian or terrestrial species? Any woody plant that is not known (as well as those that may be uncertain) to the assessors doing the survey must be collected and pressed and then identified by a credible herbarium.

Advantages:
- Less time consuming (than other methods).
- A simple method requiring less expertise.
- Can be done more frequently

Disadvantages
- Cannot determine the recruitment rate.
- Cannot determine population structure.

b) Belt Transect

Equipment required:
- Dumpy level (preferably)
- 100m tape measure
- 1m tape measure
- Steel pegs
- Spray paint
- Plant press and sample book
- Tree books (indigenous and exotic species)
- Aerial photo graphs
- Topographic map of area
- Camera

One to three belt-transects, each of 10m widths are established through different (where relevant), but representative riparian plant communities at the survey site. The belt transect extends from LHB riparian / terrestrial ecotone to RHB riparian / terrestrial ecotone. The belt transect is pegged out and little cairns of rocks piled at each peg, and then slightly spray painted. Ideally the pegs should each have a GPS reading for future location and re-establishment should they be removed for what ever reason (flood or otherwise). The particular geomorphological unit is recorded e.g. RHB or island. Then each woody plant species growing in the belt transect for each geomorphological unit is recorded. The height for that plant is noted according to one of six classes (<1m; 1-2m; 2-4m; 4-8m; 8-12m and > 12m). In the height class column of the data sheet, the growth form is also indicated by using an N to show natural growth and C to indicate coppicing. The condition of the plant is also noted and this is according to a rating of 1-5. [(1) Full canopy = good condition. (2) Full canopy losing leaves. (3) Loss of leaves & limbs. (4) Complete loss of limbs - just a stem/trunk remaining. (5) Apparently dead stem with coppice.] It is important to be able to differentiate between deciduous and damaged plants. The substrate of the plant must be recorded – this is according to general geomorphological material classes: silt, clay, sand, gravel, cobble, boulder and bedrock. Once again the status classification is used to distinguish between exotic, terrestrial and riparian species. Finally a summary of the % of grass, sedges and reeds is done for each for each geomorphic unit. A scoring system of 0-5 is used where (0) = nothing. (1)= < 5% cover. (2) = 6-25% . (3) = 26 - 50%. (4) = 51 -75%. (5)= 75 -100%.

Advantages:

- A very thorough method, which results in a good summary of the biodiversity and spatial distribution of riparian species.

<u>Disadvantages</u>:

- A very time consuming method requiring a fairly substantial knowledge of plants.
- Debate as to what plants are true riparian species and which are not. The condition rating is too subjective

c) Belt Transect and Quadrants

Equipment required:

- Dumpy level (preferably)
- 100m tape measure
- 1m tape measure
- Steel pegs
- Spray paint
- Plant press and sample book
- Tree books (indigenous and exotic species)
- Aerial photo graphs
- Topographic map of area
- Camera

One to three belt transects, each of 10m widths are established through different (where relevant), but representative riparian plant communities at the survey site. The transect runs from LHB to RHB across the active channel and extends approximately 5m into the terrestrial zone on each bank. The belt transect is pegged out and marked as with the previous method. The quadrants are laid out within the transect and are also pegged accordingly. There are two quadrants per a river bank, the first is called the ecotone quadrant, and the second the water quadrant. The ecotone quadrant is situated towards the upper part of the bank where the terrestrial and riparian plants meet (often roughly near the top of the macro channel bank). This quadrant is the width of the transect (10m) and about 5m into the terrestrial zone from the ecotone 'line', and about 5m into the riparian zone from the ecotone 'line'. Thus being approximately 10m x 10m – this quadrant must be pegged as such. The water quadrant is a 10m width (i.e. transect width) and located 5 – 10m from the water's edge. Once the quadrants have been laid out within the belt transect it is necessary to decide on 1-4 riparian key species, as applicable to the river and site. For example in the eastern lowveld rivers of Mpumalanga and the Northern Province the *Ficus capreifolia*, *Breonadia salicina* and *Syzygium* species are considered key species, because they are characteristic riparian trees. With this method there are four components to the data sheet: a diagram of the belt transect and quadrants, the quadrant monitoring, the indicator species monitoring and the summary assessment of the % cover of the different riparian zone plants. In the ecotone and water quadrants every woody plant species is recorded. The height of the plant must be noted, if the plant is less than 2m in height the actual height must be recorded, if it is more than 2m it can be classified into one of the following height classes: 2-4m; 4-6m; 6-8m; 8-12m and 12m+. The circumference of every woody species must be measured and noted. Record whether there is any damage to the plant and what it actually entail as well as the suspected reason. What is the status of the plant – riparian, exotic or terrestrial? Lastly what is the substrate in which the plant is found? If there are any indicator species in the quadrant refer to the 'indicator' component of the data sheet. All 'indicator' plants must be recorded on the applicable data sheet, irrespective of whether they are in the quadrants, or elsewhere in the belt transect. Note the location (geo-morphological unit) and species on the data sheet, as well as the height, the circumference, damage, and substrate (all as stipulated above). With the indicator species the distance from the water's edge must also be noted. Finally a separate summary for each geo-morphological unit is done (ie. LHB, RHB and each island). In the last component the percentage basal cover is recorded for grass, reeds, sedges, exotics, other (*i.e.* all woody plants and herbs not falling into any other category) and bare ground (also noting the dominant material).

Advantages:
- Not as time consuming as a plain belt transect
- Less expertise required.
- Makes use of key species.

Disadvantages:
- Not as comprehensive as belt transect.
- Perhaps insufficient information acquired on terrestrial species encroachment in the non-quadrant sectors of the belt.

4.3 MACRO-INVERTEBRATE SAMPLING METHODS

a) SASS Kicking method

Equipment required:
- waders
- SASS net (30cm square, 1000 micron mesh and long handle)
- sorting tray x 2 or 3 (at least 30cm x 30cm x 5cm)
- sample bottles
- 70% ethanol,
- SASS guide manual
- Data sheets

The site is categorized into different biotopes (stones in current, stones out of current, sand, vegetation in fast and slow areas, gravel and silt or mud). The greater the diversity of biotopes, the greater the opportunity for sampling a high diversity of taxa. A site diagram is drawn showing the different biotopes sampled. A number on the diagram indicates the habitat type sampled and correlates with the information collected and recorded on the data sheet. The flow velocity, pH, conductivity, temperature, substrate and depth of each habitat is recorded

The sampling method used is predominantly as described in SASS4, except the abundance range has been modified for IFR. Waders are worn when kicking stones and gravel, and stirring the sand and mud to dislodge organisms. For all biotopes sampled, the area sampled (in meters) and time taken to sample is recorded. The organisms collected in each biotope are transferred from the net to the sorting tray. Organisms are identified and recorded to family level. After identification organisms are returned to the water. Initially the required SASS 4 time protocol was not adhered to but as the assessors became more competent less time was taken at the identification tray. However the objective is to try and note and record every organism in the tray, rather than do a rapid assessment. Families or species that are difficult to identify in the field are preserved in 70% ethanol and taken to specialists for identification.

Any macro-invertebrate organisms caught while busy with the different fish sampling methods, or those organisms seen in a biotope but not actually caught when specifically sampling for the macro invertebrates, are noted and recorded alongside the appropriate biotope column. While other countries in the world may be using an electro-shocking method to sample specifically for invertebrates, it was not considered necessary in this project.

By using the adapted SASS 4 sampling method a new, IFR macro invertebrate monitoring protocol is evolving. This has not been actually used in the field yet. However it is believed that the SASS 4 method should be still used in the future (even if a flow scoring system is also used) because it is valuable to the water quality monitoring aspect.

Advantages:
- One person can do the work
- Equipment used is easy to carry.
- Minimal training required.
- Identification to family level easier for technician.

Disadvantages:
- There can be an overlapping of biotopes.
- In very shallow, or slow biotopes it is not possible to get a velocity reading in that particular biotope.

4.4 FISH SAMPLING METHODS

On arrival at the site a basic on site visual appraisal was made of the habitats available on that particular day at that particular flow. A site diagram was sketched indicating the different habitats and the various components there of. Sampling took place in each of the different habitats. These different habitats were sampled separately using different methods.

a) Electro-shocking

Equipment required:
- Electro shocker (generator:220 volt; 50Hz)
- Bucket
- Depth measuring stick (stick calibrated in cm),
- Flow meter
- pH meter
- Conductivity meter
- Temperature meter
- Watch
- 70% ethanol and formalin
- Sample bottles
- Rubber gloves x 2 pairs
- Boat (ARK rubber "crocodile" inflatable raft & 2 paddles)
- fish books
- fish keys

Each habitat shocked was begun in the downstream component of the habitat. One person shocking, the other using a scoop net to catch the stunned fish. The team progressed up stream, keeping the fish caught in a bucket until that particular habitat was finished. Each habitat shocked was timed. It was necessary to take care (as far as possible) when shocking so as not to disturb the rest of the habitat still to be worked. As each habitat was completed the fish species caught, were identified, recorded and released back into their respective habitats. Any fish species that could not be identified at the time was preserved in 10% formalin (in a sample bottle with label inside) for later identification by experts. The data sheet was completed for that particular habitat – recording every fish, its age class (adult, sub-adult, juvenile) and whether any fish was diseased (e.g. visible ecto-parasites). At each habitat type the category in which it fell was recorded (e.g. shoot, riffle or pool etc), as well as the width, depth, conductivity, temperature, pH, substrate, the extent sampled, the percentage of algae on substrate, whether there was any vegetation, and the turbidity. The flow of that particular habitat was classified into one of five flow classes (no flow, slow flow, medium flow, fast and very fast flow), as well as actually being measured with a flow meter.

The electro shocking device was used to sample certain habitats: shoots, riffles, rapids, shallow- medium depth pools in stream and off stream, runs and back waters.

Advantages:

- Can be used in a diverse range of habitats
- The most effective fish sampling method.
- Large numbers of fish can be caught per an effort.

Disadvantages:

- If conductivity of water low, the shocker is often not too effective
- If flow is very fast it is difficult to maintain balance.
- Frequently stunned fish get caught between or under rocks and it is not possible to scoop them.
- Carrying the generator across a multiple channel river (up to 750m) can be tiresome.
- Age classification can be subjective.
- Very small juveniles and fry frequently die, especially when hot.
- Can't access very deep or very fast habitats.
- Mainly the smaller fish species or juveniles of large species caught.

b) Cast net

Equipment required:

- 1 or 2 cast nets (size: 4 foot, mesh: 1")
- Bucket
- Standard identification and or sampling equipment

A cast net (a weighted circular net that is thrown into the water) is used in pool type or slower flow and deeper habitats. As with method (a) all aspects of the habitat type are recorded as well as the fish species, numbers, age class and health. The number of throws / efforts per a habitat are also recorded.

Advantages:

- Fish are not easily killed
- Easier to use than seine net
- Only one person needed to use cast net.

- Able to catch fairly large adults of species that are not often caught in other methods

Disadvantages:

- Need to master the technique & perfect throws to catch fish.
- Frequently the net gets caught on branches and rocks on the bottom of the stream.
- In deeper water, difficult to identify the substrate.
- Few fish caught / an effort

c) Large Seine Net

Equipment required / used:

- A 25m width x 2m length net, mesh: anchovy / 5mm x 5mm, weighted at bottom, floats above, with a bag built in
- Bucket
- Boat (sometimes)

Large net used in both deep and shallow pools. In deeper pools, a boat is needed to set large seine net.

Advantages:

- Catch more fish with only one effort, than any other method.
- No fish are killed.
- No harm to macro-invertebrates

Disadvantages:

- A boat is sometimes needed to set it.
- It is more effective in medium to slow flowing pools, which are likely to have dangerous animals such as Hippo and crocodiles.
- If the flow is too fast the method is not effective
- The net and weights can snag / catch on logs and rocks on the habitat substrate.
- Generally more effective if more than 2 people available.
- Sometimes loose fish when they jump out the net over the floats.

d) Small Seine Net

Equipment required / used:

- A small seine net of small mesh size – shade cloth works well (2-3m width x 1.5 – 2m length – can be bigger, weighted, and with floats – ideally with foot straps near the bottom to assist in dragging the net).
- Bucket

Small seine net is used to sample in small deep & shallow pools. Two people can effectively use small seine net.

Advantages:

- Do not need a boat to set small seine net
- Wet or dry it is easy to carry.
- 2 people can easily use it.

Disadvantages:

- Small areas / habitats sampled therefore decreasing chances of catching more fish.

e) Mosquito Net

Equipment required:

- A net of small mesh size (or shade cloth) 1-1.5m width x 1.2 – 1.5m length – weighted on the bottom and a pole / stick on either side.
- Bucket
- Standard identification and or sampling equipment

The mosquito net is used to sample under overhanging vegetation and small pools at the channel edge.

Advantages:

- No fish or macro-invertebrate is harmed.
- Very effective for catching small species and juveniles.
- Can catch many fish / an effort

Disadvantages:

- Some fish species such as Tilapia can jump out of the net.

4.5 HABITAT ASSESSMENT METHODS

a) IHAS (Integrated Habitat Assessment System)

Equipment used: IHAS data sheet

This mini habitat questionnaire was filled out at the site.

Advantages:

- The most beneficial habitat assessment available.
- Requires no training.

Disadvantages:

- Geared mainly towards SASS rapid monitoring

b) HAM (Habitat Assessment Matrix)

Equipment used: HAM data sheet

This mini habitat questionnaire was filled out at the site.

Advantages:

- Requires no training.

Disadvantages:

- Geared mainly towards SASS rapid monitoring.
- Some components a little vague/ not applicable

c) HQI (Habitat Quality Index)

Equipment used: IHAS data sheet

This mini habitat questionnaire was filled out at the site.

Advantages:

- Requires no training.

Disadvantages:

- Geared mainly towards SASS rapid monitoring.
- Some components a little vague/ not applicable

5. REVIEW OF PREVIOUS RESEARCH & MONITORING PROGRAMMES ON THE LUVUVHU AND SABIE RIVERS

The Sabie River is considered the most researched river in South Africa (Weeks *et al*., 1996). With a title like that there's obviously archives of literature available, but this review aims to look at some of the more pertinent research done on the Luvuvhu and Sabie Rivers in more recent times.

River conservation in South Africa has progressed considerably since 1986, when O'Keeffe edited the report on "The conservation of South African Rivers". But even then there was a need to establish a consensus view on river conservation, understand the impacts and influences, and amongst many other aspects, design applicable monitoring systems (O'Keeffe, 1986); many of the issues still being debated today fifteen years later.

One of the most recently implemented National Biomonitoring Programmes is the River Health Programme (RHP). The RHP was initiated by DWAF in 1994, the purpose being to gather information regarding the ecological state of river ecosystems in South Africa (Anon., 2001). The intention is that the information will be used to support positive management of natural resources (Anon, 2001). The designing and setting up a national biomonitoring programme such as the RHP has taken considerable amount of effort and research, which has been compiled into a seven volume series. Report No. 1 sets the framework for the programme which summarises the background to the programme, what the management of aquatic ecosystems entails, the definition of the biomonitoring concept which includes ecosystem indicators and indices, as well as outlining the requirements and scope of biomonitoring (Hohls, 1996). Report No. 2 covers the proceedings of the spatial framework workshop (Brown *et al*., 1996). In Report No. 3 the technical considerations and protocol for the selection of reference and monitoring sites is addressed (Eekhout, Brown and King, 1996). This report covers the considerations used to select monitoring sites which states that they should be randomly selected and that it is necessary to ensure that sufficient sites are selected to cover all the different river types within the country adequately. The eighteen different bioregions and the sub-regions are also described (Eekhout *et al*., 1996). Report No. 4 reviews ecological indicators and provides recommendations. This report reviews international biomonitoring programmes and assesses the degree to which (aquatic) monitoring programmes have been implemented by different institutions and agencies across South Africa, as well as establishing the current knowledge on existing monitoring systems and the needs of managers and scientists (Uys, Goetsch and O' Keeffe, 1996). The different ecological indicators and indices are reviewed; this consists of the geomorphological, riparian vegetation, hydrology, fish and invertebrates amongst others (Uys et al., 1996). Report 5 is the proceedings of consultation planning meeting, which addresses planning, management and implementation as well as an action plan for each province (DWAF, 1996). Report No. 6 gives the overview of the design process and guidelines for implementation, in this report Roux (1997) covers measuring ecological integrity, the indicators and indices that have been selected for the programme, the linking of monitoring with management and lastly the institutional arrangements for the programme.

Both the RHP and this project on designing the IFR monitoring protocol, fall within the mandate of the National Water Act (Act No 36 of 1998), which states that monitoring, recording, assessing and disseminating of information on water resources is critically important for achieving the objectives of the act. The two main objectives being protection of water resources for the benefit of current and future generations; and that utilisation of water resources take place in the most efficient and effective manner, within the constraints set by the requirements for protection (Anon., 2001). This involves the setting of the Ecological Reserve and determining the instream flow requirements for the different river systems throughout the country. A method, known as the building block methodology (BBM), has been developed to assess the water quantity component of the ecological reserve (King and Louw, 1998; Hughes, 1999). The BBM is a fairly complex process and is carried out in a workshop environment where different aquatic specialists have convened (Hughes, 1999). The aim is to assign building blocks (the different flows) to specific rivers, which includes the base flows (maintenance and drought) as well as higher flows (King and Louw, 1998). The recommended flows are intended to simulate the natural flow regime of that river for the different months and seasons of the year (King and Louw, 1998). This involves a great deal of contribution from the experts as it takes into consideration hydrology, geomorphology and all the biotic requirements as well (Hughes, 1999).

Reports have been put together after IFR workshops, which record the proceedings and the recommended IFR flows. Tharme (1996) compiled an all-inclusive report on the Sabie-Sand River system IFR's. Each site is described, allocated the recommended flows, and reasons are given for each of the flows with regards to the hydrology, geomorphology, riparian vegetation, fish and invertebrates requirements. In addition to this the desired future state (now known as ecological management class) for each site is expressed. A preliminary outline for the IFR monitoring protocol is given for the Sabie-Sand IFR sites, and initial TPC's have been proposed for each of the IFR monitoring components: hydrology, hydraulics, geomorphology and geohydrology, riparian vegetation, fish, aquatic invertebrates, water quality, and co-ordination and data management (Louw, 1997). The setting of the Luvuvhu IFR's proved to be a lot more complicated with the 1994 hydraulics being inaccurate. During the workshop that took place in 1996, insufficient hydrology information was available which meant the refinement could not be ascertained. One of the problems with the Luvuvhu River is that it does not fall into any of the ecotyping groups for which IFR's are assessed (Louw and O'Keeffe, 1998). Finally in 1988 the second Luvuvhu refinement took place, as is described in Louw and O'Keeffe's report (1998). In 1996, Louw compiled a proposed IFR monitoring programme for the Luvuvhu River. By the time it got to the second Luvuvhu IFR refinement the Kruger National Park River's Research Programme (KNPRRP) was underway, and this was found to be of fundamental importance in the refinement, because so much more information was available (Louw and O' Keeffe, 1998).

The two main goals of the KNPRRP were firstly, to provide information to researchers, system managers and stakeholders regarding water quality and quantity requirements of the KNP Rivers so that the natural environment of the rivers is sustained. Secondly to test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP and southern Africa to changing water quality and patterns of supply (Biggs *et al.*1998).

When impoundments were proposed for the Luvuvhu and Marite Rivers, assorted projects were started in an attempt to identify the impacts on aquatic biota of such constructions. Louw (1995 & 1996 (a)) compiled reports on the Injaka and Mutoti dams respectively. The physical and biotic environments are described and the expected impacts after mitigation, outlined. Chunnet, Fourie and partners (1987) assembled a very thorough briefing paper, which assesses the Sabie River instream water requirements of the natural environment and the possible impacts of the water resources development. A very valuable and comprehensive three-volume document, on a pre-impoundment study of the Sabie-Sand River system, has been created by an assortment of authors. Weeks et al., 1996, describe the ecological status of the Sabie-Sand system, and through extensive monitoring identify indicator and ecologically important fish species. The fish are described in detail and a summary of each species' specific flow and cover requirements are also included. The second volume in the series (Pollard *et al.*, 1996) summarises the responses of the aquatic fauna to what is considered to be the worst on drought on record (1991-92). In the third volume the fauna of the Sabie-Sand river ecosystem are characterised, the impacts of seven existing dams reviewed, and the instream flow requirements of the rivers in the KNP summarised. Recommendations are made with regards to the importance of maintaining perennial flows, education and dissemination of information (O' Keeffe *et al.*, 1996).

6. RESULTS AND DISCUSSION PERTAINING TO BASELINE MONITORING

6.1 GEOMORPHOLOGY

The geomorphological index (for any monitoring system) has two main components and therefore two main aims: 1) to measure the inherent stability of the channel, based on its classification (Rowntree and Wadeson's hierarchical scheme); and 2) measure the observed condition of the channel (Rowntree and Ziervogel, 1999). As is frequently iterated, geomorphology, along with other abiotic components in the aquatic monitoring systems, provides a fundamental basis against which the changes in stream biota can be assessed (Rowntree and Ziervogel, 1999; Rowntree and Wadeson, 1999).

All geomorphological monitoring only took place after the event of the floods. Each site was only monitored once. The information obtained from the monitoring has been summarised into a table each, and is accompanied with a site diagram and a cross section diagram. In the tables that follow a number of acronyms and abbreviations have been used:

- Interst. Space Interstitial space
- Isol. Pool Isolated pool
- OH Veg Over hanging vegetation
- Marg. Veg Marginal vegetation
- IS Veg Instream vegetation
- U.Cut bank Undercut bank
- FS Fine Sand
- MS Medium Sand
- CS Coarse Sand
- FG Fine Gravel
- MG Medium Gravel
- CG Coarse Gravel
- SC Small Cobble
- LC Large Cobble
- SB Small Boulder
- MB Medium Boulder
- LB Large Boulder
- BR Bedrock

Table 1 summarising the geomorphological characteristics at the Luvuvhu IFR 1 site. This is a new site, which has never had the hydrological cross-sections completed for it. This site falls into a rejuvenated foothills D/Er zone class. It is a multiple channel site, of mixed channel type (bedrock and alluvial). The rating for the riparian and in-channel vegetation scored mainly 0, 1, and 2 for the different components. The rating is as follows: 0 = none; 1 = sparse; 2 = patchy; 3 = continuous and 4 = dense (impenetrable). Some geomorphological components of the site changed drastically after the floods while others are still very similar. Prior to the floods the site was characterised by a number of (up to seven) islands across the channel, especially towards the upstream side of the site. Towards the downstream section of the site, there was one very large island, which clearly divided the river into a main channel and a secondary channel. The large island no longer exists, now there are smaller islands, and one quite main one. Formerly the island consisted of mainly sand (that which was visible), now the main island towards the right hand side of the channel, is comprised of cobble. This is a site that falls outside of a protected area, and is very close to a village. The riverbanks are heavily utilised by livestock and people (a bedrock side bar is the local washing site), and there is limited riparian vegetation. As a result of the assorted anthropogenic activities, it would be expected that there would be considerably more sub-aerial erosion activity. However for both the left and right hand banks it was found to be limited. Naturally after such extreme floods the fluvial erosion rated much higher especially on the left hand bank. The bank stability rating was moderate for both banks, both scoring 25. The habitat score was 15 out of 21 (c. 71%). Bed packing was moderate for both the hydraulic control and bars, however the hydraulic control was rated as well embedded compared to the bars which were classes as not embedded. Both the hydraulic control and the bars were found to be comprised of nine different material classifications, in the tally of bed material size and distribution. With the diversity of habitat and bed material at the site, the assorted biota should be adequately provided for, with regards to habitat diversity.

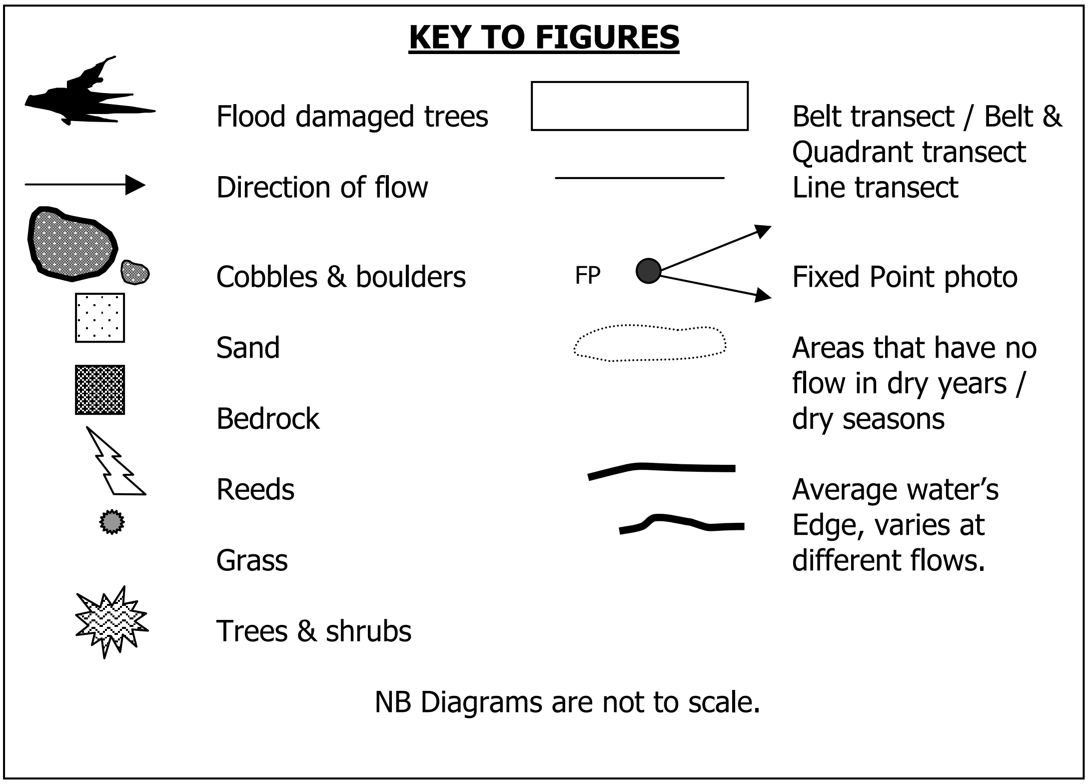
The geomorphology of the Luvuvhu IFR 2 site is summarised in table 2. This site is also in the rejuvenated foothills D/Er zone class. This site is characterised by only a single channel, of alluvial channel type. It is considered a key site (Louw and O'Keeffe, 1998) on the Luvuvhu River and has the most useful information. It is also the site with the least complications (compared to the original IFR 1(which was lost in the dam) and IFR 3, which has the added dynamics of the Pafuri flood plain). The site falls within the Kruger National Park – partly as the river is the boundary. The site is characterised by the large cobble side bar, which seems to change very little between extreme high flows. The riparian and in channel vegetation is mainly scattered or in patches after the floods. There are no channel modifications, and the bank impacts are limited to the movement of game, and the few exotic species growing there. Even after the floods the fluvial erosion is moderate for both banks (even taking into account the gradient of the right hand bank. The sub-aerial erosion is also limited, although present due to game walking down to the water's edge. The bank stability rating scored lower on the left hand bank than on the right. This is attributed to a few reasons, the bank height – right next to the channel – versus bank full is higher than the right side (which has the large cobble bar and the flood bench), and the stratification is more layered than the right hand side, and lastly because of the floods the vegetation cover is totally sparse compared to the right bank. The bed packing and embeddedness is moderate throughout the hydraulic control and the bars. The habitat rating is 13/21, which is above average but would have been higher prior to the floods, as prime undercut bank with root wads and overhanging vegetation has been lost with the removal of the vegetation during the floods. The tally of bed material and size distribution showed that there is a great diversity of material.

The Marite IFR 1 site is summarised in table 3. It has a multiple channel pattern, and the channel type is mixed where bedrock and sand dominate. The riparian and in channel vegetation was thinned out during the floods, but a remarkable amount appeared to be quite resilient. The scores lean more towards patchy than sparse. There are no visible in channel impacts at the site. The bank impacts are moderate despite there being a number of human and animal paths, and the orchards being close to the top of the macro channel banks. The right hand bank scored higher in the bank stability rating mainly because there is large area of bedrock and the vegetation is more stable. This is probably due to many of the trees being *Breonadia salicina,* which with their good rooting systems, provide excellent bank stabilising conditions. The habitat rating was fairly high at 16, but a key factor is that there is limited – if any cobble providing good interstitial spaces for organisms to inhabit. Most of the hydraulic control is comprised of bedrock or boulder, which results as the bed packing being classed as tightly packed, and moderately embedded. The bed material and size distribution tally indicated that there is not too much diversity in the bed material. With the water levels being so high since the floods the 'dry' channels behind the islands have been flowing during all the monitoring visits except for the first in 1999. According to Tharme (1996) this site has few specific flow requirements for geomorphological purposes, as those flows that influence the riparian vegetation will also affect the channel geomorphology.

The Sabie IFR 2 geomorphology is summarised in table 4. This site is a single thread channel and a mixed channel type. The reach type is of alluvial regime and partly mixed pool rapid. Bedrock and sand are the dominant bed materials. There is a fair component of reeds and sedges in the riparian and in channel vegetation, but the trees and shrubs are limited, but this was more or less the situation even prior to the floods. The site falls outside of a protected area and much of the riparian vegetation had been cut down and utilised. There is a bridge as well as a causeway at this site. The causeway was recently re-established and since the floods the bridge has undergone major re-construction which has meant there has been earth moving equipment on the banks and in the macro channel. The bank impacts include livestock and footpaths as well as the burning of flood debris. The fluvial erosion was considered moderate for both banks, and despite all the activities occurring on the banks, the sub-aerial erosion was still found to be only limited. The bank stability for both banks is moderate. The habitat rating is low, mainly due to lack of very shallow, and lateral habitats. Embeddedness is moderate, the presence of bedrock structure pushing it up. The bars are mainly comprised of sand and are loosely packed. The diversity of bed material is fair.

Sabie IFR 4 (table 5) is a multiple channelled section of the river, of mixed channel type. The dominant materials being bedrock and sand. With this site being in the KNP the channel impacts and modifications only include the game activity. Erosion is limited mainly due to the extent of the bedrock, and despite the February 2000 floods which generally changed the site significantly. The whole of the left hand channel has been reopened. While this appears to be partly due to the reduction in reeds and instream vegetation (by the floods), it also includes the fact that flows have been higher in the last two years, even in the dry season. Tharme (1996) notes that the bedrock needs to be overtopped in order to recharge the alluvium, not only in the wet season but also in winter. During this project only high flows have been experienced, even during the visit in September 1999 (when the recommended base flow is 3.4 $m^3 s^{-1}$) the flow was 4.46 $m^3 s^{-1}$. During a late November 2000 visit the flow was 20.3, this is five times the recommended base flow and double the suggested three day high flow.

Table 6 summarises the Sabie IFR 5 site's geomorphology. This is an incredibly extensive site. The channel pattern is very definitely multiple, with four main channels (although Tharme (1996) refers to eight channels). Each channel is almost like a separate river on its own. The islands are substantial (in both length and height). It is a mixed channel type where sand and bedrock dominate. Riparian and in channel vegetation is slowly recuperating after the floods. There are no channel modifications, and the only impacts are that of game and a few exotic plant species. Fluvial bank erosion is moderate on the left hand bank, and only slight on the right hand bank (the right hand bank is almost flat and in line with channel 1, but the left hand bank of channel 1, the first island is quite steep). Sub aerial erosion is limited on both banks. Although both banks were rated as moderately stable, they are very different. The left hand bank scoring low for both bank height vs bankfull depth, and bank angle. LHB scored high on the vegetation factor. The LHB seems to be very slightly influenced by floods of such magnitude. The LHB scored a 5 in the particle size and stratification components. While a considerable amount of the bank is comprised of soil and sand, there is also a significant amount of bedrock, which was most likely the stability factor in the floods (along with *Breonadia salicina*, which of course favours the bedrock substrate). Scouring away of the bank is evident in some sections. The right hand bank scored high in the stability ratings for bank height vs bankfull depth; bank angle; and stratification, but low on particle size (predominantly sand) and the vegetation factor. Because the macro-channel, and active channels within it, are so extensive, every type of habitat was recorded (although there is not the same quantity of each habitat type), thus resulting in a score of 21/21. In the tally of bed material size and distribution, the hydraulic controls were found to be fairly diverse, but dominated by bedrock, while the bars were dominated by sand and gravel.



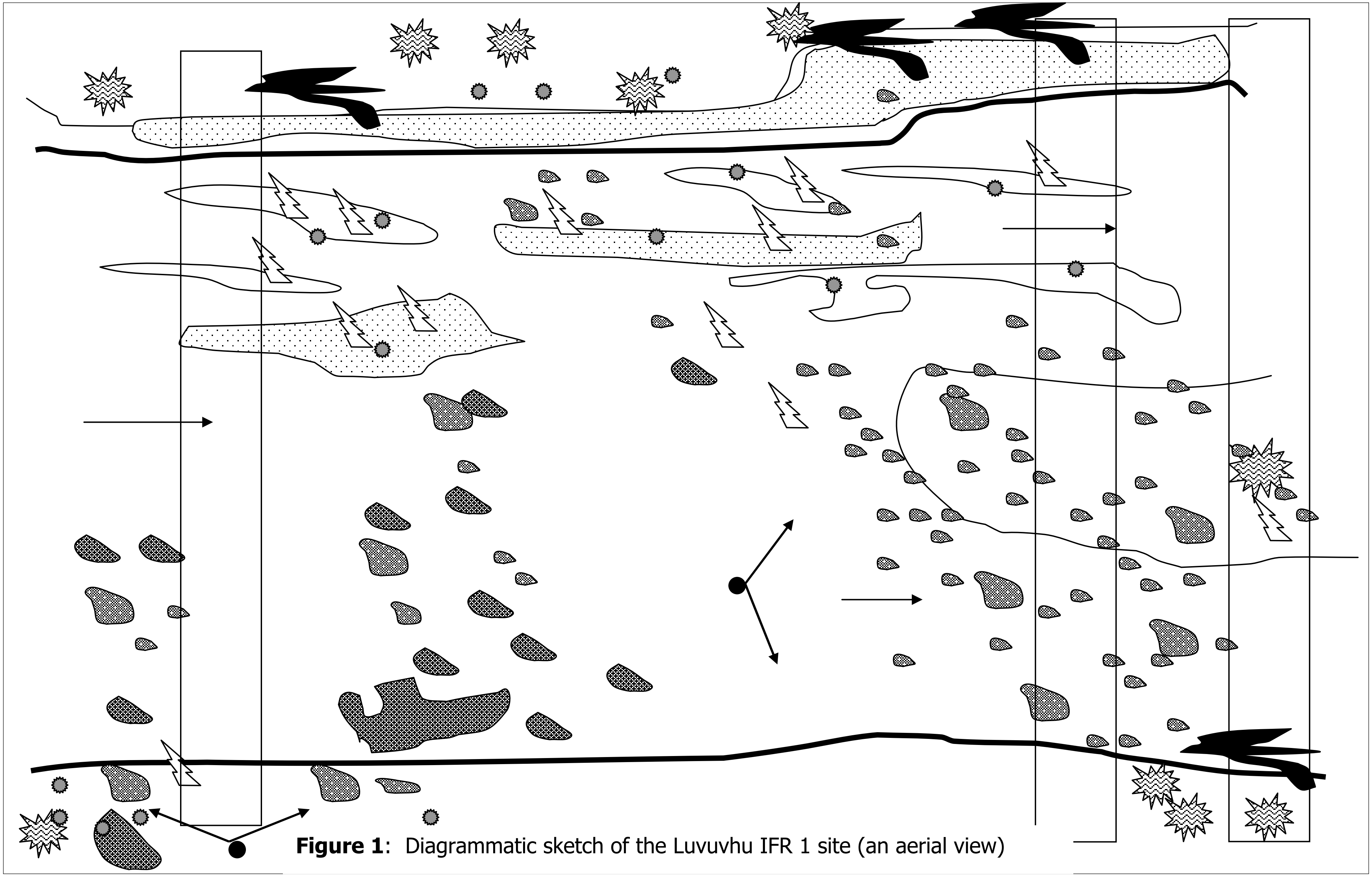


Figure 1: Diagrammatic sketch of the Luvuvhu IFR 1 site (an aerial view)

Table 1: A summary of the geomorphological characteristics of the Luvuvhu IFR 1 site.

DATE: 07/08/2000	**RIVER**: Luvuvhu	**SITE:** IFR 1 (Botsoleni)	**AV. DAILY FLOW:** Not available
FLOW REGIME: Perennial	**WATER LEVEL:** High @ time of year	**TURBIDITY:** Cloudy	
CHANNEL PATTERN: Multiple	**ACTIVE CHANNEL WIDTH:** 50-75m	**MACRO CHANNEL WIDTH:** 75-100m	
CHANNEL TYPE: Mixed (Bedrock & alluvial)	**REACH TYPE:** Alluvial (pool-riffle)		
MORPHOLOGICAL UNITS: Rapid – boulder; riffle; run; shallow pool; deep alluvial pool; backwater.			
BED MATERIAL: Bedrock + cobble; sand			
BANK MATERIAL:			
LHB: Sands & gravels; fine sand & clay	**RHB:** Bedrock; fine sand & clay		

RIPARIAN AND IN-CHANNEL VEGETATION:				**CHANNEL MODIFICATIONS & IMPACTS:**			
	Reeds & sedges	**Ground layer**	**Shrubs & trees**	**VISIBLE IN-CHANNEL MODIFICATIONS**		**BANK IMPACTS AT SITE**	
Macro-channel banks	0	2	2	None		Animals, footpaths, vegetation clearance, exotic veg.	
Top of active channel bank	1	2	1	**BANK EROSION:**			
Active channel banks	1	1	1	**A: Fluvial**		**B: Sub-aerial**	
Bars	2	2	1	**LHB:** Extensive erosion 33-75%	**RHB:** Moderate erosion 10-33%	**LHB**: Limited rilling & livestock tracks	**RHB:** limited gullying & livestock tracks
Channel Bed	1	0	0				

BANK STABILITY:									
Bank height vs. bankfull depth		**Bank angle**		**Stratification**		**Particle size:**		**Vegetation factor:**	
LHB	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**
5	5	5	5	8	5	2	5	5	5
BANK STABILITY SCORE: LHB = 25 **RHB** = 25					**BANK STABILITY INDEX: LHB** = Moderate **RHB** = Moderate				
BARS (& material): Point bar (sand); diagonal bar (cobble & bedrock); Islands & mid bars (sand, cobble, bedrock); Side bars (sand, cobble, bedrock)									

HABITAT:	Pool	Glide/Run	Broken H^2O	Lateral	Isol.pool	**BED PACKING:**		**EMBEDDEDNESS:**	
Very shallow	X	X			X	Hydraulic control	Bar	Hydraulic control	Bar
Shallow	X	X	X	X		Moderate	Moderate	Well embedded	Not embedded
Deep	X	X	X	X		**TALLY OF BED MATERIAL SIZE DISTRIBUTION:**			

Interst. space	**OH Veg.**	**Marg. Veg**	**IS Veg**	**U.Cut bank**	**Snags**	**Hydraulic control:**					**Bar:**				
X		X		X	X	4% FS	4% CS	2% FG	5% MG	12% CG	10%FS	5% MS	5% CS	9% FG	9% MG
TOTAL HABITAT INDEX: 11 + 4 = 15 **/ 21**						19% SC	40% LC	12% SB	2% MB		50% CG	5% SC	5% LC	2% SB	

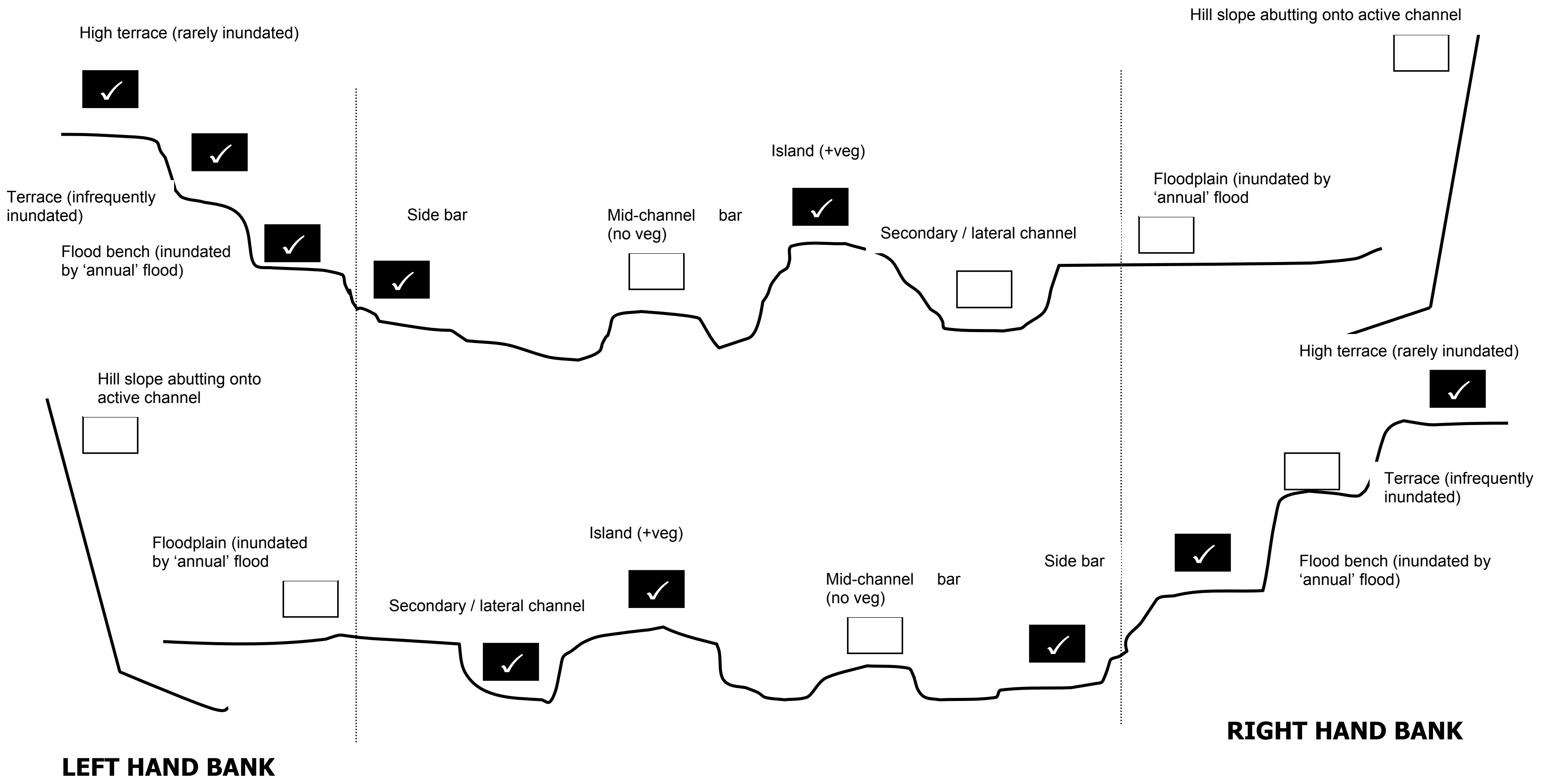


Figure 2: Cross section diagram of the Luvuvhu IFR 1 site showing the geomorphological components of the site.

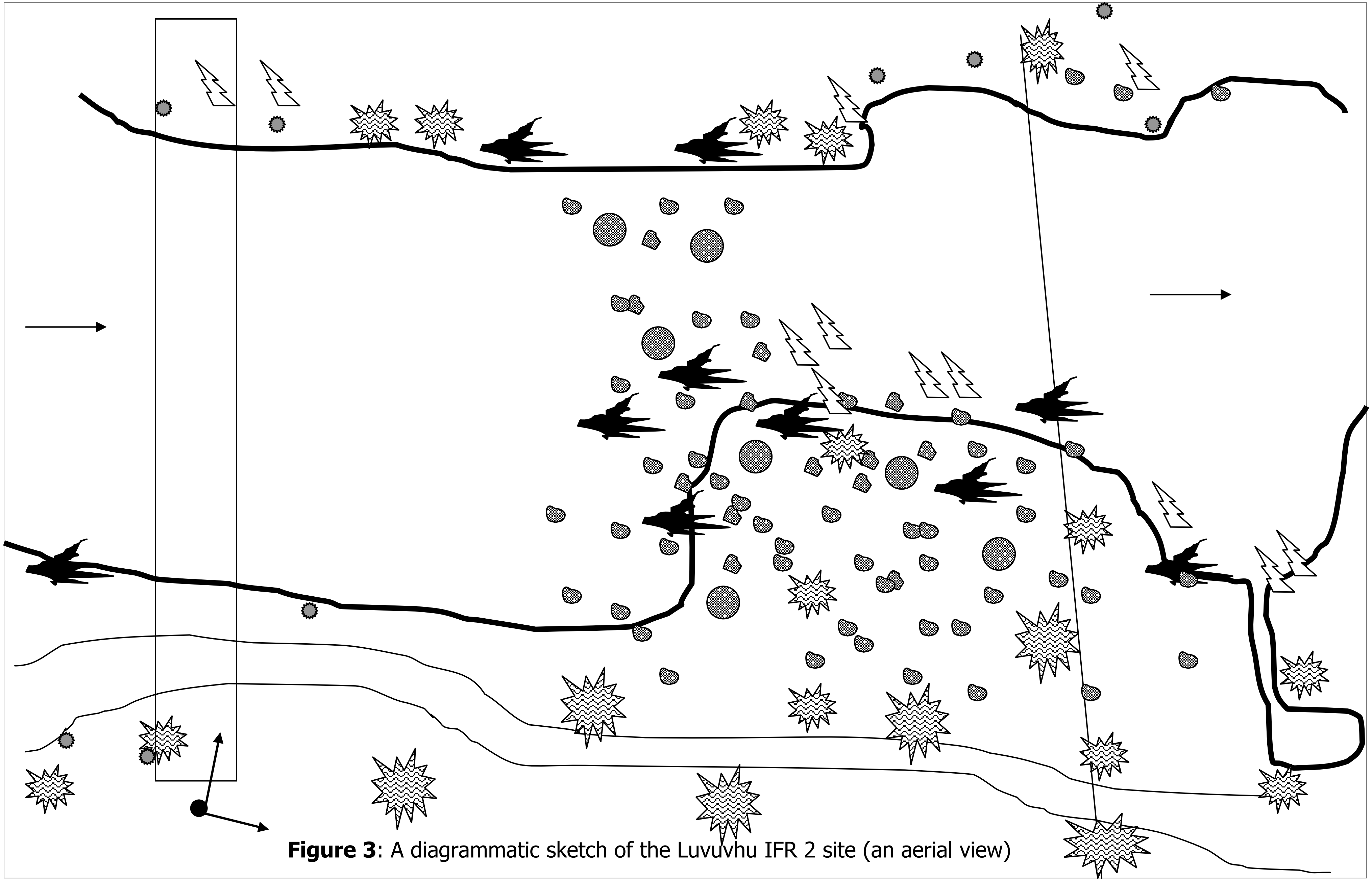


Figure 3: A diagrammatic sketch of the Luvuvhu IFR 2 site (an aerial view)

Table 2: A summary of the geomorphological characteristics of the Luvuvhu IFR 2 site.

DATE: 24/10/2000	**RIVER**: Luvuvhu	**SITE: 2 (Shidzivane)**	**AV. DAILY FLOW:** Not available
FLOW REGIME: Perennial	**WATER LEVEL:** Med- high (for this time in year)		**TURBIDITY:** Cloudy
CHANNEL PATTERN: Single	**ACTIVE CHANNEL WIDTH:** 75 - 100m		**MACRO CHANNEL WIDTH:** 150 -300m
CHANNEL TYPE: Alluvial		**REACH TYPE:** Alluvial (pool – riffle)	
MORPHOLOGICAL UNITS: Riffle, run, shallow pool; deep alluvial pool; backwater (Bedrock pavement downstream next to hill face)			
BED MATERIAL: Cobble; sand			
BANK MATERIAL:			
LHB: Cobbles with sand		**RHB:** Cobbles; cobbles with sand	

RIPARIAN AND IN-CHANNEL VEGETATION:			
	Reeds & sedges	**Ground layer**	**Shrubs & trees**
Macro-channel banks	0	2	2
Top of active channel bank	0	2	2
Active channel banks	1	1	1
Bars	1	1	2
Channel Bed	1	0	0

CHANNEL MODIFICATIONS & IMPACTS:			
VISIBLE IN-CHANNEL MODIFICATIONS		**BANK IMPACTS AT SITE**	
None		Animals, paths, exotic veg	
BANK EROSION:			
A: Fluvial		**B: Sub-aerial**	
LHB: Moderate erosion (10-33%)	**RHB:** Moderate (10-33%)	**LHB:** Limited rilling & game	**RHB**: Limited rilling & game

BANK STABILITY:									
Bank height vs. bankfull depth		**Bank angle**		**Stratification**		**Particle size:**		**Vegetation factor:**	
LHB	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**
5	8	5	5	5	8	2	2	2	5

BANK STABILITY SCORE: LHB = 19 **RHB =** 28	**BANK STABILITY INDEX: LHB** = Low **RHB** = Moderate
BARS (& material): Point bar (sand & cobble); Lateral (cobble); tributary bar (sand)	

HABITAT:	Pool	Glide/Run	Broken H^2O	Lateral	Isol.pool
Very shallow			X		X
Shallow	X	X	X		X
Deep	X	X	X		

Interstit space	**OH Veg.**	**Marg. Veg**	**IS Veg**	**U.Cut bank**	**Snags**
X		X		X	X
TOTAL HABITAT INDEX: 9 + 4 = 13 / 21					

BED PACKING:		**EMBEDDEDNESS:**	
Hydraulic control	Bar	Hydraulic control	Bar
Moderately	Moderately	Moderately	Moderately

TALLY OF BED MATERIAL SIZE DISTRIBUTION:					
Hydraulic control		**Bar:**			
8% CS	7% CG	2% FS	5% MS	7% CS	3% FG
46% SC	28% LC	5 % MG	11% CG	35% SC	8% LC
10% SB	1% MB	11% SB	4% MB	2% LB	

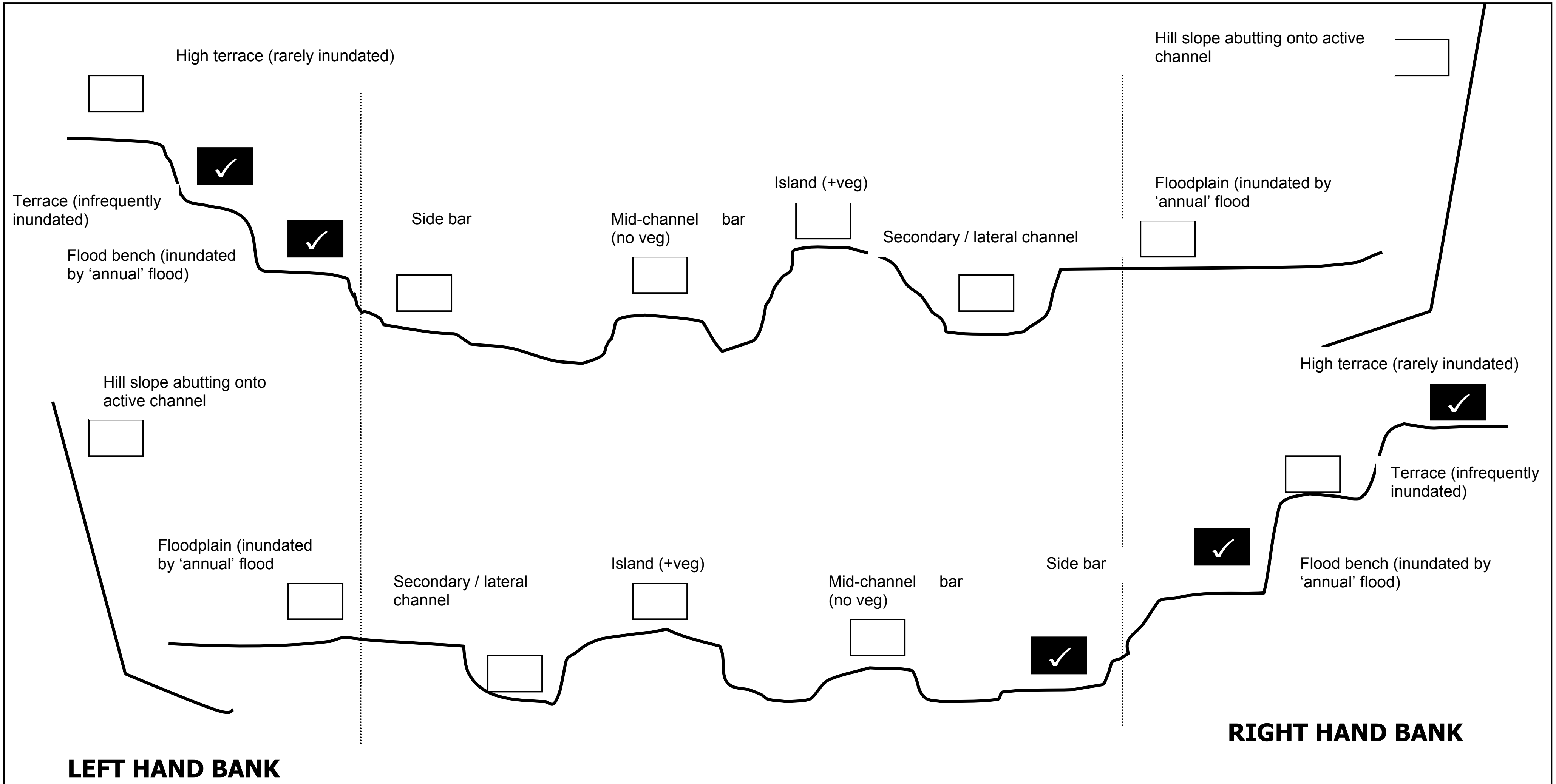


Figure 4: Cross section diagram of the Luvuvhu IFR 2 site showing the geomorphological components of the site.

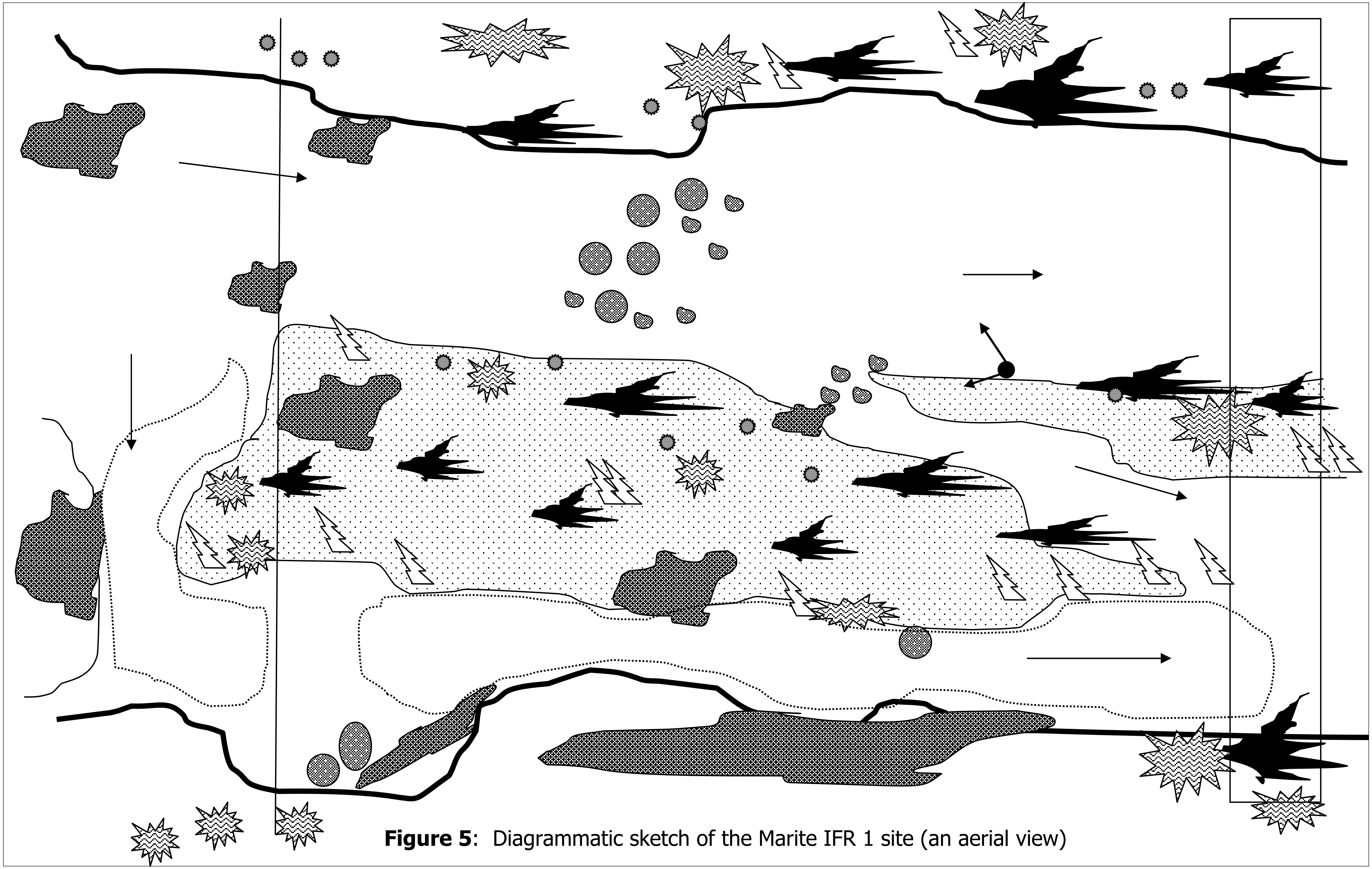


Figure 5: Diagrammatic sketch of the Marite IFR 1 site (an aerial view)

Table 3: A summary of the geomorphological characteristics of the Marite IFR 1 site.

		AV. DAILY FLOW: 1.73 m^3 s^{-1}
FLOW REGIME: Perennial	**WATER LEVEL:** High for time of year	**TURBIDITY:** Cloudy
CHANNEL PATTERN: Multiple	**ACTIVE CHANNEL WIDTH:** 30-50m	**MACRO CHANNEL WIDTH:** 75 –100m
CHANNEL TYPE: Mixed	**REACH TYPE:** Mixed: pool-rapid	

MORPHOLOGICAL UNITS: Rock steps; Bedrock rapid, plunge pool; run, shallow pool; deep alluvial pool; sand waves; backwater

BED MATERIAL: Bedrock + boulder; sand

BANK MATERIAL:

LHB: Sands & gravels	**RHB:** Bedrock, sand & gravels

RIPARIAN AND IN-CHANNEL VEGETATION:				CHANNEL MODIFICATIONS & IMPACTS:	
	Reeds & sedges	**Ground layer**	**Shrubs & trees**	**VISIBLE IN-CHANNEL MODIFICATIONS**	**BANK IMPACTS AT SITE**
Macro-channel banks	0	2	2	None	Animals, footpaths, vegetation clearance, exotic veg, agriculture on macro channel banks.
Top of active channel bank	1	2	2	**BANK EROSION:**	
Active channel banks	2	1	2	**A: Fluvial**	**B: Sub-aerial**
Bars	2	1	2	**LHB:** moderate erosion (10-33%); **RHB**: slight erosion (<10%)	**LHB:** limited rilling & livestock tracks; **RHB:** limited rilling & livestock tracks
Channel Bed	1	0	0		

BANK STABILITY:

Bank height vs. bankfull depth		Bank angle		Stratification		Particle size:		Vegetation factor:	
LHB	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**
5	5	5	5	8	8	2	5	5	8

BANK STABILITY SCORE: LHB = 25 **RHB** = 31	**BANK STABILITY INDEX: LHB =** moderate **RHB** = high

BARS (& material): Diagonal bar (sand & bedrock); mid channel bar exceeding channel width by 2-3 times (sand & bedrock)

HABITAT:	Pool	Glide/Run	Broken H^2O	Lateral	Isol.pool
Very shallow	X	X	X		X
Shallow	X	X	X	X	X
Deep	X	X	X		

Interstit space	**OH Veg.**	**Marg. Veg**	**IS Veg**	**U.Cut bank**	**Snags**
	X	X		X	X

TOTAL HABITAT INDEX: 12 + 4 = 16 / 21

BED PACKING:		**EMBEDDEDNESS:**	
Hydraulic control	Bar	Hydraulic control	Bar
Tightly packed	moderately	Moderately embedded	Not embedded

TALLY OF BED MATERIAL SIZE & DISTRIBUTION:

Hydraulic control:		**Bar:**	
10% CS	20% LB	30% MS	50 % CS
70% BR		3% CG	17% BR

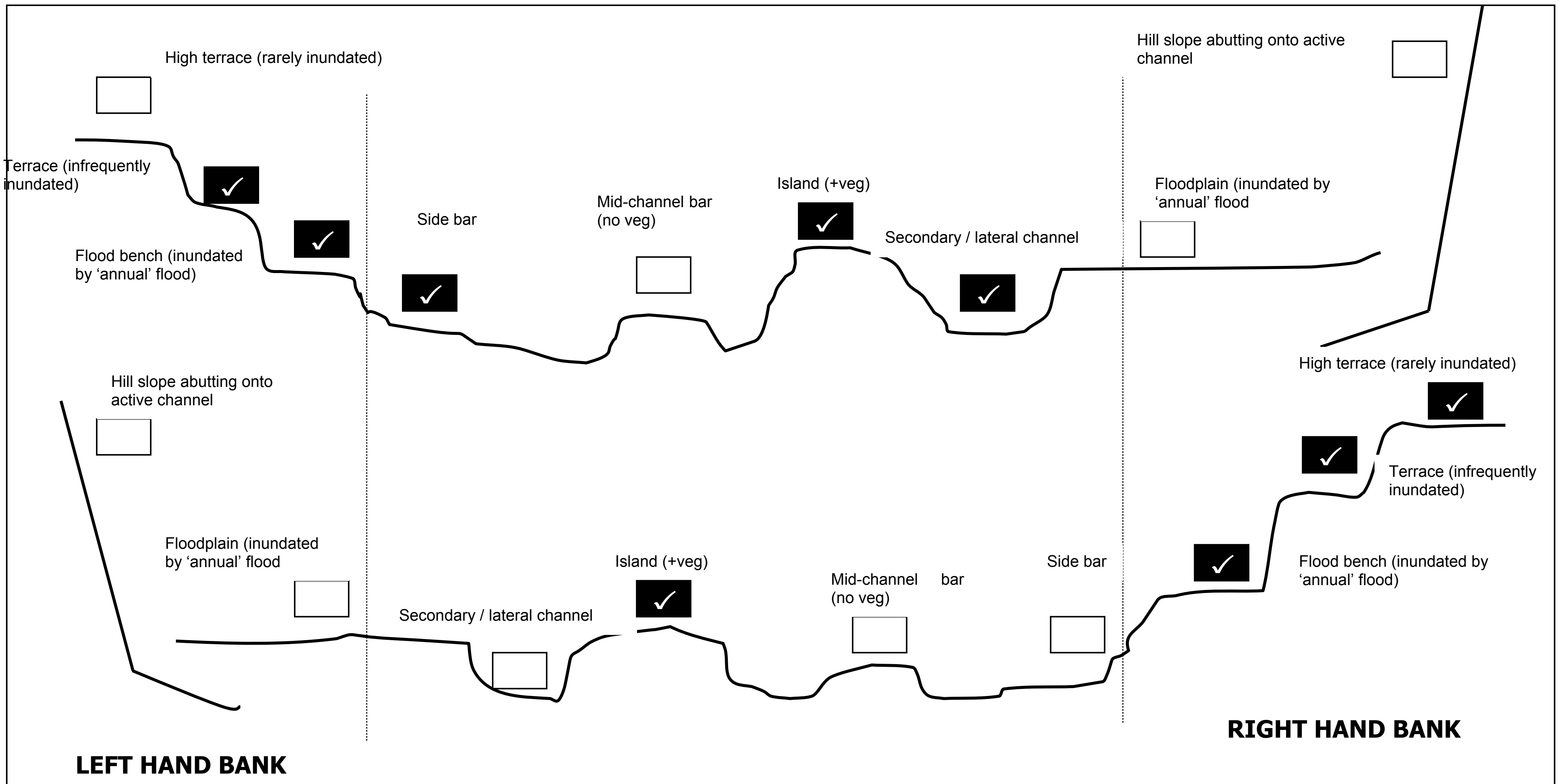


Figure 6: Cross section diagram of the Marite IFR 1 site showing the geomorphological components of the site.

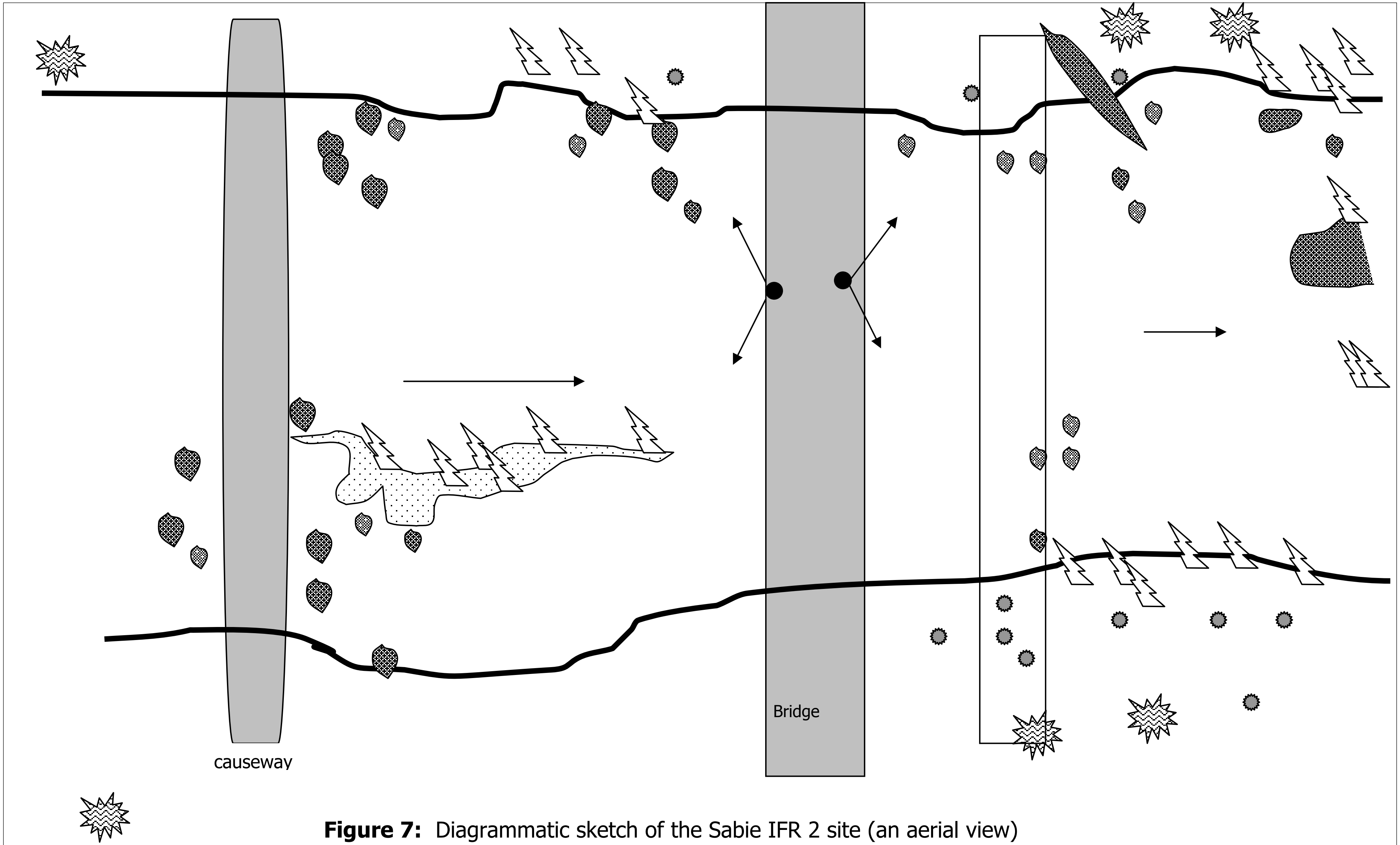


Figure 7: Diagrammatic sketch of the Sabie IFR 2 site (an aerial view)

Table 4: A summary of the geomorphological characteristics of the Sabie IFR 2 site.

DATE: 22/08/2000	**RIVER:** Sabie	**SITE:** IFR 2 (Bridge)	**AV. DAILY FLOW:** 11.8 m^3 s^{-1}
FLOW REGIME: Perennial	**WATER LEVEL:** High	**TURBIDITY:** Cloudy	
CHANNEL PATTERN: Single	**ACTIVE CHANNEL WIDTH:** 30-50m	**MACRO CHANNEL WIDTH:** 50-75m	
CHANNEL TYPE: Mixed	**REACH TYPE:** Alluvial Regime (& mixed pool rapid)		
MORPHOLOGICAL UNITS: Bedrock rapid; Riffle; run; shallow pool; deep alluvial pool; sand waves; back water			
BED MATERIAL: Bedrock + sand; silt & clay			
BANK MATERIAL:			
LHB: Sands & gravels; Bedrock	**RHB:** Bedrock + sand; silt & clay		

RIPARIAN AND IN-CHANNEL VEGETATION:				**CHANNEL MODIFICATIONS & IMPACTS:**			
	Reeds & sedges	**Ground layer**	**Shrubs & trees**	**VISIBLE IN-CHANNEL MODIFICATIONS**		**BANK** IMPACTS AT SITE	
Macro-channel banks	0	2	1	Causeway; bridge		Animals, footpaths; vegetation clearance; exotic veg; burning of flood debris	
Top of active channel bank	2	2	1	**BANK EROSION:**			
Active channel banks	2	1	1	**A: Fluvial**		**B: Sub-aerial**	
Bars	2	0	0	**LHB:** Moderate erosion (10-33%)	**RHB:** Moderate erosion (10-33%)	**LHB:** Limited rilling & livestock tracks	**RHB:** Limited rilling & livestock tracks
Channel Bed	1	0	0				

BANK STABILITY:									
Bank height vs. bankfull depth		**Bank angle**		**Stratification**		**Particle size:**		**Vegetation factor:**	
LHB	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**
5	5	5	5	8	8	2	2	5	5
BANK STABILITY SCORE: LHB = 25 **RHB** = 25					**BANK STABILITY INDEX: LHB** = Moderate **RHB** = Moderate				
BARS (& material): Numerous mid channel bars (sand & gravel; bedrock); Lee bar (sand); Bedrock core bar (sand)									

HABITAT:	Pool	Glide/Run	Broken H^2O	Lateral	Isol.pool	**BED PACKING:**		**EMBEDDEDNESS:**	
Very shallow						Hydraulic control	Bar	Hydraulic control	Bar
Shallow	X	X	X		X	Moderate	Loosely	Moderate	Moderate
Deep	X	X	X			**TALLY OF BED MATERIAL SIZE DISTRIBUTION:**			

Interstit space	**OH Veg.**	**Marg. Veg**	**IS Veg**	**U.Cut bank**	**Snags**	Hydraulic control:			Bar:	
X		X	X		X	5% FS	14% MS	55% CS	10% FS	30% MS
TOTAL HABITAT INDEX: 7 + 4 = 11 **/ 21**						3% MB	2% LB	20% BR	50% CS	10% MB

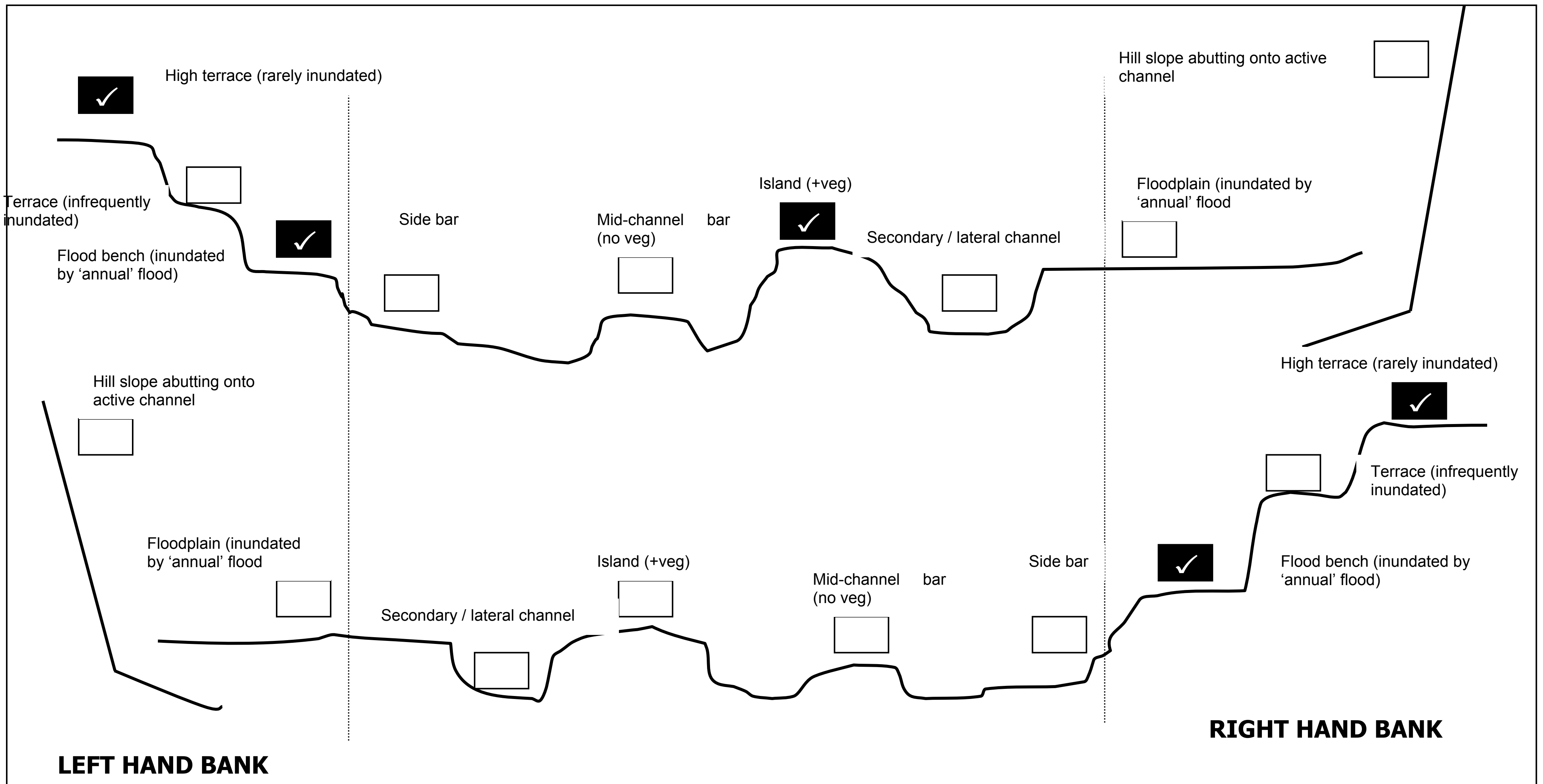


Figure 8: Cross section diagram of the Sabie IFR 2 site showing the geomorphological components of the site.

Table 5: A summary of the geomorphological characteristics of the Sabie IFR 4 site.

DATE: 3/10/2000	**RIVER**: Sabie	**SITE**: IFR 4	**AV. DAILY FLOW:** 10.4 m^3 s^{-1}
FLOW REGIME: Perennial	**WATER LEVEL:** High for time of year	**TURBIDITY:** Cloudy	
CHANNEL PATTERN: Multiple	**ACTIVE CHANNEL WIDTH**: **75-100m**	**MACRO CHANNEL WIDTH:** 100- 150m	
CHANNEL TYPE: Mixed	**REACH TYPE:** Mixed (pool-rapid) Alluvial (pool-riffle)		
MORPHOLOGICAL UNITS: Bedrock rapid; Bedrock pool; boulder step; riffle; run; shallow pool; deep alluvial pool; sand waves; backwater			
BED MATERIAL: Bedrock + gravel; silt & clay			
BANK MATERIAL:			
LHB: Sands & gravels; bedrock	**RHB:** Fine sand; bedrock		

RIPARIAN AND IN-CHANNEL VEGETATION:				**CHANNEL MODIFICATIONS & IMPACTS:**			
	Reeds & sedges	**Ground layer**	**Shrubs & trees**	**VISIBLE IN-CHANNEL MODIFICATIONS**		**BANK** IMPACTS AT SITE	
Macro-channel banks	0	2	2	None		Game; foot paths; exotic veg	
Top of active channel bank	0	2	2	**BANK EROSION:**			
Active channel banks	2	2	1	**A: Fluvial**		**B: Sub-aerial**	
Bars	2	2	1	**LHB:** Moderate (10-33%)	**RHB:** Moderate (10-33%)	**LHB:** Game tracks	**RHB:** Game tracks
Channel Bed	0	0	0				

BANK STABILITY:									
Bank height vs. bankfull depth		**Bank angle**		**Stratification**		**Particle size:**		**Vegetation factor:**	
LHB	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**
5	5	8	5	5	5	2	5	5	8

BANK STABILITY SCORE: LHB = 17 **RHB =** 28	**BANK STABILITY INDEX: LHB** =Low **RHB** = Moderate
BARS (& material): Main channel with mid bars & islands (sand & gravels; bedrock); side bars (sand & bedrock)	

HABITAT:	Pool	Glide/Run	Broken H^2O	Lateral	Isol.pool
Very shallow			X		
Shallow	X	X	X	X	
Deep	X	X	X	X	

Interstit space	**OH Veg.**	**Marg. Veg**	**IS Veg**	**U.Cut bank**	**Snags**
X	X	X		X	X
TOTAL HABITAT INDEX: 9 + 5 = 14 **/ 21**					

BED PACKING:		**EMBEDDEDNESS:**	
Hydraulic control	Bar	Hydraulic control	Bar
Tightly packed	Moderate	Moderately	Moderately

TALLY OF BED MATERIAL SIZE DISTRIBUTION				
Hydraulic control:			Bar:	
5% MG	10% CG	5 % SC	60% MS	5% CS
20% MB	60% BR		5% LB	30% BR

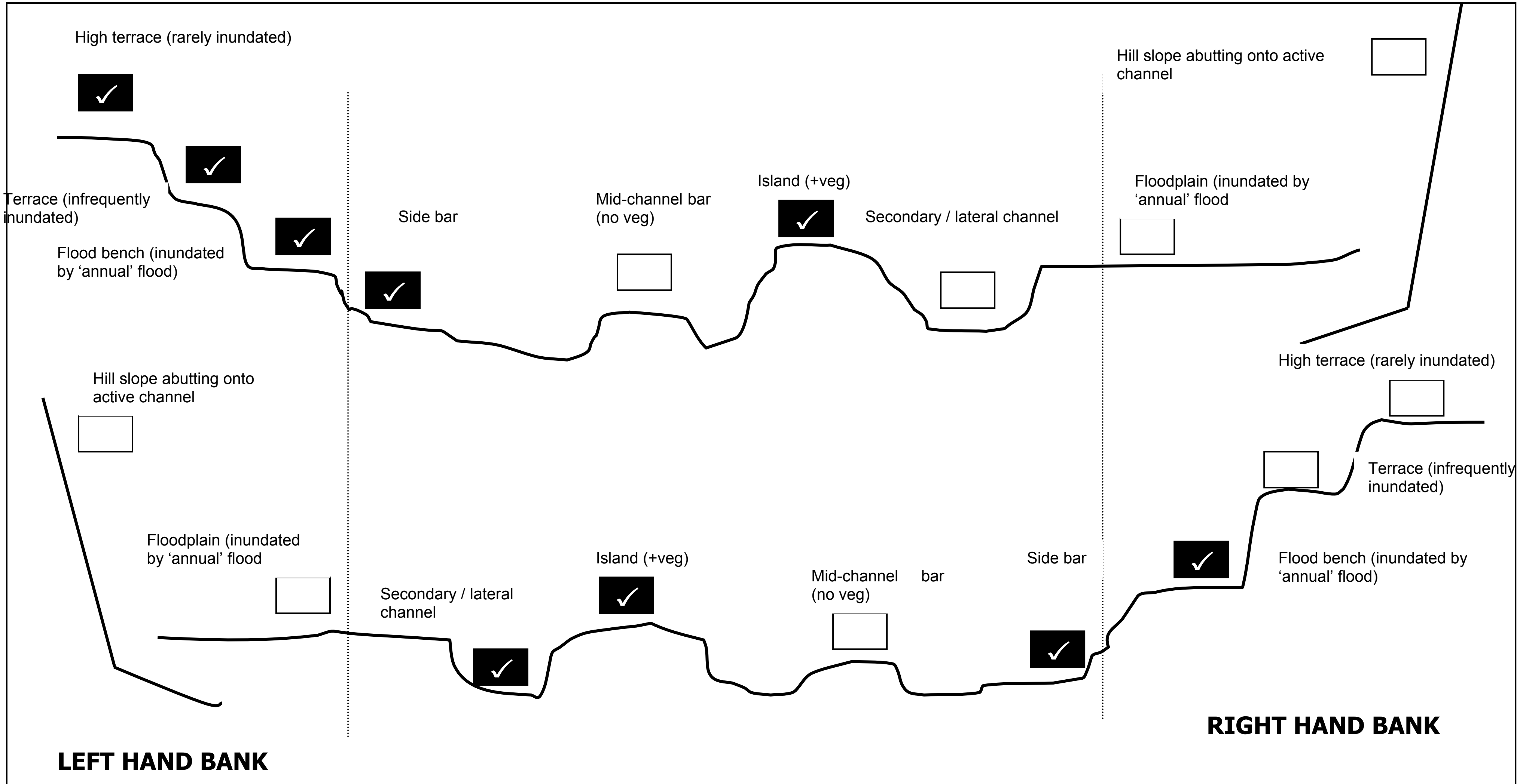


Figure 9: Cross section diagram of the Sabie IFR 4 site showing the geomorphological components of the site.

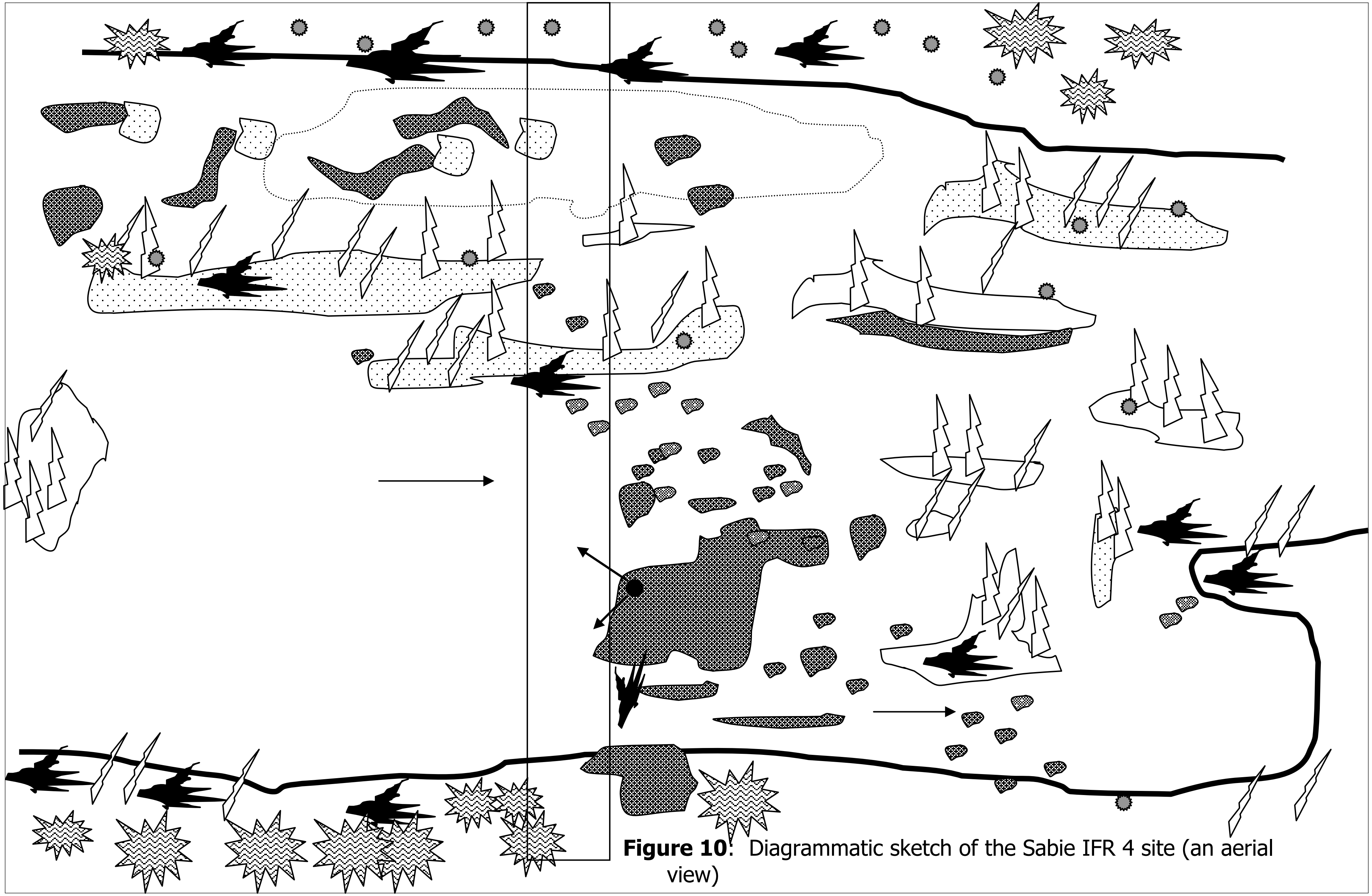


Figure 10: Diagrammatic sketch of the Sabie IFR 4 site (an aerial view)

Table 6: A summary of the geomorphological characteristics of the Sabie IFR 5 site.

DATE: 5/10/2000			**RIVER:** Sabie		**SITE:** IFR 5		**AV. DAILY FLOW:** 12.7 m^3 s^{-1}		
FLOW REGIME: Perennial			**WATER LEVEL:** Medium flow				**TURBIDITY:** Cloudy		
CHANNEL PATTERN: Multiple			**ACTIVE CHANNEL WIDTH:** > 300m				**MACRO CHANNEL WIDTH:** > 300m		
CHANNEL TYPE: Mixed					**REACH TYPE:** Mixed: pool-rapid (Alluvial pool-riffle)				
MORPHOLOGICAL UNITS: Rock steps; bedrock & boulder rapids; bedrock plunge pool; riffle; run; shallow pool; deep alluvial pool; sand waves; backwater									
BED MATERIAL: Bedrock + boulder, sand, gravel									
BANK MATERIAL:									
LHB: Fine sand & clay					**RHB:** sand & gravel; Cobbles				
RIPARIAN AND IN-CHANNEL VEGETATION:					**CHANNEL MODIFICATIONS & IMPACTS:**				
	Reeds & sedges	**Ground layer**	**Shrubs & trees**		**VISIBLE IN-CHANNEL MODIFICATIONS**		**BANK** IMPACTS AT SITE		
Macro-channel banks	0	2	2		None		Game; foot paths; exotic veg		
Top of active channel bank	2	1	1		**BANK EROSION:**				
Active channel banks	2	1	1		**A: Fluvial**		**B: Sub-aerial**		
Bars	2	1	1		**LHB:** Moderate (10-33%)	**RHB**: Slight (<10%)	**LHB:** limited game tracks	**RHB:** limited game tracks	
Channel Bed	1	0	0						
BANK STABILITY:									
Bank height vs. bankfull depth		**Bank angle**		**Stratification**		**Particle size:**		**Vegetation factor:**	
LHB	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**	**LHB**	**RHB**
2	8	2	8	5	8	5	2	8	2
BANK STABILITY SCORE: LHB = 22 **RHB =** 28					**BANK STABILITY INDEX: LHB =** Moderate **RHB =** Moderate				
BARS (& material): Side and mid channel bars exceeding 2-3 times channel width (sand & bedrock); mid bars (sand & bedrock); lee bar (sand)									

HABITAT:	Pool	Glide/Run	Broken H^2O	Lateral	Isol.pool	**BED PACKING:**			**EMBEDDEDNESS:**		
Very shallow	X	X	X	X	X	Hydraulic control		Bar	Hydraulic control		Bar
Shallow	X	X	X	X	X	Moderate		Loosely	Moderate		Not embedded
Deep	X	X	X	X	X	**TALLY OF BED MATERIAL SIZE DISTRIBUTION:**					
Interstit space	**OH Veg.**	**Marg. Veg**	**IS Veg**	**U.Cut bank**	**Snags**	Hydraulic control				Bar:	
X	X	X	X	X	X	15% MS	15% CS	5% FG	5% MG	20% MS	50% CS	5% FG
TOTAL HABITAT INDEX: 15 + 6 = 21 **/ 21**						5% CG	5% SC	10% MB	40% BR	5% MG	20% BR	

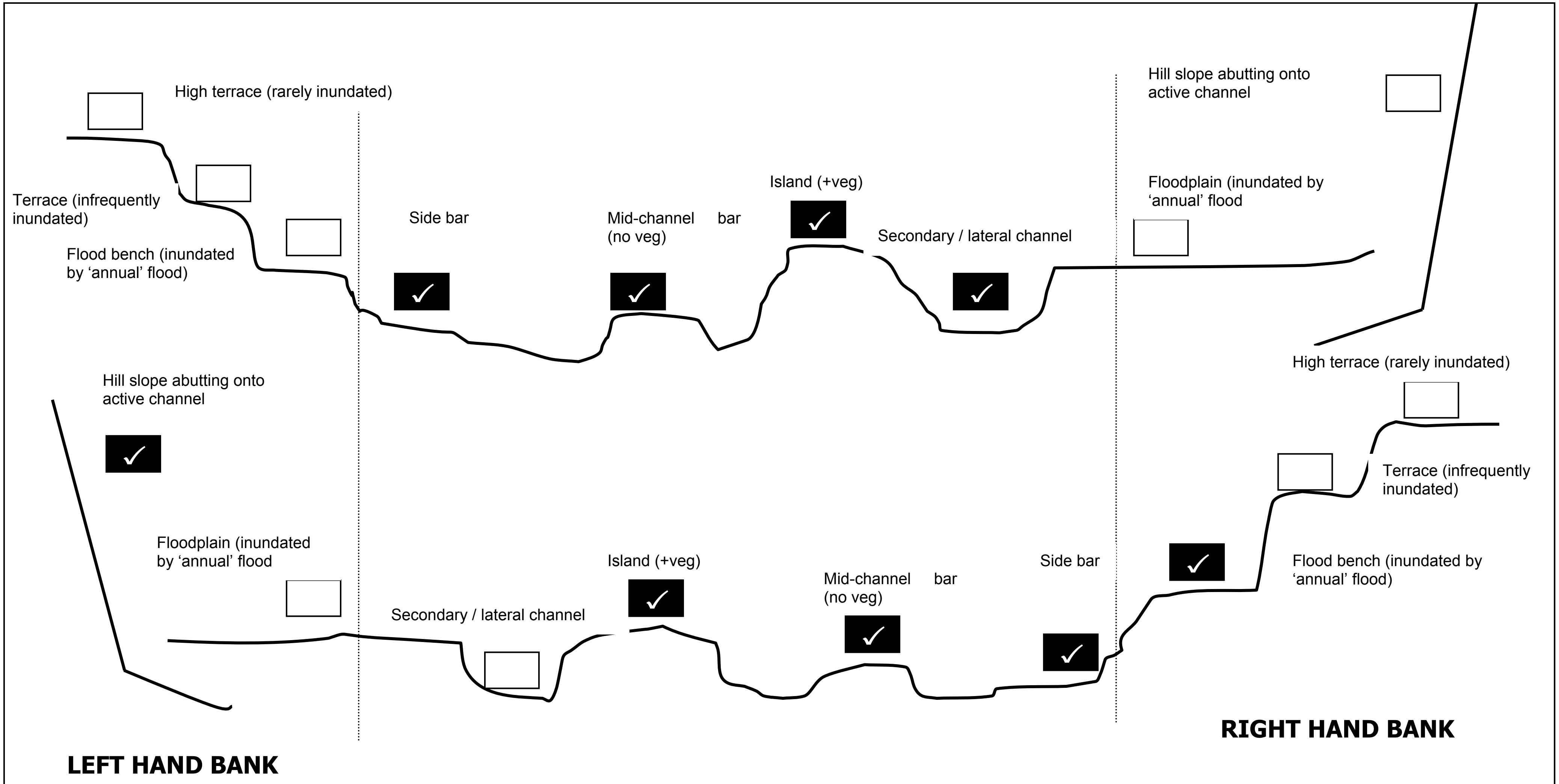


Figure 11: Cross section diagram of the Sabie IFR 5 site showing the geomorphological components of the site.

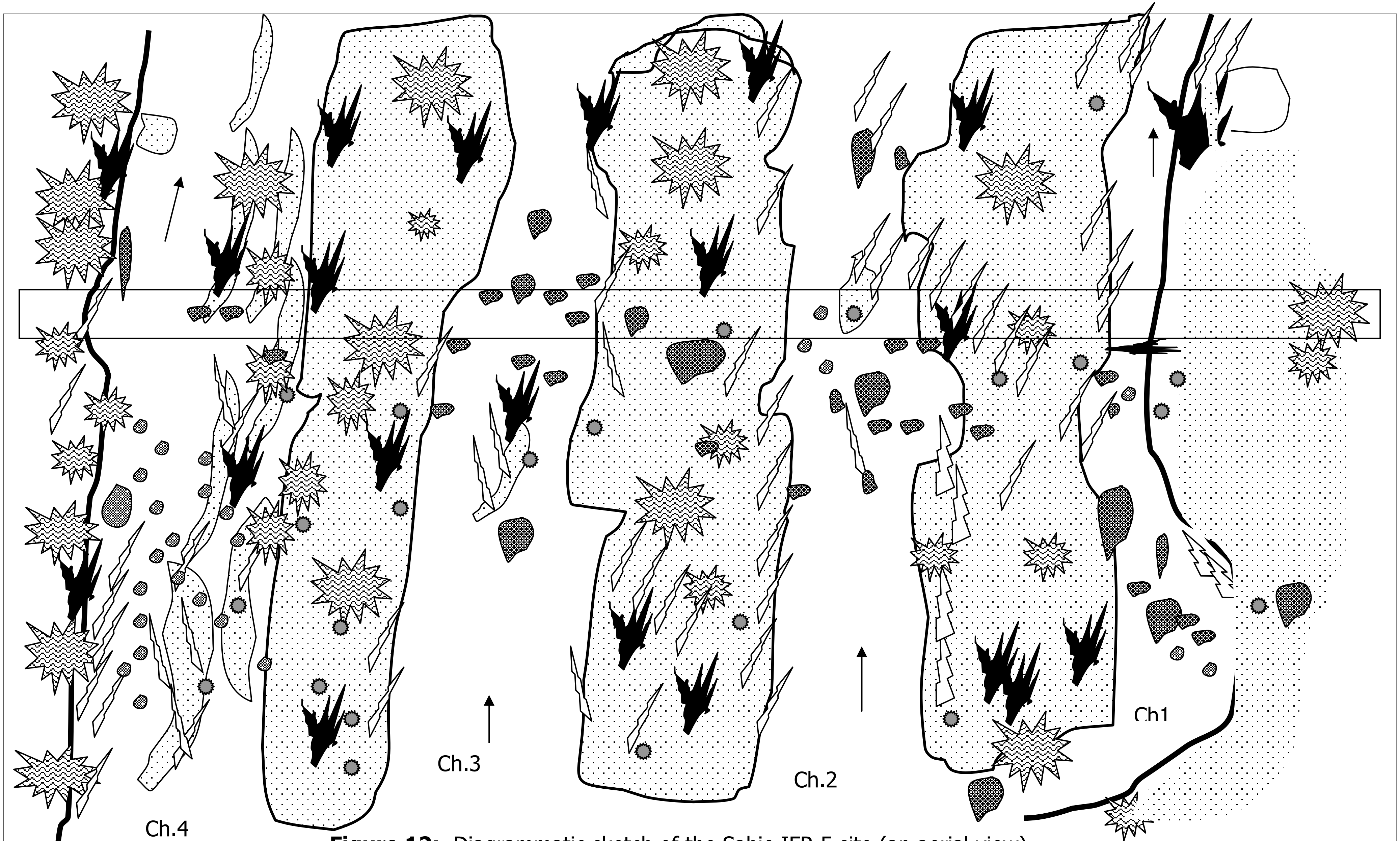


Figure 12: Diagrammatic sketch of the Sabie IFR 5 site (an aerial view).

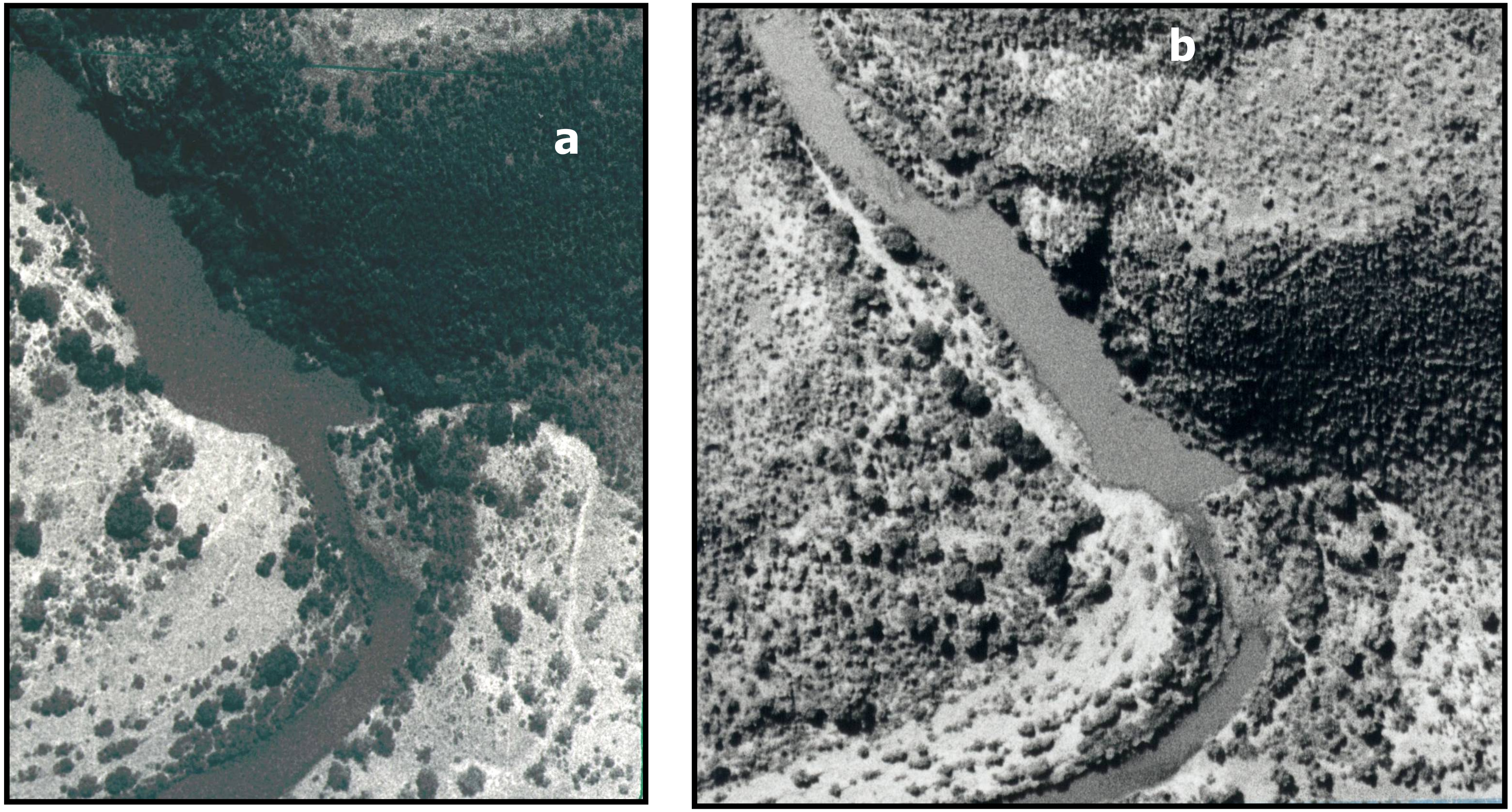


Plate 1: Luvuvhu River IFR Site 2 – Shidzivane. (a) Aerial photograph taken at the site 1970/71. (b) An aerial photograph of the same site taken 1987. The site remained very similar in the 16 years that passed between the two photo's, however (despite the slight scale difference) the left hand bank (left of photo's) geomorphology changed slightly in shape. The vegetation on the left hand bank seemed to increase in abundance in photo (b) as would be expected, but photo (b) was most likely taken in the dry season as the tree canopy seems to be less dense than that of (a). The characteristic cobbled side bar on the right of the river channel is relatively unchanged, but the river channel appears to be narrower in photo' (b).

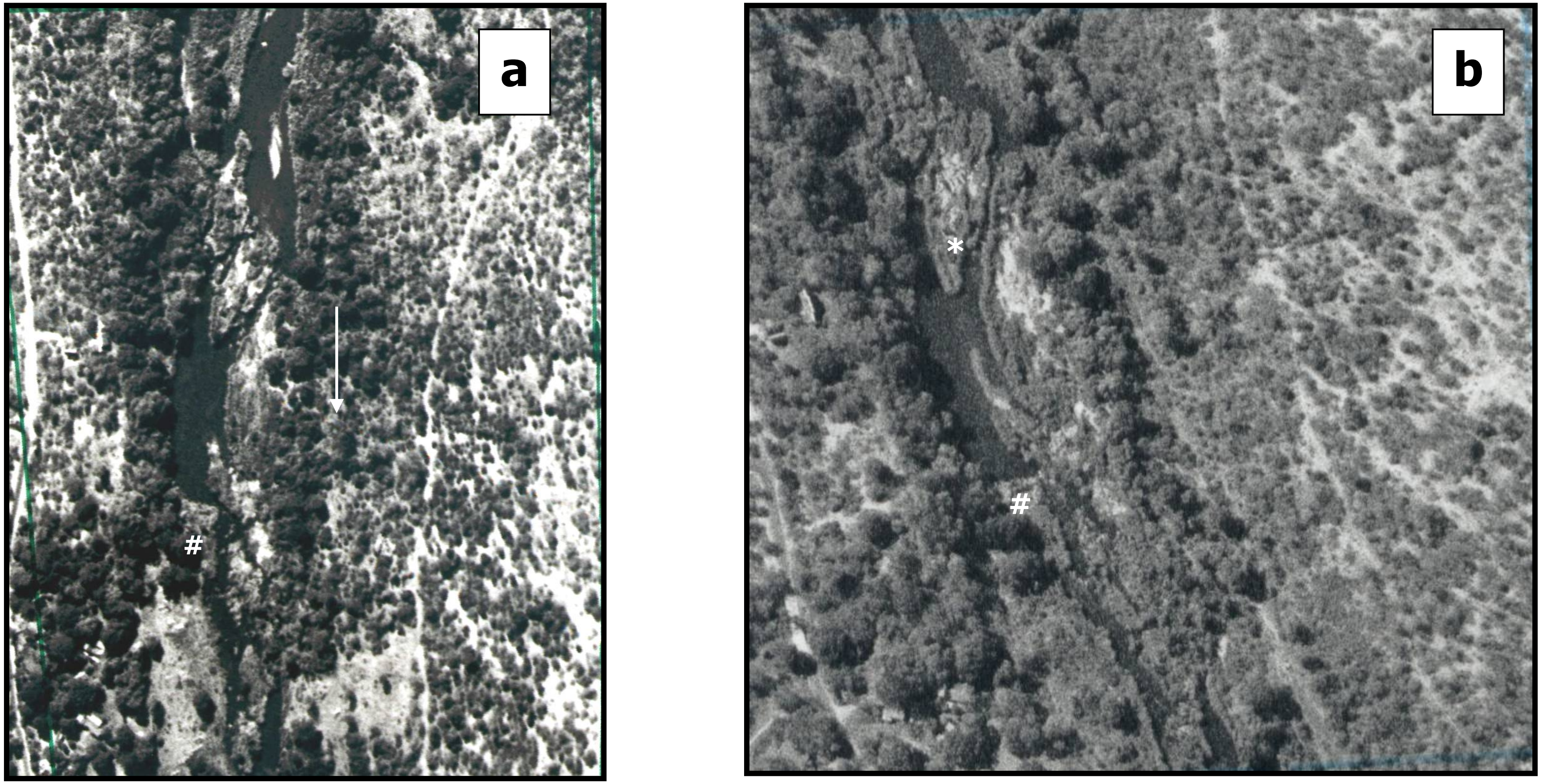


Plate 2: Sabie River IFR Site 4 – Skukuza. (a) Aerial photograph of the site taken in 1984. (b) Aerial photograph of the same site taken in 1996. There is a difference of 12 years between the two photo's. Very little changed during this period, apart from the size and shape, to a certain extent, of the island (marked with an *). In both photo's the far left channel (indicated by an arrow) remains heavily vegetated and possibly not flowing at all. At the start of this project this channel was not flowing but after the floods it was clearly reopened. (The arrow also shows the direction of flow). The # shows the location of the large bedrock island at this site.

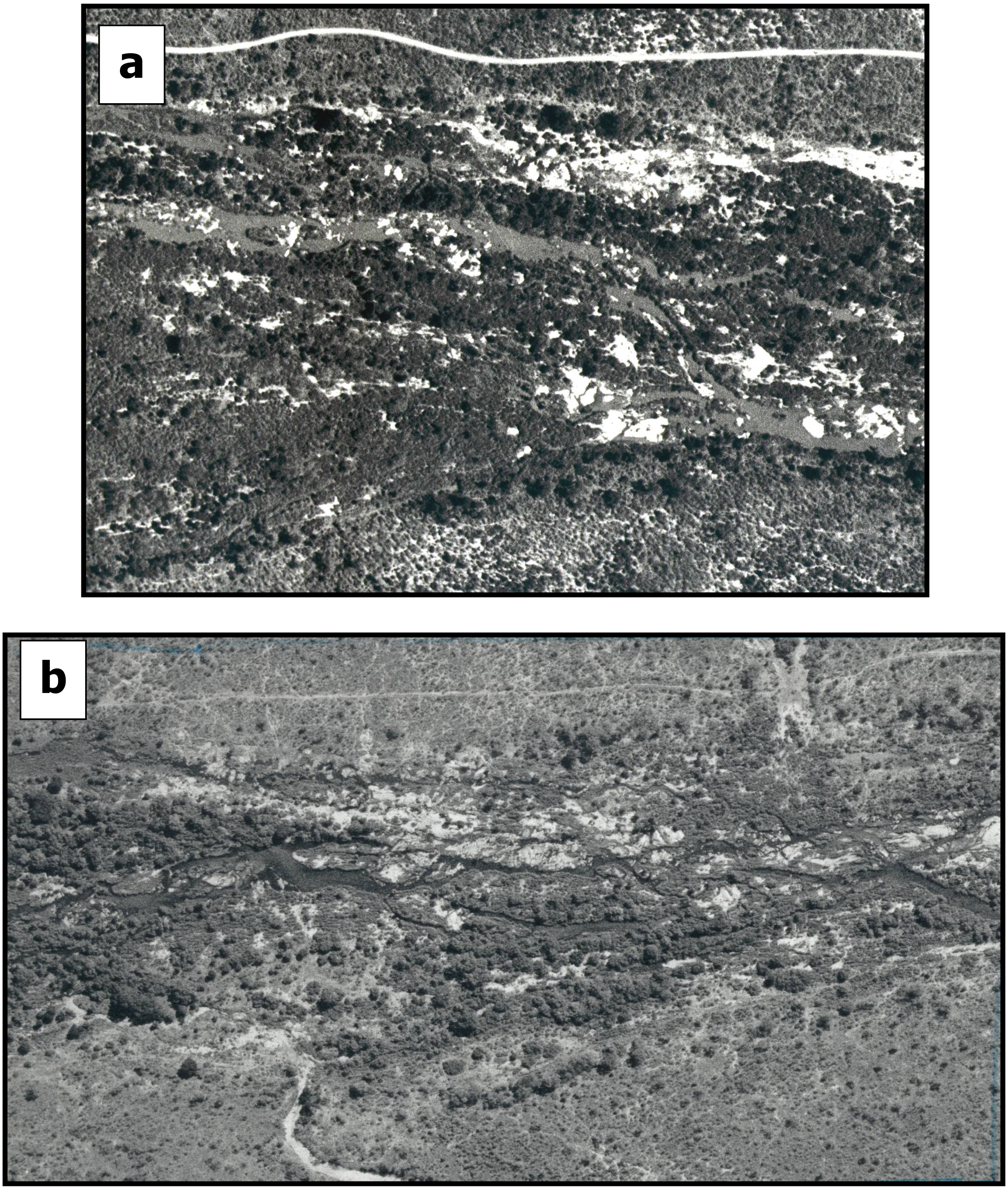


Plate 3: Sabie River IFR Site 5. (a) Aerial photograph taken in1984. (b) Aerial photograph of the same site taken in 1996. In these pictures it is not possible to see the same kinds of characteristic geomorphological features that can be compared. They do however indicate the extent of the macro channel and also show the complexity of the site in terms of multiple channels.

6.2 RIPARIAN VEGETATION

Table 7 summarises the different methods used at the different IFR sites. At most of the sites two different methods were used.

Table7 : A summary of the different methods used for monitoring Riparian Vegetation.

SITE	DATE	OVERALL SUMMARY	LINE TRANSECT	BELT TRANSECT	BELT TRANSECT & QUADRANTS
Marite 1	30/9/99	✓			
	28/11/00				✓
	10/4/01		✓		
Sabie 2	30/9/99	✓			
	27/11/00				✓
Sabie 4	13/3/01			✓	
Sabie 5	15/3/01				✓
Luvuvhu 1	17/11/99			✓ (1)	
	3/12/99			✓ (2)	
	15/11/00				✓
Luvuvhu 2	27/03/01		✓		✓

6.2.1 IFR Site 1 Luvuvhu River

On the 17/11/1999 in a standard belt transect twenty species were recorded (table 8). Of these five of them were exotic species, of which one species (*Cassia floribunda)* has since been classified as naturalised (Coates Palgrave,1988). Four are considered to be terrestrial species. *Dichrostachys cinerea*, a hardy terrestrial species, is the most abundant (in the <1 m class), and the only species to really be aware of. It has the potential to become an encroaching species forming dense thickets under certain conditions (Coates Palgrave, 1988). The site falls out of a protected area, and large riparian trees are not abundant as can be seen in the 8 – 12m + classes, where no large trees were present. This can mainly be attributed to anthropogenic reasons, and not flow. Of the 147 woody plants recorded in the belt the naturalised *Cassia floribunda* was most abundant, but most of these plants die off before they get much larger. *Dichrostachys* was the second most abundant species, with *Ficus capreifolia* only the third most abundant. Approximately 11% of the plants recorded were damaged, 6 % of these were because of flood damage, 3% were rated as condition class 2 (full canopy but loosing leaves), the other 3 % had recovered very well and were just coppicing. The other 5 % of damaged plants were all still classed as # 1 and the damage was attributed to anthropogenic reasons (4% cutting, and 1 % burnt). A soil type was the most abundant substrate (c.73%), then fine sediments at 13 %, cobble at 9 % and lastly sand at 5 %. Through out the whole transect the most abundant life form was grass (scoring a 3 rating = 51-75%); reeds were rated as 2 (25-50%) and sedges as 1 (<5%).

Throughout all of the following tables, which summarise the information gained at each of the sites, the following key has been implemented to further explain the meanings of the findings. Exotic species are indicated by (**E**), terrestrial species are (**T**), and the indicator species as used in the Belt transect and Quadrants method are marked with an asterix (*****). Species that have an uncertain or confusing status have (**^**) alongside them. These are species that are often a component of the riparian vegetation, but not characteristic. They are also species that can be found elsewhere or in another type of habitat similar to the riparian habitat, such as the indigenous or coastal forests, or habitat that overlaps with that of riparian, for example ravine vegetation. A question mark (**?**) next to a species indicates that it was not possible to ascertain its status. If the abbreviation sp. is used it invariably means that an inflorescence of the plant was required to identify the species. However in the case of Syzigium both *S. cordatum* and *S. guineense* have the same 'value' as riparian species and it is accepted that they are not identified to species level. In the life form graphs each is in terms of a percentage basal cover. The exotic species include herbaceous and woody species, other refers to all other woody and herbaceous plants (including the riparian plants), reeds include the *Phragmites* species and sedges are any sedge species.

Table 8: Summarising the species and population structure of the riparian vegetation in the belt transect # 1 at the Luvuvhu IFR 1 site on the 17/11/99.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia sieberana	1						1
Breonadia salicina		3					3
Caesalpinia decapetala (E)		1	1				2
Cassia didymobotrya (E)	1	1					2
Cassia floribunda (E)	34	1					35
Combretum paniculatum micro.	1	2					3
Dichrostachys cinerea (T)	19	4		2			25
Diospyros lycoides		1					1
Diospyros mespiliformis (^)	6						6
Dombeya rotundifolia (T)			1				1
Ficus capreifolia	11	6	2				19
Ficus sycamorus	1	1	1				3
Indigophera sp. (^)	3						3
Lantana camara (E)	8						8
Phyllanthus reticulatus	1	4					5
Bauhinia thonningii (T)			1				1
Ricinus communis (E)	4						4
Sclerocarya birrea caffra (T)	2						2
Sesbania sesban	8	5	1				14
Syzygium sp.	3	2	3	1			9

In the belt transect #2 at Botsoleni (table 9) thirty species were recorded, of these three are exotic species, five were terrestrial species and four are not true riparian species. The three most abundant species are *Ricinus communis* (exotic), *Syzygium sp* (riparian) and *Sesbania sesban* (riparian). While *Ricinus communis* is generally classed as a perennial species it is variable and can be subject to non-perennial flushes (Bromilow,1995). Fortunately all the plants are small at this stage (all in <1m class), but they should be monitored. It is encouraging to note that the next 2 species that are most abundant are both riparian species, especially *Syzygium* which is considered an indicator or key riparian plant for Lowveld Rivers. As with the previous belt there are no tall trees recorded in this belt. Once again this is mainly attributed to anthropogenic reasons. There were 243 plants recorded. Only 3 % were considered to have some kind of damage although still classed in the #1 condition class. The majority of this 3 % was as a result of high flows, but the significance is actually inconsequential. Most of the plants were found in a soil type (69%), the rest were in sand (20%), gravel (6%), cobble (3%) and silt (2%). In the life forms category for the whole of the belt transect both grass and reeds received a score of 3, while sedges were classed a 1.

Table 9: Summarising the species and population structure of the riparian vegetation in the belt transect # 2 at the Luvuvhu IFR 1 site on the 3/12/99.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia polycantha (T)		1					1
Antidesma venosum				2			2
Artabotrys sp.				1			1
Breonadia salicina	1						1
Bridelia cathartica	2	2	1				5
Carissa edulis (T)	2						2
Cassia floribunda (E)	7						7
Coddia rudis?	2						2
Combretum paniculatum micro.	1						1
Dichrostachys cinerea (T)	2						2
Diospyros lycoides	12	1	2				15
Diospyros mespiliformes (^)	6	8					14
Dombeya rotundifolia (T)	2						2
Erythroxylum emarginatum (^)	1						1
Ficus capreifolia	11	15	3				29
Ficus sycamorus			1				1
Gymnosporia senegalensis (^)		1					1
Gymnosporia sp.?	1						1
Lannea schweinfurthii				1			1
Lantana camara (E)	3	2					5
Lantana trifolia		1					1
Peltophorum africanum (T)				1			1
Phyllanthus reticulatus	17	6	3	1			27
Ricinus communis	43						43
Sesbania sesban	4	14	13				31
Syzygium sp.	18	6	7	3			34
Tabernaemontana elegans (^)	1	1					2
Trema orientalis	1						1
Trichilia emetica			1	1			2
Vernonia glabra	6			1			7

In the third belt transect at the Luvuvhu IFR 1 site (table 10), thirty-three species were recorded. Of these, five were considered terrestrial, three considered exotic species, and five are not true riparian species. Some of the remaining species have an unknown status. The most abundant species *Phyllanthus reticulatus* with most of the plants falling in the <1m category. Ficus capreifolia was also abundant in this belt transect. Unfortunately one of the most prolific exotic species of the country and the lowveld regions*, Lantana camara* was also abundant, with most of the plants being well established in the height class of 1-2m. This transect at least had some large canopy forming riparian species, *Breonadia salicina* being one of them. This is important as it a typical key indicator riparian plant, especially in the lowveld regions of Mpumalanga and the Northern Province. In this transect 328 plants were actually recorded. All plants received a condition score of 1, but some had been damaged (but recovered well to still be classed as a 1). Only 1% of the plants showed flow related damage (flood), and the anthropogenic damage was negligible. The average scores for the life forms indicated grass was once again the most abundant (grass =3, reeds = 2 & sedges = 1). Once again the dominant substrate was a soil type (83%), with sand (13%) and gravel (4%) only just featuring.

Table 10: Summarising the species and population structure of the riparian vegetation in the belt transect # 3 at the Luvuvhu IFR 1 site on the 3/12/99.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia polycantha (T)		3					3
Alchornea laxiflora	1						1
Breonadia salicina				2	3		5
Bridelia cathartica	12	3	1				16
Bridelia micrantha		2					2
Coddia rudis?	1	2					3
Combretum erythrophyllum			2				2
Combretum paniculatum micro.	5	14					19
Dichrostachys cinerea (T)	1						1
Diospyros lycoides	6		2				8
Diospyros mespiliformes (^)	18	11	3			2	34
Dombeya rotundifolia (T)	3	4	1				8
Erythroxylum emarginatum (^)	1	1					2
Ficus capreifolia	23	16					39
Ficus sycamorus		1					1
Grewia flavescens		2					2
Grewia monticola (^)			1				1
Gymnosporia buxifolia	4	2					6
Gymnosporia senegalensis (^)		2	1				3
Lantana camara (E)	7	19	2				28
Lantana trifolia	1	5	1				7
Lonchocarpus capassa (T)	1						1
Maclura africana?	1		1				2
Melia azedarach (E)			1				1
Peltophorum africanum (T)	1						1
Phyllanthus reticulatus	76	5					81
Ricinus communis (E)	12						12
Sesbania sesban	2	1					3
Strychnos potatorum				1			1
Syzygium sp.	1	1	7	5			14
Tabernaemontana elegans (^)	2		1				3
Trema orientalis		5	2				7
Trichilia emetica	6	2	2	1			11

A total of fourty six species were recorded between all three belt transects. Of these eleven were common to all three transects, and a further eleven were common to two of the transects. A total of six exotic species were recorded and eight terrestrial species. These transects were completed prior to the significant February 2000 floods. In a botanical survey of the Mutoti (Nandoni) Dam basin, Bester and van Schaik (1995), concluded that the sandy banks of the Luvuvhu River (generally, not site specific) had the greatest collection of exotic weeds, *Ficus capreifolia*, and *Nuxia* sp. The flood plains (and terraces) had good stands of *Ficus sycamorus*, and *Ficus sur*, as well as, Acacia sp., *Spirostachys africana* and *Dalbergia melanoxylon*. One of the species that was most abundant on all the transects, *Ficus capreifolia*, was one of the species that was found to have a new distribution. Despite its abundance in the basin survey, and this one, it is considered a rare South African fig species (Bester and van Schaik, 1995). In the riparian surveys done during this project *Ficus capreifolia* was considered a key species, which corresponds with the setting of key species in the proposed monitoring protocol as suggested during the IFR Monitoring workshop, refer to chapter 9 and the appendix.

The two belt transects with quadrants that were done in November 2000 were completed after the floods. Although set out along the same belt transects as done the previous year, (more or less as some of he markers had been washed away), they cannot be compared sufficiently because the methods have altered slightly. However some components such as the key species can be compared. In the belt transect #1 the ecotone quadrants (left and right hand banks) had thirteen species recorded (table 11), of which there was one exotic, two terrestrial and one non-true riparian species. The most abundant species was *Dichrostachys cinerea*, with the majority of the plants in the < 1m class. Although this is partly to be expected as the belt transect extends a little more into the terrestrial community on the macro channel banks, than the plain belt transect did in the 1999 survey, this survey shows that *Dichrostachys cinerea* had increased by fifteen plants. *Diospyros mespiliformes,* the next most abundant species, and frequently in the outer zones of the riparian, had also increased quite considerably after the floods (from 6-21 plants, all in <1m class). While this can partly be attributed to the quadrant extending up the macro channel bank a little bit (c.5m), it is still quite a significant increase. Fortunately *Lantana camara* had decreased in number after the floods, however because there is a section between the water and ecotone quadrants that is not surveyed, this is not necessarily an accurate reflection. However figure 13 shows that 20% of the banks were covered with exotic species. There were eighty-eight plants recorded in the ecotone quadrants of these 60% were growing in a soil type substrate and 40% in fine sand. There was c. 21% of the plants showing some form of damage, 8% were as a result of the floods and 13% were due to anthropogenic or non-flow reasons (cutting, browse and ploughed). The majority of the plants (20%) were coppicing in response to the damage, and only 1% had leaves missing.

Table 11: A summary of the species and population structure in the ecotone component of a belt and quadrant transect (#1) at Luvuvhu IFR 1 17/11/2000.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Bridelia cathartica	5						5
Coddia rudis?	1						1
Combretum paniculatum micr.	1	1	3				5
Dichrostachys cinerea (T)	39	1					40
Diospyros lycoides	1						1
Diospyros mespiliformes (^)	21						21
Dombeya rotundifolia (T)	2						2

*Ficus capreifolia **	1						1
Gymnosporia sp.?	3						3
Lantana camara (E)	2						2
Phyllanthus reticulatus	4						4
Strychnos potatorum	2						2
Trichilia emetica				1			1

The fact that grass was the dominant life form, as illustrated in figure 13, is a positive sign of the recovery of the banks post flood. However the bare ground was still quite high at 27%, especially as it is soil, which does not inhibit growth of riparian vegetation, as cobble or bedrock would for most species.

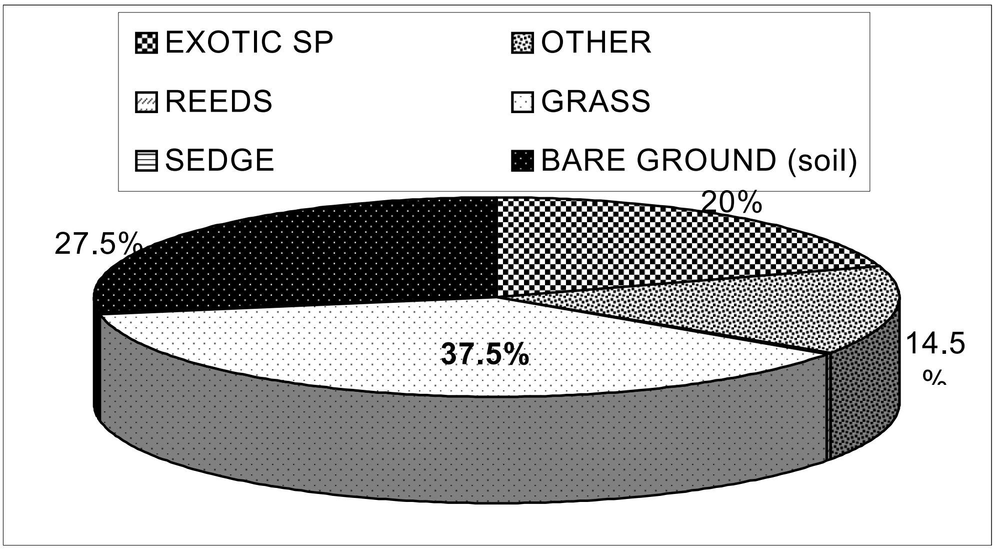


Figure 13: The % basal cover of the banks in the belt and quadrant transect #1 at Luvuvhu IFR 1 17/11/2000.

The water quadrants of transect #1 (table 12) have most of the key plants present. However a key species *Breonadia salicina* has dropped from three plants to one since the floods, it is likely that they were lost due to the high flow, despite them being a hardy riparian species adapted to living in or near the water, the flow was of such a magnitude to remove plants in most classes other than the 8-12m + ranges. Only six species were recorded in the water quadrants and six islands component of the belt. A key, riparian plant being the most abundant. No woody exotic species were recorded, although there were herbaceous exotics present on both the islands and on the banks (figures 13 & 14). The presence of *Dichrostachys cinerea* is negligible because it very low in abundance, however the fact that such a terrestrial species is located so close to the water edge, especially post flood is noteworthy. Only thirty-seven woody plants were recorded in the water quadrant survey in belt transect #1. There were 27% of the plants in this component that had some form of damage, and of this 24% were flow related, as would be expected close to the river edge and after a flood of such magnitude. The 3% remaining were due to natural non-flow reasons (termites). Despite the floods the substrate was still mainly a soil type (35%), with cobble (13%), gravel (22%) and mud (30%) making up the rest of the substrate in the water quadrants.

Table 12: A summary of the species and population structure in the water quadrants and islands of a belt and quadrant transect (#1) at Luvuvhu IFR 1 17/11/2000.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
*Breonadia salicina **			1				1
Dichrostachys cinerea (T)	1						1
Diospyros mespiliformes (^)	1						1
*Ficus capreifolia **	4	19	1				24
Ficus sycamorus	1						1
*Syzygium sp.**	5	4					9

Figure 14 indicates that reeds (c.79%) were by far the most dominant life form found on the islands in belt transect #1. In the 1999 survey grass was the most dominant for the whole transect, with reeds falling into a class of 26-50% (also the whole transect).

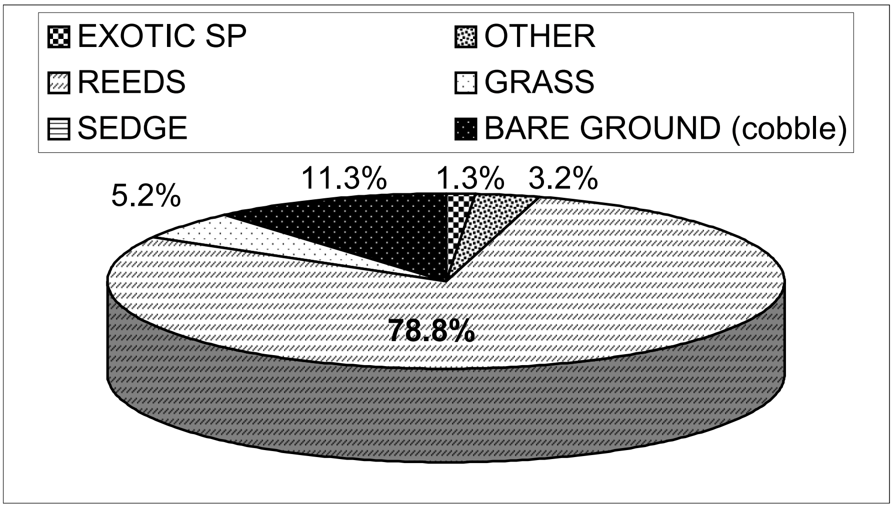


Figure 14: The % basal cover of life forms in the 6 islands in the belt and quadrant transect #1 at Luvuvhu IFR 1 17/11/2000.

Table 13 shows that there were twenty one species found in the ecotone quadrants of transect #3 on the Luvuvhu IFR 1 site. Of these six are considered terrestrial species, two exotic woody species and two of them are not true riparian species. Five have an unknown status. The three most abundant species are *Erythroxylum emarginatum, Coddia rudis* and *Dombeya rotundifolia* respectively. None are true riparian plants, *Dombeya* is a terrestrial and *Coddia rudis* is of unknown status. Most of the plants fall within the <1m class. While *Dombeya* is less abundant in the 1-2m and 2-4m classes (compared to 1999 survey) it has increased considerably in the <1m class (from 3 – 17), this can be attributed to the change in methods but even this seems a little too high. *Erythroxylum* has increased from 1 – 59 plants (in the <1m class) and *Coddia* from 3 – 33 plants (total) in the interim between the surveys. It is encouraging to note that there are still a few trees in the > 12m class – even though they are not riparian species. The exotic species appear to have decreased, this can be seen in the figures 15 & 16 as well as in comparing the decrease of abundances in both *Lantana camara* and *Ricinus communis* in tables 10, 13 & 14 from being fairly abundant in the previous survey. In the ecotone quadrants 179 plants recorded and 100% were noted to be in a soil type substrate. Only 7% of the plants were damaged, and of this only 1 plant was damaged due to flow, while 5% could not be attributed to anything specific, the remaining 2 % was due to anthropogenic reasons. Most (5.5%) of the damaged plants were showing signs of coppicing as a result of their damage.

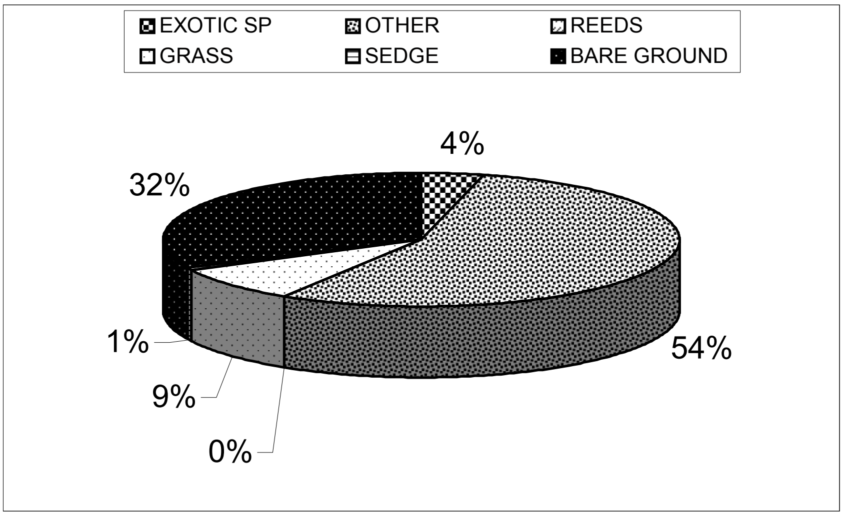


Figure 15: The % basal cover of the banks in the belt and quadrant transect #3 at Luvuvhu IFR 1 16/11/2000.

Table 13: A summary of the species and population structure in the ecotone quadrants of a belt and quadrant transect (#3) at Luvuvhu IFR 1 16/11/2000.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Afzelia quanzensis (T)						1	1
Aspilia sp.?	1						1
Bridelia cathartica	10	3					13
Canthium setiflorum	1	4					5
Coddia rudis?	17	15	1				33
Dichrostachys cinerea (T)	1						1
Diospyros mespiliformes (^)	1			1		3	5
Dombeya rotundifolia (T)	17	5	4				26
Ehretia amoena		2					2
Erythroxylum emarginatum (^)	59	7					66
Flacourtia indica (T)	2						2
Grewia flavescens		2					2
Gymnosporia sp.?	1						1
Lantana camara (E)		4					4
Maclura africana?		1					1
Monodora junodii (T)	1	1					2
*Nuxia oppositifolia **		1					1
Ochna sp.?	1						1
Ricinus communis (E)	1						1
Sclerocarya birrea caffra (T)	1						1
Strychnos potatorum	3	5	1	1			10

The water quadrants of the belt transect #3 (table 14) has only five species. No exotic woody species were found in this component. The most abundant species were *Ficus capreifolia* (an indicator species) and *Diospyros mespiliformes*. *Breonadia salicina* is the only species to have plants in the 8-12m + classes, which is of significance as this survey is post flood and the trees are right at the water's edge. Of the 15 plants recorded 46% were located in a soil substrate, 20% in sand, 27% in cobble, and 7% in gravel. In the water quadrants 67% of the plants showed a sign of damage, and of this 60% could be attributed to the high flow conditions, while only 7% was due to natural non-flow reasons.

Table 14: A summary of the species and population structure in the water quadrants and islands of a belt and quadrant transect (#3) at Luvuvhu IFR 1 16/11/2000.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
*Breonadia salicina**					1	1	2
Bridelia cathartica	1						1
Diospyros mespiliformes (^)	5						5
*Ficus capreifolia**	2	3					5
Phyllanthus reticulatus	2						2

Figure 16 shows that bare ground dominates the 3 islands, and it is comprised of gravels, cobbles and mud. This is understandable as after the floods the islands were reformed and it takes some time for them to be re-colonised with plants.

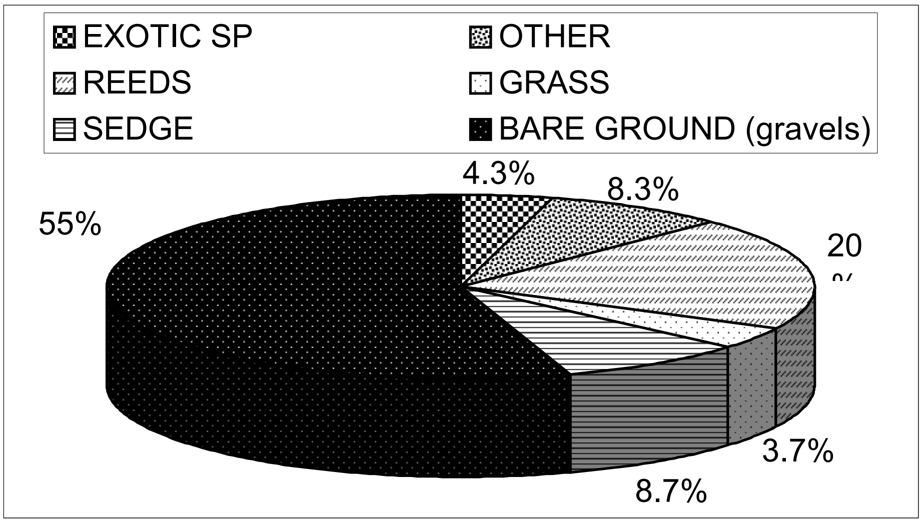


Figure 16: The % basal cover of the 3 islands in the belt and quadrant transect #3 at Luvuvhu IFR 1 16/11/2000.

6.2.2 IFR Site 2 Luvuvhu River

A mere four woody species and four actual plants were recorded in the ecotone quadrants of the Shidzivane belt transect site. This is definitely as a result of the 2000 floods, despite the survey taking place more than a year after the occurrence.

Figure 17 shows that the other component of the life forms is not too low (22.5%), which does indicate that the herbaceous species are recovering. Table 16 has a greater list of species than table 15 which also indicates there is still a woody riparian community at the site. The majority of those plants are on the right hand bank of the site. Unfortunately there is no comprehensive vegetation survey prior to the floods, to which this result can be compared. However a visit to the site in 1999 as part of the River Health Biomonitoring Program would give an indication of some of the species, as do the series of photographs, which show where the riparian vegetation was located, even if the species cannot be noted (plates 4 & 5).

Table 15: Summarising the species and population structure of the riparian vegetation in the ecotone quadrants (Belt transect & quadrant method) at the Luvuvhu IFR 2 site on the 29/03/2001.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Ricinus communis (E)	1						1
Sida acuta?	1						1
Sida rhombifolia?	1						1
Trichilia emetica	1						1

The Luvuvhu IFR 2 site has twelve species recorded in the water quadrant component of the belt transect. However there were only 23 plants recorded, while significantly more than the four ecotone quadrant plants, still not very high. This table (16) shows that there were two exotic species, one terrestrial and one non-true riparian species. The most abundant species were *Xanthium* (an exotic) and *Diospyros lycoides* (riparian). *Xanthium* is considered a serious poisonous weed (Bromilow, 1995), however it abundance is negligible at this stage. It is encouraging to note that there are a couple of large trees within the belt, one of which is a key species: *Breonadia salicina*. Of the water quadrant plants 70% showed signs of damage and almost all of this was high flow related which could be seen from the coppicing taking place as well as the broken or damaged branches of the plants. Once again soil was the dominant substrate (74%) type with the rest being distributed between cobble and sand.

Table 16: Summarising the species and population structure of the riparian vegetation in the water quadrants (Belt transect & quadrant method) at the Luvuvhu IFR 2 site on the 29/03/2001.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia robusta	1	1					2
*Antidesma venosum **		1					1
*Breonadia salicina **				1			1
Bridelia cathartica		1					1
Diospyros lycoides	2	1	1				4
Diospyros mespiliformes (^)	2	1					3
*Nuxia oppositifolia **			1				1
Sclerocarya birrea caffra (T)	1						1
Solanum sp. (E)	1						1
*Syzygium sp. **		1	2				3
Trichilia emetica					1		1
Xanthium strumarium (E)	4						4

The life forms figure 17, for the Luvuvhu IFR 2 banks show they are dominated by bare ground which was made up of sand and soil. Grass and other species are increasing considerably. The exotic component is not too high, and it is expected that a lot of exotic species, especially those of herbaceous or annual nature, will pioneer the bare ground initially.

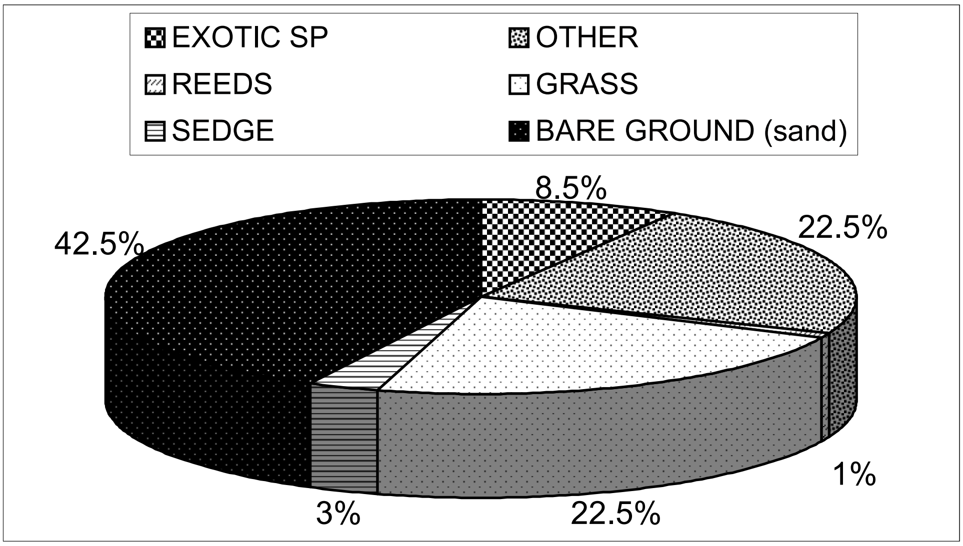


Figure 17: Shows the % basal cover of the life forms on the banks of the Luvuvhu IFR 2 site 29/03/2001.

A line transect (table 17) at the Luvuvhu IFR 2 site was also surveyed. This is effectively a 1m width belt transect, but only the woody species closest to the line are actually recorded. Including both the line transect and the belt transect with quadrants, a total of twenty-one species were recorded. Only 2 of these are classified as exotics and only 2 were terrestrial species. The line transect shows that an *Ochna sp*. was the most abundant on the line, with the one non-true riparian species, and the one species of unknown status being the next most abundant. Although the line extended 70m from the water's edge to the top of the macro-channel on the RHB, and 68m on the LHB, most of the LHB had no woody species after the 2000 floods. Of the 140 strikes (the actual point on the line) 73.5% fell on bare ground, 14.3% on grass, 8.5% on herbaceous plants, only 3% on a woody species and 0.7 on sedges. Herbs and grass were the life forms closest to the strike after a bare ground strike (20% & 18% respectively), with a woody species only having a 6% chance of being there.

Table 17: Summarising the species and population structure of the riparian vegetation in the Line transect method at the Luvuvhu IFR 2 site on the 27/03/2001.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia robusta						1	1
Antidesma venosum		1					1
Breonadia salicina			1				1
Combretum paniculatum mic.		1					1
Diospyros mespiliformes (^)	1	2					3
Gymnosporia sp. ?		3					3
Lonchocarpus capassa (T)						1	1
Mimusops obovata	1						1

Nuxia oppositifolia			1				1
Ochna sp?.	5						5

6.2.3 IFR Site 1 Marite River

In the first survey done at the Marite IFR 1 site, an overview of all the species was taken. Initially there were no transects laid out. Table 18 shows a summary of the twenty nine species found at the site. There are six exotic species, one terrestrial species and four non-true riparian species. Many of the remaining species are riparian species but are also characteristic of wooded ravines and low altitude forest, which is indicative of the Marite site where the river runs close to a steep forested koppie. *Breonadia salicina* is the most abundant species, with an exotic species, *Cassia floribunda* being the next most prolific, and *Syzygium sp*. following that. *Breonadia* and *Syzygium* are the only species in the tall tree classes, with *Breonadia* contributing most significantly. Unfortunately another ferocious exotic species *Lantana camara* is also fairly abundant. The fact that only one proper terrestrial species was recorded (*Apodytes dimidiata*) is a good indication of how limited the terrestrialisation at the site is.

Table 18: Summarising the species and population structure of the riparian vegetation at the Marite IFR 1 site on the 30/9/99. An overview of the whole site was done.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Antidesma venosum		3	1				4
Apodytes dimidiata (T)			1				1
Breonadia salicina	31	32	48	54	8	12	185
Bridelia micrantha	2	2	3	4			11
Caesalpinia decapetala (E)		1	1				2
Cassia floribunda (E)	6	52	4				62
Cassia sp.?		2					2
Combretum erthrophyllum		2					2
Dalbergia armata	4			2	1		7
Diospyros mespiliformis (^)	1						1
Engalaphytum magaliesmontanum (^)			1				1
Euclea natalense	3						3
Ficus ingens			1				1
Ficus sur	1						1
Krausii floribunda		1					1
Lantana camara (E)	1	7	13				21
Maytenus sp. (^)	6	1					7
Mimusops zeyheri	3	2	1	1			7
Nuxia oppositifolia		4	3	1			8
Ochna sp.?			1				1
Pappea capense	3						3
Phoenix reclinata			1				1
Phyllanthus reticulatus		1					1
Psidium guajava (E)	2	3					5
Sesbania punicea (E)		2	1				3
Solanum mauritianum (E)		1					1
Strophanthus speciosus (^)	12						12

Syzygium sp.	5	8	9	16	4	1	43
Trema orientalis	1	6					7

The ecotone quadrants of the Marite belt transect (table 19) had eighteen species recorded. Of these eighteen species, six are terrestrial species and three are exotic species. There are also five species with an undetermined status, which leaves only four riparian species. The number of terrestrial species can be attributed to the different method used, and that this component is right on the banks of the macro channel. *Trema orientalis* and *Senna septemtrionatus* were the two most abundant species. While *Trema orientalis* is not a key riparian species it is considered a characteristic constituent of riverine fringe thicket. It is also a common pioneer species that is quick to colonise disturbed soils (Coates Palgrave, 1988). This is precisely the circumstances in this transect. While the belt is located under a tall tree canopy, most of the under storey species have been removed during the high flow conditions leaving the banks quite open with just a leaf litter covering the sand. All of the *Trema* plants were still small, as can be noted with them falling into the <1m height class. *Albizia versicolor* is the only species falling into the 8-12m class. This species contributes to the aerial canopy at the site. Only 53 woody plants were recorded in the Marite ecotone quadrants. The dominant substrate (100%) in which the plants were located in these quadrants was a range of fine to coarse sand. Only 13% of the plants in this zone showed any sign of damage, of which 11% was due to the floods. The 2% remaining was for unknown reasons.

Table 19: Summarising the species and population structure of the riparian vegetation in ecotone quads of the Belt transect with quadrants method at the Marite IFR 1 site on the 28/11/2000.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Albizia versicolor (T)					2		2
Caesalpinia decapetala (E)	1						1
Catunaregam spinosa?			1				1
Combretum molle (T)			1				1
Dalbergia armata			1				1
Eriosema psoraleoides?	2						2
Euclea crispa (T)		1					1
Eugenia natalitia (T)		1					1
Eugenia sp.?		1	1				2
Lantana camara (E)	4						4
Maytenus undata (T)			1				1
*Nuxia oppositifolia**	3						3
Ochna natalita (T)		1					1
Phyllanthus reticulatus		3					3
Senna septemtrionatus?	10						10
Sesbania punicea (E)	2						2
Sesbania sp.?	4	1					5
Trema orientalis	14						14

Figure 18 illustrates that the bare ground is the most dominant. It is comprised of sand and bedrock, which partly accounts for the lack of reeds or other life forms growing on it. The abundance of reeds and sedges is negligible. It is noteworthy to recognise that the percentage of other plants is relatively high and that the occurrence of exotics is low.

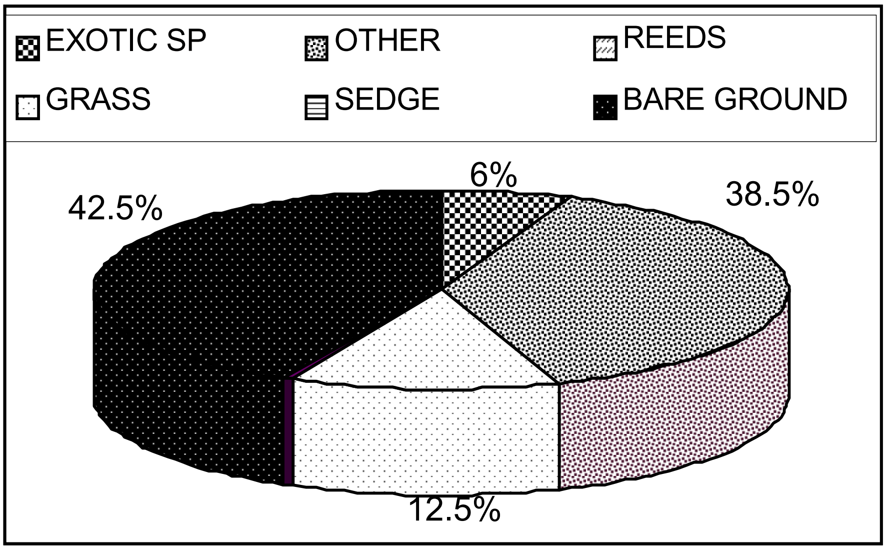


Figure 18: Depicts the % basal cover of the life forms on the banks at the Marite IFR 1 site on 28/11/2000.

There were nine species recorded in the water quadrants and island. *Breonadia salicina* remained the dominant species, even after the floods. It also maintained a broad spectrum of occurrence in the population structure classes. This is a good indication of the species' resilience to high flow conditions. It is interesting to note the presence of the two terrestrial species in the water quadrant and island section of the belt transect. Although they are not very abundant, it is unusual to find this type of species after such high flow conditions. This is particularly applicable to *Ochna natalita* as it has one plant in the 2-4m class, which it is unlikely to have attained in 9 months after the floods. It was obviously capable of surviving the high flow conditions. The presence of exotic species is negligible. There were 42 plants recorded on the island and at the water's edge. Sand was the dominant substrate (86%), this was definitely applicable to the surface substrate, but it is likely that this was covering bedrock or boulder because of the high number of *Breonadia* plants recorded, which characteristically grow on a rocky substrate. The remaining 14% comprised of a combination of bedrock, boulder and cobble. A high percentage (64%) of the plants showed indications of damage; the majority (60%) can be ascribed to the recent high flow conditions. These plants showed signs of coppicing, were missing branches, were considerably bent or had flood debris in them.

Table 20: summarising the species and population structure of the riparian vegetation in water quadrants and island of the Belt transect with quadrants method at the Marite IFR 1 site on the 28/11/2000.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
*Breonadia salicina **	2		2	7	3	1	15
*Combretum erythrophyllum **	2	1					3
Eugenia sp. (T)	3						3
*Nuxia oppositifolia **	1						1
Ochna natalita (T)	1		1				2

Psidium guajava (E)	1						1
Senna septemtrionatus?	8						8
*Syzygium sp. **	4			1	2		7
Trema orientalis	2						2

In figure 19 the bare ground component of the island is by far the most governing and the life forms presence are comparatively very low. The total number of species recorded within the belt transect and quadrants at the Marite site amounts to twenty two species, of which only four species were common to both quadrant types. A total of four woody exotic species were recorded.

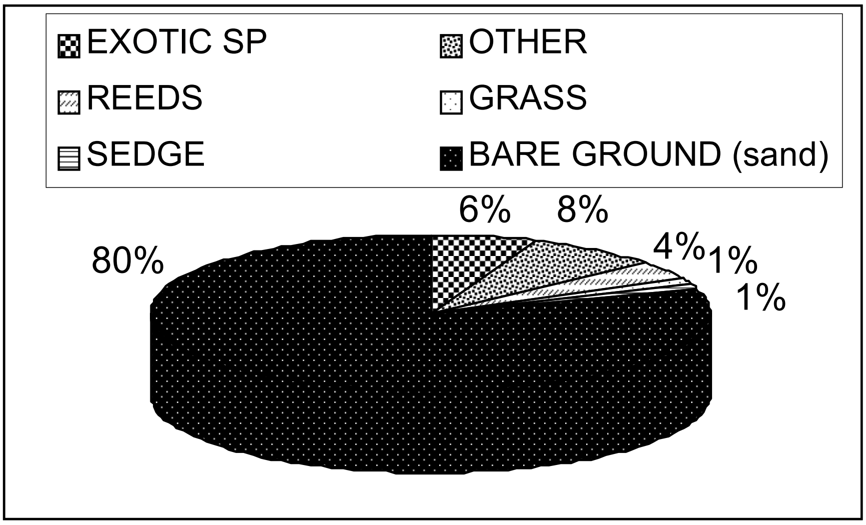


Figure 19: depicts the % basal cover of the life forms on the island at the Marite IFR 1 site on 28/11/2000.

There were eight species recorded in the line transect at Marite (table 21). Three of which, were terrestrial and one an exotic species. None of the species can really be considered abundant (although there were 3 *Breonadia salicina* species noted) because there were so few woody species within a radius of 50cm at each strike. There was a total of 37 strikes along the line transect, with only 11 woody species located along the line. A high percentage of first strikes fell on bare ground (40%), 30% were herbaceous species and 24% on grass. Only 3% hit a woody species first strike.

Table 21: summarising the species and population structure of the riparian vegetation in a line transect done at the Marite IFR 1 site on the 10/04/2001.

SPECIES	**<1m**	**1-2m**	**2-4m**	**4-8m**	**8-12m**	**>12m**	**TOTAL**
Antidesma venosum	1	1					2
Apodytes dimidiata (T)		1					1
Breonadia salicina	1					2	3
Coddia rudis?	1						1
Lantana camara (E)			1				1
Maytenus undata (T)		1					1
Ochna natalita (T)	1						1
Trema orientalis	1						1

6.2.4 IFR Site 2 Sabie River

The overall summary (table 22) of the riparian vegetation at site Sabie IFR 2 resulted in eighteen species being recorded. There were five terrestrial species, three exotic species, and one was not a true riparian specie. *Diospyros mespiliformes* was the most abundant species, with an almost even distribution in the three lower height classes. While *Diospyros mespiliformes* is commonly found on the fringes of the riparian community it is not considered a true riparian plant. A terrestrial species, *Maytenus heterophylla*, which has since been renamed and subdivided, was the next most abundant species. The Sabie IFR2 site is located at a high level bridge and where a low level cause way is also situated. It is also in communal land and is susceptible to many surrounding impacts such as wood harvesting, cattle trampling, water abstraction, and gill net fishing etc. A combination of these factors may explain the terrestrial specie presence, although it only accounts for 17% of the plants, and *Maytenus* is the only significant terrestrial species. Generally this site has a poor riparian vegetation community. This is also visible in the fixed point photographs of the site.

Table 22: A summary of the species and population structure of the riparian vegetation at the Sabie IFR 2 site on the 30/9/99 during an overall summary of the species.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia sieberana (T)		1					1
Apodytes dimidiata (T)			1				1
Breonadia salicina			2				2
Cassia didymobotrya (E)	8						8
Combretum erythrophyllum	1	1	2	1			5
Diospyros mespiliformes (^)	7	7	5				19
Euclea natalensa	2						2
Ficus sur			1	1			2
Ficus sycamorus			2	1		1	4
Lantana camara (E)			1				1
Lonchocarpus capassa (T)	1						1
Maytenus heterophylla (T)		13					13
Nuxia oppositifolia		1					1
Phyllanthus reticulatus	6	2					8
Rhus sp. (T)		1					1
Sesbania punicea (E)			3				3
Syzygium sp.	4	2					6
Trema orientalis	3		4				7

The ecotone component at the Sabie IFR 2 site had eighteen species recorded (table 23). The water quadrant survey (table 24) only added one additional species bringing the total number of species to nineteen. This is one more species than the previous survey (pre-flood) noted. There were only six species common to both surveys, of which one was an exotic woody species. The post flood belt/quadrant transect recorded seven terrestrial species compared to the 5 recorded in 1999, this is acceptable because the method had changed, where the objective was to include a small margin of the terrestrial community. While seven species may seem too high, they only account for 16% of the plants in the quadrant, which is considered apposite. With only one woody exotic species being recorded in the whole of the belt, and in such a damaged site, this is a good sign. The substrate was comprised of 85% fine sand and 15% soil. It was noted that 18% of the recorded plants were damaged, of which 15% could be attributed to the floods; this was noted from the coppicing emerging from broken and bent branches. The remaining 3% was a combination of unknown and anthropogenic causes. A species (*Sida rhombifolia*) of unknown status was the most abundant, which doesn't allow for much comment. However two riparian species (*Antidesma venosum* and *Ficus sur*) were also fairly abundant – compared to the other species recorded. *Ficus sur* was one of two key species at the site, so this is a positive sign of the riparian vegetation starting to recruit again after the floods. There are no species in this quadrant that have any representation in the three taller height classes. This is a cause for concern, especially for a lowveld river whose riparian vegetation characteristically has a tall woody specie community that provides aerial canopy.

Table 23: A summary of the species and population structure of the riparian vegetation in the belt and quadrants transect at the Sabie IFR 2 site on the 27/11/2000. This table shows the species found in the ecotone quadrants.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Antidesma venosum	5	4					9
Bauhinia galpinii (T)		2					2
Bauhinia thonningii (T)	4						4
*Combretum erythrophyllum **			1				1
Combretum hereroense (T)			1				1
Combretum molle (T)	1						1
Dichrostachys cinerea (T)	2						2
Ehretia amoena (^)	2						2
*Ficus sur **	2	4					6
Flacourtia indica (T)	1						1
Flueggea virosa (T)	1						1
Gymnosporia sp. (^)	3						3
Lantana camara (E)	3						3
Lippia javanica?		6					6
Phyllanthus reticulatus	2	3					5
Sida cordifolia?	3						3
Sida rhombifolia?	19	3					22
Trema orientalis	1						1

The water quadrant at the Sabie IFR 2 only had six species recorded (table 24), and once again a species of unknown status was the most abundant, and Ficus sur being the next most common species in the quadrant. Fine sand (79%) was the dominant substrate in which the plants were located, with the remaining plants (21%) growing in soil. Surprisingly only one plant showed any flow related damage – but this is probably due to there being hardly any plants as the species that did occur on the water's edge were washed away during the floods.

Table 24: A summary of the species and population structure of the riparian vegetation in the belt and quadrants transect at the Sabie IFR 2 site on the 27/11/2000. This table shows the species found in the water quadrants.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
*Ficus sur**		4					4
Ficus sycamorus	1						1
Lantana camara (E)	1						1
Phyllanthus reticulatus	1						1
Sida rhombifolia?	4	1					5
Trema orientalis	2						2

Figure 20 shows that while there may be very few woody species recorded in the belt transect and quadrants, there is a very high percentage of grass on the banks of the river. This is important as it reduces the potential for erosion. The occurrence of exotic species is only at 4%, this is very encouraging as often exotic species quickly pioneer an area that has been disturbed (as was the case after the floods).

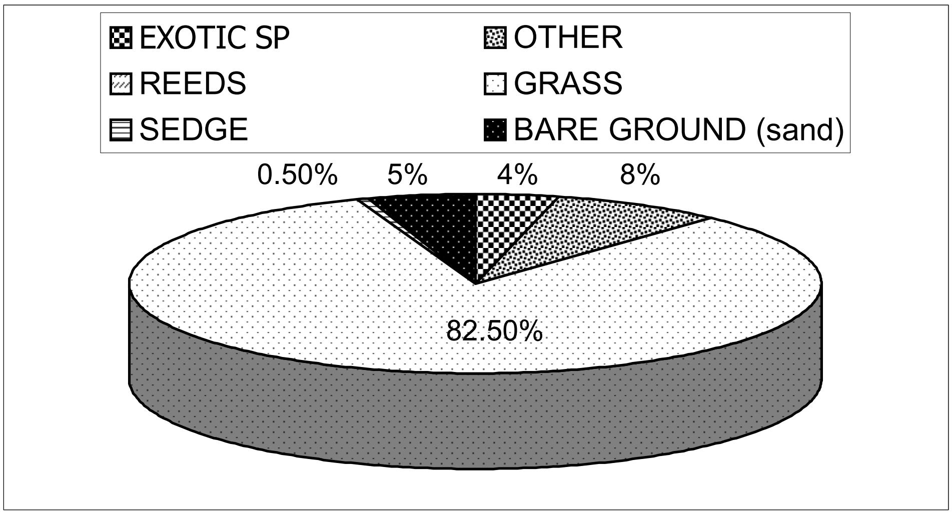


Figure 20: Life form % basal cover on the banks at Sabie IFR 2. 27/11/00

The figure 21 depicting the percentage basal cover on the islands shows that bare ground is the dominating component. In this chart the exotics, sedges and other species are much higher. The high percentage of bare ground is not a cause for concern, as the islands are subject to fluctuating flows, thus limiting the opportunity for plants re-populate the Instream areas. In time plants will re-establish themselves, as the island once again become more stable geomorphic units.

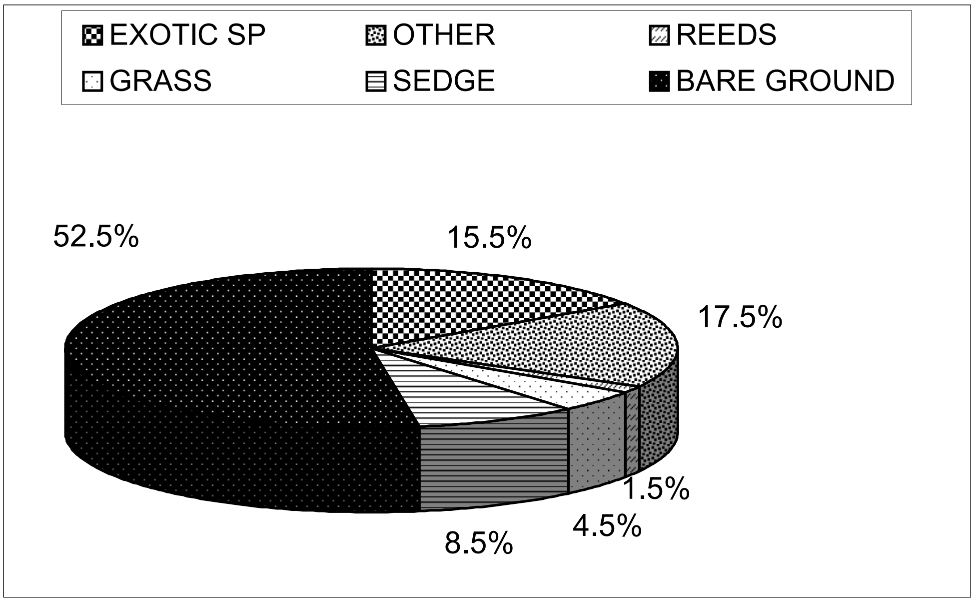


Figure 21: Life form % basal cover on the two islands at Sabie IFR 2. 27/11/00

6.2.5 IFR Site 4 Sabie River

The Sabie IFR 4 site unfortunately had no pre-flood survey done, so there is a limit to how much comparison can be made. The left hand bank of the site was considerably damaged in the floods, however the right hand bank retained its structure considerably better. The left hand channel, which was very reeded up and actually barely running, has since become open and flowing.

In the ecotone quadrants a total of twenty-six species were recorded (table 25). Seven are terrestrial species, two are exotics, two are non-true riparian and three of unknown status. The high occurrence of terrestrial species, and the fact that Dombeya rotundifolia was noted to be the most abundant, is attributed to the method of including about 5m of the terrestrial community. Even this only accounts for 29% of the plants, which is actually low considering that 50% of the quadrant theoretically falls within the terrestrial zone. The presence of woody exotic species is low (3.5%) and of no concern. None of the key tree species were encountered in this quadrant. A 100% of the substrate in this quadrant was a combination of different sand classes. Approximately 18% of the plants showed signs of damage, and of this 11% was as a result of the floods (they were coppicing from bent and broken stems), 7% was natural non-flow related and this was mainly because of browsing by game. Within the whole transect thirty-two species were recorded, and only eight species were common to both quadrant types. In the ecotone quadrant there was only three trees that fell into the 8-12m+ classes. This is mainly due to the RHB being less effected by the floods than the LHB, but is perhaps not an overall reflection of the site as whole, because the RHB has many tall trees still standing, as can be seen in the photographs.

Table 25: A summary of the species and population structure of the riparian vegetation as sampled in the belt and quadrant transect method at the Sabie IFR 4 site on the 12/03/2001. This table depicts the species in the ecotone quadrants.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia robusta	2	1			1	1	5
Acacia schweinfurthii	8	1					9
Berchemia discolour	2						2
Combretum imberbe (^)						1	1
Dichrostachys cinerea (T)	2	1					3
Diospyros mespiliformes (^)	1	3					4
Dombeya rotundifolia (T)	3	9					12
Euclea divinorum (T)		2					2
Euclea natalensis	2	4	1				7
Flacourtia indica (T)	1						1
Grewia bicolor		4					4
Grewia flavescens	3						3
Grewia villosa (T)	1	3					4
Gymnosporia sp.		2					2
Hippocratea sp. (T)		1					1
Hyptis pectinata?		1					1
Lantana camara (E)		2					2
Lippia javanica?		1					1
Pappea capensis	1						1
Pavetta catophylla?	1	3					4
Phyllanthus reticulatus	1	3					4
Senna septemtrionatus?		2					2
Solanum mauritianum (E)	1	1					2
Solanum panduriforme (T)	1						1
Strychnos madagascariensis		1					1
Trema orientalis		3					3

Figure 22 shows how the combination of woody and herbaceous species (other category) was the most dominant component in the life form summary. Grass is also relatively abundant and together with the other life forms, results in there being only 12.% bare ground. The bare ground is composed of sand and bedrock so could only be reduced to perhaps half that, as bedrock allows for limited riparian growth.

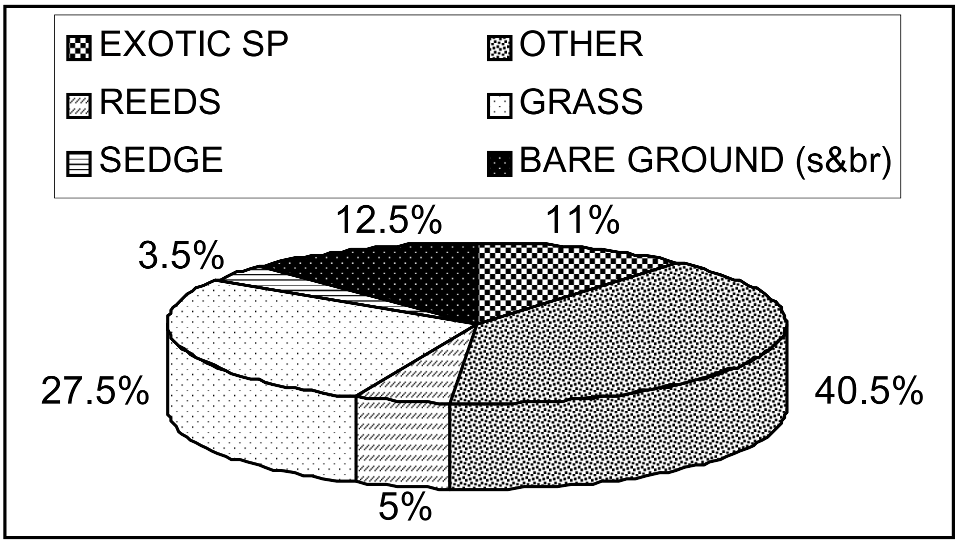


Figure 22: Life form % basal cover on the banks of the Sabie IFR 4 site 12/03/2001.

The water quadrants at Sabie IFR 4 had fourteen species recorded (table 26), and all the key species fell into this area of the riparian zone. There was only one non true riparian and one terrestrial species noted, with no woody exotic species, all of these being a good indication of the condition of the site post flood. *Krausii floribunda* was the most abundant species. A fairly high percentage of the plants showed some kind of damage (45%) and all was flow related damage due to the floods. The dominant substrate was sand over bedrock (50%)then sand and plain bedrock each had 24%, and lastly there was 2% cobble and pebbles.

Table 26: A summary of the species and population structure of the riparian vegetation as sampled in the belt and quadrant transect method at the Sabie IFR 4 site on the 12/03/2001. This table depicts the species in the water quadrants and islands.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Acacia robusta	3	1					4
Acacia schweinfurthii	2						2
*Breonadia salicina **			1				1
Bridelia cathartica		1					1
Diospyros mespiliformes (^)	2						2
Euclea divinorum (T)			1				1
Euclea natalensa	1						1
Gymnosporia sp.	1	1	1				3
Hippocratea sp.	2						2
Krausii floribunda	3	4	4				11
*Nuxia oppositifolia **		1	3	1			5
*Syzygium sp. **		2					2
Trema orientalis	4	2					6
Ziziphus mucronata	1						1

Unlike the life forms composition of the banks at Sabie IFR 4 site, reeds mainly cover the islands (figure 23), which is typical of the site pre and post flood. The other woody and herbaceous species are slowly starting to re-colonise the islands again. No exotic species were observed which is a good sign because this survey was completed a year after the floods so they would have had time to invade the islands once again.

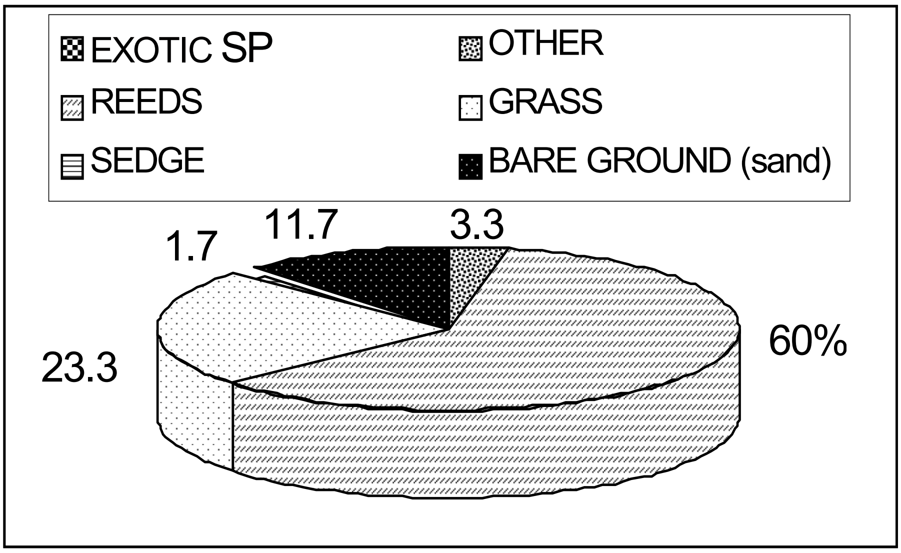


Figure 23: Life form % basal cover on the three islands of the Sabie IFR 4 site 12/03/2001.

6.2.6 IFR Site 5 Sabie River

The Sabie IFR 5 site is a huge site with at least four main channels. The macro channel is close to 800m wide. This is also a site that had no pre-flood survey so there can be minimal comparisons made.

Table 27: Summarising the species and population structure of the riparian vegetation in ecotone quadrants of the Belt transect with quadrants method at Sabie IFR 5 site on the 14/03/2001.

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Bridelia cathartica	1		1				2
Dichrostachys cinerea (T)		1					1
Diospyros mespiliformes (^)				1			1
Ehretia obtusifolia	2						2
*Ficus capreifolia **	2	3					5
Gymnosporia sp.	1	2	1				4
Hyptis pectinata		3					3
Lantana camara (E)	12	1					13
Ludwigia octovalvis	1						1
Melia azderach (E)	2						2
*Nuxia oppositifolia **				1			1
Phyllanthus reticulatus	3						3
Senna obtusifolia (E)	2						2

Sesbania bispinosa (E)	1	1					2
Solanum nigrum (E)	2						2
Vernonia glabra		1					1

Table 27 summarises the species found in the ecotone quadrant at Sabie IFR 5. There were sixteen species recorded, of which five are exotic, one is terrestrial and there is also only one pseudo-riparian species. *Lantana camara*, an exotic, was the most prolific in these quadrants. Almost 47% of the plants in these quadrants were exotic species. While there were not many plants in total, this is still a high percentage of exotic woody species representation. However with reference to figure 24, the exotic percentage for the whole of both banks (within the transect) is recorded as only 6.5%, and this includes herbaceous and annual species, so the ecotone quadrants appear to be a poor overall representation of exotic species invasion. It is surprising to see the terrestrial species presence so low – one specie and only one plant. The substrate was combination of sand (40%) and flood debris (60%). The LHB was peculiar to see, because the whole bank has become elevated into the tree tops, because of all the flood debris deposited there after the floods. The LHB is naturally very steep, and now under these circumstances it is level but high up (at the top of the macro channel) and very unstable. Some plants have started to emerge through the debris. Only 4% of the plants showed any damage, 2% due to flow, and 2% due to browsing.

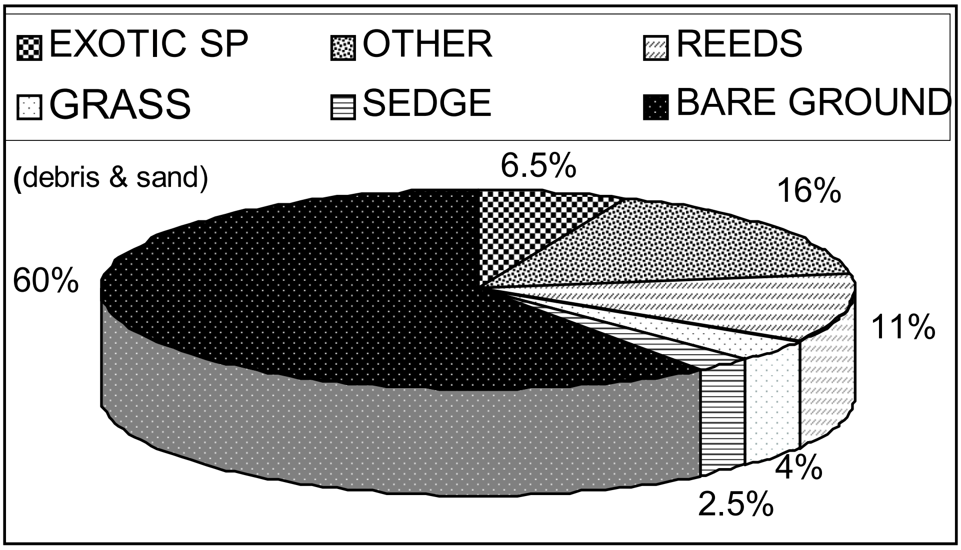


Figure 24: Life form % basal cover on the banks of the Sabie IFR 5 site 14/03/2001.

In the water quadrants and islands summary (table 28), there was only one exotic species amongst the nine species recorded. The key species are dominant, but this to be expected, as they are the only species recorded on the islands, and at this site the islands are very extensive.

Table 28: Summarising the species and population structure of the riparian vegetation in water quadrants and islands of the Belt transect and quadrants method at the Sabie IFR 5 site on the 14/03/2001

SPECIES	<1m	1-2m	2-4m	4-8m	8-12m	>12m	TOTAL
Breonadia salicina *	1		1	4	6		12
Ehretia amoena	1						1
Euclea natalensis			1				1
*Ficus capreifolia**	4	9	2				15
Hyptis pectinata		3					3
Ludwigia octovalvis		1					1
*Nuxia oppositifolia**		2	10	1			13
Sesbania bispinosa (E)	3						3
Syzygium sp. *	2	1		1			4

Breonadia salicina once again shows its ability to withstand high flow conditions, and this especially pertinent at the far left channel, where the majority of the plants were counted. This species is represented in the three classes, which range from 2- 12m. Even *Ficus capreifolia*, a characteristically multi-stemmed, straggly plant was found to be represented in the classes greater than the <1m class, as was *Nuxia oppositifolia*. Damaged plants in the water quadrant amounted 55% and almost all of this was as a result of the floods. The trees were severely bent and washed over, but all flourishing well since the event. Figure 25 shows that grass and other species were the dominant life forms, with grass and bare ground following. This shows a great recovery on behalf of the life forms, as still five to six months after the floods the extensive island were just sand, and if the survey had been conducted then would surely have recorded 90% for bare ground.

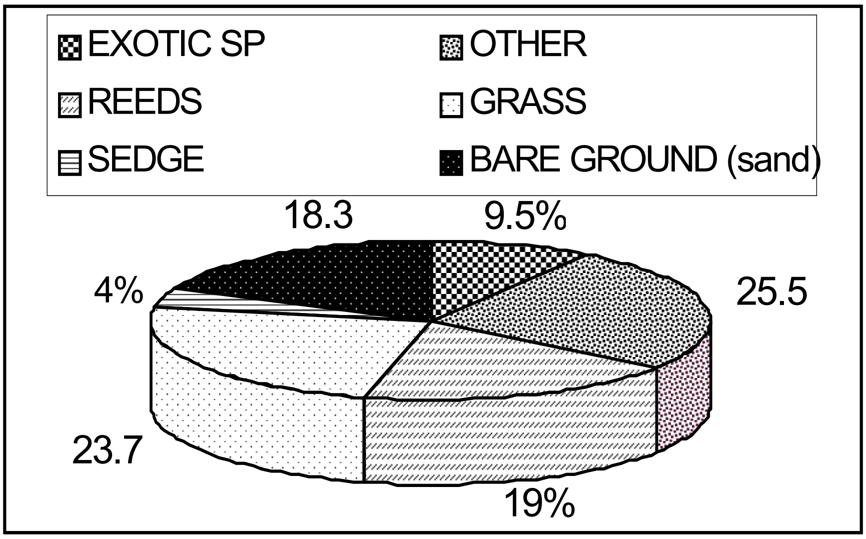


Figure 25: Life form % basal cover on the three islands at Sabie IFR 5 site 14/03/2001

Plate 4: Photographs taken at the Luvuvhu River IFR 2 site, Shidzivane. (a) This photo' is taken pre flood 18 October 1999. The cobble bar on the right hand bank (right of photo') is more exposed and more vegetated than in photo' (b). Photo' (b) was taken 24 October 2000, almost a year later and after the February 2000 floods. This picture shows the extent of the fluvial damage to the riparian vegetation on the left hand bank.

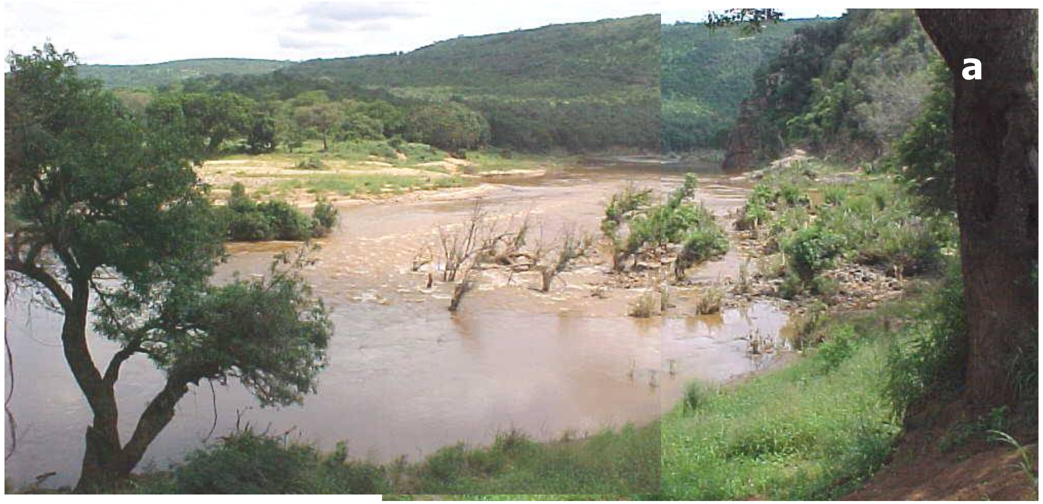


Plate 5: Photographs taken at the Luvuvhu River IFR 2 site, Shidzivane. (a) This photo' was taken on 27 March 2001. The flow was still high as can be seen with the amount of exposed cobble side bar on the right of the picture. (b) This photo' was taken 30 May 2001, when the river had dropped marginally. The riffle in the main stream was still too high to enter. The vegetation is re-colonising the left hand bank.

Plate 6: Photographs taken at the Luvuvhu River IFR 1 site, Botsoleni. (a) This picture was taken on the 22 September 1999, which was pre floods; numerous vegetated islands can be seen here. (b) This was taken post floods on the 7 August 2000. The pictures are taken from the right hand bank. In picture (b) most of the islands have been washed away, and bank erosion on the left bank is visible. The * indicates a large fig tree (*Ficus sycamorus*) which survived the floods initially.

Plate 7: The Luvuvhu River IFR 1 site continued. These pictures were taken at a smaller scale therefore incorporating more of the river length. (a) A series of photo's taken on 16 November 2000. The * marks where the fig tree collapsed. (b) This was taken on the 29 May 2001. In this picture it is possible to see the re-growth in the reeds on the islands.

Insert picture 1

Plate 8: Photographs of the Marite River IFR 1 site. All of the photo's in plates 8 & 9 are of the large cobble and boulder riffle rapid, taken from the island to the left hand bank (the left hand channel). (a) The site before the floods 30 September 1999. (b) The first visit after the floods 22 August 2000. The river was still too high to sample this habitat.

Plate 9: Photographs of the Marite River IFR site. The (a) & (b) pictures are of the same geomorphological structure as those depicted in plate 8, but are from a slightly different perspective. (a) This facing more upstream, taken on 14 November 2000. (b) The pictures were taken on the 10 April 2001. On both these occasions it was not possible to sample in the riffle / rapid due to the flow still being too high. (c) – (f) are facing downstream in the far right channel which does not flow permanently. (c) 30 September 1999 – just a pool – pre flood. (d) 22 August 2000. (e) 14 November 2000. (f) 10 April 2001.

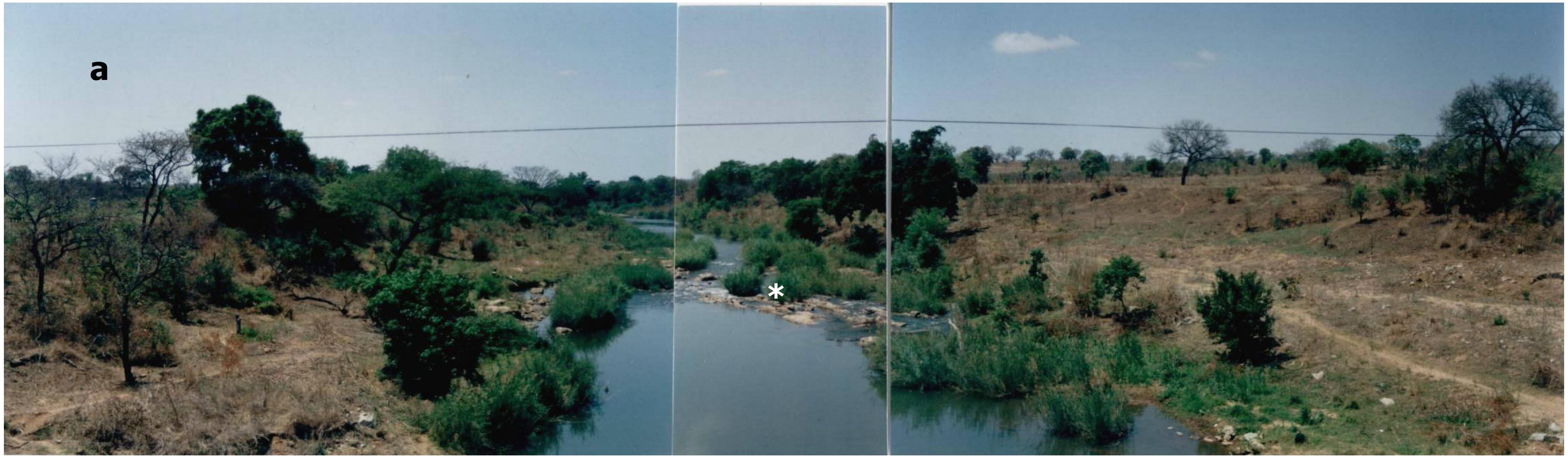


Plate 10: Photographs of the Sabie River IFR 2 site, The Bridge. This series is taken from the bridge facing downstream. (a) This photo' was taken on the 30 September 1999, before the February 2000 floods. Although this is a site with limited riparian vegetation due to anthropogenic reasons it has considerably more vegetation before floods. The bedrock bars indicated with an * were no longer visible after the floods due to increased sand deposits. (b) Taken on 23 August 2000.

Plate 11: Photographs of the Sabie River IFR 2 site, The Bridge. The pictures are taken from the same site plate 10. (a) This photo was taken on the 14 November 2000. (b) In this picture, taken on the 9 April 2001, it is possible to see how the bank vegetation is recovering. At this site visit repairs were being conducted on the bridge, hence the sand mound in the foreground on the right of the picture.

Insert picture 2

Plate 12: Sabie River IFR 4 site, Skukuza. (a) The site facing upstream from the bedrock island towards the pool, photo' taken on 27 September 1999. (b) A view from an island towards the RHB, across the pool, taken after the floods on 12 June 2000.

Insert picture 3

Plate 13: Sabie River IFR 4 site, Skukuza. Theses pictures were taken from the island facing towards the RHB, across the pool. (a) Picture taken on 2 October 2000. At this site the visit the water was lower than the previous visit (see plate 12 (b)), the rocks to the left of the picture are visible. (b) Photo's of the site on 14 May 2001. It is possible to see how the island vegetation is recovering since previous post flood visits. (Bulrushes and reeds visible in foreground of the picture).

Plate 14: Sabie IFR 5 site, N'watimhiri. A series of photo's taken at the site facing downstream in channel 2. The * marks a rock that is common in all pictures and # marks the rapid at the site. (a) The picture was taken 29 September 1999. (b) This was taken after the floods on 4 October 2000. (c) This photo was taken on the 15th May 2001. The series of pictures were not taken at the exact same point or the same scale.

Insert picture 4

Insert picture 5

Plate 15: Sabie IFR 5 site, N'watimhiri. Some pictures taken at the site, of channel 1 facing downstream. (a) This photo' was taken on 29 September 1999. (b) A picture taken after the floods on 14 June 2000. The geomorphological and vegetation changes are substantial as can be seen. (c) A photo' taken on 15 May 2001.

6.3 FISH

Fish monitoring took place at the six sites. Each site was monitored extensively at least three times but generally four times over the period of the project. The high flows resulted in visits being postponed, and therefore were not monitored at the same times each year. Initially the fish specialists from the different areas joined the researchers at the surveys so help was received with fish identification. But later on the researchers monitored on their own, and if there was any specie that was difficult to identify or not a confirmed identification, a sample was taken and identified by an expert. At each site an overall summary is presented for the fish species caught compared to the historic records. The ✓ indicates the species caught during the monitoring visit. There is a table summarising each site visit, the habitats, flow and depths. The three rows at the end of each table, part of the totals section refer to the total catch in the juveniles, sub-adults and adults columns; the total number of species for the habitat, with the total number of fish caught at the habitat in (); and the last row is the total number of species for the site on the visit. Table 29 refers to the velocity ranges allocated to the different categories used in monitoring the flows of the different habitats.

Table 29: Classifying actual water velocities (m/s) into five categories.

CATEGORY	VELOCITY RANGE FOR THE CATEGORY
VERY FAST	> 4.1 m/s
FAST	0.46 m/s to 4.0 m/s
MEDIUM	0.16 m/s to 0.45m/s
SLOW	0.06 m/s to 0.15 m/s
NO FLOW	< 0.05 m/s

6.3.1 IFR Site 1 Luvuvhu River

Table 30 summarises the species caught over the period of the project and compares the results to the historic records. There were three additional species recorded at the site during the period of baseline monitoring. Louw (1996a) presents a list of expected and collected fish species in the Luvuvhu River. The historic and current records for this site represent 53% of the fish at the site. Considering that this is one site in about 38 sites, this is probably quite acceptable. In that same list five species had not been collected after 1990, one of which, is *Amphilius uranoscopus*, which was collected three out of the four times that the site was visited. This is certainly seen as a positive. *Amphilius uranoscopus* favours clear flowing water in rocky habitats (Skelton, 1993). It most probably occurred at the site prior to this survey, but was most likely limited to the main cobble riffle, which has changed since the floods, and there is much more available habitat since the floods, which obviously increases the chance of catching it. This site may have been subjected to low flows and turbid waters between 1990 and 2001, creating unfavourable conditions at the site for *Amphilius uranoscopus*.

The number of species caught at each visit fluctuated between 16 and 10. Each species on the historic list was caught at least once during the survey. The fluctuation between species diversity at each site will be discussed with each site, but it was mainly due to the loss of certain habitats after the floods.

Table 31 is the summary of the monitoring done on 22/9/1999. This was prior to the floods. Sixteen species were caught, and six habitats sampled. The habitats, which yielded the most species, were the mixed; the deep, fast, cobble riffle and the shallow, medium, sand and cobble riffle, with twelve, ten and ten species respectively. The habitats with the total greatest abundances were the mixed site (one hundred and twenty four individuals); habitat 4 (one hundred and nineteen) and habitat 3 (one hundred and five). The most abundant species throughout the sampling site was *Chiloglanis pretoriae*. This species favours shallow rocky reaches, riffles and rapids in permanent rivers; it is an insectivore and is common (Skelton, 1993). On a sensitivity scale of 1-4 it is considered semi sensitive (3) (Louw, 1996a). The next two most abundant species were *Barbus viviparus* and *B. marequensis. B.viviparus* is species that prefers the lowveld areas. Its habitat preferences include vegetated pools of streams and rivers (Skelton, 1993). This implies it prefers the slower flowing habitats, which corresponds with where it was caught, in the mixed habitat and the medium flow riffle. It is also scored as a semi sensitive species (Louw, 1996a). *Barbus marequensis* occurs in flowing waters of perennial rivers (Skelton, 1993) and received a sensitivity score of 1 (Louw, 1996a), which classifies it as a hardy species.

Table 30: Luvuvhu IFR 1 (Botsoleni) historic fish specie records versus current monitoring records. Historic records provided by Angliss, 2000.

HISTORIC RECORDS		**RECENT MONITORING RECORDS**			
		AVERAGE DAILY FLOW ($m^3 s^{-1}$)			
		2.5	NR	NR	NR
		NUMBER OF HABITATS MONITORED			
		6	6	6	5
FAMILY	**FISH SPECIES**	**22/9/1999**	**7/8/2000**	**15/11/2000**	**29/5/2001**
Anguillidae	*Anguilla mossambica*	✓	✓		
Amphiliidae			*Amphilius uranoscopus*	✓	✓
Cyprinidae	*Barbus annectens*	✓			
	Barbus marequensis	✓		✓	✓
	B.toppini				✓
	B.trimaculatus	✓	✓	✓	✓
	B.unitaeniatus	✓		✓	
	B.viviparus	✓	✓	✓	✓
	Labeo cylindricus	✓	✓	✓	✓
	L. molybdinus	✓	✓	✓	✓
	Mesobola brevianalis	✓			
Mochokidae	*Chiloglanis paratus*	✓	✓	✓	✓
	C. pretoriae	✓	✓	✓	✓
	C. swierstrai	✓			
Clariidae	*Clarias gariepinus*	✓	✓	✓	✓
Characidae	*Micralestes acutidens*	✓			
Cichlidae	*Pseudocrenilabrus philander*	✓			
				Tilapia rendalli	✓
	Tilapia sparrmanii	✓			
			Oreochromis		✓

			mossambicus		
TOTAL # OF SPECIES	**17**	**16**	**10**	**11**	**12**

Table 32 shows the fish species and their abundances, as caught on the 7/10/2000. Six habitats were monitored at the site. Originally seven habitats were sampled, but in the shallow slow backwater pool, no fish were caught. This was the first time the site was visited after the floods. The site had changed after the high flow (see geomorphology section), but the most significant change was the loss of overhanging and marginal vegetation. More rapid and riffle sections had been created. A combination of these changes, most likely attributes to the drop in the species diversity between visits. There was limited slow flow and pool type habitats available. Habitat 1 (fast, large cobble, riffle) was the most species diverse, yielding seven of the ten species recorded. It was the habitat in which *Amphilius uranoscopus* was recorded for the first time. *Amphilius* has a sensitivity rating of 4, meaning that it is a sensitive species (Louw, 1996a). Habitat 1 had the most number of individuals caught per a habitat (but the most time was also spent at this habitat). The next most abundant habitats were habitats 3 & 6. Habitat 3 was a fast riffle, and habitat 6 was a fast run. Both these habitats were worked for longer than the others. *Chiloglanis pretoriae* was the most abundant species throughout the whole site. It was followed by *Barbus viviparus*. Only one slow habitat was sampled, where just three species and four individuals were caught.

Table 31: Summarising the fish caught at the Luvuvhu IFR 1 site 22/9/1999. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**	**2**	**3**	**4**	**5**	**6**
METHOD	Shock 40 min	Seine net x 1	Shock 28 min	Shock	Shock 20min	Shock 5 min
HABITAT	Mixed	Back-water	Riffle	Riffle	Riffle	Pool instream
SUBSTRATE	Assorted	Sand (& cobble)	Cobble	Sand & cobble	Boulder	Sediment & boulder
FLOW	Medium	Slow	Fast	Medium	Fast	Slow
DEPTH	Assorted	Shallow	'Deep'	Shallow	'Deep'	Shallow
SPECIES (& total #'S)	**T**	**T**	**T**	**T**	**T**	**T**
Anguilla mossambica (1)				1		
Barbus annectens (2)				2		
Barbus marequensis (66)	23			23	20	
Barbus trimaculatus (20)	7	2	1	10		
Barbus unitaeniatus (1)				1		
Barbus viviparous (69)	33		1	31	2	2
Chiloglanis paratus (3)	1	1	1			
Chiloglanis pretoriae (227)	42		63	31	84	7
Chiloglanis swierstrai (4)	1		3			
Clarias gariepinus (5)	1		2	1	1	

Labeo cylindricus (1)	1					
Labeo molybdinus (32)	8		6	4	12	2
Mesobola brevianalis (3)	2		1			
Micralestes acutidens (3)			3			
Pseudocrenilabrus philander (5)	4			1		
Tilapia sparrmanii (2)	1		1			
Totals	124	3	82	105	119	11
	12 species	2 species	10 species	10 species	5 species	3 species
	16 species					

Table 33 refers to the fish sampled on 15/11/200. Six habitats were sampled, and eleven species were collected (one more than the previous visit). The species composition was slightly different to that of the previous visit. *Tilapia rendalli* was added to the list of species for the site. *T. rendalli* is a species that is tolerant of a wide range of temperatures as well as having a salinity tolerance; it prefers quiet well-vegetated water along rivers, backwaters, floodplains and swamps (Skelton, 1993) and is classed as a hardy species (Louw, 1996a). This fish was found in two of the habitats (2&3). It was unusual to find it in habitat 2 because the site had mainly a fast flow, but it did have marginal vegetation as favoured by the tilapia species, and the habitat was quite small, with slower flow towards the edges, which would account for its presence in this habitat. Habitat 3 was more like the typical habitat preferred by *T. rendalli*, slow, deep backwater habitat. Habitat 2 had the most number of species as well as the most individual fish caught. *Barbus viviparus* and *Chiloglanis pretoriae* dominated the habitat. Habitat 5 had the next highest number of fish caught. This habitat, a fast flowing cobble and boulder riffle, was dominated by the two *Chiloglanis* species. *Chiloglanis pretoriae* was the most abundant fish at the whole of site 1 on the Luvuvhu River. *Chiloglanis paratus* and *Barbus marequensis* were the next two most abundant species for Botsoleni.

Table 32: Summarising the fish caught at the Luvuvhu IFR 1 site 7/10/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**		
METHOD	Shock 36.05 min			Shock 8.45 min			Shock 30.07min			Shock 7min			Shock 16.3 min			Shock20.5 min		
HABITAT	Riffle			Riffle edge (snags)			Riffle			Backwater			Run			Run		
SUBSTRATE	Large cobble (& gravel)			Cobble & gravel			Cobble mix			Coarse gravel & silt			Coarse gravel & clay			Cobble & clay		
TURBIDITY	Coloured			Coloured			Coloured			Clear			Coloured			Coloured		
FLOW	Fast			Medium			Fast			Slow			Medium			Fast		
DEPTH	20 -40cm +			12cm			25cm			5-15cm			25cm			25cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (4)		1	3															
Anguilla mossambica (1)	1																	
Barbus trimaculatus (3)										2						1		

Barbus viviparas (57)													14			42	1	
Chiloglanis paratus (35)	3	6	7				3	7	7									2
Chiloglanis pretoriae (116)	33	6	19				14	7	17				11		1	7	1	
Clarias gariepinus (4)	1			2						1								
Labeo cylindricus (5)	1						2									2		
Labeo molybdinus (3)	2	1																
Oreochromis mossambicus (1)										1								
TOTALS	41	14	29	2			19	14	24	4			25		1	52	2	2
	7 species (84)			**1** species (2)			**3** species (62)			**3** species (4)			**2** species (26)			**5** species (56)		
	10 species																	

Table 33: Summarising the fish caught at the Luvuvhu IFR 1 site 15/11/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**		
METHOD	Shock 34.5min			Shock 33.5min			Shock 16.3 min			Shock 10.4 min			Shock 41.3min			Cast net x 8		
HABITAT	Riffle			Riffle (& marginal reeds)			Backwater (& slight undercut bank)			Pool instream (reeds)			Riffle			Pool instream (Reeds & trees with root wads)		
SUBSTRATE	Cobble & gravel			Cobble & gravels (& sand)			Mud & cobble (bit)			Mud & cobble			Cobble (& boulder & gravel)			Cobble & sand		
TURBIDITY	Muddy			Coloured			Muddy			Coloured			Coloured			Muddy		
FLOW	Fast			Fast			Slow			Medium			Fast (– V. Fast)			Medium		
DEPTH	5-15cm			20-35cm			35-55cm			<55cm			20-50cm					
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (11)	2			1									8					
Barbus marequensis (43)	13			24			1			2			2			1		
Barbus trimaculatus (5)										3	1	1						
Barbus unitaeniatus (1)								1										
Barbus viviparas (39)		1		1	10	7	10	6			1	3						
Chiloglanis paratus (50)	1				2	5							7	14	21			
Chiloglanis pretoriae (146)	26	5	22	39	4	14							18	16	23			
Clarias gariepinus (1)							1											
Labeo cylindricus (6)	1			4									1					
Labeo molybdinus (10)	1			6						1			2					

Tilapia rendalli (7)				3			4											
TOTALS	44	6	22	78	16	26	16	7		6	2	4	38	30	44	1		
	7 species (72)			8 species (120)			3 species (23)			4 species (12)			6 species (112)			1 specie (1)		
	11 species																	

The last visit to IFR 1 on the Luvuvhu River (29/5/2001) is presented in table 34. Five habitats were sampled during this visit and a total of twelve species were caught. One other species was added to the site list, *Oreochromis mossambicus*. This species occurs in all but fast–flowing waters and loves standing waters. It is a tolerant species, surviving in fresh, brackish and marine environments (Skelton, 1993). It is considered to be a hardy species (Louw, 1996a). *Amphilius uranoscopus* was caught again at this site, but just one individual was present in the catch. The first time it was caught there were four, the second time, there were eleven but in two habitats, and this time only one in one habitat. This could be attributed to the amount of effort spent, which was less on this last occasion. The two most species diverse habitats were habitats 2 & 4, both with six species. Habitat 2 was a fast to very fast riffle with vegetation, and habitat 4 was a slow flowing instream pool with flood debris. The most number of individual fish were caught in habitat 6, a very fast cobble and boulder riffle. *Chiloglanis paratus* was the dominant specie for the site, followed by *Chiloglanis pretoriae*.

Table 34: Summarising the fish caught at the Luvuvhu IFR 1 site 29/05/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**		
METHOD	Shock 19min			Shock 7 min			Shock 4.4 min			Shock 26 min			Shock 29.1 min		
HABITAT	Riffle (& few reeds)			Riffle (marginal reeds)			Pool instream (reeds & flood debris)			Pool instream (logs, flood debris & reeds & grass)			Riffle		
SUBSTRATE	Cobble (& silt)			Cobble (& mud)			Mud (& cobble & silt)			Mud (& cobble & silt)			Cobble (& boulder)		
TURBIDITY	Coloured			Coloured			Coloured			Turbid			Coloured		
FLOW	Fast			Fast – v. fast			Slow			Slow			Fast – v. fast		
DEPTH	20-30cm			35-45cm			20-40cm			40-75cm			25-45cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (1)															1
Barbus marequensis (6)	2						2						2		
Barbus toppini (1)												1			
Barbus trimaculatus (4)							3					1			
Barbus viviparas (14)									10			4			
Chiloglanis paratus (93)		2	3	1	2	6		1	1				4	40	33
Chiloglanis pretoriae (90)	11	12	8		2	9							7	22	19
Clarias gariepinus (1)											1				
Labeo cylindricus (1)				1											

Labeo molybdinus (10)	2			2						1	1		4		
Oreochromis mossambicus (2)										2					
Tilapia rendalli (1)							1								
TOTALS	15	14	11	4	4	15	6	1	11	3	2	6	17	62	53
	5 species (4)			6 species (23)			5 species (18)			6 species (11)			5 species (132)		
	12 species														

Chiloglanis pretoriae was by far the most abundant specie for the Luvuvhu IFR1 site, for all visits to the site.

6.3.2 IFR Site 2 Luvuvhu River

This site is located in the Kruger National Park. The site was visited four times; each time about 50% of the historic fish species were collected. The species list stood at twenty-five species. In the Luvuvhu River at the Shidzivane site (IFR 2) three new fish species i.e. *Barbus annectens*, *B. trimaculatus* and *Glossogobius callidus*, were recorded during baseline monitoring.

Table 35: Luvuvhu IFR 2 (Shidzivane) fish species records (historic versus recent). Historic records provided by Deacon, 2000a.

HISTORIC RECORDS		**RECENT MONITORING RECORDS**			
		AVERAGE DAILY FLOW ($m^3 s^{-1}$)			
		1.71	NR	NR	NR
		NUMBER OF HABITATS MONITORED			
		6	9	8	5
FAMILY	**FISH SPECIES**	**18/10/1999**	**24/10/2000**	**28/03/2001**	**30/05/2001**
Anguillidae	*Anguilla marmorata*				
	Anguilla mossambica				✓
Cyprinidae	*Barbus marequensis*	✓	✓	✓	✓
				B. annectens	✓
	B. afrohamiltoni	✓		✓	
			B.trimaculatus	✓	✓
	B. radiatus	✓		✓	✓
	B.viviparus	✓	✓	✓	✓
	Labeo cylindricus		✓	✓	✓
	L. molybdinus	✓	✓	✓	✓
	L. congoro	✓	✓		
	L. rosae		✓		
	L. ruddi				
	Mesobola brevianalis	✓		✓	
Mochokidae	*Chiloglanis paratus*			✓	✓
	C. pretoriae	✓	✓	✓	✓
Amphiliidae	*Amphilius uranoscopus*		✓		

Clariidae	*Clarias gariepinus*		✓		
Schilbeidae	*Schilbe intermedius*				
Characidae	*Micralestes acutidens*	✓		✓	✓
	Brycinus imberi	✓			
	Hydrocynus vittatus				
Cichlidae	*Oreochromis mossambicus*	✓	✓		✓
	Tilapia rendalli	✓		✓	✓
Gobiidae	*Glossogobius giuris*				
					G. callidus
Mormyridae	*Petrocephalus catostoma*	✓			
	Marcusenius macrolepidotus				
TOTAL # OF SPECIES	**25**	**13**	**11**	**13**	**14**

The first visit to the site was pre-flood. Thirteen species were recorded at the site in six habitats (table 36). Habitats 3 & 4 had the most species present. Habitat 3 was a slow, deep, sandy pool off stream, and habitat 4 a slow, shallow run with overhanging vegetation. Each had six species present. Habitat 3 was the habitat with the greatest number of fish caught. *Barbus marequensis* was the most abundant fish for the whole of the site. It occurred in three of the habitats that were sampled. *Petrocephalus catostoma*, one of the Mormyridae species preferring quiet reaches of rivers and flood plains (Skelton, 1993), was located at this site only during this first survey, it is most likely attributed to the loss of marginal vegetation and overhanging root wads that tend to be preferred by this family. Louw, (1996a) has this species listed as a 2 on the sensitivity grading which means that it is semi hardy.

Table 36: Summarising the fish species and abundances, as caught at the Luvuvhu IFR 2 site on 18/10/1999. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**		
METHOD	Shock 12 min			Cast net x 13			Seine net x 1			Shock 13 min			Shock 8 min			Shock 12 min		
HABITAT	Riffle			Pool			Pool off stream			(Overhang reeds)								
SUBSTRATE	Cobble & rock			Sand & rock			Sand			Cobbles			Cobbles & rock					
TURBIDITY																		
FLOW	Fast			Slow			Slow			Slow			Slow			Fast		
DEPTH	Shallow			Deep			Deep			Shallow			Shallow			Deep		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus afrohamiltoni (4)										1	3							
Barbus marequensis (33)	1						31									1		
Barbus radiatus (10)											4	3			1		1	1
Barbus viviparas (13)								1	1	1	5	5						

Brycinus imberi (3)									1		2							
Chiloglanis pretoriae (24)	1		2													1	11	9
Labeo congoro (2)						2												
Labeo molybdinus (16)	8	1														4	2	1
Mesobola brevianalis (7)					3			1				3						
Micralestes acutidens (14)				7			1	5				1						
Oreochromis mossambicus (3)							2	1										
Petrocephalus catostoma (2)													2					
Tilapia rendalli (16)				15	1													
TOTALS	10	1	2	22	4	2	38	8	2	2	14	12	2	0	1	6	14	12
	3 species (13)			3 species (28)			6 species (44)			6 species (28)			2 species (3)			4 species (32)		
	13 species																	

Table 37 shows the results of the monitoring on 24/10/2000. This was the first visit after the floods and only eleven species were caught in the eight habitats sampled. Post flood, the site was very similar to pre flood, the most significant damage being the loss of marginal vegetation. Habitat 3 (a medium flow, cobble, riffle) had the most number of species (five) and the greatest number of fish per a habitat. The most abundant fish for the whole of the site was *Barbus marequensis*. *Barbus trimaculatus* was an additional species to the site. *Barbus trimaculatus* is a species that is hardy, common and found in a wide variety of habitats, especially those that are vegetated (Skelton, 1993). It is surprising that it has not been recorded at the site before.

Table 38: A summary of the monitoring on the 29/3/2001 shows that a total of thirteen species were recorded in the eight habitats sample. Habitat 8 (slow to no flow, deep, pool off stream) was the most species diverse (7 species) as well as being the most abundant with fish. This habitat only exists at high flows (and probably during the wet season) because it is actually a tiny tributary flowing into the main stream. The two most abundant species for the whole site were *Barbus viviparus* and *B. marequensis* respectively. *Barbus annectens,* a species that favours slow flowing streams with vegetation (Skelton, 1993), was located in habitat 3 (a medium flow instream pool) for the first time. Only one fish was caught*. B. annectens* received a sensitivity rating of 2, which means it is a semi hardy species (Louw, 1996a).

The last visit to the site on 30/5/2001 (see table 39) had the most species recorded out of all the visits. There were fourteen species recorded in five habitats. The water level was still to high to get into the main part of the riffle, but other habitats were created at this flow. Habitat 1, a slow, cobble pool instream with root wads had the most species (eight). Habitat 3, a fast cobble riffle had six species but the greatest number of individual fish. *Barbus marequensis*, although only recorded in three habitats was by far the most abundant species for the site. *Chiloglanis pretoriae* was the next most abundant, but had a total of less than half that of *Barbus* *marequensis*. For the first time *Glossogobius callidus* was found at this site. This species lives in pools on the bottom amongst cobble or vegetation (Skelton, 1993), which is exactly the habitat in which it was located during the monitoring of this site. *Glossogobius callidus* is not mentioned in the list of fish species for the Luvuvhu River, as part of the pre-impoundment study of Mutoti (Nandoni) Dam (Louw, 1996a). However a close relative *Glossogobius giuris* is recorded on the list and it received a semi sensitive rating (Louw, 1996a), which is likely to be similar to *G. callidus*.

Table 37: Summarising the fish species and abundances, as caught at the Luvuvhu IFR 2 site on 24/10/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**		
METHOD	Shock 12.55 min			Shock 9.4 min			Shock 22.6 min			Shock 13.4 min			Seine net x 2 Cast net x 3			Cast net x 3			Seine net x 2			Seine net x 2		
HABITAT	Backwater (few tree root wads)			Pool off stream (marginal reeds)			Riffle (marginal reeds)			Riffle			Pool off stream			Pool instream			Pool off stream			Pool off stream		
SUBSTRATE	Cobble & rock			Cobble			Cobble			Cobble			Cobble & sand			Cobble & sand			Sand (& cobble)			Sand		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Muddy			Muddy		
FLOW	No – slow			Slow			Medium			Fast			Slow			Slow			Slow			No flow		
DEPTH	< 45cm			15-30cm			25-30cm			30-40cm			10-50cm			30-50cm			< 70 cm			1m		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (1)										1														
Barbus marequensis (48)				7			29			11			1											
Barbus trimaculatus (7)	6	1																						
Barbus viviparas (16)	2	2	1	4	2		1	3	1															
Chiloglanis pretoriae (7)							4	1	2															
Clarias gariepinus (7)	5			1							1	7												
Labeo congoro (6)																	2				1		1	2
Labeo cylindricus (4)							2	2																
Labeo molybdinus (6)							4			2														
Labeo rosae (1)																	1							
Oreochromis mossambicus (9)	8																						1	
TOTALS	21	3	1	12	2	0	40	6	3	14	1	7	1	0	0	0	3	0	0	0	1	0	2	2
	4 species (25)			3 species (14)			5 species (49)			4 species (22)			1 species (1)			2 species (3)			1 species (1)			2 species (3)		
	11 species																							

Table 38: Summarising the fish species and abundances, as caught at the Luvuvhu IFR 2 site on 29/3/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**		
METHOD	Shock 8.7 min			Shock 6.2min			Shock 15.3 min & SASS net x 1			Shock 17.2min			Shock 12 min			Shock 6.3 min			Small seine net x 1			Cast net x 10; seine net x 1		
HABITAT	Pool instream (few tree root wads)			Riffle			Pool instream			Riffle (stumps & dead trees)			Riffle			Structure in run/pool			Shoot			Pool off stream / backwater		
SUBSTRATE	Cobble, mud & silt			Cobble			Cobble, mud & silt			Cobble			Cobble			Cobble, rock, mud & silt			Sand (& mud & silt)			Sand (& mud & silt)		
TURBIDITY	Muddy			Muddy			Muddy			Muddy			Muddy			Muddy			Coloured			Turbid		
FLOW	Slow			Fast			Medium			Fast			Fast			Slow			Slow – medium			Slow – no		
DEPTH	5-35cm			10-20cm			10-40cm			30-50cm			20-45cm			10-25cm			10-20cm			65 – 100cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus afrohamiltoni (1)																						1		
Barbus annectens (1)							1																	
Barbus marequensis (79)	4			2			9			8			4			3			5			44		
Barbus radiatus (7)																						3	3	1
Barbus trimaculatus (29)	1																		1			10	17	
Barbus viviparas (86)	9	3	3		1											2	2	1	4		4		3	54
Chiloglanis paratus (8)							1				1	2	1	2	1									
Chiloglanis pretoriae (8)						2					3	2	1											
Labeo cylindricus (6)				1						3			2											
Labeo molybdinus (1)													1											
Mesobola brevianalis (1)	1																							
Micralestes acutidens (7)								1				2											3	1
Tilapia rendalli (5)																						5		
TOTALS	15	3	3	3	1	2	11	1	0	11	4	6	9	2	1	5	2	1	10	0	4	63	26	56
	4 species (21)			4 species (6)			4 species (12)			5 species (21)			5 species (12)			2 species (8)			3 species (14)			7 species (145)		
	13 species																							

Table 39: Summarising the fish species and abundances, as caught at the Luvuvhu IFR 2 site on 30/05/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**		
METHOD	Shock 21.1 min			Shock 12.3 min			Shock 19.5min			Shock 10.2 min			Cast net x 6		
HABITAT	Pool instream (some tree root wads)			Run (marginal reeds and tree)			Riffle (marginal reeds)			Riffle			Pool off stream		
SUBSTRATE	Cobble & silt			Cobble & silt			Cobble			Cobble & boulder			Sand, mud & silt		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Coloured		
FLOW	Slow			Medium- slow			Fast			Fast – v. fast			No		
DEPTH	10-50cm			15-45cm			20-45cm			35cm			50cm+		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Anguilla mossambica (2)										2					
Barbus annectens (7)	1	3	3												
Barbus marequensis (88)	17			42			29								
Barbus radiatus (2)		1	1												
Barbus trimaculatus (20)	7	8	5												
Barbus viviparas (13)	2	1	10												
Chiloglanis paratus (29)							5	2	18			3			
Chiloglanis pretoriae (33)							1	11	19			2			
Glossgobius callidus (1)			1												
Labeo cylindricus (1)							1								
Labeo molybdinus (5)							3	1		1					
Micralestes acutidens (1)									1						
Oreochromis mossambicus (8)	4												4		
Tilapia rendalli (6)	1												5		
TOTALS	32	13	20	42	0	0	39	14	38	3	0	5	9	0	0
	8 species (65)			1 species (42)			6 species (83)			4 species (8)			2 species (9)		
	14 species														

6.3.3 IFR Site 1 Marite River

The records of the fish monitoring at the Marite IFR 1 site are presented in table 40. The site was monitored four times during the period of the baseline survey. The historic species list contains nineteen species. Six of the species were not caught during the survey, and six additional species were added to the list. This is the only site for which average daily flows could be obtained for all of the visits. Surprisingly the last visit yielded the least species. Despite eight habitats being sampled the flow was too high to get into certain habitats, which is probably why less species were in the catch. The last visit had a flow of almost four times the flow of the first visit. Tharme (1996) reports that the assemblage of fish in the Marite River does not show the same seasonal variability as the lowveld assemblage, because the flows are perennial and less variable. While less species diverse than the lowveld, the Marite River has more sensitive species (Tharme, 1996).

Table 40: Marite River IFR 1 fish species records. The historic species list was compiled from: Tharme (1996), Weeks *et al* (1996) and Chunnet (1987).

HISTORIC RECORDS		**RECENT MONITORING RECORDS**			
		AVERAGE DAILY FLOW ($m^3 s^{-1}$)			
		0.941	1.73	2.02	3.59
		NUMBER OF HABITATS MONITORED			
		3	2	7	8
FAMILY	**FISH SPECIES**	**30/09/1999**	**23/08/2000**	**13/11/2000**	**10/04/2001**
Anguillidae	*Anguilla mossambica*	✓			
Cyprinidae	*Barbus marequensis*	✓	✓	✓	✓
		B. annectens	✓		
	B. eutaenia	✓	✓	✓	✓
	B. brevipinnis		✓		✓
			B. unitaeniatus		
	B. argenteus				
	B.trimaculatus	✓	✓		
	B. polylepis				
	B. paludinosus			✓	
			B.viviparus		
	Labeo cylindricus				
	L. molybdinus	✓	✓	✓	
	Opsaridium peringuey		✓	✓	✓
	Varicorhinus nelspruitensis				
Mormyridae	*Marcusenius macrolepidotus*	✓	✓	✓	✓
	Petrocephalus catostoma	✓			
Mochokidae				*Chiloglanis paratus*	✓
	C. anoterus	✓		✓	✓
		C. swierstrai	✓	✓	✓
Amphiliidae	*Amphilius uranoscopus*	✓	✓	✓	
Clariidae				*Clarias gariepinus*	
Characidae	*Micralestes acutidens*		✓	✓	
Cichlidae	*Tilapia rendalli*				
	Tilapia sparrmanii				
TOTAL # OF SPECIES	**19**	**10**	**13**	**12**	**8**

Three habitats were sampled at the Marite site in September 1999 (table 41). A total of ten species were recorded – just over 50% of the species known to occur at the site. Habitats 1 & 2 yielded the most fish numbers, but habitat 2 (the overhanging vegetation and under cut banks) had the most species. *Chiloglanis anoterus* was the most abundant species for he whole of the site. It only occurred in habitat 1, the rapid. *C. anoterus* has been described as an indicator species for the foothill zone of the Sabie catchment (Weeks *et al*, 1996). This species is an endemic to the escarpment streams of the Pongola and Inkomatie systems, and occurs in riffles and rapids (Skelton, 1993). Weeks *et al* (1996) found that despite this species having a fairly limited distribution, it made up 70% of the catch in the foothill zone and 9% of the catch in the lowveld zone. *Chiloglanis anoterus* adults and juveniles were found to prefer the fastest of flows in cobble and boulder habitats (Weeks *et al*, 1996). *Barbus marequensis* and *Barbus eutaenia* were found to be the next most prolific species at the site. *Barbus eutaenia* is one of Weeks *et al's* (1996) ecologically important species, and favours clear flowing waters (Skelton. 1993). Preferred substrates included pebble and cobble, and vegetation over bedrock (Weeks *et al*, 1996). Although *Barbus annectens* was in low abundance, it was a new species for the site (as far as was possible to ascertain). *B. annectens* is another of the ecologically important species as described by Weeks *et al* (1996). This species favours warm water (Weeks *et al*, 1996) and is considered a lowveld species (the Marite site appears to be on the ecotone of the foothill, and lowveld zones) so it is unusual for this species to have been recorded at this site. In the IFR workshop proceedings *Chiloglanis anoterus* was considered a key species and much of the setting of flows took this fish species into consideration (Tharme, 1996).

Table 41: Marite River IFR 1 fish species and abundance summary 30/9/1999. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**		
METHOD	Shock 11.4min			Shock 15.4 min			Shock 7.2 min		
HABITAT	Rapid			(Overhang veg & undercut banks)			Run		
SUBSTRATE	Bedrock						Rock		
TURBIDITY									
FLOW	Fast			Slow			Slow		
DEPTH	Deep			Deep			Deep & shallow		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (4)			3			1			
Anguilla mossambica (1)	1								
Barbus annectens (1)						1			
Barbus eutaenia (19)						13		6	
Barbus marequensis (19)		11			1		4	3	
Barbus trimaculatus (7)			2		2	3			
Chiloglanis anoterus (36)		8	28						
Labeo molybdinus (8)	3		1		3			1	
Marcusenius macrolepidotus (10)					1	9			
Petrocephalus catostoma (6)					1	5			
TOTALS	4	11	34	0	8	32	4	10	0
	6 species (49)			8 species (40)			3 species (14)		
	10 species								

The August 2000 visit had thirteen species recorded within it, but only two habitats were sampled (table 42). All thirteen species were recorded in habitat 1 (a run in the lateral channel with over hanging vegetation). This habitat also yielded 154 fish. *Barbus unitaeniatus* was found to be the most abundant species for the site. It is a new species (as far as was possible to ascertain) for the site. *B. unitaeniatus* is considered one of the ecologically important species and it is not surprising that it was found at the site because although a warm water species it is tolerant of colder waters as well (Weeks *et al*, 1996). It was found to make up 5% of the catch in Weeks *et al's* (1996) survey. The next most abundant species *Opsaridium peringuey* (formerly *Opsaridium zambezense*) is classified as a rare species in the Red Data

Book (Skelton, 1993). Skelton (1993) notes that this species shows a preference for clear, flowing waters of larger perennial rivers, frequenting the pools below rocky rapids. *Opsaridium peringuey* is mainly threatened by water abstraction and pollution (Skelton, 1993). Weeks *et al (*1996) had it as one of the ecologically important species and recorded that it is a warm-cold tolerant species. It was noted to be most abundant in the cooler waters of the Sabie-Sand system, and decrease in numbers from the foothill zone to the lowveld zone (Weeks *et al*, 1996). This would account for its great abundance at this site. *Barbus viviparus* was not abundant at this site but it was recorded at the site for the first time. Although it is a target species as well as an ecological indicator (Weeks *et al*, 1996) it is considered a lowveld zone species and was not found beyond the confluence of the Sabie and Komatie Rivers or in the Marite River (Weeks *et al*, 1996). It is interesting to note that no *Chiloglanis anoterus* fish were caught at this site visit. *Barbus brevipinnis* is classed as a regional endemic and the most viable populations of this species occur at the Marite IFR 1 site (Tharme, 1996). Skelton (1993) notes that *Barbus brevipinnis* inhabits headwater streams with vegetation. *B. brevipinnis* was only found on two occasions at this site and never in great abundance. Considering that this visit was the first after the floods it was important that this species was still part of the catch, because it could possibly be indicating that the habitat of this species was not as denuded as one would have expected, especially as vegetated habitats are favoured.

Table 42: Marite River IFR 1 fish species and abundance summary 23/08/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**		
METHOD	Shock 25 min			Shock 20 min		
HABITAT	Run (lateral channel – overhanging flood debris)			Long pool		
SUBSTRATE	Sand over bedrock			Bedrock (marginal & overhanging trees)		
TURBIDITY	Coloured			Coloured		
FLOW	Medium			Slow		
DEPTH	20cm			35cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (1)		1				
Barbus annectens (3)			3			
Barbus brevipinnis (2)		2				
Barbus eutaenia (36)	1		12		2	21
Barbus marequensis (31)	22			9		
Barbus trimaculatus (16)			4	11	1	
Barbus unitaeniatus (52)		1	32		8	11
Barbus viviparas (6)			6			
Chiloglanis swierstrai (4)		2	2			
Labeo molybdinus (1)			1			
Marcusenius macrolepidotus (8)			6	2		
Micralestes acutidens (3)			3			
Opsaridium peringuey (83)	7	23	6	4	11	32
TOTALS	13 species (154)			6 species (69)		
	13 species					

The November 2000 site visit (table 43) had twelve species recorded in six habitat types. Originally there were seven habitats sampled but one habitat, a fast flowing, sandy shallow run had no species caught within it. Both habitats 1 & 3 had seven species recorded from them. Habitat 1 is a run with overhanging vegetation and flood debris, of medium to fast flow; and habitat 3 is a shoot with a small rapid, where there was a combination of bedrock, sand and boulder. Habitat 5 had the most fish numbers caught within it. *Barbus marequensis* and *Chiloglanis anoterus* were once again the most abundant species. There were three new specie records for the site. They were *Chiloglanis paratus, Chiloglanis swierstrai* and *Clarias gariepinus*. *Chiloglanis paratus* inhabits rocky riffles and rapids, but may occur in rocky pools of intermittent streams (Skelton, 1993). This correlates with the habitats in which it was found, because habitat 4 is not always a pool, as it is part of a lateral channel behind an island, which only flows at high flows. *C. swierstrai* was only found in one habitat, which was typically characteristic of what it favours: sandy stretches of flowing rivers (Skelton, 1993). *Chiloglanis swierstrai* prefers warmer waters (Skelton, 1993). *Clarias gariepinus* is probably the most widely distributed fish in Africa, and is known to occur in almost any habitat, but prefers slow flow conditions (Skelton, 1993). It is not surprising that this species was found at the site because of its wide tolerance of different habitats, it most likely occurred here but was not previously caught, as this species is capable of avoiding capture.

Table 44 refers to the site visit on 10/4/2001. Eight species were recorded at this site. The maximum number of species at a habitat was just four. Four of the habitats (2; 4; 5 & 7) had all four species. Habitat 5 (a fast, bedrock rapid in a shoot with overhanging vegetation) had the most individual fish caught within it. The most abundant species for the site (double the next abundant species) was *Chiloglanis anoterus.*

Table 43: Summarises the fish species and their abundances at the Marite IFR 1 site 13/11/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**		
METHOD	Shock 33.4 min			Shock 11 min			Shock 24 min			Shock 8 min			Shock 10.2min			Shock 8 min		
HABITAT	Run (overhang veg & flood debris)			Riffle (bit of marginal)			Shoot with small rapid (& some flood debris)			Pool instream (marginal vegetation)			Rapid			Shoot / pool instream		
SUBSTRATE	Sand (& bedrock)			Sand			Bedrock & sand			Sand (bedrock)			Bedrock			Sand & bedrock		
TURBIDITY	Muddy			Muddy			Muddy			Muddy			Muddy			Muddy		
FLOW	Medium – fast			Fast			Medium - fast			Medium			Fast			Fast		
DEPTH	20-45cm			25cm			30-70cm			25-40cm			20cm			7cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Amphilius uranoscopus (2)	1								1									
Barbus eutaenia (9)			1	1		1	1		1	2	1						1	
Barbus marequensis (14)	4			2			2			1			4			1		
Barbus paludinosus (1)								1										
Chiloglanis anoterus (13)							1		2				2	2	4	2		

Chiloglanis paratus (2)			1									1						
Chiloglanis swierstrai (2)	1		1															
Clarias gariepinus (1)												1						
Labeo molybdinus (1)							1											
Marcusenius macrolepidotus (2)	1						1											
Micralestes acutidens (4)															4			
Opsaridium peringuey (3)	1													2				
TOTALS	8	0	3	3	0	1	6	1	4	3	1	2	6	4	8	3	1	0
	7 species (11)			2 species (4)			7 species (11)			4 species (6)			4 species (6)			3 species (4)		
	12 species																	

Table 44: Summarises the fish species and their abundances at the Marite IFR 1 site 10/4/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**		
METHOD	Shock 12.3 min			Shock 9min			Shock 11 min			Shock 10.5 min			Shock 12.2 min			Shock 1.5 min			Shock 8.42 min			Cast net x 14		
HABITAT	Overhang & instream structure with root wads and flood debris			Shoot with overhang			Rapid with overhang			Pool instream with overhang			Rapid in shoot with overhang			Pool off stream			Run (margin of stream) & few branches in water			Rapid pool / instream		
SUBSTRATE	Sand & gravel			Bedrock (gravel & sand)			Sand & bedrock			Sand , boulder & bedrock			Bedrock			Bedrock (& sand)			Sand			Bedrock, boulder (& sand)		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured		
FLOW	Fast			Medium – fast			Fast – v. fast			Medium - fast			Fast			Slow			Medium			Fast		
DEPTH	30 – 75cm			15-30cm			25 – 35cm			25-50cm			25-35cm			15cm			30-45cm			45cm +		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus brevipinnis (1)										1														
Barbus eutaenia (12)	1				2		1	1		2			1	1		1		1	1					
Barbus marequensis (5)													2									3		
Chiloglanis anoterus (25)							4	2	2	1			10	2	2				2					
Chiloglanis paratus (3)		1			1														1					
Chiloglanis swierstrai (1)												1												
Marcusenius macrolepidotus (1)	1																							
Opsaridium peringuey (4)				1									2						1					
TOTALS	2	1	0	1	3	0	3	3	2	4	0	1	15	3	2	1	0	1	5	0	0	3	0	0
	3 species (3)			4 species (4)			2 species (8)			4 species (5)			4 species (20)			1 species (2)			4 species (5)			3 species (3)		
	8 species																							

6.3.4 IFR Site 2 Sabie River

The Sabie IFR 2 site was monitored four times over the period of the project. There were twenty-seven species on the historic species list. Eleven of the species were not caught during the period of the project. No additional species were recorded at the site. In the report compiled by Tharme (1996) the key aspects regarding this site are that it is within an ecotone where cold-water species can occur during the winter months, *Barbus eutaenia* occurs at the site but seldom further downstream *Opsaridium peringuey* occurs in the general area.

Table 45: Sabie River IFR 2 (Bridge) fish specie records. Historic records were compiled from site 6 (Weeks, O' Keeffe, Fourie and Davies, 1996); and IFR 2 site (Tharme *et al*, 1996).

HISTORIC RECORDS		RECENT MONITORING RECORDS			
		AVERAGE DAILY FLOW ($m^3 s^{-1}$)			
		4.37	**11.8**	**16.8**	**NR**
		NUMBER OF HABITATS MONITORED			
		3	2	6	5
FAMILY	**FISH SPECIES**	**30/9/1999**	**23/08/2000**	**14/11/2000**	**09/04/2001**
Anguillidae	*(Anguilla bengalensis)*			(✓)	
	A. mossambica				
Amphiliidae	*Amphilius uranoscopus*				
Mormyridae	*Marcusenius macrolepidotus*	✓			
	Petrocephalus catostoma				
Cyprinidae	*Barbus marequensis*	✓	✓	✓	
	Barbus annectens				
	B. eutaenia			✓	✓
	B. radiatus				
	B.trimaculatus	✓		✓	✓
	B.unitaeniatus	✓			
	B.viviparus	✓		✓	✓
	Labeo cylindricus				
	L. molybdinus	✓	✓	✓	
	Mesobola brevianalis				✓
	Opsaridium peringuey			✓	✓
Mochokidae	*Chiloglanis paratus*			✓	
	C. anoterus	✓	✓	✓	
	C. swierstrai		✓	✓	✓
	Synodontis zambezensis				
Clariidae	*Clarias gariepinus*				
Characidae	*Micralestes acutidens*			✓	
Schilbeidae	*Schilbe intermedius*				

Cichlidae	*Pseudocrenilabrus philander*	✓		✓	✓
	Serranochromis meridianus				
	Tilapia rendalli				✓
	Tilapia sparrmanii				
	Oreochromis mossambicus				✓
TOTAL # OF SPECIES	**27**	**8**	**4**	**12**	**9**

Eight species, in three habitats were recorded at the site during the first (30/9/1999) monitoring visit (table 46). Habitat 3 (a slow, deep overhanging pool in stream) had five species recorded within it. Habitat 1, a fast, shallow to deep run / rapid, had the most individual fish in the catch. The most abundant fish for the site was *Chiloglanis anoterus*, although this is a foothill zone species (Weeks *et al*., 1996), it is possible for this species to occur because the site is on an ecotone, however it is surprising to see it come out as the most abundant for this particular visit. The next most abundant species were *Barbus unitaeniatus*, and *Labeo molybdinus* respectively. *Barbus unitaeniatus* is one of the five important minnows within the lowveld zone, and also one of the ecologically important species (*Weeks et al*, 1996). This species was noted to make up about 5% of the catch in the pre-impoundment and drought survey, and was noted to be relatively more abundant in the upper lowveld zone (this site falls into that) and decrease with increasing stream order (Weeks *et al.,* 1996). Weeks *et al* (1996) also included *Labeo molybdinus* as an ecologically important species, the juveniles were noted to prefer moderate flows and adults favour high velocity flows.

Table 46: Sabie River IFR 2 (Bridge) fish specie and abundances as recorded on 30/9/1999. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**		
METHOD	Shock 19.5 min			Shock 5min			Shock 13.5 min		
HABITAT	Rapid / run			Rapid / run			(with overhanging vegetation)		
SUBSTRATE	Bedrock			Bedrock					
TURBIDITY									
FLOW	Fast			Fast			Slow		
DEPTH	Shallow -deep			Shallow -deep			Deep		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus marequensis (14)		12			2				
Barbus trimaculatus (14)			2						12
Barbus unitaeniatus (27)									27
Barbus viviparas (5)									5
Chiloglanis anoterus (68)		26	14		13	15			
Labeo molybdinus (24)		9			6	2		7	
Marcusenius macrolepidotus (1)									1
Pseudocrenilabrus philander (1)						1			
TOTALS	0	47	16	0	21	18	0	7	45
	4 species (63)			4 species (39)			5 species (52)		
	8 species								

Table 47 summarises the findings on the survey completed on 23/8/2000. This was the first visit after the floods, when water levels were still high and the general velocity was too fast to enter. As a result one struggled to find suitable sampling habitat, hence the poor results. At this stage there was also very limited vegetated habitat, due to the recent high flows. Just four species were recorded in the two habitats. Habitat 1, the rapid / run had al four species, but habitat 2, the pool instream had the most actual fish in the catch. *Chiloglanis swierstrai* was the most abundant species. This was probably due to the increase in sand materials at the site after the floods, which covered up the bedrock bed material.

Table 47: Sabie River IFR 2 (Bridge) fish specie and abundances as recorded on 23/8/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**		
METHOD	Shock 30min			Shock 25 min		
HABITAT	Rapid & run (marginal reeds)			Run – pool instream		
SUBSTRATE	Bedrock (& sand)			Sand & bedrock		
TURBIDITY	Coloured			Coloured		
FLOW	Fast			Fast		
DEPTH	40-100cm			40-100cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus marequensis (1)	1					
Chiloglanis anoterus (5)		1	4			
Chiloglanis swierstrai (38)			9			29
Labeo molybdinus (4)			2	1		1
TOTALS	1	1	15	1	0	30
	4 species (17)			2 species (31)		
	4 species					

The third visit on 14/11/2000 yielded the most species (twelve) out of all the visits during this project (table 48). There were six habitats sampled. Habitat 2, a riffle with many small instream pools within this habitat, had eight species recorded within it. The substrate for this habitat mainly consisted of a rock like concrete debris, which had most likely been washed down with the floods. No habitat was greatly abundant with fish, but habitat 3, a riffle with instream structure, had the most individual fish. *Chiloglanis anoterus* was the most abundant species for the site, followed by *C. paratus*. It was surprising to find *C. paratus* so abundant as the species prefers rocky riffles and rapids but also occurs rocky pools in intermittent streams during low water conditions, which is not the situation under these post flood conditions (albeit the floods having occurred nine months prior to this survey) when water levels were still relatively high. *Anguilla bengalensis* has been put in parentheses because its identification was not confirmed, it was a large adult specimen that was caught and it was not possible to retain it within the net or in a bucket, so it got away! It was a large mottled eel, which was originally considered to be *A. marmorata*, but seeing that *A. bengalensis* is on the species list it was thought to be more likely that species. Whatever the species it is always encouraging to catch a large specimen of any species, especially in an area that is heavily fished for local consumption.

Table 48: Sabie River IFR 2 (Bridge) fish specie and abundances as recorded on 14/11/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**		
METHOD	Cast net x 4			Shock 25 min			Shock 25 min			Shock 16 min			Shock 2 min			Cast net x 14		
HABITAT	Rapid			Riffle & small pools instream			Riffle with instream structure			Pool off stream			Isolated pool			Run		
SUBSTRATE	Sand (& bedrock)			Rock & sand			Imbedded boulder, rock & sand			Mud & sand (silt & boulder)			Mud, rock & sand			Sand		
TURBIDITY	Muddy			Muddy			Muddy			Muddy			Coloured			Muddy		
FLOW	Fast			Medium (with slow sections)			Fast			Slow			No			Fast		
DEPTH	70 – 100cm			10-25cm in riffle component; 30-45cm in pool sections									25-50cm			Deep		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Anguilla bengalensis (1)									1									
Barbus eutaenia (3)					3													
Barbus marequensis (4)				2						1						1		
Barbus trimaculatus (2)				1		1												
Barbus viviparas (2)					1	1												
Chiloglanis anoterus (16)							7	4	5									
Chiloglanis paratus (12)				2		2	1	1	6									
Chiloglanis swierstrai (2)			1						1									
Labeo molybdinus (4)							2									1	1	
Micralestes acutidens (4)						3						1						
Opsaridium peringuey (4)					2						2							
Pseudocrenilabrus philander (3)				1						1			1					
TOTALS	0	0	1	6	6	7	10	5	5	1	2	1	1	0	0	2	1	0
	1 species (1)			8 species (19)			5 species (20)			4 species (4)			1 species (1)			2 species (3)		
	12 species																	

The last monitoring visit resulted in only nine species being caught in the five habitats sampled (table 49). This is attributed to the construction work that was taking place at the site. The bridge was being repaired and sections reconstructed, which resulted in a lot of disturbance in and near the waters edge. Habitats 1 & 2 both had five species recorded within them. Habitat 1 was a no to slow flowing backwater and habitat 2 a medium flow run. No habitat was particularly abundant with fish, but habitat 1, had the most individual fish caught within it. The two most abundant species for the site were *Barbus viviparus* and *Oreochromis mossambicus*, although they cannot really be classed as abundant (six individual fish of each species). *Oreochromis mossambicus* is another of Weeks *et al's,* (1996) ecologically important species. It was found to be the second most abundant species in the lowveld zone, but its abundance is highly seasonal (Weeks et *al*, 1996). The juveniles prefer shallow waters of no flow, while the adults prefer no flow but are tolerant of higher flows and a range of depths (Weeks *et al*, 1996*). Tilapia rendalli* had two individuals recorded, but prior to this survey it had been noted that it had been recorded in the vicinity for the first time in years (Tharme, 1996), so it is encouraging to note its presence.

Table 49: Sabie River IFR 2 (Bridge) fish specie and abundances as recorded on the 9/4/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**		
METHOD	Shock 9 min			Shock 10 min			Shock 2 min			Shock 7 min			Cast x 11		
HABITAT	Backwater			Run (margin of bank with reeds & rushes)			Backwater			Margin of channel (run)			Run (riffle)		
SUBSTRATE	Rock & silt			Bedrock, mud & silt			Mud (& rock)			Sand & fine gravel			Sand (cobble)		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Coloured		
FLOW	No – slow			Medium			No-slow			Medium			Fast – v. fast		
DEPTH	20-60cm			25-60cm			20-25cm			30-35cm					
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus eutaenia (1)				1											
Barbus trimaculatus (2)				1											1
Barbus viviparas (6)	3			3											
Chiloglanis swierstrai (4)											3	1			
Mesobola brevianalis (1)				1											
Opsaridium peringuey (1)	1														
Oreochromis mossambicus (6)	5												1		
Pseudocrenilabrus philander (1)	3			1											
Tilapia rendalli (2)	1						1								
	13	0	0	7	0	0	1	0	0	0	3	1	1	0	1
TOTALS	5 species (13)			5 species (7)			1 species (1)			1 species (4)			2 species (2)		
	9 species														

6.3.5 IFR Site 4 Sabie River

The Sabie IFR 4 site was monitored five times, one of which was not a full survey. This site has quite an extensive species list (historic) due to the early work that was done by Pienaar, which started in 1960 (Deacon, 2000b). There are twenty-nine species on the historic species list, eight of which were not caught at any stage during the recent monitoring trips. There was one additional species added to the list during baseline monitoring: *Glossogobius callidus*. This species favours the bottom of pools amongst the cover of cobbles and vegetation (Skelton, 1993). The species diversity for the site, varied from visit to visit, this is mainly attributed to the floods, and the loss of vegetated habitats. The first visit in September 1999 yielded sixteen species, and the last visit in May 2001 (about thirteen months after the floods) had fifteen species recorded, which perhaps indicates that as the vegetation started to re-establish, the species diversity increased again.

Table 51 shows that the visit in September 1999 had six habitats sampled. The most species diverse habitat was habitat 2, where there were seven species recorded. This was a fast shallow coble and bedrock riffle / rapid. However this habitat did not yield the most fish caught. Habitat 5, a shallow vegetated run of no flow had fifty-one actual fish caught. A mosquito net was used for sampling habitat 5. However, only three species were actually represented at this habitat. The most abundant fish for the whole of the site was *Barbus viviparus*; it was represented in all the habitats except for habitat 6, a deep, medium flow bedrock pool. In a study done on the Sabie-Sand river system by Weeks *et al* (1996), *B.viviparus* was identified as one of the target species, where the aim was identify species that were representative, had a diversity of requirements, were of importance and were abundant (because information was limited on the scarce species. Weeks *et al* (1996) noted that *B. viviparus* was typically the most abundant lowveld fish in all the lowveld zones. The next most abundant species (at the site) were *Micralestes acutidens*, and *Mesobola brevianalis* respectively*. Mesobola brevianalis* was found in three of the habitats, and its greatest abundance was in habitat 5 (the vegetated slow, shallow run). This does not really correlate with Skelton (1993) who states that this species occurs in well-aerated open water of flowing rivers. *Micralestes acutidens* was only found in habitats 3 & 5. This species shoals in clear, flowing or standing open water (Skelton, 1993). In Weeks *et al's* study (1996) *Micralestes acutidens* was included as an ecologically important species because of its wide distribution and abundance.

Table 50: Sabie River IFR 4 (warden site) fish species records. Historic records compared to recent monitoring. Historic species list compiled from Kruger National Park literature (Deacon, 2000).

HISTORIC RECORDS		RECENT MONITORING RECORDS				
		AVERAGE DAILY FLOW ($m^3 s^{-1}$)				
		4.46	22.3	10.4	20.3	NR
		NUMBER OF HABITATS MONITORED				
		6	14	9	2	
FAMILY	**FISH SPECIES**	**27/09/1999**	**12/06/2000**	**02/10/2000**	**30/11/2000**	**14/05/2001**
Anguillidae	*Anguilla mossambica*					
Mormyridae	*Marcusenius macrolepidotus*			✓		
	Petrocephalus catostoma					
Cyprinidae	*Barbus marequensis*	✓	✓	✓	✓	✓
	B. annectens	✓				
	B. eutaenia		✓			✓
	B. paludinosus					

	B.trimaculatus	✓	✓	✓	✓	✓
	B. unitaeniatus	✓	✓			✓
	B.viviparus	✓	✓	✓	✓	✓
	Labeo cylindricus		✓		✓	
	L. molybdinus	✓	✓	✓	✓	✓
	L. congoro					
	L. rosae		✓			
	Opsaridium peringuey	✓				✓
	Mesobola brevianalis	✓				✓
Mochokidae	*Chiloglanis paratus*	✓	✓	✓	✓	✓
	C. swierstrai	✓	✓			✓
	C. anoterus		✓	✓	✓	✓
	Synodontis zambezensis					
Clariidae	*Clarias gariepinus*	✓				✓
Schilbeidae	*Schilbe intermedius*					
Characidae	*Micralestes acutidens*	✓		✓	✓	✓
	Brycinus imberi	✓				
	Hydrocynus vittatus					
Cichlidae	*Oreochromis mossambicus*	✓	✓			✓
	Pseudocrenilabrus philander	✓		✓		
	Serranochromis meridianus					
	Tilapia rendalli	✓				✓
Gobiidae	*Glossogobius giuris*			✓		
					G. callidus	
TOTAL # OF SPECIES	**29**	**16**	**12**	**10**	**9**	**15**

Table 51: Sabie River IFR 4 fish specie and abundances as recorded on the 27/9/1999. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**		
METHOD	Shock 10min			Shock 10min			Seine net x 2			Mosquito net x 5			Mosquito net x 5			Cast net x 4		
HABITAT	Root wads			Riffle/ Rapid			Pool			Pool (overhang reeds)			Run (few overhang reeds)			Pool		
SUBSTRATE	Mud & detritus			Cobble & bedrock			Sand			Detritus			Sand			Bedrock		
TURBIDITY																		
FLOW	Slow			Fast			Medium			No			Slow			Medium		
DEPTH	Shallow			Shallow			Deep			20-40cm			Shallow			Deep		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus annectens (6)		1	4			1												
Barbus marequensis (3)							2		1									
Barbus trimaculatus (5)		1	3		1													
Barbus unitaeniatus (1)		1																

Barbus viviparas (69)	1	2	3	1	3	3	1	3	1		21	8	6	13	3			
Brycinus imberi (1)						1												
Chiloglanis paratus (1)					1													
Chiloglanis swierstrai (5)								5										
Clarias gariepinus (3)	2			1														
Labeo molybdinus (2)				1														1
Mesobola brevianalis (18)								3	1			1	2	5	6			
Micralestes acutidens (21)			3					1	1				4	12				
Opsaridium peringuey (7)								4	3									
Oreochromis mossambicus (1)	1																	
Pseudocrenilabrus philander (3)											2	1						
Tilapia rendalli (4)																		4
TOTALS	4	5	13	3	5	4	3	15	7	0	25	10	12	30	9	0	0	5
	6 species (22)			7 species (12)			6 species (25)			3 species (35)			3 species (51)			2 species (5)		
	16 species																	

The monitoring done at the site in June 2000 is summarised in table 52. Originally there were fourteen habitats sampled, three of which did not yield any fish. These were fast deep rapids or shoots that were sampled with a cast net. They appeared to be too deep (two of them over a meter deep) and too fast, as the net was not reaching the bottom. The eleventh habitat was joined with habitat 7. The average daily flow (22.3 $m^3 s^{-1}$) was still high for the site and the large bedrock structure on the right hand bank was still covered with water, therefore most of the sampling took place at the left hand channel. There were twelve species recorded at the site. The most species were recorded in habitats 3 & 8. Habitat 3 was a shoot of medium flow, with embedded rock and gravel and deep (45cm), habitat 8 was a fast flowing, bedrock and sand shoot with some root wads. Both sites had five species recorded. Habitat 8 had the most fish caught within it. The most abundant species was once again *Barbus viviparus*. It was located in seven of the ten habitats.

On 2/10/2000 only ten species were recorded (table 53) There were ten habitats sampled but one, a slow to medium flow; bedrock, pool in stream had no catch. Habitats 2 & 7 were the most species diverse with five species each. Habitat 2 was a slow flow, deep (40cm), silt pool instream with marginal reeds. Habitat 7 (a fast, bedrock rapid / shoot) also had the most individual fish caught within the habitat. *Barbus marequensis* (juveniles) was the most abundant fish species throughout the whole site. It occurred in six of the nine habitats*. B. marequensis* was considered one of the ecologically important species as determined by Weeks *et al* (1996). This species occurs in the foothill zone as well as the lowveld zone. In the lowveld zone it was noted that there was seasonal variability in the % catch. At the start of the dry season (May) this species made up about 19% of the catch and by the peak of the wet season (February) the catch had dropped to 3% (Weeks *et al*, 1996). *Labeo molybdinus* was noted to be the next most abundant species. Although its numbers were quite considerably lower than *Barbus marequensis*, it occurred in more habitats (seven). *Labeo molybdinus* was considered an ecologically important species by Weeks *et al* (1996). Skelton (1993) notes that this species appears to prefer deeper waters especially pools, but it does enter rapids, and migrates upstream in swollen rivers to breed.

The sampling that took place on 30/11/2000 (table 54) was not a full survey, hence the fewer habitats sampled, and fewer species caught. Only two habitats were sampled. Habitat 2 had the greatest species diversity (eight species). This was a bedrock rapid with fast flow. This habitat had the greatest number of fish caught. Habitat 1 (a deep, fast flowing, rocky run with overhanging vegetation) had the Glossogobius callidus the only additional species that was collected at this site. The two most abundant species were *Barbus marequensis* and *Chiloglanis paratus* respectively. *Chiloglanis paratus* favours shallow rocky reaches, riffles and rapids of perennial rivers (Skelton, 1993). Because this survey was not a complete one, there can only be limited deductions.

The last visit to the site yielded a total of fifteen species. There were twelve habitats sampled. Habitat 12 was joined with habitat 10 in table 55, and habitat 11 was combined with habitat 1. Habitats 1 &7 had the greatest diversity of species at the site; each had eight species recorded at it. Habitat 1 was a run with overhang, the dominant substrate was sand with some boulder, it was of medium flow and had a broad depth range of 15-40cm. Habitat 7 rapid with root wads, fast flowing and the substrate was angular rock and coarse gravel. Habitat 10 had the greatest number of fish caught from it. The most abundant species was *Chiloglanis paratus*, which was considerably more abundant than the next two most abundant species *Barbus marequensis*, and *B.viviparus*. Further upstream at other sites *Chiloglanis anoterus*, a foothills zone target species (Weeks *et al*, 1996) was the most abundant species, but in the lowveld zone *Chiloglanis paratus* appears to take its place, perhaps C. paratus has a wider tolerance of temperatures or altitudinal ranges. *C. paratus* was caught in 60% of the habitats sampled.

Table 52: Sabie River IFR 4 (Skukuza) fish specie and abundances as recorded on the 12/6/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**10**		
METHOD	Shock 7 min			Shock 8 min			Shock 12.3 min			Shock 6.3 min			Cast net x 4			Shock 11.3 min			Cast net x 14, Cast net x 9			Shock 35.2 min			Shock 11.4min			Shock 15 min		
HABITAT	Narrow shoot (with root wads			Shoot (with root wads			Shoot			Riffle (with few root wads)			Instream plunge pool			Shoot (& riffle with root wads)			Rapid (& shoot)			Shoot (root wads)			Pool off stream			Shoot		
SUBSTRATE	Silt			Fine sand			Embedded rock (& gravel)			Gravel (& mud)			Sand			Sand (& cobble, & mud)			Bedrock & rock (sand)			Bedrock & sand			Scattered rock			Gravel & coarse sand		
TURBIDITY	Coloured			Clear			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured		
FLOW	Medium – fast			Medium			Medium			Fast			Fast			Medium			Fast			Fast			Slow			Fast		
DEPTH	20 cm			15 cm			45cm			20cm			150cm			>30cm			<150cm			25cm			35cm			20cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus eutaenia (1)																													1	
Barbus marequensis (7)							1			1					2	1	1			1										
Barbus trimaculatus (13)	1	1					1	1								3	2						1		1				2	
Barbus unitaeniatus (3)								1	2																					
Barbus viviparas (49)	3	1		2				6								1	2	1				4	6	3	6	6		5	2	1
Chiloglanis anoterus (1)										1																				
Chiloglanis paratus (11)		1								1												4	3	2						
Chiloglanis swierstrai (5)				2	1																			1					1	
Labeo cylindricus (2)										1													1							
Labeo molybdinus (5)																				4	1									
Labeo rosae (4)															1						3									
Oreochromis mossambicus (1)																									1					
TOTALS	4	3	0	4	1	0	2	8	2	4	0	0	0	0	3	5	5	1	0	5	4	8	11	6	8	6	0	5	6	1
	3 species (7)			2 species (5)			5 species (12)			4 species (4)			2 species (3)			3 species (11)			3 species (9)			5 species (25)			3 species (14)			4 species (12)		
	13 species																													

Table 53: Sabie River IFR 4 (Skukuza) fish specie and abundances as recorded on 2/10/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**		
METHOD	Shock 8.2 min			Shock 20.4 min			Shock 23 min			Shock 10.1 min			Shock 4.5min			Shock 10.3 min			Shock 18.2 min			Shock 3.1 min			Seine net x 2		
HABITAT	Riffle			Pool instream (marginal reeds)			Shoot/ rapid			Shoot			Overhang / run			Riffle / rapid			Rapid (& shoot)			Rapid			Pool instream		
SUBSTRATE	Coarse gravel			Silt			Bedrock & rock			Bedrock			Rock & silt			Bedrock & rock (& gravel)			Bedrock			Bedrock			Fine sand & silt		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured		
FLOW	Medium			Slow			Fast			Fast			Slow – medium			Medium			Fast			Fast			Slow		
DEPTH	20 cm			40 cm			40cm +			35-55cm			25cm			20cm			15-25cm			15 cm			100cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus marequensis (40)	3						2			6						2			19			8					
Barbus trimaculatus (6)				3	3																						
Barbus viviparas (25)	5	9	2	2		1							3												3		
Chiloglanis anoterus (10)							1	2	1										2	4							
Chiloglanis paratus (11)	1						2	2	1	1	2						1				1						
Glossogobius giuris (1)				1																							
Labeo molybdinus (26)	3						5	1		2			1			2			5	4		3					
Marcusenius macrolepidotus (1)				1																							
Micralestes acutidens (4)																				3	1						
Pseudocrenilabrus philander (1)				1																							
TOTALS	12	9	2	8	3	1	10	5	2	9	2	0	4	0	0	4	1	0	26	11	2	11	0	0	3	0	0
	4 species (23)			5 species (12)			4 species (17)			3 species (11)			2 species (4)			3 species (5)			5 species (39)			2 species (11)			1 species (3)		
	10 species at site																										

Table 54: Sabie River IFR 4 (Skukuza) fish specie and abundances as recorded on 30/11/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**		
METHOD	Shock 4.5 min			Shock 10 min		
HABITAT	Overhang / run			Rapid		
SUBSTRATE	Rock (& sand)			Bedrock, rock & sand		
TURBIDITY	Coloured			Coloured		
FLOW	Fast			Fast		
DEPTH	40-45cm			35-50cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus marequensis (14)	1			12	1	
Barbus trimaculatus (2)					1	1
Barbus viviparas (3)		1			1	1
Chiloglanis anoterus (2)				2		
Chiloglanis paratus (16)				6	2	8
Glossogobius callidus (1)			1			
Labeo cylindricus (1)				1		
Labeo molybdinus (5)	1			4		
Micralestes acutidens (2)			1			1
TOTALS	2	1	2	25	5	11
	5 species (5)			8 species (41)		
	9 species					

Table 55: Sabie River IFR 4 (Skukuza) fish specie and abundances as recorded on the 17/05/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**10**		
METHOD	Shock 15 min			Shock 15 min			Shock 10min			Shock 3 min			Shock 4 min			Shock 9.1 min			Shock 12.2 min			Shock 5.2min			Shock 9 min			Shock 11.2 min & cast net x 4		
HABITAT	Run / overhang			Rapid			Overhang			Riffle			Pool instream			Pool instream (with logs)			Rapid (root wads)			Pool instream (dam behind flood debris)			Rapid / shoot			Bedrock pool to rapid / shoot		
SUBSTRATE	Sand (& boulder – ltd)			Sand & bedrock			Sand			Coarse gravel & small cobble			Sand (mud & silt)			Coarse gravel & scattered rock			Angular rock, coarse gravel & bedrock			Bedrock			Bedrock (& rock)			Bedrock		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Turbid			Turbid			Coloured			Coloured			Coloured			Coloured		
FLOW	Medium			Fast			Slow			Medium			Slow			Medium			Fast			Slow			Fast – v. fast			Medium (pool) – Fast (rapid)		
DEPTH	15-40cm			20-50cm			15-40cm			10-20cm			30-50cm			30-65cm			20-45cm			35-70cm			40-55cm			40-60cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus eutaenia (1)		1																												
Barbus marequensis (51)	1			3						3						2			4			26	1					11		
Barbus trimaculatus (21)	3	1		1			2	3			1								1				3	6						
Barbus unitaeniatus (8)	1	1					2	3									1													
Barbus viviparas (45)		1	1	1	12	4	2	11	7					1			1	3			1									
Chiloglanis anoterus (11)																			4	1	1							2	3	
Chiloglanis paratus (104)				1							1					1	1		10	5	4				5	9	13	10	26	18
Chiloglanis swierstrai (35)	8	12	10	1	2	2																								
Clarias gariepinus (1)																														1
Labeo molybdinus (18)										1									5						2	1		8		1
Mesobola brevianalis (4)										1						1		2												
Micralestes acutidens (11)																	1				2		1	7						
Opsaridium peringuey (3)				1																1										1
Oreochromis mossambicus (15)	6			9	1		4									1														
Tilapia rendalli (2)	1						1																							
TOTALS	20	16	11	17	15	6	11	17	7	5	2	0	0	1	0	5	4	5	24	7	8	26	5	13	7	10	13	31	29	21
	8 spp (47)			7 spp (38)			5 spp (35)			5 spp (7)			1 spp (1)			7 spp (14)			8 spp (39)			3 spp (44)			2 spp (30)			6 spp (81)		
	15 species																													

6.3.6 IFR Site 5 Sabie River

The Sabie IFR 5 site is extensive, the macro channel being between 750m and 1km wide at parts. It is made up of many channels. There appears to be four main, consistent channels. Channel no. 4 is the far left hand channel. This site was monitored three times. Only nine species (out of the historic species list of twenty-five species) were not caught at any stage during the survey this is about 36%. However there were five additional species included in the list (*Labeo rosae, Opsaridium peringuey*, *Chiloglanis anoterus*, *Chiloglanis paratus* and *Chiloglanis swierstrai*) during baseline monitoring. It is a little surprising that there were no *Chiloglanis* species on the historic records, perhaps the site changed considerably after the floods. However Tharme (1996) does make reference to *Chiloglanis anoterus* (it was most affected by the 1991-92 drought, especially in relation to its breeding grounds) so it must have been recorded at some stage.

Table 56: Sabie River IFR 5 (N'watimhiri) fish specie records, historic compared to recent records. Historic records from KNP records (Deacon, 2000b).

HISTORIC RECORDS		**RECENT MONITORING RECORDS**		
		AVERAGE DAILY FLOW ($m^3 s^{-1}$)		
		N/R	**12.7**	**N/R**
		NUMBER OF HABITATS MONITORED		
		8	10	13
FAMILY	**FISH SPECIES**	**14/6/2000**	**04/10/2000**	**15/05/2001**
Anguillidae	*Anguilla mossambica*			
Mormyridae	*Marcusenius macrolepidotus*	✓		
	Petrocephalus catostoma			
Cyprinidae	*Barbus marequensis*	✓	✓	✓
	B. afrohamiltoni	✓		✓
	B. radiatus	✓	✓	✓
	B. annectens		✓	
	B.toppini			
	B. paludinosus			
	B. eutaenia			
	B.trimaculatus	✓	✓	✓
	B.unitaeniatus			✓
	B.viviparus	✓	✓	✓
	Labeo cylindricus	✓		✓
		L. rosae		
	L. molybdinus	✓	✓	✓
	Mesobola brevianalis	✓		
		Opsaridium peringuey		✓
Mochokidae		*Chiloglanis paratus*		✓
				C. anoterus
		C. swierstrai	✓	✓
Clariidae	*Clarias gariepinus*	✓	✓	✓

Characidae	*Micralestes acutidens*	✓		✓
	Brycinus imberi			
Schilbeidae	*Schilbe intermedius*			
Cichlidae	*Pseudocrenilabrus philander*		✓	✓
	Serranochromis meridianus			
	Tilapia rendalli	✓	✓	✓
	Oreochromis mossambicus	✓	✓	✓
Gobiidae	*Glossogobius giuris*			
TOTAL # OF SPECIES	**25**	**17**	**11**	**17**

Table 57 summarises the results at the site on 14/6/2000. Only channel 1 was monitored as it was still too high to get into the other channels, seventeen species were recorded in the eight habitats sampled. Habitat 7 was the most species diverse with twelve species being recorded within it. Habitat 7 was a medium flow, 35cm deep, run/shoot with rock and sand forming the substrate. Habitat 1, a shoot with overhanging vegetation had ten species in it. Habitat 7 had a total of 129 fish collected from it. *Barbus viviparus* was the most abundant fish species for the site. It is considered an indicator species for the lowveld zone, and is sensitive to summer flow (or the lack of it), while able to tolerate or survive drought conditions, by seeking refuge in shallow pools, their numbers did drop considerably, and as a result went from being the most abundant species for the lowveld to the third most abundant (on average) (Weeks *et al*, 1996). *Barbus trimaculatus* was the next most abundant species, but less than half the numbers of *B. viviparus* were collected. *Barbus trimaculatus* is considered one of the ecologically important species, and was found to be a highly tolerant species, with its numbers not being unduly affected by the drought (Weeks *et al.*, 1996). Four of the five additional species were sampled during this visit. *Labeo rosae* is a species that prefers sandy stretches of larger perennial and intermittent rivers (Skelton, 1993). Of the *two L. rosae's* caught the one was in a similar habitat to that which Skelton describes, however the second was in a cobble and rock run. Only one *Opsaridium peringuey* was caught, and it was also out of its preferable habitat, which Skelton (1993) describes as clear flowing waters of large perennial rivers, frequenting pools below rocky rapids. The other two additional species, *Chiloglanis paratus* and *C. swierstrai* were caught in very low numbers.

The visit to the site on 4/10/2000 is summarised in table 58. Channel 1 had more or less stopped flowing on this occasion, so most of the sampling took place in channel 2. Eleven species were recorded in seven habitats. Initially nine habitats were sampled, but two of the habitats yielded no fish. The one habitat was a medium flow pool instream and the other was a slow flowing pool off stream. Both these habitats were sampled by means of an electro shocker. Habitats 2 & 3 were the most species diverse with five species being recorded in each. Both habitats were slow flowing sand and bedrock; pools in stream, except that habitat 3 also had root wads and dead branches in it. Habitat 7 had the greatest number of fish collected in it. The most abundant species was *Barbus viviparus*, which appears to be able to tolerate drought as well as flood conditions. The next most abundant species was *B. trimaculatus,* at less than half that of *B. viviparus*.

The sampling that took place on 15/05/2001, included channels no.1, 2, & 4. Table 59 refers to channels 1&2, while table 60 covers channel 4. They will be discussed together. A total of seventeen species were recorded in the thirteen habitats sampled. Habitat 5, a slow, sand and silt run with overhanging vegetation, was the most species diverse, with eight species being recorded. The three most abundant habitats (in terms of total fish numbers) were habitats 13, 1, & 6 respectively. Habitat 13 was in channel 4, and was a very fast flowing, cobble, and boulder riffle / rapid with marginal reeds all the way along the waters edges, it had five species found within it. Habitat 1 was a fast flowing rapid with marginal reeds, and habitat 6 was a slow flowing sandy run with root wads. Both these habitats had five species recorded within them. The most abundant species for the whole of the site was *Barbus marequensis*, a species that is present in both the foothill and lowveld zones, but more typically abundant in upper lowveld zones (Weeks *et al.,* 1996). The populations of this species were reported to have been influenced by drought conditions, mainly due to loss of fast flowing rapids and runs (Weeks *et al.,* 1996). Perhaps its high abundance during this particular visit is indicative of how it reacts positively to high flow conditions. Although it was not possible to get an average daily flow reading for this day, the river was higher than the previous visit, which was recorded at $12.7m^3\ s^{-1}$. On this occasion channel 1 was flowing properly again, and it was necessary to use a boat to cross the other channels to get to channel 4. The next most abundant species was *Oreochromis mossambicus*, although considerably less abundant than *Barbus marequensis*. *Oreochromis mossambicus*, one of the ecologically important fishes in Weeks *et al's* survey (1996), was recorded as the second most abundant species for the lowveld zone, and is considered as one of the most successful species of the lowveld rivers. *Oreochromis mossambicus* is tolerant of high salinities as well as high temperatures, and is able to breed independent of the rainy season (Weeks *et al,* 1996). *Barbus viviparus* was the third most abundant species for the site. *Chiloglanis anoterus* was recorded at the site, for what is debatable, as the first time. It is a species that was seriously affected by the drought (Tharme, 1996), and is actually a foothill zone indicator species (Weeks *et al,* 1996). It was found in relatively high abundance (considering it is not supposed to be present, and because it was the fifth most abundant species for the site), but was only located in one of the thirteen habitats sampled. The fact that this was the first time during this project that *C. anoterus* was collected could be attributed to three factors. The first being that this was the first time that channel 4 was sampled, and it is the only place on the transect with such a habitat (habitat 13, a very fast flowing cobble and boulder riffle / rapid). Secondly the temperature ranges were quite significantly different (21°C at 09h55 in habitat 13, and 24°C in channel 2 at 15h45). Although the times that the water temperatures were taken differ considerably, channel 4 is almost totally shaded by the continuous marginal reeds, it is also a narrow channel (about 3m wide) compared to channel 2 which is exposed to the sun, and is considerably wider (about 20m). Thirdly, with the influence of the floods, it was possible that scouring took place, thus exposing the habitat and substrate type that is favoured by *C. anoterus* (rocky riffles and rapids (Skelton, 1993) of the fastest flows (Weeks *et al*, 1996)). It is most likely a combination of all three: sampling a habitat for the first time, cooler water temperatures and the availability of preferred habitat.

Table: 57: Sabie River IFR 5 fish specie and abundances as recorded on the 14/6/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**		
METHOD	Shock 18 min			Shock 9.5 min			Shock 3 min			Small seine net x 1			Shock 7 min			Shock 2.7 min			Shock 11.5 min			Shock 11.2 min		
HABITAT	Shoot / overhang			Run / Overhang			Run			Pool in stream			Run			Run			Shoot			Shoot (riffle)		
SUBSTRATE	Fine sand			Sand			Coarse sand			Coarse sand & detritus			Cobble (& rock)			Sand			Large rocks & sand			Bedrock (& cobble & some root wads)		
TURBIDITY	Clear			Clear			Clear			Coloured			Coloured			Clear			Clear			Clear		
FLOW	Medium			Slow			Fast			Slow			Medium			Medium			Medium			Fast		
DEPTH	20cm			36cm			15cm			40cm			25cm			15cm			35cm			25cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus afrohamiltoni (3)																				2	1			
Barbus marequensis (21)	2			1						9			6						3					
Barbus radiatus (16)	1	2	2			1								1					1	1	7			
Barbus trimaculatus (82)	19			3	8					1	2		11	5	4		1		18	6	4			
Barbus viviparas (176)	25	19	38	15	2	8							7	3	2	1			17	16	23			
Chiloglanis paratus (2)													2											
Chiloglanis swierstrai (4)										1						1			2					
Clarias gariepinus (3)	2			1																				
Labeo cylindricus (24)	2												8		1				11		1		1	
Labeo molybdinus (4)	3												1											
Labeo rosae (2)													1						1					
Marcusenius macrolepidotus (4)	1	1				1																		1
Mesobola brevianalis (1)																				1				
Micralestes acutidens (4)	1																		1		1			1
Opsaridium peringuey (1)									1															
Oreochromis mossambicus (20)				6	2					1									11					
Tilapia rendalli (14)		1			1					11									1					
TOTALS	56	23	40	26	15	10	0	0	1	23	2	0	36	9	7	2	1	0	66	26	37	0	1	2
	10 sp (119)			7 sp (51)			1 species (1)			5 species (25)			8 sp (52)			3 species (3)			12 sp (129)			3 species (3)		
	17 species																							

Table 58: Sabie River IFR 5 fish specie and abundances as recorded on the 4/10/2000. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**		
METHOD	Shock 5 min			Shock 6 min			Shock 12 min			Shock 11 min			Shock 9.5 min			Shock 15.4 min			Shock 8 min		
HABITAT	Pool instream / shoot (dead branches)			Pool instream			Pool instream (root wads & dead branches)			Run			Run & overhang (margin of bank)			Rapid			Rapid		
SUBSTRATE	Sand			Sand & bedrock			Sand & bedrock			Sand			Bedrock & sand			Bedrock			Bedrock & mud		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Coloured			Coloured			Coloured		
FLOW	Slow			Slow			Slow			Medium			Slow			Fast			Medium		
DEPTH	20cm			25 – 30cm			25-40cm			30cm			25cm			10-40cm			15cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus annectens (3)													1						2		
Barbus marequensis (7)																6	1				
Barbus radiatus (7)								1					3	3							
Barbus trimaculatus (20)		4		7			6	1											2		
Barbus viviparas (52)	2		1				14	1					8	3					13	8	2
Chiloglanis swierstrai (15)										7	8										
Clarias gariepinus (4)				4																	
Labeo molybdinus (2)																1			1		
Pseudocrenilabrus philander (1)				1																	
Oreochromis mossambicus (9)	4	1	1	1			2														
Tilapia rendalli (3)					1		1	1						1							
TOTALS	6	5	2	13	1	0	23	4	0	7	8	0	12	7	0	7	1	0	18	8	2
	3 species (13)			5 species (14)			5 species (27)			1 species (15)			4 species (19)			2 species (8)			4 species (28)		
	11 species																				

Table 59: Sabie River IFR 5 fish specie and abundances as recorded for the right hand channels on the 15/05/2001.

HABITAT #	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**10**		
METHOD	Shock 10min			Shock 5.1 min			Shock 10.3 min			Shock 5.3 min			Shock 17.2 min			Shock 6.3 min			Shock 9.3 min			Shock 1.5 min			Shock 8.2 min			Small seine net x 3		
HABITAT	Rapid (marginal reeds)			Pool instream (marginal & over hang reeds)			Rapid			Run			Run & overhang			Run (with root wads & flood debris)			Instream structure			Pool off stream (few root wads)			Run (branches & root wads)			Pool instream (reeds)		
SUBSTRATE	Bedrock (& sand)			Bedrock (& sand)			Bedrock (& coarse gravel & sand)			Sand			Sand / silt			Sand			Cobble & boulder in sand & silt			Sand (& few big boulders)			Bedrock & coarse gravel & silt			Bedrock (mud & silt)		
TURBIDITY	Coloured			Coloured			Coloured			Coloured			Clear			Coloured			Coloured			Coloured			Clear			Turbid		
FLOW	Fast			Medium			Fast			Fast			Slow			Slow			Slow			No			Medium			Medium – slow		
DEPTH	10-30 cm			30-50cm			20-35cm			20cm									30cm			10-30cm						30-70cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus afrohamiltoni													1																	
Barbus marequensis	62			1			16						4			4			14	3					12					
Barbus radiatus															1												1			
Barbus trimaculatus													1	3	3				2	5					1	2		1		2
Barbus viviparas	5	2	1	1									5		1	15	6	1	8		8				3	1	9	2		2
Chiloglanis paratus							4	3	3																					
Chiloglanis swierstrai										11		1																		
Labeo cylindricus		1																												
Labeo molybdinus																									3					
Micralestes acutidens																												1		1
Opsaridium peringuey	10						1																					2		
Oreochromis mossambicus	1			6									15			14	2		19			12			6					
Pseudocrenilabrus philander													6			3			1			5								
Tilapia rendalli				1									2			18			1			2								
	78	3	1	13	0	0	21	3	3	11	0	1	34	3	5	54	8	1	45	8	8	19	0	0	25	3	10	6	0	5
TOTALS	5 spp (82)			4 spp (13)			3 spp (27)			1 spp (12)			8 spp (42)			5 spp (63)			6 spp (61)			3 spp (19)			5 spp (38)			4 spp (11)		
	14 species																													

Table 60: Sabie River IFR 5 fish specie and abundances as recorded for the far left hand channel on 15/05/2001. The total abundances for each of the species, for the whole site are included in () alongside the name of the species.

HABITAT #	**11**			**12**			**13**		
METHOD	Shock 3.1 min			Shock 7.25 min			Shock 20 min		
HABITAT	Run alongside riffle (marginal & overhang reeds)			Run / riffle (& flood debris)			Riffle / rapid (marginal reeds)		
SUBSTRATE	Sand & embedded cobble			Sand (& embedded cobble)			Cobble& boulder (quite embedded) & sand		
TURBIDITY	Coloured			Coloured			Coloured		
FLOW	Fast			Medium			Very fast		
DEPTH	30-50cm			15-30cm			25-50cm		
SPECIES	**J**	**SA**	**A**	**J**	**SA**	**A**	**J**	**SA**	**A**
Barbus afrohamiltoni (1)									
Barbus marequensis (121)				1			4		
Barbus radiatus (2)									
Barbus trimaculatus (21)						1			
Barbus unitaeniatus (1)		1							
Barbus viviparus (70)									
Chiloglanis anoterus (41)							5	21	15
Chiloglanis paratus (52)				1	1	2	11	13	14
Chiloglanis swierstrai (12)									
Clarias gariepinus (1)				1					
Labeo cylindricus (2)							1		
Labeo molybdinus (7)							1	3	
Micralestes acutidens (2)									
Opsaridium peringuey (13)									
Oreochromis mossambicus (75)									
Pseudocrenilabrus philander (15)									
Tilapia rendalli (24)									
TOTALS	1 species			4 species			5 species		
	+ 3 additional species to site as a whole								

6.4 AQUATIC INVERTEBRATES

More recent research indicates that some riverine invertebrates may have narrower tolerances (particularly different life stages) to flow changes than do many fish species (Weeks *et al.*, 1996). Aquatic invertebrates are rarely considered as an integral part of habitat management. If a flow is reduced permanently, with probable periods of no-flow during drought, the result would be the disappearance of many species, particularly mayflies, caddisflies and simulid flies (O'Keeffe *et al.*, 1996). In the situation where by the system is reduced in terms of its flow, riffle species that require flowing water over and between cobbles will be vulnerable to reduced or no-flow. The invertebrates of the marginal habitats will also be affected as the water's edge recedes from the vegetated river margins.

The nature and diversity of organisms in the system is determined by the habitat diversity that is determined by the stream flow. O'Keeffe *et al.* (1989b) indicated that a reduction in relative to the natural flow regime can result in reduction in habitat diversity, the appearance of pest species, desynchronisation of life cycles and, ultimately, elimination of part of the natural biota of the system. The consequence of biological modification, which occurs after dam closure, is an increase in the density of the fauna downstream from the dam (Palmer & O'Keeffe, 1990).

During the baseline monitoring of the six selected IFR sites of the two rivers (*i.e.* two sites in the Luvuvhu River and four sites in the Sabie River) invertebrates sampled were recorded per site. Each site was visited four to five times, excluding training period. Table 61 shows invertebrate taxa recorded at the site in either site visit, and also the total number of the taxa/family recorded during four or five baseline monitoring periods of the site. No IFR site-specific invertebrates historic records were found during baseline monitoring. Only general (not IFR site-specific) historic record was available (Palmer & O'Keeffe, 1994). The strong rheophilic components, such as simulidae and trichorythid mayfly larvae (Palmer & O'Keeffe, 1994) were found in the fauna of Luvuvhu and Sabie Rivers. Trichorythid mayfly larvae were absent in of each river. The two sites in both rivers are outside Kruger National Park, this might be the reason of Trichorythid mayfly larvae to be absent because It is a flow dependent species, but sensitive to pollution with the SASS score of 9. The two sites are IFR1 (Botsoleni) in the Luvuvhu River and IFR 1 (Marite) in the Sabie River. At Botsoleni site, there is removal of riparian vegetation and a Banana farm just near the riverbank, while near the right hand bank of Marite site (IFR1) there is a citrus farm that might have an impact in the river systems. According to the results obtained during the baseline monitoring, the taxon/ family, such as Prosopistomatidae occurs at Marite River (Sabie IFR 1) only, which is the tributary of Sabie River. There are some taxa found exclusively in one of the rivers. This does not really conclude that they are not found in other river. Taxa which were exclusivel to the Luvuvhu River are Zygoptera juveniles (Odonata), Melaniidae (Gastropoda) and Ancylidae (Gastropoda), and those which were exclusive to the Sabie River are Prosopistomatidae (Ephemeroptera), Calopterygidae (Odonata), Philopotamidae (Trichoptera), Haliplidae), Psephenidae (Coleoptera), Dixidae(Diptera) and Muscidae (Diptera).

Table 61 : Invertebrates recorded from the six monitored IFR sites of the two river systems (Luvuvhu and Sabie Rivers). The √ indicate the taxon recorded during baseline monitoring at the monitored IFR sites.

TAXON/ FAMILY	LUVUVHU RIVER		SABIE RIVER			
	IFR 1 (Botsoleni)	IFR 2 (Shidzivane)	IFR 1 (Marite)	IFR 2 (Bridge)	IFR 4 (Warden)	IFR 5 (N'watimhiri)
Turbellaria Planaria		√	√	√	√	√
Annelida Oligochaeta	√	√	√	√	√	√
Hirudinea	√	√			√	
Crustacea Crabs	√	√	√	√	√	√
Shrimps	√	√			√	√
Hydracarina Hydrachnellae	√	√	√	√		√
Plecoptera Perlidae	√	√	√	√	√	√
Ephemeroptera Baetidae >2 spp	√	√	√	√	√	√
Oligoneuridae		√	√		√	√
Heptageniidae	√	√	√	√	√	√
Leptophlebiidae	√	√		√	√	√
Tricorythidae		√		√	√	√
Prosopistomatidae			√			
Caenidae	√	√	√	√	√	√
Odonata Coenagriidae	√	√	√	√	√	√
Calopterygidae						√
Chlorocyphidae	√	√	√	√	√	√
Zygoptera juveniles		√				
Gomphidae	√	√	√	√	√	√
Aeshnidae	√				√	
Corduliidae	√	√		√	√	√
Libellulidae	√	√	√	√	√	√
Hemiptera Notonectidae	√	√	√	√	√	√
Pleidae	√	√			√	
Naucoridae	√	√	√	√	√	√
Nepidae	√	√			√	
Belostomatidae		√			√	√
Corixidae	√	√	√	√	√	√
Gerridae	√	√	√		√	√
Veliidae	√	√	√	√	√	√
Trichoptera Hydropsychidae 1 spp						√
2 spp	√		√		√	
>2 spp		√		√		
Philopotamidae					√	

Hydroptilidae	√			√		√
Case larvae 2 spp	√	√		√		
>2 spp			√		√	√
Coleoptera Dytiscidae	√	√	√	√	√	√
Elmidae/ Dryopidae	√	√	√	√	√	√
Gyrinidae	√	√	√	√	√	√
Haliplidae					√	
Hydrophilidae		√			√	
Psephenidae				√		
Diptera Tipulidae	√	√	√		√	
Culicidae	√	√	√	√	√	√
Dixidae					√	
Simuliidae	√	√	√	√	√	√
Chironomidae	√	√	√	√	√	√
Ceratopogonidae	√	√	√	√	√	√
Tabanidae	√	√	√	√	√	√
Athericidae	√	√	√	√	√	
Muscidae				√		
Gastropoda Lymnaeidae	√	√			√	
Melaniidae	√	√				
Planorbidae	√	√			√	
Ancylidae	√					
Pelecypoda Sphaeridae	√	√			√	
TOTAL # OF TAXA	**41**	**44**	**31**	**34**	**45**	**35**

6.4.1 IFR Site 1 Luvuvhu River

Table 62: Invertebrates recorded from the IFR 1 (Botsoleni) in the Luvuvhu River during four different site visits. The tick (√) indicates the taxon/family recorded.

Taxon/Family	**Site visit number and date**			
	1 (22/09/99)	**2 (07/08/00)**	**3 (15/11/00)**	**4 (29/05/01)**
Annelida Oligochaeta	√	√	√	√
Hirudinea	√			
Crustacea Crabs	√	√	√	√
Shrimps	√			√
Hydracarina Hydrachnellae	√			
Plecoptera Perlidae	√	√	√	√
Ephemeroptera Baetidae >2 spp	√	√	√	√
Oligoneuridae				√

Heptageniidae	√	√	√	√
Leptophlebiidae	√	√	√	√
Tricorythidae				√
Caenidae	√	√	√	√
Odonata Coenagriidae	√		√	√
Chlorocyphidae	√			√
Gomphidae	√	√		√
Aeshnidae	√			
Corduliidae	√			√
Libellulidae		√	√	√
Hemiptera Notonectidae	√	√	√	√
Pleidae	√			√
Naucoridae	√	√	√	√
Nepidae	√			√
Corixidae	√	√	√	√
Gerridae	√	√		
Veliidae	√	√	√	√
Trichoptera Hydropsychidae 2 spp	√			√
>2 spp		√	√	
Philopotamidae				
Hydroptilidae		√		√
Case larvae 1 spp		√		
2 spp	√		√	√
Coleoptera Dytiscidae	√	√	√	√
Elmidae/ Dryopidae	√	√	√	√
Gyrinidae	√	√	√	√
Diptera Tipulidae	√			√
Culicidae		√	√	√
Simuliidae	√	√	√	√
Chironomidae	√	√	√	√
Ceratopogonidae	√	√	√	√
Tabanidae	√	√	√	√
Athericidae	√			
Gastropoda Lymnaeidae	√			
Melaniidae	√			
Planorbidae	√			
Ancylidae	√			√
Pelecypoda Sphaeridae	√			√
TOTAL # OF TAXA	**38**	**25**	**23**	**35**

Table 62 shows invertebrate taxa recorded, site visit date and the total number of taxa/families recorded per site visit. Table 63 refers to the overall SASS scores obtained when monitoring at the new site on the Luvuvhu River. The previous IFR 1 site on the

Luvuvhu was lost with the forming of the Nandoni Dam. It is for this reason that there are no values for the refined IFR column. The no records of flows for two months in the average daily flow column is as a result of the floods and the new weir breaking again. The drop in the SASS score from September 1999 to August 2000 can be attributed to the very high flows that took place in February 2000. However the SASS score is still classified as excellent, and the average score per a taxon (ASPT) is still classified as good (Thirion *et al*, 1995).

Table 63: Luvuvhu River IFR site 1 (Botsoleni) SASS scores, number of taxa and average score per a taxon. The average daily flow is the daily flow record obtained from DWAF or a gauging weir. The refined IFR refers to the recommended flow for that month.

DATE	AV. DAILY FLOW	REFINED IFR (Louw, 1996)	SASS SCORE	# OF TAXA	AV. SCORE / TAXON	AIR BREATHERS SCORE	# AIR BREATHERS	# OF BIOTOPES
22 Sep '99	2.5 $m^3 s^{-1}$	Unknown	234	38	6.2	52	13	6
7 Aug '00	NR	Unknown	152	25	6.1	31	7	5
15 Nov '00	NR	Unknown	146	23	6.3	28	6	4
29 May '01	NR	Unknown	223	35	6.4	44	10	6

6.4.2 IFR Site 2 (Shidzivane) Luvuvhu River

Table 64: Invertebrates recorded from the IFR 2 (Shidzivane) in the Luvuvhu River during four different site visits. The tick (√) indicates the taxon/family recorded.

Taxon/Family	Site visit number and date			
	1 (18/10/99)	2 (24/10/00)	3 (29/03/01)	4 (30/05/01)
Turbellaria Planaria	√	√		√
Annelida Oligochaeta	√		√	√
Hirudinea			√	
Crustacea Crabs		√		
Shrimps	√	√	√	√
Hydracarina Hydrachnellae	√			
Plecoptera Perlidae	√		√	√
Ephemeroptera Baetidae > 2 spp	√	√	√	√
Oligoneuridae			√	√
Heptageniidae	√	√	√	√
Leptophlebiidae		√		√
Tricorythidae			√	√
Caenidae	√	√	√	√
Odonata				

Coenagriidae		√	√	√
Chlorocyphidae			√	√
Zygoptera juveniles				√
Gomphidae	√	√	√	√
Corduliidae	√	√		
Libellulidae		√	√	√
Hemiptera Notonectidae	√	√	√	√
Pleidae			√	√
Naucoridae	√	√	√	√
Nepidae		√		√
Belostomatidae			√	√
Corixidae	√	√	√	√
Gerridae		√	√	√
Veliidae	√	√	√	√
Trichoptera Hydropsychidae 1 spp				√
2 spp	√	√	√	
Case larvae 1 spp		√		
2 spp	√			√
>2 spp			√	
Coleoptera Dytiscidae	√	√		√
Elmidae/ Dryopidae	√	√	√	√
Gyrinidae	√	√	√	√
Haliplidae				
Hydrophilidae			√	
Diptera Tipulidae		√		√
Culicidae		√	√	√
Dixidae				
Simuliidae	√	√		√
Chironomidae	√	√	√	√
Ceratopogonidae		√		
Tabanidae	√			√
Athericidae	√			√
Gastropoda Lymnaeidae	√			
Melaniidae	√			
Planorbidae	√			
Pelecypoda Sphaeridae	√			
TOTAL # OF TAXA	**27**	**27**	**27**	**34**

Similarly in table 64 there were no daily flows available when the gauging weir was damaged or washed away. The refined IFR magnitudes refer to the maintenance base flows (the first figure given) to the recommended high flow magnitudes applicable for that month. The high flows are usually for about two days depending on the objectives. Refer to Louw, 1996 for more details regarding the flows. The slight dip in the SASS scores between October 1999 and October 2000, can once again be attributed to the very high flows that took place in between the two visits to the site. In fact it was not possible to gain access to the site during that year. Never the less the SASS scores were consistently over 140 which is classified as excellent, and the ASPT was consistently good (Thirion *et al*, 1995). In the first, second and third site visits 27 invertebrates taxa/families were recorded. This might be due to the high flows caused by 1999/2000 floods.

Table 65: Luvuvhu River IFR site 2 (Shidzivane) SASS scores, number of taxa and average score per a taxon.

DATE	AV. DAILY FLOW	REFINED IFR (Louw, 1996)	SASS SCORE	# OF TAXA	AV. SCORE / TAXON	AIR BREATHERS SCORE	# AIR BREATHERS	# OF BIOTOPES
18 Oct '99	1.71 $m^3 s^{-1}$	0.2 - 0.46 $m^3 s^{-1}$	174	27	6.2	42	10	3
24 Oct '00	NR	0.2 - 0.46 $m^3 s^{-1}$	151	27	5.6	39	9	5
29 Mar '01	NR	0.5 – 0.95 $m^3 s^{-1}$	177	27	6.5	43	9	7
30 May '01	NR	0.33 $m^3 s^{-1}$	222	34	6.5	46	11	5

6.4.3 IFR Site 1 Marite River

Table 66: Invertebrates recorded from the IFR 1 (Marite) in the Sabie River during four different site visits. The tick (√) indicates the taxon/family recorded.

Taxon/Family	Site visit number and date			
	1 (30/09/99)	2 (22/08/00)	3 (13/11/00)	4 (10/04/01)
Turbellaria Planaria	√			
Annelida Oligochaeta				√
Crustacea Crabs			√	√
Hydracarina Hydrachnellae		√		
Plecoptera Perlidae		√	√	√
Ephemeroptera Baetidae 2 spp	√			√
>2 spp		√	√	
Oligoneuridae				√
Heptageniidae			√	√
Leptophlebiidae			√	
Prosopistomatidae	√			
Caenidae	√		√	√
Odonata Coenagriidae			√	

Chlorocyphidae			√	√
Gomphidae	√		√	√
Libellulidae	√	√	√	√
Hemiptera Notonectidae		√		√
Naucoridae		√	√	√
Corixidae				√
Gerridae	√	√		√
Veliidae		√	√	√
Trichoptera Hydropsychidae 1 spp				√
2 spp		√	√	
>2 spp				
Case larvae 1 spp			√	
2 spp		√		√
>2 spp	√			
Coleoptera Dytiscidae			√	√
Elmidae/ Dryopidae	√		√	√
Gyrinidae	√	√	√	√
Diptera Tipulidae	√			
Culicidae		√		√
Simuliidae	√	√	√	√
Chironomidae	√	√	√	√
Ceratopogonidae		√		
Tabanidae	√	√		√
Athericidae	√	√		
TOTAL # OF TAXA	**15**	**17**	**19**	**24**

The Marite River a tributary of the Sabie River and the river, in which the Injaka Dam has been built, is the only river with a full set of daily flow rates available. Once again a drop in the SASS score is noted after the February 2000 flood (table 66). The SASS score of 83 falls within the 'fair' classification, and the ASPT of 4.6 also drops to a 'fair' classification (Thirion et al, 1995). At all stages the daily flow magnitudes were above the recommended base flows sometimes quite considerably as noted in November 2000 and April 2001. The SASS scores after the February floods show indicate an improvement as the flows return to 'normal'. There is a consistent improvement in the number of taxa recorded. The August 2000, November 2000 and April 2001 can attribute this to the re-colonisation of the invertebrates into the different biotopes in the river after the floods. However this does not account for the SASS score and number of taxa (table 67) being lower prior to the floods, although still considered good and excellent respectively.

Table 67 : Marite River (Sabie River tributary) IFR site 1 SASS scores, number of taxa and average score per a taxon.

DATE	AV. DAILY FLOW	REFINED IFR (Tharme, 1996)	SASS SCORE	# OF TAXA	AV. SCORE / TAXON	AIR BREATHERS SCORE	# AIR BREATHERS	# OF BIOTOPES
30 Sep '99	0.94 $m^3 s^{-1}$	0.8 $m^3 s^{-1}$	110	15	7.3	10	2	2
22 Aug '00	1.73 $m^3 s^{-1}$	1.0 $m^3 s^{-1}$	113	17	6.6	25	5	6
13 Nov '00	2.02 $m^3 s^{-1}$	1.1 – 3.0 – 8.0 $m^3 s^{-1}$	131	19	6.8	22	4	3
10 Apr '01	3.59 $m^3 s^{-1}$	2.0 $m^3 s^{-1}$	146	24	6.1	44	9	5

6.4.4 IFR Site 2 Sabie River

Table 68: Invertebrates recorded from the IFR 2 (Bridge) in the Sabie River during four different site visits. The tick (√) indicates the taxon/family recorded.

Taxon/Family	Site visit number and date			
	1 (30/09/99)	2 (23/08/00)	3 (14/11/00)	4 (09/04/01)
Turbellaria Planaria			√	
Annelida Oligochaeta	√	√	√	√
Crustacea Crabs	√			
Hydracarina Hydrachnellae		√		
Plecoptera Perlidae	√			
Ephemeroptera Baetidae 2 spp		√		
>2 spp	√		√	√
Heptageniidae		√		√
Leptophlebiidae			√	√
Tricorythidae	√			
Caenidae	√	√	√	√
Odonata Coenagriidae			√	√
Chlorocyphidae	√		√	
Gomphidae	√	√	√	√
Corduliidae				√
Libellulidae	√	√	√	
Hemiptera Notonectidae			√	√
Naucoridae	√		√	√
Corixidae		√	√	√
Veliidae			√	√

Trichoptera Hydropsychidae 2 spp			√	
>2 spp	√			
Hydroptilidae		√		
Case larvae 1 spp	√			
2 spp		√	√	√
Coleoptera Dytiscidae			√	√
Elmidae/ Dryopidae	√	√	√	√
Gyrinidae	√	√	√	
Psephenidae		√		
Diptera Tipulidae	√			
Culicidae		√		√
Dixidae				
Simuliidae	√	√	√	
Chironomidae	√	√	√	√
Ceratopogonidae	√	√		√
Tabanidae	√			
Athericidae			√	
Muscidae	√	√		
TOTAL # OF TAXA	**20**	**18**	**21**	**18**

In table 68, the SASS scores fluctuate. As with previous sites the decrease after the floods is predictable, and is still classified as a good quality of water. The increase in the SASS score in November 2000 is a bit surprising, because the average daily flow is so high (four times the base flow and almost three times the required high flow for that month) it would be expected that the invertebrates might have been flushed down stream. This site is a heavily damaged site not only post floods but also prior to the February 2000 high flows. It falls within the old trust land, where most of the riparian vegetation has been removed. Not only is there a high bridge at the site, but also a low level causeway, which was re-constructed after the floods. The main 'high level' bridge was being worked on at the time of the April 2001 visit. There was considerable activity by large earth moving equipment in and around the river. These activities probably account for a decrease in the April 2001 SASS score. The decrease in both SASS score and number of taxa/families (table 69) might due to the drastically change in flow from 4.37m^{3}s-1 in September 1999 to 11.8m^{3}s-1 in August 2000.

Table 69: Sabie River IFR site 2 (Bridge) SASS scores, number of taxa and average score per a taxon.

DATE	AV. DAILY FLOW	REFINED IFR (Tharme, 1996)	SASS SCORE	# OF TAXA	AV. SCORE / TAXON	AIR BREATHERS SCORE	# AIR BREATHERS	# OF BIOTOPES
30 Sep '99	4.37 $m^3 s^{-1}$	2.3 $m^3 s^{-1}$	126	20	6.3	15	3	1
23 Aug '00	11.8 $m^3 s^{-1}$	2.6 $m^3 s^{-1}$	102	18	5.7	8	2	4
14 Nov '00	16.8 $m^3 s^{-1}$	3.0 – 6.0 $m^3 s^{-1}$	138	21	6.6	28	6	4

9 Apr '01	NR	5.0 – 8.0 $m^3 s^{-1}$	114	18	6.3	23	5	4

6.4.5 IFR Site 4 Sabie River

Table 70: Invertebrates recorded from the IFR 4 (Warden) in the Sabie River during four different site visits. The tick (√) indicates the taxon/family recorded.

Taxon/Family	Site visit number and date				
	1 (27/9/99)	**2 (12/16/00)**	**3 (2/10/00)**	**4 (30/11/00)**	**5 (14/5/01)**
Turbellaria Planaria	√		√		
Annelida Oligochaeta	√		√	√	√
Hirudinea	√				
Crustacea Crabs		√			
Shrimps	√				√
Hydracarina Hydrachnellae	√				√
Plecoptera Perlidae	√		√	√	√
Ephemeroptera Baetidae 2 spp	√				
>2 spp		√	√	√	√
Oligoneuridae				√	
Heptageniidae	√	√	√	√	√
Leptophlebiidae	√	√	√	√	√
Tricorythidae	√	√			√
Caenidae	√	√	√	√	√
Odonata Coenagriidae	√	√	√		
Chlorocyphidae	√	√		√	√
Gomphidae	√	√	√	√	√
Corduliidae		√	√		√
Libellulidae	√		√	√	√
Hemiptera Notonectidae	√		√		
Pleidae				√	
Naucoridae	√	√	√	√	√
Nepidae	√				
Belostomatidae	√		√		
Corixidae	√		√		√
Veliidae	√	√	√	√	√
Gerridae	√			√	
Trichoptera Hydropsychidae 1 spp			√		
2 spp				√	

Hydroptilidae					
Philopotamidae	√	√		√	√
Case larvae 2 spp			√	√	√
> 2 spp	√	√			
Coleoptera Dytiscidae	√		√		
Elmidae/ Dryopidae	√	√	√	√	√
Gyrinidae			√		√
Hydrophilidae	√				
Haliplidae					√
Psephenidae					
Diptera Tipulidae	√			√	
Culicidae	√		√		
Dixidae	√				
Simuliidae	√	√	√	√	√
Chironomidae	√	√	√	√	√
Ceratopogonidae	√	√	√	√	√
Tabanidae	√	√	√	√	√
Athericidae	√		√		
Muscidae					
Gastropoda Lymnaeidae	√				
Planorbidae	√				
Pelecypoda Sphaeridae	√				
TOTAL # OF TAXA	**38**	**18**	**27**	**23**	**26**

The SASS score was 250 with 38 taxa/ families in September 1999 before the flood (table 71). In June 2000 the average daily flow was so high ($22.3m^3s^{-1}$) resulting into decrease in both SASS score and number of taxa/families. There was an increase in SASS score (by 31) and taxa/families (by 9) from June 2000 to October 2000 while there was a decrease in average daily flow (by $11.9m^3s^{-1}$.

Table 71: Sabie River IFR site 4 (Skukuza / Warden) SASS scores, number of taxa and average score per a taxon.

DATE	AV. DAILY FLOW	REFINED IFR (Tharme, 1996)	SASS SCORE	# OF TAXA	AV. SCORE / TAXON	AIR BREATHERS SCORE	# AIR BREATHERS	# OF BIOTOPES
27 Sep '99	$4.46\ m^3\ s^{-1}$	$3.4\ m^3\ s^{-1}$	250	38	6.6	45	11	4
12 Jun '00	$22.3\ m^3\ s^{-1}$	$5.2\ m^3\ s^{-1}$	139	18	7.7	11	3	5
2 Oct '00	$10.4\ m^3\ s^{-1}$	$3.0 – 6.0\ m^3\ s^{-1}$	170	27	6.3	31	7	6
30 Nov '00	$20.3\ m^3\ s^{-1}$	$4.0 – 8.0\ m^3\ s^{-1}$	171	23	7.4	29	5	3
14 May '01	NR	$6.0\ m^3\ s^{-1}$	186	26	7.2	25	5	7

6.4.6 IFR Site 5 (N'watimhiri) Sabie River

Table 72: Invertebrates recorded from the IFR 5 (N'watimhiri) in the Sabie River during four different site visits. The tick (√) indicates the taxon/family recorded.

Taxon/Family	**Site visit number and date**			
	1 (14/06/00)	**2 (04/10/00)**	**3 (29/11/00)**	**4 (15/05/01)**
Turbellaria Planaria	√			
Annelida Oligochaeta		√	√	√
Crustacea Crabs		√	√	√
Shrimps	√	√		√
Hydracarina Hydrachnellae				√
Plecoptera Perlidae				√
Ephemeroptera Baetidae >2 spp	√	√	√	√
Oligoneuridae				√
Heptageniidae	√	√	√	√
Leptophlebiidae	√	√	√	√
Tricorythidae				√
Caenidae	√	√	√	√
Odonata Coenagriidae	√	√	√	√
Chlorocyphidae	√			√
Gomphidae	√	√	√	√
Corduliidae		√		
Libellulidae	√	√	√	√
Hemiptera Notonectidae		√		√
Naucoridae	√	√	√	√
Nepidae				√
Belostomatidae		√	√	√
Corixidae		√		√
Gerridae	√			√
Veliidae		√	√	√
Trichoptera Hydropsychidae 1 spp	√	√	√	√
Hydroptilidae				√
Case larvae 1 spp	√			
2 spp		√		√
>2 spp			√	
Coleoptera Dytiscidae		√		
Elmidae/ Dryopidae			√	√
Gyrinidae		√		√

Diptera Tipulidae	√			
Culicidae		√		√
Simuliidae		√	√	√
Chironomidae	√	√	√	√
Ceratopogonidae	√	√	√	
Tabanidae	√	√	√	√
TOTAL # OF TAXA	**18**	**25**	**19**	**31**

In all four of the site visits, the SASS score shows good water quality. The increase in number of taxa/family in October 2000 than in June 2000 It might be an indication of re-colonisation of the invertebrates into the different biotopes in the river after the floods. In November 2000 there was a decrease in both SASS score and number of taxa/families, this might be due to the increase in average daily flow as compared to the IFR 4 during the same month.

Table 73: Sabie River IFR site 5 (N'watimhiri) SASS scores, number of taxa and average score per a taxon.

DATE	AV. DAILY FLOW	REFINED IFR (Tharme, 1996)	SASS SCORE	# OF TAXA	AV. SCORE / TAXON	AIR BREATHERS SCORE	# AIR BREATHERS	# OF BIOTOPES
14 Jun '00	NR	6.0 $m^3 s^{-1}$	124	18	6.9	12	2	6
4 Oct '00	12.7 $m^3 s^{-1}$	4.0 – 20.0 $m^3 s^{-1}$	143	25	5.72	34	8	9
29 Nov '00	NR	8.0 $m^3 s^{-1}$	123	19	6.5	18	4	4
15 May '01	NR	8.0 $m^3 s^{-1}$	201	31	6.5	37	9	7

7. DEVELOPING AN INVERTEBRATE IFR SCORING SYSTEM

7.1 OBJECTIVES OF AN IFR MACRO INVERTEBRATE SCORING SYSTEM

- The purpose of this document is to provide a straw dog that can form the basis for discussion and further development by invertebrate specialists around the country.
- Assess the results obtained from monitoring.
- Refer to some available literature.
- Assign scores to the invertebrates, which reflect their preference to different flow velocities.

7.2 THE PROCESS APPLIED TO ALLOCATING SCORES

- During monitoring, the biotopes of different substrates and velocities were separated as far as possible.
- Summarise the information obtained into tables reflecting the percentage of occurrence, habitat / biotope preferences and flow preferences.
- Refer to immediately available literature.
- Establish a rating system. Used a scoring system of 1-15, where 1 is non-flow sensitive and 15 is flow sensitive. The range was roughly allocated as such: very fast only = 15, Fast = 10-14; Medium = 7-9; Slow = 3-6; No flow = 1-2.
- Allocate preliminary scores to the taxa encountered while monitoring, *i.e.* not all the taxa on the SASS data sheet.

7.3 ALLOCATION OF SCORES TO THE TAXA

Tables 75 & 76 show the preferences of habitat and flow respectively amongst the macro invertebrate communities. The taxa listed are only those that were caught and this information is that which was collected at all six sites on the three rivers. In table 75 the mix column refers to sampling that was done when the biotopes were not sampled independently, this took place in the early stages when the project was just started and the training was still taking place and specific objectives pertaining to the sampling had not been clarified. Similarly in the table depicting the flow preferences the column listed as unknown refers to the early stages of the project when the biotopes were not being properly separated and also prior to the researchers being in possession of a current meter. Table 74 summarises the classification of different velocity flows into very fast, fast, medium, slow and no flow. Due to the monitoring and sampling having taken place over a two-year period of generally very high flows, the category of very fast was included. However it is suspected that it is not likely that there will always be this category present in drier or average years of rainfall. Most of the time it is not possible to actually sample in the very fast flowing biotope. Attempts were made to measure the flow as close to the substrate as possible as this is where the invertebrates are generally located. These figures of invertebrate flow preference only give a rough indication of the invertebrate's preferences because frequently they inhabit the micro habitats for example little eddies of no flow or areas of protection that are found in the main, fast flowing stream, but those conditions are not easy to record or monitor. It will be noted that the biotope types have been separated quite considerably more than for example when doing SASS monitoring. This was done to see if there is biotope preference by specific taxa, however it may not be necessary to separate to such a degree when proper monitoring is implemented.

It was decided that it was more practical to have a flow category, so the velocity of a range of flows were measured and then the readings were assigned to a category. The velocity was measured in revolutions per time (40 – 60 seconds), the reading was then converted to feet per second as the velocity meter was non metric and then converted to meters per second (m/s or m s^{-1}). Table 74 illustrates the ranges allocated to a visual category.

Table 74: Classifying actual water velocities (m/s) into five categories.

CATEGORY	VELOCITY RANGE FOR THE CATEGORY
VERY FAST	> 4.1 m/s
FAST	0.46 m/s to 4.0 m/s
MEDIUM	0.16 m/s to 0.45m/s
SLOW	0.06 m/s to 0.15 m/s
NO FLOW	< 0.05 m/s

But the HAM habitat score-sheet uses a much broader classification i.e.
Slow = < 0.3 m/s and fast = > 0.3 m/s.]

The preliminary scores assigned to the taxa encountered while monitoring, refer to appendix for an example of proposed data sheet:

- **Planarians**: Were never found to be in great abundance during the survey, but did reach a B in the abundance rating in a fast riffle biotope. The few that were collected showed a preference for a vegetated habitat in medium flow conditions. Thirion *et al*, 1995 states that Planarians prefer well oxygenated water (i.e. where water is flowing). Weeks *et al*, 1996 found them to be most abundant in riffle biotopes, and Pollard *et al,* 1996 found them to prefer vegetated biotopes. **7**

- **Oligochaeta**: Although collected fairly frequently, only once received an abundance rating higher than A, a C in a slow flowing vegetated biotope. Generally the vegetation biotope was preferred, as was the slow flow velocity, although found in most of the flow categories. Thirion *et al*, 1995 mentions they prefer stagnant mud pools, Pollard *et al*, 1996 found them predominantly in vegetation, as did Weeks *et al*, 1996. **3**

- **Hirudinea**: Were collected infrequently, but when in the sample they were found to prefer the sand biotope but equally preferred both the slow and medium velocities. They were mainly found to have an A or 1 abundance rating. Weeks *et al*, 1996 found them to be predominant in the vegetation biotope, Pollard *et al,* 1996 found them to be predominant in the bedrock gullies and vegetation biotopes although also found in riffles. **6**

- **Crabs:** Crabs are not easily caught with the SASS kicking method, so their abundance in the trays was never rated higher than an A (although when shocking many more were caught). Crabs were found to be dominant in the slow flowing vegetation or stones out of current biotopes. Weeks *et al,* 1996 found the *Potomonautes* genus mainly in riffles. **6**

- **Shrimps:** Were found to prefer slow flow habitats, although found in medium and fast flows as well, and preferred vegetated biotopes. They were found to have abundance ratings of B in slow vegetated biotopes quite frequently and even a D in the same biotope. Thirion *et al*, 1995 states that they are mainly located in the overhanging streams. **5**

- **Hydrachnelle:** Were seldom abundant (only A or 1 ratings) and were noted to prefer medium flow velocity, although also recorded in very fast and fast flows. They preferred the vegetated biotope. Thirion *et al*, 1995 states that they occur mainly in slow flowing vegetation biotopes, but also in faster flow areas as well. Weeks *et al*, 1996 located *Hydrachnelle* mainly in the riffle biotope. **9**

- **Perlidae**: Occurred mainly in the fast flow habitat, and preferred the stones in current biotope. They were found to have an abundance rating of B quite frequently in stones in current fast flow habitat, and also received a C in the fast flowing riffle as well. Thirion *et al*, 1995 states that they like warm, sluggish turbid rivers, while Weeks *et al*, 1996 found them in riffles the majority of the time. **13**

- **Baetidae**: While the *Baetidae* groups of 1sp, 2sp and > 2sp were separated in the table they will be addressed together here. They were found to be dominant in the slow, fast, and slow flows (respectively), and prefer the stones in current, stones in current and vegetation biotopes (also respectively). The abundance ratings ranged from A to F. Thirion *et al*, 1995 mentions that they are the most common mayflies generally preferring gently flowing water. **1sp = 4; 2sp = 5; > 2sp = 7**

- **Oligoneuridae:** Preferred fast flowing stones in current biotopes. They generally received an abundance rating of A or B. Thirion *et al*, 1995 states that they occur in riffles of swift flowing streams. Weeks *et al*, 1996 found them mainly in riffles. **13**

- **Heptageniidae:** Were quite frequently found to have an abundance rating of C in slow vegetation habitats. They preferred the slow flowing vegetation biotopes. Weeks *et al*, 1996 found the *Heptageniid* species in great abundances in both the vegetation and riffle biotopes, with vegetation being the predominant only marginally. **6**

- **Leptophlebiidae**: Were only marginally more dominant in the slow flow habitat (above the fast flow), and preferred the stones in current biotope. They received abundance ratings of D in both the fast stones in current, and the stones out of current – slow biotopes. But mainly received A or B ratings. Weeks *et al*, 1996 found that generally the different species of *Leptophlebiidae* were located in the riffles, but not only, and species had their different preferences. **7**

- **Tricorythidae:** Liked the fast flow habitat and were located mainly in the stones in current biotope. Their abundance rating was normally an A or B, but occasionally received a C or D in the stones in current fast flow habitat. Thirion *et al*, 1995 states that they inhabit assorted substrates in swift currents. **12**

- **Prosospistomatidae**: Was seldom collected, and when it was it was found to prefer medium flow, stones in current. However this is not sufficient enough information to allocate a reliable score. Thirion *et al*, 1995 states they inhabit swift currents, and Weeks *et al*, 1996 located the species in riffles. Apparently they are not found in the southern and western Cape (Thirion *et al*, 1995). **13**

- **Caenidae**: Were one of the most frequently sampled taxa, and were found to prefer the slow flow velocity and the vegetation biotope. They received mainly C or B abundance ratings in an assortment of biotopes. They prefer slow flowing water and mud / debris type biotopes (Thirion *et al*, 1995). Soft sediment and vegetation were found to be the preferred biotopes of the *Caenidae* species (Weeks *et al*, 1996). **6**

- **Coenagriidae:** The slow flowing vegetation habitats were preferred. The abundance rating received ranged from A – C, with B being the most common. Thirion *et al*, 1995 notes that they occur mainly in vegetated areas where there is a flow. Weeks *et al,* 1996 recorded that they are most dominant in the vegetation biotope. **5**

- **Calopterygidae:** Were found to prefer the fast and slow habitats equally, but preferred the vegetation biotope. They never received an abundance rating over A. Weeks et al, 1996 found them to prefer vegetation. **7**

- **Chlorocyphidae**: Preferred the fast and slow flows equally, but vegetation was preferred marginally to the stones in current. Their abundance rating was mainly an A or 1, but occasionally received a B in the stones out of current and slow flow habitat. **7**

- **Gomphidae:** This was one of the most frequently encountered taxa, and was noted to prefer slow flow and soft sediments (mainly sand). The majority of the time this taxa received an A or B abundance rating, but on occasion the rating reached D for fast flow stones in current or slow sand (two extremes, showing that this taxa is not flow specific). Weeks *et al,* 1996 and Thirion *et al*, 1995 both note that the soft sediments are preferred, with Thirion *et al*, 1995 adding that the slower reaches are preferable. **6**

- **Aeshnidae:** Was mainly found in the mix or unknown biotopes, but slow flow amongst vegetation showed up as the dominant choice. However Weeks *et al,* 1996 found it to occur in stones in current with by far the greatest abundance. **4**

- **Corduliidae**: Slow flow vegetation was the preferred choice with backwater and stones in current also frequently chosen. The abundance rating was mainly an A. Thirion *et al,* 1995 and Weeks *et al*, 1996 found the soft sediments and stones in current or debris the preferred biotopes. **7**

- **Libellulidae**: is clearly not a habitat or flow specialist. This project found medium flow vegetation was preferred, but only marginally over stones in current. While Weeks *et al*, 1996 noted that stones in current biotopes was preferred over vegetation, and Thirion *et al*, 1995 stated that vegetation and debris were the usual choices. **9**

- **Notonectidae**: Were mainly recorded as an A or B abundance rating, occasionally reaching D in assorted biotopes. Slow vegetation was preferred with stones out of current also frequently inhabited. Thirion *et al,* 1995 notes that standing or slow flow water is preferred, Weeks *et al*, 1996 recorded vegetation as the most prominently used biotope. **4**

- **Pleidae:** Preferred slow flow vegetation, biotopes where an A abundance rating was mainly received. Thirion *et al,* 1995 states vegetation as the preferred biotope while Weeks *et al*, 1996 found that stones in current was frequently inhabited. **6**

- **Naucoridae:** Were found mainly in slow flow, vegetation biotopes, with sand being the next most preferred, which correlates with Pollard *et al*, 1996 findings. Weeks *et al*, 1996 noted vegetation as the most inhabited and Thirion *et al*, 1995 states that stones in and out of current is the usual biotope. **6**

- **Nepidae:** Inhabits slow flow vegetation biotopes predominantly, which is what Weeks *et al*, 1996 noted. Thirion *et al*, 1995 states that mud is a preferred biotope. **6**

- **Belostomatidae:** Slow flow and vegetation the dominant choice, with abundance ratings of A being most common, with the exception of an F in a mud, no flow biotope. Weeks *et al,* 1996 shows that vegetation is predominantly utilised, and Thirion *et al*, 1995 notes that shallow standing water in vegetation or stones in or out of current is preferable**.** **3**

- **Corixidae**: Mud, sand and vegetation in a slow flow environment are equally preferable. Generally the abundance rating was an A or B, occasionally reaching a D in one of the no or slow flow habitats. Weeks *et al* (1996) and Thirion *et al* (1995) both note vegetation as the preferred biotope, while Pollard *et al,* 1996 notes that bedrock gullies and sandy substrates are most inhabited. **5**

- **Gerridae:** Slow, vegetated habitats are preferred. Weeks *et al*, 1996 and Thirion *et al*, 1995 both refer to vegetation being the prominent choice, with Thirion *et al* (1995) adding slow flow and pools**. 3.**

- **Velidae:** Slow flow and vegetation is preferred with the abundance rating mainly at A or B, but frequently reaching a rating of C in slow vegetation biotope. Weeks *et al*, 1996 recorded this taxa in vegetation mainly while Thirion *et al,* 1995 mentions that they do occur in rapids as well. **4**

- **Hydropsychidae:** Most of the species (1sp, 2sp and > 2sp) were found predominantly in a fast flowing stones in current biotope (2sp even reaching an abundance rating of E in this biotope). Thirion *et al*, 1995 notes that they are located in shallow moving water of all substrates, while Weeks *et al*, 1996 showed that the riffle was by far the most prominent. Perhaps it is not necessary to give 1sp to > 2sp each a different score? **1sp = 10; 2sp = 11; > 2sp = 12**

- **Philopotamiidae:** The figures / records (fast flow stones in current) for this taxa are actually too low to consider significant, although they do correspond with Weeks *et al* (1996) and Thirion *et al's* (1995) findings that riffles and rapidly moving water are the preferred habitats. **10**

- **Hydroptilidae:** Were found in fast flowing bedrock, stones in current and vegetation biotopes, scoring a C abundance rating on occasion in the fast flowing, stones in current biotope. Weeks *et al*, 1996 recorded a number of species in the riffle biotope, where it was by far the most prominent choice. **12**

- **Case caddis:** Were found predominantly in fast or medium flow environments (stones in current and vegetation), with 3 & 4 species being encountered too infrequently to be of significance. Weeks *et al*, 1996 found that different species are biotope specific. Thirion *et al*, 1995 notes that the case caddis' generally prefer standing or slow flow and quiet habitats. (Is it necessary to differentiate between the numbers of species caught?). Range from **6 – 9**

- **Dytiscidae**: Were found to prefer the slow, vegetated biotope, as was noted by Weeks *et al* (1996) and Pollard *et al* (1996). Thirion *et al*, 1995 mentions that generally any still water will be inhabited. **5**

- **Elmidae:** Were found to inhabit fast flowing vegetation habitats. Weeks *et al* (1996) and Thirion *et al*, 1995 mention riffles and running water being the preferred biotopes respectively. **10**

- **Gyrinidae:** Were dominant in no flow and vegetated environs. Thirion *et al,* 1995 states that they mainly found near shore, while Weeks *et al*, 1996 found that they occurred mainly in vegetated biotopes**. 2**

- **Haliplidae**: Was collected infrequently so records are not of major significance. Preliminary findings were that they equally preferred medium and slow, and mud and vegetation biotopes. Weeks *et al*, 1996 shows records of them inhabiting vegetation. **4**

- **Hydrophilidae**: According to Thirion *et al* (1995) this taxon prefers quiet shallow water. Weeks *et al,* 1996 found vegetation to be utilised the most frequently. The findings during this project are considered insignificant because of the low percentage of occurrence, however slow and no flows in vegetated environs were dominant**. 2**

- **Psphenidae**: Were found in slow, sandy biotopes, this however does not correspond with the more reliable findings of Weeks *et al* (1996) and Thirion *et al* (1995) who noted that riffles were preferred, and rocky or gravel substrates in shallow swift water were inhabited, respectively. **7**

- **Tipulidae:** Were recorded in stones in current, fast or slow biotopes, which shows that perhaps they are not flow sensitive or that the species are biotope specific. Weeks *et al*, 1996, noted that riffles were definitely the prominent choice**. 6**

- **Culicidae:** were found to prefer slow flowing vegetation biotopes, generally with an abundance rating from A to C, but once received a rating of D in the backwater slow flow biotope. Stones in current, was the next most preferred habitat. Weeks *et al* (1996) and Pollard *et al* (1996) both showed vegetation to be the preferred choice. Thirion *et al,* 1995 notes that they occur in standing or running water. **4**

- **Dixidae**: Were another of the tax that occurred too infrequently to be of any significance, but never the less were found to prefer medium flow, stones in current biotopes, with vegetation being the next most preferred. Weeks *et al*, 1996 found vegetation to be the dominant choice**. 4**

- **Simuliidae**: Were dominant in fast flowing stones incurrent biotopes, mainly with abundance ratings of B or C, but occasionally a D in the stones in current very fast flow. Weeks *et al,* 1996 showed that riffles were very notably the prominent choice. Thirion *et al* (1995) notes that they prefer shallow swift flowing water. **14**

- **Chironomidae:** Were found to prefer slow flow habitats in stones in current or vegetation, with an abundance rating of B or C except for once when an F was given in a medium flow vegetation biotope. Thirion *et al* (1995) mentions that they occur in all types of habitats while Weeks *et al* (1996) showed that most species preferred riffles. Pollard *et al* (1996) recorded high abundances in a sandy substratum. **6**

- **Ceratopogonidae:** Were located in slow flowing vegetation biotopes, generally in low abundance. Weeks *et al*, 1996 found them predominantly in riffles. **5**

- **Tabanidae:** Were quite contradictorily noted to equally prefer fast and slow habitats in the stones in current biotopes. Thirion *et al*, 1995 noted that they prefer mud or rock substrates. **6**

- **Athericidae:** Were found to prefer fast flowing stones in current environs. Similarly Weeks *et al,* 1996 and Thirion *et al* (1995) note riffles as a preferred habitat. **9**

- **Muscidae**: Appeared to prefer fast flowing bedrock biotopes but insufficient organisms were sampled to ascertain the reliability of this preference. Thirion *et al*, 1995 notes that they favour shallow waters in algal beds**.** **5**

- **Lymnaeidae**: Medium flow and vegetation habitats were favoured. Thirion *et al* (1995) states that they prefer quiet waters while Weeks *et al* (1996) showed that vegetation was preferred. **6**

- **Melaniidae**: Although this taxon was found infrequently it appeared to prefer medium or slow flowing habitats and sand or vegetation biotopes. Weeks *et al*, 1996, noted vegetation as the preferred biotope. **6**

- **Planorbidae**: Favour medium flows in gravel, stones in current or vegetation habitats. Weeks *et al* 1996 recorded them in vegetation predominantly**.** **5**

- **Ancylidae:** Were found to prefer an assortment of biotopes, fast or medium flow in gravel or vegetation habitats. This correlates with Weeks *et al* (1996) and Thirion *et al's*, 1995 findings (*i.e.* vegetation and on the surfaces of stones or leaves was preferred). **4**

- **Sphaeridae:** Were found predominantly in fast flowing stones in current biotopes. Weeks *et al* (1996) found species to be habitat specific with vegetation and soft sediments being the main preferences. **5**

In table 75 the following abbreviations have been used for the headings: % OCUR is the percentage of occurrence that the taxon had in the sampling over the whole period of the project i.e. the frequency with which the taxon occurred in total. I.POL is the isolated pool biotope. POOL, MUD, and SAND are the other type of biotopes in which taxa were located. GRAV stands for a gravel biotope. SOOC is the acronym for stones out of current. SIC is the acronym for the stones in current biotope. VEG is vegetation. BROC is a bedrock biotope. B.H^2O is an abbreviation for a backwater biotope. And lastly MIX is a combination of biotopes; they were not separated during monitoring.

Table 75: Habitat preference amongst the invertebrate taxa as sampled in 122 biotopes in 6 sites on the Luvuvhu and Sabie Rivers – expressed in percentages.

TAXA	% OCUR	I.POL	POOL	MUD	SAND	GRAV	SOOC	SIC	VEG	BROC	B.H^{2}O	MIX
Planarians	4.9	0	0	0	16.6	0	0	16.6	66.6	0	0	0
Oligochaeta	22.7	0	0	22	14.2	0	14.2	8.4	25.7	2.8	5.7	5.7
Hirudinea	4	0	0	0	40	0	20	20	20	0	0	0
Crabs	13.1	0	0	6.2	0	6.2	31.3	18.8	31.3	0	0	6.2
Shrimps	15.5	0	5.3	10.5	5.3	0	0	15.7	57.9	0	5.3	0
Hydrachnelle	6.5	0	0	0	0	0	0	25	50	25	0	0
Perlidae	15.5	0	0	0	0	5.2	0	63.1	15.9	10.6	0	5.2
Baetidae 1 sp	27.8	2.9	2.9	5.9	0	11.7	8.8	17.6	5.9	11.7	2.9	2.9
2 sp	32.7	2.5	2.5	7.5	7.5	5	7.5	25	22.5	15	5	0
>2 sp	27	0	0	3	0	0	6	24.2	54.5	6	3	3
Oligoneuridae	9.8	0	0	8.3	0	8.3	0	50	33.3	0	0	0
Heptageniidae	37.7	0	2.2	2.2	6.5	2.2	10.9	23.9	45.6	4.3	0	2.2
Leptophlebiidae	27	0	0	3	3	6	12	42.4	21.2	9	3	0
Tricorythidae	11.5	0	0	0	0	7	0	50	21.4	14.2	0	7.1
Prosospistomatidae	0.8	0	0	0	0	0	0	100	0	0	0	0
Caenidae	50	1.6	1.6	6.5	11.4	6.5	11.5	22.9	24.6	8.2	4.9	0
Coenagriidae	21.3	0	0	7.7	3.8	0	3.8	3.8	73	0	3.8	3.8
Calopterygidae	5.7	0	0	0	14.3	0	14.3	0	71.4	0	0	0
Chlorocyphidae	9	0	0	0	0	0	18.2	27.3	36.3	9.1	0	9.1
Gomphidae	52.4	0	1.6	9.4	23.4	12.5	4.7	20.3	12.5	6.2	6.2	3.1
Aeshnidae	2.4	0	0	0	0	0	0	0	66.6	0	0	33.3
Corduliidae	10.6	0	7..6	0	7.6	7.6	15.4	15.4	23	0	15.4	7.6
Libellulidae	45.9	1.8	1.8	3.5	5.3	3.5	3.5	26.8	32.1	14.3	5.3	1.8
Notonectidae	24.6	10	3.4	10	13.3	0	16.6	6.6	20	3.4	13.3	3.4
Pleidae	4.1	0	0	0	0	0	0	20	80	0	0	0
Naucoridae	42.6	5.6	2	2	25	9.6	9.6	7.7	26.8	7.7	2	2
Nepidae	7.3	0	0	11.1	0	11.1	0	11.1	55.6	0	0	11.1
Belostomatidae	9	0	0	0	18.2	0	0	0	81.8	0	0	0
Corixidae	27.8	5.9	5.9	17.6	17.6	0	14.7	2.9	17.6	2.9	11.7	2.9
Gerridae	10.6	15.3	0	0	0	0	30.7	7.7	38.4	0	0	7.7
Velidae	34.4	2.3	4.7	9.5	7.1	0	9.5	9.5	54.7	0	2.3	0
Hydropsychidae 1 sp	14.7	0	0	5.5	5.5	5.5	0	33.3	22.2	27.7	0	0
2 sp	10.6	0	0	0	0	7.6	0	61.5	15.3	7.6	0	7.6
> 2 sp	0.8	0	0	0	0	0	100	0	0	0	0	0
Philopotamiidae	1.6	0	0	0	0	0	0	50	0	50	0	0
Hydroptilidae	4.9	0	0	0	0	0	0	33.3	33.3	33.3	0	0
Case caddis 1 type	26.2	0	3.1	0	3.1	15.6	0	28.1	25	18.7	3.1	3.1
2 types	20.5	0	0	4	4	4	0	20	60	0	4	4
3 types	3.3	0	0	0	0	0	0	25	75	0	0	0
4 types	0.8	0	0	0	0	0	0	0	100	0	0	0
Dytiscidae	21.3	3.8	3.8	11.5	15.4	0	15.4	3.8	23.1	3.8	15.4	11.5
Elmidae	31.9	0	0	0	7.7	2.5	2.5	35.9	38.4	7.7	2.5	2.5
Gyrinidae	17.2	14.3	9.5	0	9.5	0	4.7	14.3	38.1	0	4.7	4.7
Haliplidae	1.6	0	0	50	0	0	0	0	50	0	0	0
Hydrophilidae	1.6	0	0	0	0	0	0	0	100	0	0	0
Psphenidae	0.8	0.8	0	0	100	0	0	0	0	0	0	0
Tipulidae	10.6	0	0	7.7	15.4	7.7	7.7	38.4	15.4	0	0	7.7
Culicidae	18.0	9	0	4.5	9	0	13.6	22.7	27.2	10.2	0	0
Dixidae	0.8	0	0	0	0	0	0	0	100	0	0	0
Simuliidae	31.9	0	0	2.5	0	5.1	5.1	43.6	30.7	10.2	0	2.6
Chironomidae	65.5	2.5	1.2	5	10	3.7	8.7	25	25	11.2	5	2.5
Ceratopogonidae	27.8	0	2.9	8.8	5.9	5.9	11.7	23.5	29.4	2.9	2.9	5.9
Tabanidae	22.1	0	0	7.4	7.4	11.1	3.7	37	11.1	11.1	3.7	7.4
Athericidae	6.5	0	0	0	0	0	0	75	25	0	0	0
Muscidae	0.8	0	0	0	0	0	0	0	0	100	0	0
Lymnaeidae	3.3	0	0	0	0	25	0	0	50	0	0	25
Melaniidae	2.4	0	0	0	33.3	0	0	0	33.3	0	0	33.3
Planorbidae	2.4	0	0	0	0	33.3	0	33.3	33.3	0	0	0
Ancylidae	1.6	0	0	0	0	50	0	0	50	0	0	0
Sphaeridae	4.9	0	0	0	0	16.6	0	50	16.6	0	0	16.6

Table76: Flow preferences among the different macro invertebrate taxa as sampled.

TAXA	% OF OCCUR.	VERY FAST	FAST	MEDIUM	SLOW	NO FLOW	UN KNOWN
Planarians	7.3	0	22.2	44.4	33.3	0	33.3
Oligochaeta	29.5	0	8.3	14.4	51.6	17.4	8.3
Hirudinea	3.2	0	0	50	50	0	0
Crabs	13.1	0	25	12.5	50	6.25	6.2
Shrimps	16.4	0	10.5	20.3	41.8	21.0	6.4
Hydrachnelle	6.5	12.5	12.5	62.5	0	0	12.5
Perlidae	15.5	5.3	47.3	36.8	0	0	10.6
Baetidae 1 sp	27.8	2.9	17.6	29.4	32.3	11.7	6.1
2 sp	32.8	2.5	40	20	22.5	12.5	2.5
>2 sp	27.8	0	24.2	24.1	39.4	9	3.3
Oligoneuridae	9.8	8.3	58.3	16.6	8.3	8.3	0
Heptageniidae	37.7	0	28.2	19.5	41.2	4.3	6.8
Leptophlebiidae	27.8	3	36.2	14.9	39	3	6.9
Tricorythidae	11.5	7.1	49.7	28.4	7.1	0	7.1
Prosospistomatidae	0.8	0	0	100	0	0	0
Caenidae	52.4	0	27.6	19.5	45.6	6.5	0.8
Coenagriidae	21.3	0	7.7	19.2	57.7	11.5	3.9
Calopterygidae	5.7	0	28.6	14.3	28.6	28.6	0
Chlorocyphidae	9	0	27.3	18.2	27.3	9.1	18.1
Gomphidae	52.4	0	20.3	24.7	39	12.9	3.1
Aeshnidae	2.4	0	0	0	36.2	0	63.7
Corduliidae	10.6	0	15.4	15.4	61.5	0	7.7
Libellulidae	45.9	5.6	30.3	31.1	26.1	7.0	0
Notonectidae	24.6	0	4.6	3.3	46.6	36.6	8.9
Pleidae	4.1	0	20	20	40	20	0
Naucoridae	42.6	0	13.4	28.7	46.1	9.6	2.2
Nepidae	7.3	0	11.1	22.2	44.4	11.1	11.1
Belostomatidae	9	0	9.1	9.1	72.6	9	0
Corixidae	27.8	0	2.9	11.7	58.9	23.5	3
Gerridae	10.6	0	7.7	7.7	46.1	30.7	7.8
Velidae	34.4	0	11.9	19	54.7	11.9	2.5
Hydropsychidae 1 sp	14.7	5.5	38.8	33.2	16.6	5.5	0
2 sp	9.8	16.2	58.3	8.3	0	0	16.2
> 2 sp	0.8	0	0	0	100	0	0
Philopotamiidae	1.6	0	100	0	0	0	0
Hydroptilidae	4.9	0	100	0	0	0	0
Case caddis 1 type	26.2	3.1	31.2	31.2	27.9	3.1	3.1
2 types	20.5	4	40	16	36	0	4
3 types	3.3	0	25	25	25	25	0
4 types	0.8	0	0	100	0	0	0
Dytiscidae	21.3	0	3.8	15.3	57.7	19.2	4
Elmidae	31.9	2.5	43.4	28.1	15.4	5	5.6
Gyrinidae	17.2	0	14.3	19	23.8	28.5	9.5
Haliplidae	1.6	0	0	50	50	0	0
Hydrophilidae	1.6	0	0	0	50	50	0
Psphenidae	0.8	0	0	0	100	0	0
Tipulidae	10.6	0	30.8	15.4	30.8	7.7	15.3
Culicidae	18.0	0	9	13.5	64	13.5	0
Dixidae	0.8	0	0	100	0	0	0
Simuliidae	31.9	5.1	48.8	33.3	7.7	5.1	0
Chironomidae	65.5	2.5	31.2	14.4	37.5	7.5	3.8
Ceratopogonidae	27.8	0	17.6	14.7	52.9	5.9	8.8
Tabanidae	22.1	7.4	29.6	14.8	29.6	7.4	11.1
Athericidae	6.5	0	62.5	12.5	12.5	0	12.5
Muscidae	0.8	0	100	0	0	0	0
Lymnaeidae	3.3	0	25	50	0	0	25
Melaniidae	2.4	0	0	33.3	33.4	0	33.3
Planorbidae	2.4	0	33.3	66.6	0	0	0
Ancylidae	1.6	0	50	50	0	0	0
Sphaeridae	4.9	0	66.7	0	0	0	33.3

While SASS has been developed to reflect and evaluate the changes in water quality by means of aquatic invertebrates (Uys, Goetsch and O'Keeffe, 1996), the intention of the flow scoring system is to evaluate the response of the macro invertebrate (the indicator organism) to different flows. SASS 4 (and now SASS 5) is a rapid and robust method that does not require a specialist to do the fieldwork, and can be adapted and implemented regionally (Uys *et al*, 1996). It is the intention that this method ultimately is also able to be easily adapted between the regions of South Africa, and simple to implement. It is important to ensure that no extra time is required to use the flow scoring system, as anything more time consuming becomes more costly. It is intended that the SASS 5 and new flow scoring system can be used simultaneously and neither is intended to replace the other.

8. DEVELOPING A HABITAT ASSESSMENT SHEET

It is debatable as to whether a habitat assessment for the IFR monitoring is required. It has been agreed that the geomorphology makes the fundamental basis for any aquatic habitat, and should be used as a template. There has been some discussion pertaining to existing habitat assessments (refer to section 4), however the general consensus seems to be that some components of some types are too vague, and that they are particularly geared towards the sampling of macro-invertebrates. In fact the IHAS was specially designed to adjust the scores of SASS so that should a SASS score be low due to the lack of habitat (for whatever reason) the score can be adjusted so that the low SASS score will not be construed as a water quality problem, but rather a habitat problem. Nevertheless apparently the habitat adjustment is no longer being used.

A great deal of what instream flow requirements is about is that it revolves around the habitats (geomorphological and vegetated) that are created under different flow conditions. The existence (or non existence) of the different habitats is what determines the presence of the diversity of instream biota. There have been comments made that there is a need for quantifying the habitats that do exist (which could perhaps assist in extrapolating population numbers). For example if a riffle of *x* m/s flow and 3m x 4 m in area, was sampled, and four fish species were caught in different abundances. Then perhaps it would be possible to estimate that for all the same types of habitats there are *p, q, r* and *z* abundances for species1-4. Naturally it is more complex than that, but it would save sampling time, especially habitats that are not easily accessible.

Kleynhans (1995) did a qualitative assessment of the habitat integrity status of the Luvuvhu River, much of which encompassed assessing modifications to the river, taking water abstraction specifically into consideration, because one of the major issues was lack of surface water during droughts and low flows because of anthropogenic reasons.

8.1 OBJECTIVES OF AN IFR HABITAT ASSESSMENT

- Having a rapid habitat assessment to which biota can be compared
- Having a habitat assessment which is common to all components of biomonitoring (*i.e*. Not specific to one biotic component such as fish)
- Identifying and establishing what the available habitat is.
- Putting a value or score to the amount of available habitat.
- Based on geomorphology template.
- Total time spent monitoring different key habitats (site specific)
- Establish what (habitat) was sampled out of what (habitat) exists.

8.2 DESIGNING AND DISCUSSING THE PROPOSED IFR HABITAT ASSESSMENT

The idea is that the habitat be assessed for the hydraulic transect, with 15m either side of the transect. With reference to figure 27 the different parts are discussed. Parts 1 – 4 are self-explanatory. 5. The daily flow obtained either from DWAF records and / or gauging weir. 6. The recommended flow for that time of the year as obtained from the IFR workshop report / refinement. 7. A site diagram. The intention is to get a scaled diagram (aerial view) from when the hydraulic cross sections are done for an IFR site. This template can then be filled in with the present habitats and their composition. Only one habitat diagram then needs to be done for the whole site, i.e. all components can be drawn onto the template. 8. PEMC, is the present ecological management class that has been allocated for the quaternary catchment delineations. 9. The DEMC, is the desired ecological management class, also for the quaternary catchment allocation. 10. Comments: any comments to be made, in particular regarding flow, for example a drought is taking place, or there was a 1:20 year flood two months ago. 11. Critical issues refers to any important points that need to be made that relate to certain habitat requirement for that particular site, for example, the far left hand channel needs to be flowing at all times, or a certain habitat needed at that site as a nursery for fish fry (these issues would usually be obtained from an IFR workshop report). 12. This section relates to general and geomorphological components of habitat. There is the risk that too much of this is duplicated in the geomorphology section. There is also a concern that perhaps too many assumptions are made. 12 a) & b). The widths of the macro and active channels, with the assumption that the wider the channels the greater diversity of habitats to be found. 12 c). Channel pattern and channel type, assuming a multiple thread and mixed type channels create more habitat diversity potential. 12 d). Morphological units, the greater number results in a greater diversity of habitat potential. 12 e) & f). Refers to any in channel or bank impacts. 12 g); h) & I). Refers to the combination of materials in the bed, on the banks and on the island respectively. The more diverse the material composition, the greater potential for habitat diversity. 12 j). Turbidity of the water at the site. High turbidity readings are limiting to many organisms and some species are more sensitive than others.13. Refers to Riparian vegetation type components of habitat. Wetted ground has not been addressed and perhaps there should be a part that deals with the percentage wetted ground.13 a), b) , c) & d) refer to the percentage cover for the whole transect in terms of bare ground, basal cover of reeds, exotic species, and undercut banks with root wads type habitat. Overhanging vegetation has not been considered, and perhaps it needs to be considered, possibly in conjunction with root wads and undercut banks.13 e). The composition of the riparian vegetation, the actual percentage of each life form is covered in the proposed long-term riparian vegetation monitoring programme. The total percentage of riparian vegetation can be deduced from deducting bare ground and exotic species. 14. This section refers to the fish habitat – that which is sampled and that which is available. 14a) - i) looks at what extent of habitat is sampled for fish in riffles/ rapids, runs, and either instream or off stream pools. The flow and depth choices (slow deep, slow shallow, fast deep or fast shallow, refer directly to the FAII. The percentage of the habitat out of the available habitat, is an attempt to ascertain the quantity of that habitat available for the site. It doesn't specify the substrate for the runs though, but perhaps knowing the channel types and bed material is sufficient. 14 j) Is trying to get an idea of the species diversity for the site on that particular visit in relation to the potential for the site. 15) This last section is mainly around the habitats preferred by invertebrates and that which was sampled. It may be assumed to a certain extent that if there is instream habitat for fish then invertebrates are catered for, this however is not the case, as invertebrates frequently make use of the smaller micro habitats, which is why the 15 a) & b) parts are included. These refer to microhabitats specifically favoured by many invertebrate populations. If the substratum is very embedded or tightly packed there is less or no habitat for some taxa such as Trichoptera. 15 c) is the percentage of algae covering the substratum, a high percentage also limits the available habitats for invertebrates. 15 d) looks at what habitats were sampled for invertebrates.

Finally, 15 e) attempts to ascertain the percentage of invertebrates sampled on that particular visit in relation to the potential for the site.

Interpretation of the scores will require the implementation of such a score sheet to establish its value and whether it is practical to implement, but preliminary guidelines of the scores might be along the lines of the following summary.

Table 77: A summary of the possible meanings of the total scores obtained in the IFR habitat assessment scoring sheet.

SCORE	GENERAL MEANING
185 - 210	**Excellent**: seldom achieved, high habitat diversity, condition and diversity, additional species sampled, low / no impacts.
165 – 184	**Very good**: good habitat diversity, availability and condition, good specie diversity, minor impacts if any.
96 – 164	**Good:** good habitat diversity and condition, limited habitat availability, good specie diversity, limited impacts.
61 – 95	**Fair:** Limited habitat and organism diversity – could be attributed to site location *e.g.* mountain stream; limited impacts if any
36 – 60	**Poor:** of concern - poor habitat availability / condition / diversity, low species diversity, high impacts. Could be soon after an extreme event – resilience of system being tested.
0 -35	**Bad**: of serious concern – high impacts, low habitat availability, diversity and condition, low organism diversity.

Kleynhans (1999) has designed a comprehensive classification system of ecological management classes for the quaternary catchment classifications. But because these delineations are not based on ecological principles, it was decided to use flow requirements on an index of ecological importance and sensitivity of rivers in the quaternary catchments, (of which there are 1946 in South Africa) (Kleynhans, 1999). To assess the ecological importance the following were considered: the presence of red data, unique / endemic species; the habitat diversity; biodiversity generally; the importance of the particular stretch of river *(e.g.* Is it a migration route), the presence of conservation / natural areas; and the sensitivity of the system and it resilience (Kleynhans, 1999). Figure 26, illustrates the procedure followed to determine the attainable ecological management class. The method involves an aerial video off the river system, literature review, field survey/s and a workshop with assorted aquatic specialists contribution. Kemper and Kleynhans (1998) emphasise that a site based assessment lacks any longitudinal continuity, and may not adequately reflect a true comparison of the present status of the river, and there is no true replacement for an aerial video of the river. It is not the intention of the this proposed IFR habitat assessment to replace the determination of ecological management classes, but hopefully to contribute to fairly regular site assessment to which biotic changes can be compared, it is therefore important to know the ecological management classes for the section which the site fits.

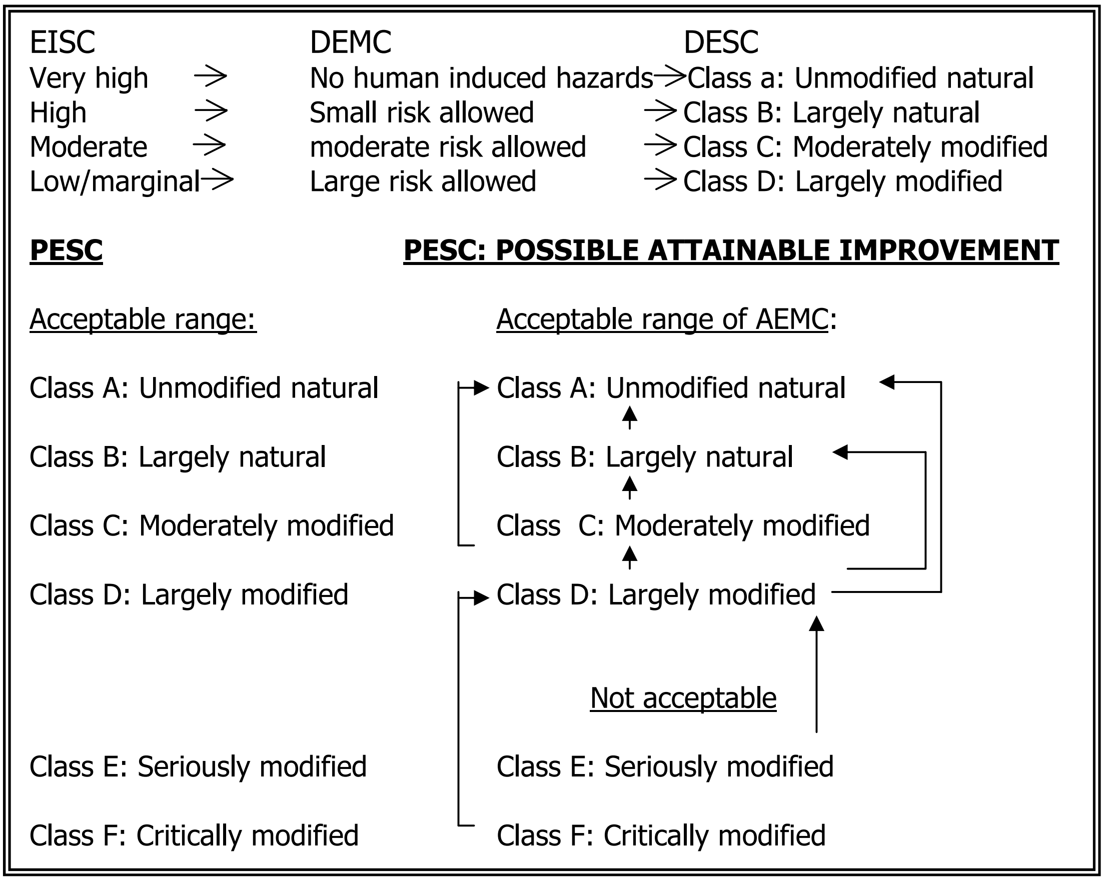


Figure 26: Procedure followed in the determination of the AEMC.→ Indicates the relationship, and ⟶ indicates the possible direction of desirable change. (After Kleynhans, 1999)

PROPOSED HABITAT ASSESSMENT SCORING SHEET

1. DATE:	**2. RIVER** (and province**):**	**3. SITE:**
4. ASSESSOR/S:	**5.AV. DAILY FLOW ($m^3 s^{-1}$):**	**6. RECOMMENDED FLOW ($m^3 s^{-1}$):** (for this month)
7. SITE DIAGRAM (using the scaled template of the site, obtained from hydraulic cross section/s fill in habitats)		
8. PEMC:	**9.DEMC:**	
10. COMMENTS (any recent / current extreme events):		
11. CRITICAL ISSUES FOR SITE:		

DESCRIPTION (mark appropriate scoring box)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
12. GEOMORPHOLOGY / GENERAL								
a) Width of the macro channel 1=<0.5m; 2 = 0.5-1.5m; 3 = 1.5-5m; 4 = 5-15m; 5 = 15-50m; 6 = 50-150 7 = 150 - >300m	NA							
b) Width of the active channel: 1=<0.5m; 2 = 0.5-1.5m; 3 = 1.5-5m; 4 = 5-15m; 5 = 15-50m; 6 = 50-150 7 = 150 - >300m	NA							
c) Channel pattern & channel type: 2=single bedrock / single boulder bed; 3= Multiple bedrock; 4 = single mixed / alluvial; 5= Multiple boulder bed; 6= multiple alluvial; 7= multiple mixed.	NA	NA						
d) Morphological units: waterfall, rock steps, bedrock pavement, bedrock / boulder rapid, bedrock / plunge pool, cobble / boulder step/ plain bed/ riffle/ run/ shallow pool/ deep alluvial pool, sand waves, backwater. 1= 1 type; 2= 2 types; 3 = 3 / 4; 4 = 5/6; 5 = 7/8; 6 = 9-11; 7 = 12-14 types.	NA							
e) In channel modifications: (causeway, bridge; weir; pump; gabions; canal; channelisation; mining; other) 0 = 5 /9; 1 = 3 / 9; 2= 2 / 5 (incl. Mine/ weir); 3 = 2 / 5 (incl. Causeway/ gabion / alien veg).; 5 = 2 / 5 (bridge/ pump/bank gabions); 7 = none.								
f) Bank impacts: (animals; footpaths; vegetation clearance; invasive vegetation; other). 0 = all 5; 1 = 4/ 5; 2 = 3 /5; 3 = 2/5; 4 = invasive vegetation; 5= animals/ footpaths; 6 = mild animal use; 7 = none.								
g) Bed material: (silt/ mud, sand, gravel, cobble, bolder, bedrock) 1 = 1 type; 2= 2 types (excl. cobble); 3 = 2 types (incl. Cobble) 4 = 3 types, 5 = 4 types; 6 = 5 types; 6 = 5 types; 7= 6 types	NA							
h) Banks material: (silt/ mud, sand/ soil, gravel, cobble, bolder, bedrock) 1 = 1 type; 2= 2 types (excl. cobble); 3 = 2 types (incl. Cobble) 4 = 3 types, 5 = 4 types; 6 = 5 types; 6 = 5 types; 7= 6 types	NA							
i) Island/s material: (silt/ mud, sand, gravel, cobble, bolder, bedrock) 1 = 1 type; 2= 2 types (excl. cobble); 3 = 2 types (incl. Cobble) 4 = 3 types, 5 = 4 types; 6 = 5 types; 7= 6 types	NA							
j) Turbidity: 0= chocolate brown and gritty to touch; 1 = muddy; 4= coloured; 7 = clear.								
13. RIPARIAN VEGETATION								
a) % Bare ground (whole transect): 0 = 100% (not bedrock / cobble); 1 = 81-94%; 2 = 71-80%; 3 = 51-70%; 4 = 31-50%; 5 = 16-30%; 6 = 6-15%; 7 = 0-5%								
b) % Basal cover reeds (whole transect): 0 = 100% (not bedrock / cobble); 1 = 81-94%; 2 = 71-80%; 3 = 51-70%; 4 = 31-50%; 5 = 16-30%; 6 = 6-15%; 7 = 0-5%								
c) % Basal cover exotic plants (woody & annuals): 0 = 100% (not bedrock / cobble); 1 = 81-94%; 2 = 71-80%; 3 = 51-70%; 4 = 31-50%; 5 = 16-30%; 6 = 6-15%; 7 = 0-5%								
d) % Of root wads & undercut banks in active channel: 0 = 100% 1 = 81-94%; 2 = 71-80%; 3 = 51-70%; 4 = 31-50%; 5 = 16-30%; 6 = 6-15%; 7 = 0-5%								
e) Composition of riparian: (trees, shrubs, reeds, grass, sedges) 0 = nothing; 1 = 1 type, 2 = 2 types (grass/reeds/ sedge dominant); 3 = 2 mix; 4 = 3 mix (incl. Shrubs); 5 = 4 mix (grass/reeds/ sedge dominant); 6 = 4 mix (shrubs dominant); 7 = 5 mix (80-100% total cover).								

14. FISH								
a) Extent of riffle/s / rapid/s sampled: 0= 0m; 1= 1-5m^2 ; 2 = 6-10 m^2; 3 = 11-20 m^2; 4 = 21-29 m^2; 5 = 30-39 m^2; 6 = 40-50 m^2; 7=> 50 m^2								
b) Flow / depth diversity of riffle/s / rapid/s: (slow/shallow, slow/deep, fast shallow, fast deep) 1= 1 type; 3 = 2 types; 5 = 3 types; 7 = all 4	NA							
c) % Of riffle / rapid sampled out of what is available: 1 = 100%; 2 = 80-99%; 3 = 56 – 70%; 4 = 31-55%; 5 = 16-30%; 6 = 6-15%; 7 = 1-15%.	NA							
d) Extent of runs sampled: 0= 0m; 1= 1-5m^2 ; 2 = 6-10 m^2; 3 = 11-20 m^2; 4 = 21-29 m^2; 5 = 30-39 m^2; 6 = 40-50 m^2; 7=> 50 m^2								
e) Flow / depth diversity of run/s: (slow/shallow, slow/deep, fast shallow, fast deep) 1= 1 type; 3 = 2 types; 5 = 3 types; 7 = all 4	NA							
f) % Of run sampled out of what is available: 1 = 100%; 2 = 80-99%; 3 = 56 – 70%; 4 = 31-55%; 5 = 16-30%; 6 = 6-15%; 7 = 1-15%.	NA							
g) Extent of pool/s sampled: 0= 0m; 1= 1-5m^2 ; 2 = 6-10 m^2; 3 = 11-20 m^2; 4 = 21-29 m^2; 5 = 30-39 m^2; 6 = 40-50 m^2; 7=> 50 m^2								
h) Flow / depth diversity of pool/s: (slow/shallow, slow/deep, fast shallow, fast deep) 1= 1 type; 3 = 2 types; 5 = 3 types; 7 = all 4	NA							
i) % Of pool sampled out of what is available: 1 = 100%; 2 = 80-99%; 3 = 56 – 70%; 4 = 31-55%; 5 = 16-30%; 6 = 6-15%; 7 = 1-15%.	NA							
j) % fish species caught out of historic list: 1= 1-19%; 2 = 20-39%; 3 = 40-59%; 4 = 60- 99%; 5 = 100%; 6 = 100% +1-5% over; 7 = 100% + 6-10% over.	NA							
15. INVERTEBRATES								
a) Bed packing: 0= no space at all; 1= tightly packed; 4 = moderately packed; 7 = loosely packed (can choose a score in between)								
b) Embeddedness: 1= well embedded; 4 = moderately embedded; 7 = not embedded (can choose a score in between)	NA							
c) % Algal cover on exposed substrate 0=100%; 1=85-99%; 2= 61-84%; 3 =46-60%; 4= 21-45%; 5 = 11-20% ; 6 =6-10% ; 7= 0-5% .								
d) Biotopes sampled: 0= nothing; 1= one type only; 2= SIC & 1 X Veg; 3= SIC, SOOC; 4= SIC, SOOC, 1 X Veg; 5= SIC, SOOC, 1 X Veg & sand / gravel / mud; 6= SIC, SOOC, 1 X Veg, 1 x sand / gravel ; 7= SIC, SOOC; 2 X Veg; sand, gravel; mud.								
e) % Invertebrate taxa caught out of historic list: 1= 1-19%; 2 = 20-39%; 3 = 40-59%; 4 = 60- 99%; 5 = 100%; 6 = 100% +1-5% over; 7 = 100% + 6-10% over.								
TOTAL SCORE								

Figure 27: A proposed IFR habitat assessment scoring system.

9. THE PROCEEDINGS OF THE IFR MONITORING PROTOCOL WORKSHOP

The full report can be located in the appendix. The main aims of the workshop were: to assist Department of Water Affairs in defining a monitoring policy for the Ecological Reserve; to design a monitoring system which will feedback into management, to review IFR monitoring methods and suggest further priorities, and to design a monitoring system which can be implemented and effective within available resources. Alison Howman of DWAF presented the Monitoring and Assessment Information System (MAIS) that DWAF are in the process of implementing, the system is in phase III and aims to be completed by 2004. The mandate to monitor, record, assess, and disseminate information pertaining to water resources, has come from the 'new' National Water Act, chapter 14. Information management has been identified as one of DWAF's six essential functions. Dirk Roux presented the model of Strategic Adaptive Management (SAM), and assessment criteria, which contribute to the success of the design and implementation of an environmental monitoring programme, using the River Health Programme as a case study. After discussions it was agreed that the vision or main objectives with regards to IFR monitoring are: compliance with reserve (quantity) objectives and monitoring of the essential biophysical components, which are influenced by managed river flows. It was agreed that TPC's (Thresholds of probable concern) were appropriate, but the TPC's for each component of the monitoring programme need to be defined and refined. A process diagram was devised to represent the processes involved in IFR monitoring and the proposed steps to be taken if a TPC is exceeded. On the second day Jenny Newenham and Support Chavalala presented methods they had been trying out and using on six sites, two on the Luvuvhu River and four on the Marite / Sabie River, as part of the baseline monitoring. They concentrated on geomorphology, riparian vegetation, macro-invertebrates and fish monitoring techniques. The workshop participants then divided into different speciality groups: geomorphology; riparian vegetation; invertebrates and fish. Each group was tasked to devise a monitoring programme taking certain aspects into consideration. These aspects included a once off site rating, baseline monitoring, long term monitoring and the collection, interpretation and processing of data. The participants were required to outline the purpose, actions, resources required, personnel needed and the proposed frequency of monitoring for each type. The different levels of details also needed to be addressed with the aim being to establish what minimum effort is required, to enable management decisions. On the third day a short presentation was made to two DWAF officials. The presentation included a summary of the workshop thus far and then using the Sabie/ Luvuvhu case study (because of the imminent closing of the dams), a proposed costing required to implement the programme on these rivers. A framework for a possible monitoring management structure was also suggested. The workshop was closed.

10. CONCLUSION

While the February 2000 floods may have burdened the project to a certain degree (loss of cross sections, loss of gauging weirs and continued high flow conditions for most of the project), there has certainly been interesting and valuable information to be gained as well.

With both the Injaka and Nandoni dams to be closed soon, at least there has been some form of monitoring and data collection that has taken place prior to the events. The Sabie has a lot more information available than the Luvuvhu River, so it is not as critical that additional baseline data be obtained for the Sabie before the Injaka dam closes, but for the Luvuvhu River it is imperative. Especially as there is a new IFR site (Botsoleni), and that the Pafuri flood plain site has not been addressed because of its complexities.

Although this project only concentrated on six sites, and four of the components in IFR monitoring: geomorphology, riparian vegetation, fish and macro-invertebrates; interesting observations were made under the high flow conditions. This is something a little different to previous work, when drought conditions have formed the basis of the research. Drought conditions have much more serious implications to the aquatic biota than floods. Floods (depending on the magnitude) have a considerable more influence on the geomorphology, and the riparian vegetation (which of course does indirectly effect the other biotic components), than droughts do. It is not likely that these rivers will experience a flood of the same magnitude for a while (50 / maybe 100 years), and even then because of the current impoundments sections of the rivers will never experience the same conditions. Therefore, while it was not the objective of the project to monitor the responses of biota to high flow conditions, nor were sufficient sites monitored to gain a broader spectrum of information, the information collected is valuable under the circumstances. For example during the high flow conditions a total of eighteen fish were added to all the historic species lists, some being the same species at different sites, and some being debatable as to whether they are actually additional species, and have been recorded at the site or in the vicinity, but for some reason are not on the list. Whatever the case it is definite that additional species were recorded at some sites and it can be attributed to the different habitat conditions that have been created as a result of the floods. But then there are species that were not caught at any stage in the survey, that were caught fairly regularly in the past and are on the historic species list. This can also be attributed to a few reasons (sampling method, chance of capture, capture avoidance, and loss of habitat), but at least some some of the species were not caught because of the flood conditions. Whether the species composition will stabilise or gradually change to the former, remains to be seen, much of which depends on whether previous habitats re-establish themselves. This refers particularly to the vegetation component of a habitat.

Initially it was thought that perhaps a fish scoring system needs to be developed, something similar to SASS for example, but flow related. But after the IFR Monitoring Protocol Workshop it was evident from discussions that the current RHP method FAII (Fish assemblage integrity index) is more than sufficient. A great deal of previous research on macro-invertebrate communities in the Sabie River in particular, identified the organisms to species level. At the out start of the project it was considered an option to do the same. However it was decided that for the present, that to the existing taxon level (mainly families) was sufficient. Perhaps this is not ideal, but to the current taxa levels will mean the monitoring will be a bit quicker and that it will be easier for the technicians involved in the monitoring in the future. Perhaps certain indicator species could be identified at a site rating for a river and specific site, that could be used in the future long term IFR monitoring.

One of the objectives of the project was to train technicians in the different sampling techniques used for monitoring different biota in IFR monitoring. It was believed that this was probably the most successful objective for the project. Another aspect of the project that is considered to have been of great importance and a valuable contribution to the continuation of IFR monitoring, is the workshop held in August 2001. Now the proposed monitoring programme just needs to be accepted and adopted by DWAF and implemented.

11. RECOMMENDATIONS

- That the proposed IFR Monitoring Programme be absorbed into DWAF's MAIS programme, and be implemented as soon as possible. It is imperative that rivers like the Luvuvhu and Sabie Rivers (Luvuvhu in particular) are monitored appropriately before the dams are completed.

- That a group of aquatic invertebrate specialists meet to discuss and further develop (or discard) the proposed macro-invertebrate flow scoring system.

- Because habitat creation is a significant section of IFR's it is necessary to decide whether a habitat assessment is needed, and if so, is the proposed type appropriate. Secondly it is important that IFR monitoring link up with / adopt or adapt any current habitat modelling methods and any work that has due to be published.

- Technicians have a historic fish species and invertebrate taxa list for each site, when they go to monitor the site.

- That the hydraulic cross sections and ratings take place as soon as possible at the IFR sites that were effected by the floods, as well as the new Botsoleni site.

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APPENDICES

Determining the IFR Monitoring Protocol

PROPOSED MACRO INVERTEBRATE IFR MONITORING DATA SHEET

DATE:	**GAUGING WEIR READING:**
RIVER:	**DAILY FLOW $m^3 s^{-1}$:**
IFR SITE:	**ASSESSOR/S:**

TAXON	SASS 4 SCORE	PROPOSED FLOW SCORE	ABUNDANCE VALUES / BIOTOPE (ABUNDANCE: 1=1; A = 2-5; B = 6-10; C = 11-20; D = 21 – 50; E = 51 – 100; F = 101 – 201; G = 201-500; H = 501 +)					
BIOTOPE:								
Porifera	**5**							
Coelenterata Hydra sp.	**1**							
Turbellaria Planarians	**5**	**7**						
Annelida Oligochaeta	**1**	**3**						
Hirudinea	**3**	**6**						
Crustacea Amphipoda	**15**							
Crabs *	**3**	**6**						
Shrimps	**8**	**5**						
Hydracarina Hydrachnellae	**8**	**9**						
Plecoptera Notonemouridae	**12**							
Perlidae	**12**	**13**						
Ephemeroptera Polymitarcyidae	**10**							
Ephemeridae	**15**							
Baetidae 1 sp	**4**	**4**						
2 sp	**6**	**5**						
> 2 sp	**12**	**7**						
Oligoneuridae	**15**	**13**						
Heptageniidae	**10**	**6**						
Leptophlebiidae	**13**	**7**						
Ephemerellidae	**15**							
Tricorythidae	**9**	**12**						
Prosopistomatidae	**15**	**13**						
Caenidae	**6**	**6**						
Odonata Chlorolestidae	**8**							
Lestidae	**8**							
Protoneuridae	**8**							
Platycnemidae	**10**							
Coenagriidae	**4**	**5**						
Calopterygidae	**10**	**7**						
Chlorocyphidae	**10**	**7**						
Zygoptera juveniles	**6**							
Gomphidae	**6**	**6**						
Aeshnidae	**8**	**4**						
Corduliidae	**8**	**7**						
Libellulidae	**4**	**9**						
Hemiptera Notonectidae *	**3**	**4**						
Pleidae *	**4**	**6**						
Naucoridae *	**7**	**6**						

Nepidae *	**3**	**6**							
Belostomatidae *	**3**	**3**							
Corixidae *	**3**	**5**							
Gerridae *	**5**	**3**							
Veliidae *	**5**	**4**							
Megaloptera Corydalidae	**8**								
Trichoptera Hydropsychidae 1 spp	**4**	**10**							
2 spp	**6**	**11**							
>2 spp	**12**	**12**							
Philopotamidae	**10**	**10**							
Polycentropodidae	**12**								
Psychomyiidae	**8**								
Ecnomidae	**8**								
Hydroptilidae	**6**	**12**							
Other case larvae: Type score family									
1 8 1	**8**	**6**							
2 15 1	**15**	**6**							
3 20 1	**20**	**7**							
4 30 2	**30**	**8**							
5 40 2	**40**	**8**							
>5 50 3	**50**	**9**							
Lepidoptera Nymphulidae	**15**								
Coleoptera Dytiscidae (adults*)	**5**	**5**							
Elmidae/Dryopidae	**8**	**10**							
Gyrinidae (adults *)	**5**	**2**							
Haliplidae (adults *)	**5**	**4**							
Helodidae	**12**								
Hydraenidae (adults *)	**8**								
Hydrophilidae (adults *)	**5**	**2**							
Limnichidae	**8**								
Psephenidae	**10**	**7**							
Diptera Blephariceridae	**15**								
Tipulidae	**5**	**6**							
Psychodidae	**1**								
Culicidae *	**1**	**4**							
Dixidae *	**13**	**4**							
Simuliidae	**5**	**14**							
Chironomidae	**2**	**6**							
Ceratopogonidae	**5**	**5**							
Tabanidae	**5**	**6**							
Syrphidae *	**1**								
Athericidae	**13**	**9**							
Empididae	**6**								
Ephydridae	**3**								
Muscidae	**1**	**5**							
Gastropoda Lymnaeidae *	**3**	**6**							
Melaniidae *	**3**	**6**							
Planorbidae *	**3**	**5**							
Physidae *	**3**								
Ancylidae	**6**	**4**							
Hydrobidae *	**3**								
Pelecypoda Sphaeridae	**3**	**5**							
Unionidae	**6**								

PROPOSED DATA SHEET FOR LINE TRANSECT SAMPLING METHOD FOR IFR RIPARIAN VEGETATION MONITORING

DATE:	RIVER:	IFR SITE & NAME:
RECORDERS:	PRESCRIBED FLOW:	OVERALL FLOW:

GEOMORPH. UNIT: LHB ☐ **RHB** ☐ **OTHER:** ☐
Mark appropriate box

METRE MARK	ACTUAL STRIKE NEAREST PLANT NEAREST WOODY (species) (within 50cm radius of point)	DISTANCE FROM POINT	SUBSTRATE	HEIGHT OF WOODY	CIRCUM. OF WOODY	DAMAGE AND REASON IF ANY	STATUS (R/ T / E)

PROPOSED IFR RIPARIAN DATA SHEET – BELT TRANSECT METHOD

DATE:	**RIVER:**	**SITE:**
BELT / TRANSECT:	**CO-ORDINATES:**	**GUAGING WEIR:**

GEO = Geomorphological unit (eg LHB, island); **HEIGHT CLASS** = N for natural growth and C for coppicing at each plants height class; **CONDITION** = Scale 1-5 and record reason if not 1; **SUBSTRATE** = soil, rock etc; **STATUS** = Terrestrial / Exotic / Riparian; **REEDS etc** = score % for each at each geomorph unit where 0 = 0%, 1= <5%, 2 = 5-25%, 3 = 26 - 50%, , 4 = 51 - 75%, 5 = 76 - 100%.

GEO	**SPECIES**	**HEIGHT CLASS**						**CONDITION**	**SUBST R-ATE**	**STATU S**	**REEDS SEDGE GRASS**
		< 1m	**1-2**	**2-4**	**4-8**	**8-12**	**>12m**				

PROPOSED IFR RIPARIAN VEGETATION DATA SHEET – BELT TRANSECT & QUAD. METHOD

DATE:	**RIVER:**	**IFR SITE & NAME:**
GUAGING WEIR READING:	**FLOW:**	**BELT TRANSECT #:**
ASSESSORS:		
SLOPE OF BANK: LHB = RHB =	**HEIGHT OF BANK: LHB = RHB =**	

QUAD.ET / W = Quadrant in the Ecotone or at the Water. **GEO.UNIT** = Geomorphological Unit (ie. LHB /island & #). **SPECIES** = the species of the plant. **HEIGHT / Ht. CLASS** = The measured height of the plant up to 2m / the height class (2-4m; 4-6m; 6-8m; 8-12m and 12m+). **CIRCUM OF STEM** = The measurement of the stem or trunk of the plant. **IS THERE ANY DAMAGE & REASON** = State if plant is damaged (Yes / No), and if known the reason (increased flow / decreased flow / anthropogenic / fire / animals). **DESCRIBE DAMAGE**: Describe the damage seen on the plant eg: (Coppicing / leaves missing / branches dropped / parasites). **STATUS (T/R/E)** = If known what is the tree a terrestrial species / riparian / exotic. **SUBSTRATE** = What kind of substrate is the plant growing in / on?(soil, bedrock, cobble etc).

QUAD. ET / W	**GEO. UNIT**	**SPECIES**	**HEIGHT / Ht. CLASS**	**CIRCUM. OF STEM**	**IS THERE ANY DAMAGE? & REASON**	**DESCRIBE DAMAGE**	**STATUS (T/R/E/)**	**SUBSTRATE**

QUAD. ET / W	GEO. UNIT	SPECIES	HEIGHT / Ht. CLASS	CIRCUM. OF STEM	IS THERE ANY DAMAGE? & REASON	DESCRIBE DAMAGE	STATUS (T/R/E/)	SUBSTRATE

RIVER:	**IFR SITE:**
LIST INDICATOR SPECIES (3-4 chosen riparian species, characteristic of this river and reach):	
1)	**2)**
3)	**4)**

Every indicator species must be recorded in the whole of the belt transect

GEO. UNIT	SPECIES	HEIGHT	CIRCUM. OF STEM	ANY DAMAGE & REASON	DESCRIBE DAMAGE	DISTANCE FROM WATER EDGE	SUBSTRATE

Record the % basal cover for **exotic species, grass, sedge, reeds, bare ground and other.** Other includes all the woody and herbaceous species. This is done for each geomorphologic unit as labeled on the accompanying

GEO UNIT: ....

EXOTIC: ....

OTHER: ....

GRASS: ....

SEDGE: ....

REEDS: ....

BARE GROUND : ....

(& NAME DOMINANT TYPE): ....

GEO UNIT: ....

EXOTIC: ....

OTHER: ....

GRASS: ....

SEDGE: ....

REEDS: ....

BARE GROUND : ....

(& NAME DOMINANT TYPE): ....

GEO. UNIT: ....

EXOTIC: ....

OTHER: ....

GRASS: ....

SEDGE: ....

REEDS: ....

BARE GROUND : ....

(& NAME DOMINANT TYPE): ....

GEO. UNIT: ....

EXOTIC: ....

OTHER: ....

GRASS: ....

SEDGE: ....

REEDS: ....

BARE GROUND : ....

(& NAME DOMINANT TYPE):

GEO. UNIT: ....

EXOTIC: ....

OTHER: ....

GRASS: ....

SEDGE: ....

REEDS: ....

BARE GROUND : ....

(& NAME DOMINANT TYPE): ....

GEO. UNIT: ....

EXOTIC: ....

OTHER: ....

GRASS: ....

SEDGE: ....

REEDS: ....

BARE GROUND : ....

(& NAME DOMINANT TYPE): ....

DRAW A DIAGRAM SUMMARISING THE IFR VEGETATION BELT TRANSECT. DATE:………………………………. BELT TRANSECT #:……………….. RIVER:…………………………………..GEO. UNITS LABELED CLEARLY.

PROPOSED MACRO INVERTEBRATE IFR MONITORING DATA SHEET

DATE:	**GAUGING WEIR READING:**
RIVER:	**DAILY FLOW $m^3 s^{-1}$:**
IFR SITE:	**ASSESSOR/S:**

TAXON	**SASS 4 SCORE**	**ABUNDANCE VALUES / BIOTOPE** (ABUNDANCE: 1=1; A = 2-5; B = 6-10; C = 11-20; D = 21 – 50; E = 51 – 100; F = 101 – 201; G = 201- 500; H = 501 +)							
	BIOTOPE:								
Porifera	5								
Coelenterata Hydra sp.	1								
Turbellaria Planarians	5								
Annelida Oligochaeta	1								
Hirudinea	3								
Crustacea Amphipoda	15								
Crabs *	3								
Shrimps	8								
Hydracarina Hydrachnellae	8								
Plecoptera Notonemouridae	12								
Perlidae	12								
Ephemeroptera Polymitarcyidae	10								
Ephemeridae	15								
Baetidae 1 sp	4								
2 sp	6								
> 2 sp	12								
Oligoneuridae	15								
Heptageniidae	10								
Leptophlebiidae	13								
Ephemerellidae	15								
Tricorythidae	9								
Prosopistomatidae	15								
Caenidae	6								
Odonata Chlorolestidae	8								
Lestidae	8								
Protoneuridae	8								
Platycnemidae	10								
Coenagriidae	4								
Calopterygidae	10								
Chlorocyphidae	10								
Zygoptera juveniles	6								
Gomphidae	6								
Aeshnidae	8								
Corduliidae	8								
Libellulidae	4								
Hemiptera Notonectidae *	3								
Pleidae *	4								
Naucoridae *	7								
Nepidae *	3								

Belostomatidae *	3								
Corixidae *	3								
Gerridae *	5								
Veliidae *	5								
Megaloptera Corydalidae	 8								
Trichoptera Hydropsychidae 1 spp	 4								
2 spp	6								
>2 spp	12								
Philopotamidae	10								
Polycentropodidae	12								
Psychomyiidae	8								
Ecnomidae	8								
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Other case larvae: Type score family									
1 8 1	8								
2 15 1	15								
3 20 1	20								
4 30 2	30								
5 40 2	40								
>5 50 3	50								
Lepidoptera Nymphulidae	 15								
Coleoptera Dytiscidae (adults*)	 5								
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Hydrophilidae (adults *)	5								
Limnichidae	8								
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Diptera Blephariceridae	 15								
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Dixidae *	13								
Simuliidae	5								
Chironomidae	2								
Ceratopogonidae	5								
Tabanidae	5								
Syrphidae *	1								
Athericidae	13								
Empididae	6								
Ephydridae	3								
Muscidae	1								
Gastropoda Lymnaeidae *	 3								
Melaniidae *	3								
Planorbidae *	3								
Physidae *	3								
Ancylidae	6								
Hydrobidae *	3								
Pelecypoda Sphaeridae	 3								
Unionidae	6								

BIOTOPE # (Type & # - as recorded on map):..

BIOTOPE DESCRIPTION

Substrate (type & extent):	**Flow** (circle appropriate): no / slow / medium / fast / v.fast. Actual flow m/sec:	**Depth** (average):
Instream veg. (type & extent):	**O.hang veg.** (type & extent):	**Marg veg.** (type & extent):
% Algae on substrate:	**Turbidity:**	**Sampling time** (approx.)
Temperature (& time):	**Conductivity:**	**Ph:**

SUMMARY OF BIOTOPE

SASS SCORE:	**GENERAL COMMENTS** (Species ID'd, samples collected etc)
AV. SCORE / TAXON:	
NUMBER OF FAMILIES:	
AIR BREATHERS' SCORE:	
# AIR BREATHERS:	

BIOTOPE # (Type & # - as recorded on map):..

BIOTOPE DESCRIPTION

Substrate (type & extent):	**Flow** (circle appropriate): no / slow / medium / fast / v.fast. Actual flow m/sec:	**Depth** (average):
Instream veg. (type & extent):	**O.hang veg.** (type & extent):	**Marg veg.** (type & extent):
% Algae on substrate:	**Turbidity:**	**Sampling time** (approx.)
Temperature (& time):	**Conductivity:**	**Ph:**

SUMMARY OF BIOTOPE

SASS SCORE:	**GENERAL COMMENTS** (Species ID'd, samples collected etc)
AV. SCORE / TAXON:	
NUMBER OF FAMILIES:	
AIR BREATHERS' SCORE:	
# AIR BREATHERS:	

BIOTOPE # (Type & # - as recorded on map):..

BIOTOPE DESCRIPTION

Substrate (type & extent):	**Flow** (circle appropriate): no / slow / medium / fast / v.fast. Actual flow m/sec:	**Depth** (average):
Instream veg. (type & extent):	**O.hang veg.** (type & extent):	**Marg veg.** (type & extent):
% Algae on substrate:	**Turbidity:**	**Sampling time** (approx.)
Temperature (& time):	**Conductivity:**	**Ph:**

SUMMARY OF BIOTOPE

SASS SCORE:	**GENERAL COMMENTS** (Species ID'd, samples collected etc)
AV. SCORE / TAXON:	
NUMBER OF FAMILIES:	
AIR BREATHERS' SCORE:	
# AIR BREATHERS:	

BIOTOPE # (Type & # - as recorded on map):..

BIOTOPE DESCRIPTION

Substrate (type & extent):	**Flow** (circle appropriate): no / slow / medium / fast / v.fast. Actual flow m/sec:	**Depth** (average):
Instream veg. (type & extent):	**O.hang veg.** (type & extent):	**Marg veg.** (type & extent):
% Algae on substrate:	**Turbidity:**	**Sampling time** (approx.)
Temperature (& time):	**Conductivity:**	**Ph:**

SUMMARY OF BIOTOPE

SASS SCORE:	**GENERAL COMMENTS** (Species ID'd, samples collected etc)
AV. SCORE / TAXON:	
NUMBER OF FAMILIES:	
AIR BREATHERS' SCORE:	
# AIR BREATHERS:	

DETAILED SITE DIAGRAM: (Record positioning of photographs, biotopes, fish and MI biotopes sampled, anything of importance)

DATE:	RIVER:	IFR SITE:

PROPOSED FISH IFR MONITORING DATA SHEET (revised: 8/5/01)

DATE:	**RIVER:**	**IFR SITE & NAME:**
GUAGING WEIR NAME & READING:		**DWAF DAILY FLOW RECORD:**
ASSESSOR/S:		**RECOMMENDED IFR:**

COMMENTS (Site overall eg. New weirs, erosion, mining, water abstraction, grazing etc)**:**

PHOTO'S:

DESCRIBE AND NUMBER EACH HABITAT ACCORDING TO SITE DIAGRAM:-

HABITAT#:	**RIVER:**	**IFR SITE:**

Category: (circle appropriate) **Shoot / riffle / rapid / pool off stream / pool in stream / run**
Back water / overhang / in stream structure / other:

Flow:	No	Slow	Medium	Fast	Very fast	m/sec	**Width:** (of this habitat)	**Depth:**

Conductivity:	**Temperature:**	**pH:**

Substrate: (circle appropriate – can be more than 1 – underline dominant) **mud / detritus / silt / sand / gravel / pebble / cobble / rock / boulder / bedrock** **Extent:**	**% Algae on (exposed) substrate:**

Marginal Vegetation: (type, o.hang, submerge, extent) **O.hang:**... **Root wads:**.. **Undercut banks:**..	Turbidity**: clear / coloured / turbid / muddy** **Comments / Reasons:**.. ....

Sample technique/s:	**Efforts:**	**Sample technique/s:**	**Efforts:**
Sample technique/s:	**Efforts:**	**Sample technique/s:**	**Efforts:**

Record species & size (J, SA, A) for each sample method (note health of fish when diseased – if apparent)**:**

Summary of the Proceedings
of the
IFR Monitoring Protocol Workshop

13 -15 August, 2001
at the Water Research Commission, Pretoria.

Workshop Facilitator:
Steve Mitchell, Water research Commission

Report compiled by:
Jay O'Keeffe and Jenny Newenham, Institute for
Water Research, Rhodes University.

1. PROGRAMME AND PARTICIPANTS

PROGRAMME FOR THE IFR MONITORING WORKSHOP

AUGUST 13 – 15 2001 AT THE WATER RESEARCH COMMISSION

Monday August 13

11h00 Opening & welcome (Steve Mitchell)
11h10 Aims of the workshop (Jay O'Keeffe)
- To assist DWAF in defining a monitoring policy for the Ecological Reserve.
- To design a monitoring system which will feed back into management
- To review IFR monitoring methods and suggest further priorities
- To design a monitoring system which can be implemented and effective within available resources

12h00 DWAF monitoring policy (Alison Howman)
13h00 Lunch
14h00 Connecting monitoring to management: SAM (Dirk Roux)
15H00 Discussion
16h00 Conclusions
17h00 Close

Tuesday August 14

08h00 Presentation of current methods (Jenny Newenham & Support Chavalala).
- Geomorphology
- Riparian vegetation
- Invertebrates
- Fish
- (Water quality; hydrology; other?)

10h00 Discussion & split into groups
13h00 Lunch
14h00 Group report back
- Geomorphology
- Riparian vegetation
- Invertebrates
- Fish
- General

With regards to designing an IFR /Reserve monitoring system taking the following into consideration:
- Technical requirements
- Personnel
- Costs
- Integration with management

16h00 Close

Wednesday August 15

08h00 Summary of monitoring system design & priorities
10h00 Presentation to DWAF personnel on developments so far (Jay O'Keeffe, Kate Rowntree, James MacKenzie, Support Chavalala & Wynand Vlok)
11h00 Way forward & conclusions
11h30 Close

LIST OF PARTICIPANTS WITH AFFILIATIONS AND CONTACT DETAILS

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Mr	James MacKenzie	CWE, Wits.	james@gecko.biol.wits.ac.za	(011) 7176425	(011) 7176499
Mr	Mick Angliss	N.P.Enviro. Affairs	fish@pixie.co.za	(015) 2959300	(015) 2955819
Mr	Stan Rodgers	N.P.Enviro. Affairs	monit.nprov@pixie.co.za	(015) 2959300	(015) 2955819
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Prof	Kate Rowntree	Geography, Rhodes	k.Rowntree@ru.ac.za	(046) 6038024	(046) 6361199
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Mr	Cornelius Ruiters	DWAF	Deo@dwaf.gov.za	(012) 3367255	(012) 3368678
Mr	Nigel Kemper	IWR Environmental	iwr@mega.co.za	(012) 2590291	same
Dr	Andrew Deacon	SA National Parks	andrewd@parks-sa.co.za	(013) 7355437	?
Dr	Wynand Vlok	UNIN	wynandv@yahoo.com	(015) 2682707	(015) 2682303

2. OBJECTIVES

The workshop was planned within the context of the WRC project to develop monitoring methods specifically for evaluating the effects of recommended flow regimes for the ecological Reserve under the 1998 Water Act. Through the Institute for Water Research (Rhodes University), the project has funded the training of two researchers (Jenny Newenham and Support Chavalala) to undertake initial baseline monitoring on the Sabie/Marite Rivers downstream of the Injaka Dam site, and the Luvuvhu River downstream of the Nandoni Dam site. These dams are in an advanced stage of construction, but to date DWAF has no monitoring programme in place to assess biophysical conditions in the river prior to the closure of the dams. An objective of the WRC project is to provide trained personnel and methods, which could be taken over by DWAF to implement the monitoring required under chapter 14 of the 1998 Water Act.

The aims defined prior to the workshop were:

- To assist DWAF in defining a monitoring policy for the Ecological Reserve.
- To design a monitoring system which will feed back into management
- To review IFR monitoring methods and suggest further priorities
  - To design a monitoring system which can be implemented and effective within available resources

An initial discussion produced a consensus that the workshop should confine itself to the following aspects of monitoring:

- ◎ Compliance with the objectives of the quantity component of the ecological Reserve for rivers.
- ◎ Concentrate on the essential Biophysical components necessary to assess (a) whether the recommended flows were being provided at critical points down the river, and (b) whether the ecological and geomorphological resource quality objectives were being achieved by these flows.
- ◎ Deal with the above components only insofar as they are influenced by managed river flows.

3. MONITORING AND MANAGEMENT

The first day of the workshop was devoted to discussion and recommendations as to the relationship between monitoring and management implementation. In many monitoring programmes, an initial monitoring design is followed in the long-term, often without reference to changing management priorities, and without any attempt to use the information gained to support the decision making process. The philosophy of Strategic Adaptive Management (SAM) includes the concept of "closing the loop" between monitoring and management, so that monitoring methods are constantly being updated in the light of changing priorities, and monitoring information is automatically fed into the management decision making process. The consensus of the workshop was that the following aspects of SAM should become integral to the design of the any IFR monitoring programme:

- ◎ Strategic Adaptive Management
  - Facilitating management response
  - Dealing with uncertainty
  - Feedback: Monitoring ⟺ Management
- ◎ Set detailed biophysical objectives
- ◎ Define an objectives hierarchy and Thresholds of Probable Concern (TPC's)

The precise management structure through which to achieve SAM would be the prerogative of the catchment management authority (CMA). The model, which the workshop adopted, to work with was that a CMA would appoint an officer with the responsibility for monitoring (probably in addition to other duties rather than full time). This officer (the Monitoring Coordinator) would need a scientific background and would be responsible for:

- The design and implementation of monitoring;
- Overseeing the technicians who would do the field monitoring;
- First level interpretation of the monitoring results;
- Publication and dissemination of monitoring information;
- Reporting to the relevant committee on compliance with RQO's;
- Recommending management responses;
- Checking that responses achieved the desired effect;
- Checking and revising monitoring methods in line with management priorities.

3.1 Biophysical objectives and an Objectives Hierarchy

An essential part of the process of setting the ecological Reserve is to define objectives which (with the flow requirements) will become the Resource Quality Objectives (RQO's) for the river. These objectives, if set clearly enough and in sufficient detail, should be the basis for the design of the monitoring system. The methods used can be designed to measure specific indicators which are used to provide an early warning of deteriorating conditions in the river (see TPC's below). At present, for the quantity component of the ecological Reserve for rivers, objectives are being recommended at four levels of increasing detail, in accordance with the Objectives Hierarchy method suggested by Rogers and Bestbier (1997). The highest level of objective is an overall vision, describing the general desired condition of the river, and best expressed by the provisional categories A to D defined in the RDM manuals, where A is virtually unmodified, and B to D imply increasing levels of modification from natural. The fourth level should define precisely a measurable condition of an indicator species or component, which would be the target of a monitoring action. The following is a summary

of the 4 levels of objectives currently defined by specialists in the ecological Reserve process for each of geomorphology; riparian vegetation; water quality; fish; and benthic macro invertebrates (an example of these objectives for invertebrates at a site in the Molenaars River of the Breede system is provided in Figure 1):
The ecological category from A to D.
General flow requirements
General objectives for each speciality
Objectives for indicator species/components.

Figure 1: BREEDE IFR. MOLENAARS SITE: OBJECTIVES FOR AQUATIC INVERTEBRATES (From Bruce Paxton)

Present state: A/B Ecological Class: A/B

General flow objectives:

Maintenance of full range of flows presently in the river

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

General objectives for invertebrate component

- SASS4 score = >140 and ASPT score >8.
- Community to include a large proportion of sensitive taxa such including three or more *baetid* species, *Notonemeuridae, Leptophlebiidae, Elmidae, Dryopidae, Helodidae and Limnichidae* with lower relative abundances of *Chironimidae* and *Oligochaeta.*

Community diversity = H' >4 *ie.* An even distribution of individuals amongst species, reflected low gradient rank-abundance curve.

Objectives for target species

The community rather than individual species will be used. If essential to use target species, the following could be used with the objective of maintaining reasonable abundances of them.
Target species: *Demoreptus capensis*: (riffles)
Cloeodes sp. (slow flow over sand)

3.2 Thresholds of Probable Concern

The concept of thresholds of probable concern (TPC's) is being applied with considerable success in the Kruger National Park, and is considered to be an effective way of ensuring that monitoring information is fed back into management, and of providing clear guidelines as to when management intervention is required.

According to Rogers and Bestbier (1997), "TPC's" provide a set of **end points**, which describe the **desired state** in scientific detail and also provide the basis of a parsimonious programme of monitoring for a wide range of **"biodiversity indicators".**

Examples of provisional TPC's for the Sabie River include:

- The absence or reduction in density of seedlings of *Breonadia salicina,* a tree which roots into cracks in bedrock, and is an indicator for the bedrock anastomosing sections typical of parts of the Sabie.
- A reduction by more than 33% in the index of fish community integrity index.
- A 50% reduction in abundance of selected invertebrate taxa.

These are all measurable indicators, changes in which would provide information about overall changes in the state of the Sabie River at a system level. They link to the higher level objectives expressed in the objectives hierarchy. Because of the uncertainty inherent in river system responses, the TPC's should be subject to periodic revision. When monitoring indicates that any TPC has been exceeded, there must be some management response. This may be simply to review the TPC in the light of additional knowledge, but there is a requirement for the implications of the TPC exceedence to be considered. In this way, TPC's ensure that monitoring information is assessed within the management framework, and that some reaction is guaranteed.

The following qualities of a TPC are likely to make it meaningful, durable and useful:

- Biologically & ecologically meaningful.
- Statistically robust & definable.
- Logical & concise, unequivocally stated in exact detail.
- Conceptually understandable & sufficiently intuitive to be "manager-friendly". Also for this reason, as far as possible consistent within the suite.
- Technically and financially feasible to develop, implement & maintain.

3.2.1 Summary of TPC's

◎ Conservative thresholds to indicate PROBABLE violation of desired condition

◎ Measurable defined end-points

◎ Requirement for some management response

◎ This may be to:

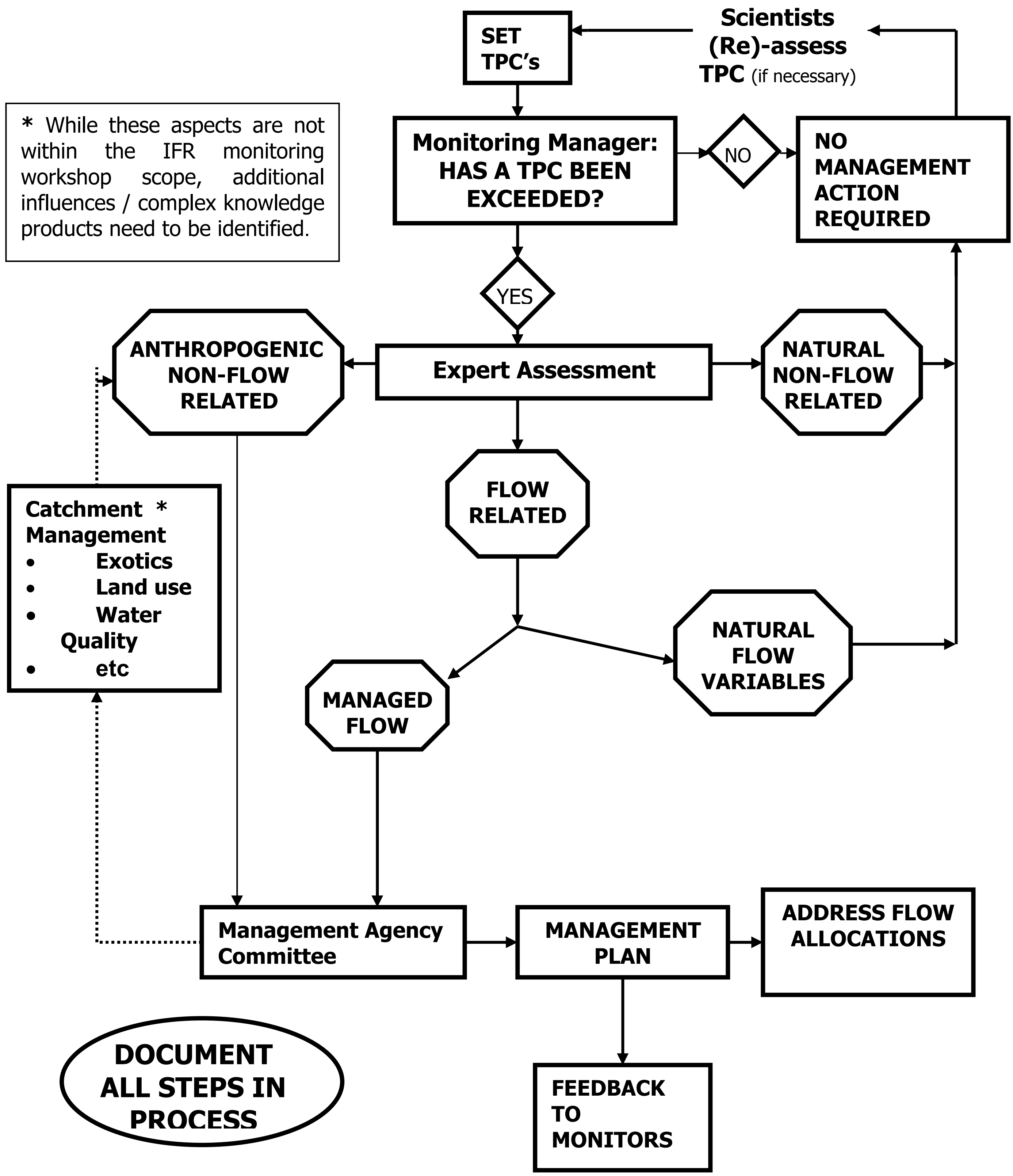
  - To refine the TPC

- To implement more detailed monitoring
- To apply remedial action

⊚ Pragmatic (securely linked to management objectives) and possible to measure within the resources of the monitoring programme. Indicative of system response

Figure 2 provides a flow diagram summarising a possible process through which a monitoring programme could be linked to management response in an adaptive manner.

Figure 2: PROPOSED PROCESS FOR IFR MONITORING



4. DESIGNING THE MONITORING PROTOCOL

The aim of the second day of the workshop was to design and recommend monitoring protocols for each of the specialities, which are normally used to set and check instream flow requirements for the ecological Reserve. The delegates were asked to consider monitoring actions, which could be undertaken in the long term, by technical personnel. It was recognised that the initial stages of any monitoring programme would have to rely on specialist input, not least in order to optimise the level and relevance of information to be collected by the technical personnel. The following were the terms of reference to be considered by the delegates when recommending monitoring actions:

4.1 Terms of Reference

◎ Information that would normally be available from the IFR Workshops:
- Some baseline data on biota, water quality, and geomorphology
- A description of reference conditions (usually the natural state)
- Present conditions
- Ecological and social importance and sensitivity
- Recommended objectives (to 4 levels)
- Rated hydraulic sections
- Hydrological Time Series

◎ When designing the monitoring protocol the following requirements should be considered, each in terms of their purpose; actions; resources; personnel; and frequency:
- Site Rating (A once off site visit and information synthesis, usually requiring specialist and technical personnel, designed to calibrate the site, so that long term monitoring visits can collect the most information for the least effort. *E.g.* an initial hydraulic rating and instalment of a gauge plate, provides discharge measurements at subsequent visits simply by reading the depth off the gauge plate).
- Baseline Monitoring (opportunity to obtain information on natural variability, especially prior to any development. Ideally 2 – 3 years, depending on time before development. Also an opportunity to train technical staff in the monitoring techniques)
- Long-term Monitoring (a sustainable programme of actions that can be accomplished by technical staff with minimal resources).

◎ Data Collection → Interpretation → Storage → Reporting → Management Response
(Data storage and reporting are critical to the long term success of a monitoring programme, and should be carefully planned at the inception of the programme. Naming conventions should be standardised within the

programme, and also between programmes *(e.g.* with the River Health Programme). Ideally, international conventions should be followed. Quality control during collection is also vital.)

◎ Levels of detail required for IFR monitoring:
There was considerable discussion of the possible need for different levels of monitoring for different levels of reserve determination (*e.g.* rapid, intermediate and comprehensive), but the decision within the workshop was to concentrate at two levels of detail:
- Minimum effort to facilitate management decisions
- Incremental actions to add value to the information collected.

5. DETAILED IFR MONITORING ACTIONS RECOMMENDED FOR EACH SPECIALTY

The following section lists the proposed minimum and additional monitoring actions decided on at the workshop, under the following headings:
- Common actions and data requirements
- Geomorphology
- Riparian vegetation
- Macro-invertebrates
- Fish

These were the specialities for which there was expertise at the workshop. In addition to these requirements, there could be actions required for water quality and hydrology, in addition to the standard DWAF monitoring at gauging stations.

5.1 Common actions and data requirements

(Common to all components of the IFR monitoring programme)

◎ Set TPC's for all components of the monitoring programme
◎ Hydrological time series extrapolated to each site (DWAF Hydrology responsibility).
◎ Hydraulic rating curve
Resources: dumpy level / fixed stage plate
Local gauging station / current meter
Personnel: field technician
Frequency: annually during site visit (usually low flow, but sometimes required at high flow).
◎ Site plan and Habitat map to scale (once off, and then can be used thereafter).
Resources: base map from IFR
Personnel: field technician

◎ Fixed point photography (overall of site & habitats within site).

5.2 Geomorphology

Purpose / Rationale:

- Describes the physical habitat template
- Channel form & substrate both flow dependent
- Spatial & temporal scales of change
  - Small scale, short term (substrate)
  - Large scale, long term (channel form)
- Geomorphic system exhibits natural cycles within a dynamic equilibrium.

	ACTIONS	RESOURCES	PERSONNEL	FREQUENCY
SITE RATING	• Assessment according to standard data sheets, integrated with hydraulic transects	Data forms, tape measure	Geomorphology specialist	At the IFR assessment and then after major changes such as the 2000 floods (each site)
BASELINE MONITORING	• Comparison of historical aerial photo's • Analysis of hydrological (flood) record • Assessment of non-flow, catchment impacts	Photo's as available, hydrological record, maps	Geomorphology specialist	NA (can fit in with long-term monitoring)
LON-TERM MONITORING	1. Desk top analysis of hydrological time series linked to hydraulic sections index of stream power (potential for change). TPC: Set in terms of % change over the long-term. 2. Field assessment using standard data sheets. TPC: Set in terms of a change in class for specified components. 3. Aerial photograph monitoring. 4. Re-survey of hydraulic transects. TPC: Set in terms of % change.	1. 1 hr 2. Data sheets (1hr) 3.Photo's as available from external source 4. Survey equipment	1. DWAF hydrologist 2. Field technician 3. Geomorpho logy specialist (Honours level @ least) 4. Survey team	1. Annually updated for each site 2. Annual - @ each site (low flow) 3. As available 4. In response to obvious change or shifts in rating curve.

The use of satellite imagery would be valuable at catchment level – but is not specific enough at site level.

5.3 Riparian Vegetation

Purpose / Rationale:

- To monitor and evaluate the response of riparian vegetation to flow regimes.
- To monitor and evaluate the population structure of selected riparian plant species in order to facilitate their maintenance and conservation (a management objective).

	ACTIONS	RESOURCES	PERSONNEL	FREQUENCY
SITE RATING (To provide critical information to facilitate monitoring)	• Cross-section and placement of species within their zone. • Determination of key & other common species • Description of biological size class	2 hours / transect	1 specialist (& 1 technician depending on whether x section done.)	Once off on first visit
BASELINE MONITORING (To provide a reference point for comparison)	• Belt transect with contiguous plots (10m) • Transect: one of 20m (woody spp.) / 10m (reeds) / 2m (grass /sedges). • Elevation (average / plot) • Horizontal distance from water (average / plot)	4 hours / transect (average)	1 specialist 1 technician (part of training)	Once off After a 1:10 year event (flood / drought)
LON-TERM MONITORING	Rapid: • Quick belt – key species (population structure) • Life forms (trees, shrubs, reeds, grass, sedge, bare ground) % cover. • Assess stress in terms of leaf vigour (1=vigorous green leaf; 2=leaf dicolour (out of season); 3 = loosing leaves).	c. 2 hours per transect	1 technician	• Every 3 years (each site) • After large events 1:20 yr • Indications of a drought.
	Comprehensive: • As above • Add more common species (not every sp & can add annuals if applicable) and / or • Add sites			As financial resources allow

What constitutes a key species (or indicators if they exist)?

- Most abundant
- Situation specific up to 3 woody species (if they exist)
- Sensitive / common cover geomorphic variation
- Reeds
- Woody exotics
- Terrestrial spp.

5.4 Macro-invertebrates

Purpose / Rationale:

◎ To check if the managed IFR flows maintain the habitats that are required by the invertebrates at that particular IFR site**.**

	ACTIONS	RESOURCES	PERSONNEL	FREQUENCY
SITE RATING (ID key habitat features & link to hydraulic cross section)	• Desk top analysis of past work (if any) • Presence at setting of hydraulic profile • ID key species at that specific site	Standard SASS equipment	1 Specialist	Once off
BASELINE MONITORING (To assess if there is any temporal change)	• SASS 5 & Flow SS (new) Monitoring	Standard SASS equipment	1 Specialist	Annually for three years (at same time of year - & low flow)
LON-TERM MONITORING (To ID significant change)	• Implement Flow SS (being developed) • SASS 5 • Compare to photo' data bank to assess trends	Standard SASS equipment	1 technician	• Selected key sites annually • Other IFR sites every 3 years

5.5 Fish

Purpose /Rationale:

◎ To verify if the managed IFR flows do maintain the required habitat for all the different life stages of fish.

	ACTIONS	RESOURCES	PERSONNEL	FREQUENCY
SITE RATING	Desk top (historic records if any, determine ecological management class) Available habitat assessment	As required	1 Specialist 1 Technician	Once off (at each site) & after an extreme event (1:100yr flood)
BASELINE MONITORING	Survey using index (FAII) model applicable to all habitats and collection of population data.	Electro shocker Mosquito net Seine net & boat	2 Technicians 2 Labourers	Once off (@ each site)
LON-TERM MONITORING	1.Survey for indicator species in sensitive habitats (*e.g.* Overhanging vegetation & riffles), but 2. if an extreme event.	Electro shocker & mosquito net	2 Technicians	Annually @ each Rapid Reserve site
	2.Survey using index (FAII) model applicable to all habitats and collection of population data.	Electro shocker Mosquito net Seine net & boat	2 Technicians 2 Labourers	~~Every three years or~~ if TPC violated

6. CASE STUDIES

In the final part of the workshop, in order to provide an idea of the resources required to set up a monitoring programme as envisaged for the ecological Reserve, two cases were considered. The first is specific to the urgent requirement to initiate a DWAF monitoring programme on the sections of the Sabie and Luvuvhu systems, which will be affected by the Injaka and Nandoni Dams. In this case there are established IFR sites, and the present WRC project has collected some baseline monitoring data. However, the February 2000 floods significantly altered the calibrated river cross-sections, so that they will need to be resurveyed, and the hydraulic modeling repeated to provide rated cross-sections. The costings provided here reflect the need to carry out these recalibrations, and the fieldwork involved in baseline and long-term monitoring. They do not reflect the costs involved in the appointment of a monitoring coordinator, nor for the data storage and dissemination, nor for the management structures, which may be necessary to respond to the monitoring results. It is assumed that these would be the responsibility of DWAF.

In the second case, the workshop considered the probable level of resources needed to provide for the IFR monitoring needs of a Catchment Management Authority. The example CMA is that proposed for the Nkomati River system, which includes the Sabie, Crocodile, Lomati and Komati Rivers. In this case a rough estimate has been made of the number of IFR sites at levels of detail, and of the personnel and costs of carrying out the long term monitoring, assuming that the sites have already been rated. (NB The costs given in this section are intended as a rough guide only, and should not be taken as absolute.)

6.1 Sabie / Luvuvhu case study

- Sabie / Marite downstream of Injaka Dam
- Luvuvhu downstream of Nandoni Dam
- 4 sites each (IFR 1,2,4,5 on Sabie; IFR 1, 2 & 2 additional sites on the Luvuvhu)
- Sites need to be re-rated following the February 2000 floods
- Initial Training

Annual long-term monitoring – visit each site in the dry season

Site rating:

- Survey, 1 day (Hydraulics engineer & DWAF)
- Hydraulics, 3 days (to calibrate the hydraulic model for different flows) (Hydraulics engineer/specialist)
- Geomorphology, 2 hours (Geomorphology specialist)
- Costs for 8 sites:

  1 specialist for 34 days @ R300 / hr = R81 600

  S&T = R16 000

  = R97 600

Initial (Training) Visit:

- Geomorphology 2hrs (Technician & Specialist)
- Riparian Veget. 4hrs (Technician & Specialist)
- Invertebrates 2 hr (Technician & Specialist)
- Fish 4 hr (Technician & Specialist)
- Costs for 8 sites:

  2 Technicians @ R100 / hr for 8 days = R12 800
  1 Specialist @ R300 / hr for 8 days = R19 200
  S&T = R11 600
  = R43 600

Annual Long-term Monitoring:

- Geomorphology 2hrs (Technician)
- Riparian Veg. 2hrs (Technician)
- Invertebrates 1 hr (Technician)
- Fish 1 hr (Technician)
- Costs for 8 sites:

  2 technicians for 4 days @ R100 /hr = R6 400
  S&T = R 3 600
  = R10 000

6.2 Possible IFR monitoring structure for a CMA

- Example: Nkomati CMA
- circa. 25 comprehensive reserve sites
- circa. 75 other sites
- CMA Monitoring co-ordinator:
  Scientist / Manager, capable of interpreting (first line) all IFR components, and being first to initiate management / hierarchical response to TPC violation.
  4 months / year (dry season monitoring)
- 2 technicians (outsourced) for monitoring at the sites
  3 months / year
  2 labourers to (outsourced) to assist with monitoring procedures at the sites.
  3 months / year
- Rough estimate of costs:
  R100 000 Personnel / year
  R100 000 Travel & equipment / year
  = **R200 000 / year**

7. REFERENCE

Rogers, K. H. and Bestbier, R. 1997. Development of a protocol for the definition of the desired state of riverine systems in South Africa. Department of Environmental affairs and Tourism, Pretoria. 100 Pages.