PRELIMINARY ECOLOGICAL RESERVE DETERMINATIONS ON ESTUARIES

Determination of the Preliminary Ecological Reserve on a Rapid Level for the Siyaya Estuary

Department of Water Affairs and Forestry

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EXECUTIVE SUMMARY

Assumptions and Limitations

The following assumptions and limitations need to be noted:

- The determination of the Ecological Reserve on a Rapid level is based on the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods of which the documentation is currently in draft form (DWAF 2004).

- The determination of the Ecological Reserve on a Rapid level for the Siyaya Estuary was based on available data and information (refer to Appendix A).

- The Siyaya catchment (quaternary catchment W13B), comprises the Amanzimnyama and Siyaya Rivers. The simulated runoff data obtained for this Rapid Reserve Determination indicates that the natural mean annual runoff (MAR) into the Siyaya Estuary was approximately 6.5 x 10^6 m^3, which is equivalent to an average flow of 0.21 m^3s^{-1} .

- The accuracy of predicted Abiotic States for the Siyaya Estuary and the distribution of these states under Reference Conditions, Present State and Future Scenarios depends largely on the accuracy of the simulated runoff data and on river inflow at the head of the estuary. Should at a future time it be found that the simulated runoff for the Present State and/or the Reference Condition was not representative of the actual situation, the Present Ecological Status, the recommended Ecological Category, the recommended Ecological Water Requirement Scenario as well as the Ecological Categories associated with the different future runoff scenarios, provided in this report would have to be re-assessed.

- The results of this study are based on the simulated runoff data provided to the study team by the project hydrologist Mr Peter Shepherd of SRK consulting engineers. The overall confidence in the hydrological data provided to the team was medium. Sufficient information was available to allow for calibration of the high flow periods, while limited accurate runoff data were available for the low flow periods.

- Due to both time and budgetary constraints not all the biotic categories recommended in the Methodology documents were included in this assessment. The categories chosen were agreed upon by the specialist team to be the key components which would provide an indication of flow-related changes to the system.

- Criteria for confidence limits attached to statements throughout this report are as follows:

LIMIT	DEGREE OF CONFIDENCE
Low	If no data were available for the estuary or similar estuaries (i.e. < 40%)
Medium	If limited data were available for the estuary or other similar estuaries (i.e. 40%–80%)
High	If sufficient data were available for the estuary (i.e. > 80%)

Geographical Boundaries

For the purposes of the Rapid Ecological Reserve determination on the Siyaya Estuary, the geographical boundaries are estimated as follows (WGS 84):

- **Downstream boundary:** The estuary mouth (28^{0}58.034' S, 31^{0}45.723' E).
- **Upstream boundary:** Head of tidal influence, approximately 2.5 km from the mouth (28°58.785 S, 31°44.453 E)
- **Lateral boundaries:** 5 m contour above MSL along the banks.

Present Ecological Status (PES) of the Siyaya Estuary

The Present Ecological Status is determined using the Estuarine Health Index. The Health Index consists of a Habitat health score and a Biological health score. The average of these two scores provides the Estuarine Health Index (EHI) score. In the case of the Siyaya Estuary the score was 37, as indicated below:

VARIABLE	WEIGHT	SCORES FOR PRESENT STATE
Hydrology	25	56
Hydrodynamics and mouth condition	25	95
Water quality	25	41
Physical habitat alteration	25	40
Habitat health score		**58**
Macrophytes	25	30
Invertebrates	25	10
Fish	25	10
Birds	25	10
Biotic health score		**15**
ESTUARINE HEALTH SCORE		**37**

The EHI score for the Siyaya Estuary, based on its Present State, is **37**, translating into a Present Ecological Status of **Category E:**

EHI SCORE	PRESENT ECOLOGICAL STATUS	GENERAL DESCRIPTION
91 – 100	A-/A+	Unmodified, natural
76 – 90	B-/B+	Largely natural with few modifications
61 – 75	C-/C+	Moderately modified
41 – 60	D-/D+	Largely modified
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

Importance of the Siyaya Estuary

The Estuarine Importance Score allocated to the Siyaya Estuary was as follows:

CRITERION	SCORE	WEIGHT	WEIGHTED SCORE
Estuary Size	40	15	6
Zonal Rarity Type	10	10	1
Habitat Diversity	60	25	15
Biodiversity Importance	70	25	18
Functional Importance	60	25	15
ESTUARINE IMPORTANCE SCORE			**55**

IMPORTANCE SCORE	DESCRIPTION
81 – 100	Highly important
61 – 80	Important
0 – 60	Low to average importance

The Estuarine Importance Score for the Siyaya Estuary, based on its Present State, is **55**, placing the estuary at the upper end of the **"low to average importance"** category on a national scale. However, it was emphasized by the specialists at the workshop that the Siyaya estuary is **regionally important** as the only temporarily open / closed system north of the Thukela river. This was a key factor influencing the recommended ecological category for the Siyaya estuary.

Recommended Ecological Category for the Siyaya Estuary

The recommended Ecological Category (EC) represents the level of protection assigned to an estuary. In turn, it is used to determine the recommended Ecological Water Requirement Scenario.

For estuaries the first step is to determine the 'minimum' Ecological Category of an estuary, equivalent to Present Ecological Status (PES). The relationship between Estuarine Health Index Score, Present Ecological Status and Ecological Category is as follows:

ESTUARINE HEALTH INDEX SCORE	PRESENT ECOLOGICAL STATUS	DESCRIPTION	ECOLOGICAL CATEGORY	CORRESPONDING MANAGEMENT CLASS
91 – 100	A	Unmodified, natural	A-/A+	Natural (Class I)
76 – 90	B	Largely natural with few modifications	B-/B+	Good (Class II)
61 – 75	C	Moderately modified	C-/C+	Fair (Class III)
41 – 60	D	Largely modified	D-/D+	
21 – 40	E	Highly degraded	E	Poor (unacceptable)
0 – 20	F	Extremely degraded	F	

NOTE: Should the present ecological status of an estuary be either a Category E or F, recommendations must be made as to how the status can be elevated to at least achieve a Category D (as indicated above).

The degree to which the 'minimum' Ecological Category (based on its Present Ecological Status) needs to be modified to assign a recommended EC depends on:

- Importance of the estuary.
- Modifying determinants, i.e. protected area status and desired protected area status - a status of 'area requiring high protection' should be assigned to estuaries that are identified as vital for the full and most efficient representation of estuarine biodiversity in South Africa.

The proposed rules for allocation of the recommended Ecological Category are as follows:

CURRENT/DESIRED PROTECTION STATUS AND ESTUARINE IMPORTANCE	ECOLOGICAL CATEGORY	POLICY BASIS
Protected area	A or Best Attainable State	Protected and desired protected areas should be restored to and maintained in the best possible state of health.
Desired Protected Area (based on complementarity)	A or Best Attainable State	
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B class.
Important	PES + 1, min C	Important estuaries should be in an A, B or C class.
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D class.

During the workshop great emphasis was placed on the Siyaya Estuary as a 'regionally important' system and in addition the estuary falls within a protected area under the jurisdiction of Ezemvelo KZN Wildlife. Following the rules listed above it is recommended that the Ecological Category be raised to an **A or the Best Attainable State.**

The achievability of the recommended Ecological Category for the Siyaya Estuary was assessed by evaluating the reversibility of present anthropogenic influences that have resulted in a Category E. At the estuarine specialist workshop it was concluded that the main reason for the estuary being in a Category E was the reduction in river flows (although other anthropogenic influences such as flood plain development, sedimentation and other human disturbance have also contributed). This has reduced flow through the mouth, resulting in a decrease in frequency and duration of mouth openings compared to the Reference Condition. The sedimentation of the system coupled with this reduction in river flow has resulted in accelerated encroachment of the reed *Phragmites australis*. A reduction in forestry in the catchment as well as a reed removal programme were considered viable options to 'reverse' present anthropogenic influences on the estuary and to improve the Ecological Category to a Category B.

Thus, the recommended Ecological Category for the Siyaya Estuary is Category B.
Confidence = Low

NOTE:

Other factors, such as the socio-economic and financial implications of removing or at least significantly reducing forestry from the catchment, would need to be discussed by the DWAF and other stakeholders. It is also important to confirm through measurements whether sedimentation in the system is still a major issue and appropriate actions taken if this is shown to be the case.

Quantification of Ecological Water Requirement Scenarios

A summary of the simulated future runoff scenarios (in comparison with the Present State and Reference flows) is as follows:

SCENARIO	DESCRIPTION	MAR (x 10^6 m^3)	% NATURAL MAR
Reference	Reference river flows	6.5	100
Present	Present day conditions: a reduction in overall MAR but with the base flows severely impacted	4.6	71
1	Mining scenario: an increase in discharge from the mining operation and a decline in streamflow-reduction activities	4.8	74
2	Post-mining scenario (short term):	5.7	89
3	Post-mining scenario (long term) with flows equivalent to present day	4.6	71
4	Post-mining scenario with base flows at 0.05 m^3 s^{-1} or corresponding with the reference condition where this is lower	6.2	95
5	Post mining scenario with base flows at 0.05 m^3 s^{-1} or corresponding with the reference condition where this is lower and with management interventions	6.2	95

The individual Estuarine Health Index scores, as well as the corresponding Ecological Category for the different scenarios are presented below:

VARIABLE	WEIGHT	Present State	Future Scenario 1	Future Scenario 2	Future Scenario 3	Future Scenario 4	Future Scenario 5
MAR (x 10^6 m^3)		**4.6**	**4.8**	**5.7**	**4.6**	**6.2**	**6.2**
Hydrology	*25*	56	66	72	56	92	92
Hydrodynamics	*25*	95	95	95	95	98	98
Water quality	*25*	41	49	49	41	54	83
Physical habitat alterations	*25*	40	48	48	40	63	83
Habitat Score	***50***	**58**	**64**	**66**	**58**	**77**	**89**
Macrophytes	*25*	30	30	30	30	40	75
Invertebrates	*25*	10	35	35	17	50	80
Fish	*25*	10	35	35	25	50	80
Birds	*25*	10	35	35	17	50	80
Biological Score	***50***	**15**	**34**	**34**	**22**	**48**	**79**
EHI INDEX SCORE		**37**	**49**	**50**	**40**	**62**	**84**
EC		**E**	**D**	**D**	**E**	**C**	**B**

To select the recommended 'Ecological Water Requirement Scenario', the general rule for estuaries states that the simulated runoff scenario representing the largest modification in flow, but that which would still keep the estuary in the recommended Ecological Category (in this case a **Category B)** should be the recommended 'Ecological Water Requirement Scenario'.

The only scenario evaluated as part of this Rapid determination that provided an Ecological Category B was the one in which flow was returned to 95% of the MAR, coupled with management interventions. The workshop concluded that this was the only way in which an Ecological Category of B could be attained. This was because the reduction in base flows coupled with the sedimentation and reed encroachment accounted for most of the degradation observed in this estuary. The recommended

'Ecological Water Requirement Scenario' for an Ecological Category of B would therefore require the liberation of water within this catchment as well as deliberate management actions such as the removal of sediment and reeds.

For the purposes of this rapid assessment, a conservative estimate of the **recommended 'Ecological Water Requirement Scenario'** for the Siyaya Estuary (to meet the recommended Ecological Category of B) is estimated at a MAR of 6.2 x 10^6 m^3, similar to the Reference Condition, with the following distribution:

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	**1.050**	**1.034**	**2.711**	**1.385**	**1.955**	**2.874**	**2.344**	**1.665**	**1.631**	**1.283**	0.437	**1.718**
90%ile	0.358	0.435	0.419	0.574	**1.271**	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.050	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.050	0.050	0.050	0.050	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.050	0.047	0.050	0.041	0.043	0.050
40%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.036	0.041	0.036	0.037	0.045
30%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.042	0.034	0.032	0.027	0.029	0.038
20%ile	0.044	0.043	0.050	0.050	0.042	0.048	0.035	0.027	0.026	0.021	0.021	0.029
10%ile	0.031	0.031	0.037	0.033	0.031	0.029	0.023	0.018	0.019	0.015	0.018	0.021
1%ile	0.016	0.012	0.020	0.019	0.017	0.013	0.013	0.009	0.010	0.009	0.011	0.014

NOTE:

- **Although the recommended 'Ecological Water Requirement Scenario' provided in this Rapid assessment resembles the flows during the Reference Condition, the re-introduction of such a flow regime will on its own not be enough to lift the estuary to an Ecological Category B, due to the impact of other non-flow related anthropogenic activities on the estuary, such as sedimentation, reed encroachment and removal of supporting wetland and riparian habitats.**

- **The Present Ecological Status of the Siyaya Estuary (Ecological Category E) is considered to be on a negative trajectory rather than stable. Present flows are therefore insufficient to maintain the estuary in its present category.**

- **Increasing flows can marginally lift the system to an Ecological Category D but increases approaching 80% of the MAR are required to lift the system to a C and ultimately a B.**

Recommendations on Additional Monitoring Requirements

Data requirements to improve the confidence of the preliminary Ecological Reserve determination are set out in the method for Intermediate level determination (medium confidence), as well as for comprehensive level determinations (medium to high confidence). In particular, acquisition of the following data sets is required to improve the confidence of the preliminary determination of the Ecological Reserve on the Siyaya Estuary:

- Water level recordings as undertaken by DWAF to be continued. Continuous record of water level variation in the estuary near the mouth (for medium confidence as required for the Intermediate level at least a 5-year record is recommended).

- Continuous flow gauging of river inflow to the estuary (for medium confidence as required for the Intermediate level at least a 5-year record is recommended). This information would be required to establish a relationship between flow and mouth condition, as well as to calibrate the simulated runoff data sets.

- Mouth observations as undertaken by Ezemvelo KZN Wildlife to be continued.

- A bathymetric survey of the estuary should be undertaken, including a detailed survey of the inlet and cross-sections upstream at the locations at which earlier cross-sections were surveyed by the CSIR (Van der Elst *et al.*, 1999).

- Monitoring of longitudinal and vertical salinity distributions.

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1. INTRODUCTION

1.1 Background

The Regional office of the Department of Water Affairs and Forestry (DWAF) has received licence applications in the Siyaya and Manzimnyama catchments which could alter the flow and/or impact upon the Siyaya estuary. In order to comply with the National Water Act 36 of 1998 a Rapid Ecological Reserve Determination for the Siyaya Estuary is required. The licences issued would then contain conditions which would give effect to the reserve to ensure the long term sustainable use of the water resource.

A terms of reference approved by the RDM directorate of the DWAF was provided to MER on Tuesday 21st February 2006 and detailed the requirements to conduct this specific rapid reserve determination.

The core specialist team appointed for this project was as follows:

TEAM MEMBER	ROLE/EXPERTISE	CONTACT DETAILS
Ms Nicolette Demetriades	Project Coordination / report preparation	Marine & Estuarine Research (nicolette@mer.co.za)
Mr Piet Huizinga	Hydrodynamics & preparation of templates	Private consultant (p.huizinga@adept.co.za)
Ms Lara van Niekerk	Hydrodynamics & preparation of templates	CSIR, Stellenbosch (lvnieker@csir.co.za)
Ms Shamilla Pillay	Macrophytes	CSIR, Durban (spillay@csir.co.za)
Ms Fiona McKay	Benthic invertebrates & macro-crustacea	Oceanographic Research Institute (fmackay@ori.org.za)
Prof Digby Cyrus	Macro-crustacea & fish	CRUZ, University of Zululand (dcyrus@pan.uzulu.ac.za)
Prof Ticky Forbes	Birds	Marine & Estuarine Research (ticky@mer.co.za)

The Department of Water Affairs and Forestry was represented by:

PERSON	CONTACT DETAILS
Ms Barbara Weston	SWRR Resource Directed Measures (WestonB@dwaf.gov.za)
Mr Hugh Dixon-Paver	Kwazulu Natal Regional Office (hughDP@dwaf.gov.za)
Mr Dana Grobler	Blue Science Consulting (dana@bluescience.co.za)

The following people attended as observers:

PERSON	CONTACT DETAILS
Mr R. Hattingh	TICOR SA rob.hattingh@ticor-sa.com
Ms J. Adam	TICOR SA/Exigent jacolette@ticor-sa.com/jacolette@exigent.co.za

1.2 Assumptions and Limitations

The following assumptions and limitations need to be taken into account for this study:

- The determination of the Ecological Reserve on a Rapid level is based on the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods of which the documentation is currently in draft form (DWAF 2004).

- The determination of the Ecological Reserve on a Rapid level for the Siyaya Estuary was based on available data and information (refer to Appendix A).

- The Siyaya catchment (quaternary catchment W13B), comprises the Amanzimnyama and Siyaya Rivers. The simulated runoff data obtained for this Rapid Reserve Determination indicates that the natural mean annual runoff (MAR) into the Siyaya Estuary was approximately 6.5 x 10^6 m^3, which is equivalent to an average flow of 0.21 m^3s^{-1} .

- The accuracy of predicted Abiotic States for the Siyaya Estuary and the distribution of these states under Reference Conditions, Present State and Future Scenarios depends largely on the accuracy of the simulated runoff data and on river inflow at the head of the estuary. Should at a future time it be found that the simulated runoff for the Present State and/or the Reference Condition was not representative of the actual situation, the Present Ecological Status, the recommended Ecological Category, the recommended Ecological Water Requirement Scenario as well as the Ecological Categories associated with the different future runoff scenarios, provided in this report would have to be re-assessed.

- The results of this study are based on the simulated runoff data provided to the study team by the project hydrologist Mr Peter Shepherd of SRK consulting engineers. The overall confidence in the hydrological data provided to the team was medium. Sufficient information was available to allow for calibration of the high flow periods, while limited accurate runoff data were available for the low flow periods.

- Due to both time and budgetary constraints not all the biotic categories recommended in the Methodology documents were included in this assessment. The categories chosen were agreed upon by the specialist team to be the key components which would provide an indication of flow-related changes to the system.

- Criteria for confidence limits attached to statements <u>throughout this report</u> are as follows:

LIMIT	DEGREE OF CONFIDENCE
Low	If no data were available for the estuary or similar estuaries (i.e. < 40%)
Medium	If limited data were available for the estuary or other similar estuaries (i.e. 40%–80%)
High	If sufficient data were available for the estuary (i.e. > 80%)

1.3 Process for Preliminary Determination of Ecological Reserve (Rapid Level) for Estuaries

The process followed in the preliminary determination of the Ecological Reserve on a Rapid level for estuaries is illustrated in Figure 1.1. The rapid determination is generally based on available information. It is therefore important that a desktop assessment of available information on the different abiotic and biotic components is conducted prior to the workshop. The process comprises the following steps:

Step 1: Initiation of RDM study. During the initiation of an RDM study, it is important to establish the level at which the study needs to be conducted (e.g. rapid, intermediate or comprehensive), as well as the reserve components that need to be addressed (e.g. rivers, estuaries, wetlands or groundwater). The key outcome of Step 1 is therefore the detailed scope of the RDM study. In the case of the Siyaya Estuary, it was decided to conduct the Ecological Reserve study on the estuary at the Rapid level.

Step 2: Definition of Resource Units. Each estuary is delineated as a separate resource unit within a larger catchment, characterized by site dependent abiotic and biotic characteristics. For estuaries, the default geographical boundaries are defined as follows:

- **Downstream boundary:** The estuary mouth. It should be noted that there are systems where the 'estuary' expands to the near-shore marine environment and where this boundary definition may need to be reconsidered in future.
- **Upstream boundary:** The extent of tidal influence, i.e. the point up to where tidal variation in water levels can still be detected or the extent of saline intrusion, whichever is furthest upstream.
- **Lateral boundaries:** The 5 m above MSL contour along each bank.

The geographical boundaries for the Siyaya Estuary are addressed in Chapter 2 of this report.

Step 3: Ecological Categorisation. The main outcome of this step is a recommended Ecological Category for the estuary. For the Siyaya Estuary, the ecological categorisation step is dealt with in Chapter 3.

The method for estuaries uses simulated runoff scenarios, where scenarios are typically simulated over a 50-70 year period and are presented as average monthly flows that represent inflows at the head of the estuary. For the definition of the recommended Ecological Category simulated runoff scenarios for the *present state* and the *reference condition* are used.

Firstly, the Present State of an estuary is defined as a quantitative description of the present abiotic and biotic characteristics and functioning of the system (Chapter 3.1). For estuaries, the following components are recognised:

Abiotic (or driving components):

- Physical dynamics (including hydrodynamics and sediment dynamics)
- Water quality

Biotic (response) components:

- Estuarine flora (microalgae and macrophytes)
- Estuarine fauna (invertebrates, fish and birds).

(Sediment dynamics are not included as part of a Rapid level determination and were therefore not included in this study on the Siyaya Estuary.)

Thereafter the Reference Condition of an estuary is defined (Chapter 3.2). For the purposes of the preliminary determination of the Ecological Reserve, the reference condition of an estuary refers to the ecological status that it would have had:

- when receiving 100% of the natural MAR
- before any human development in the catchment or within the estuary
- before any mouth manipulation practices (e.g. artificial breaching).

Typically, the reference conditions in an estuary refer to its ecological status 50 to 100 years ago.

The present state and reference condition of an estuary are then used to determine the Present Ecological Status (PES) (Chapter 3.3). The PES is a measure of the health of a resource, based on a comparison between the reference condition and the present state. An Estuarine Health Index (EHI) is used to determine the PES for estuaries.

Also included in this step is an assessment of the Estuarine Importance (ecological) of an estuary (Chapter 3.4). Estuarine importance is an expression of the importance of an estuary to the maintenance of ecological diversity and functioning on local and wider scales. Variables were discussed in a workshop setting, regarding their suitability for inclusion in an Estuarine Importance Index. The importance scores have been derived for most South African estuaries as part of a project entitled: *Classification and prioritisation of South African estuaries on the basis of health and conservation status for determination of the estuarine water reserve* (Turpie *et al.*, 2002). The only importance score that needs to be derived by the estuarine ecological reserve team at the specialist workshop is the functionality score (*e.g.* links between estuary and freshwater and marine environments).

Finally, the Present Ecological Status and estuarine importance score are used to come to a recommended Ecological Category for an estuary, according to pre-defined guidelines as discussed in Chapter 3.5.

Step 4: Quantification of Ecological Water Requirement Scenarios. The method for the preliminary determination of the Ecological Reserve for estuaries uses a 'top down' approach, i.e. simulated runoff scenarios are used to assess the response of the estuary to changes in freshwater input. For the quantification of Ecological Water Requirement Scenarios simulated flows for a range of future scenarios are required. Scenarios are typically simulated over a 50-70 year period and are presented as average monthly flows and should represent inflows at the head of the estuary. For the Siyaya Estuary, three future runoff scenarios were provided by the DWAF.

To determine the Ecological Category of the estuary associated with each of the flow scenarios, the runoff simulations together with an understanding of the present state are used to determine changes in abiotic states within an estuary for each of the scenarios. Changes in abiotic characteristics are then assessed in terms of the biological implications, using the same estuarine health index that was used to derive the Present Ecological Status. Results from these evaluations are then used to select the 'recommended Ecological Water Requirement scenario', defined as the run-off scenario, or a slight modification thereof, that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended Ecological Category.

The quantification of ecological reserve scenarios for the Siyaya Estuary is dealt with in Chapter 4.

The output of a preliminary determination of the Ecological Reserve on a Rapid level provides:

- A recommended Ecological Category and the associated recommended Ecological Water Requirement Scenario
- Ecological Categories for different runoff scenarios assessed as part of Step 4.

If requested, the specialist team can also provide additional monitoring requirements. However, these can be obtained from the data requirements stipulated in the preliminary determination of the Ecological Reserve on a Intermediate or Comprehensive level in the Estuaries methods, depending on the level of confidence that would be required by the DWAF.

The preliminary determination of the Ecological Reserve on a Rapid level does not require the determination of Ecological Specifications (*i.e.* Resource Quality Objectives for the Ecological Component).

Although the rapid method also does not require the preparation of a detailed Resources Monitoring Programme, key baseline data requirements, that would be required to improve the confidence of the rapid preliminary ecological reserve determination, should be provided. In this regard, the data requirements recommended in the methodologies for the intermediate and comprehensive ecological reserve determinations need to be consulted.

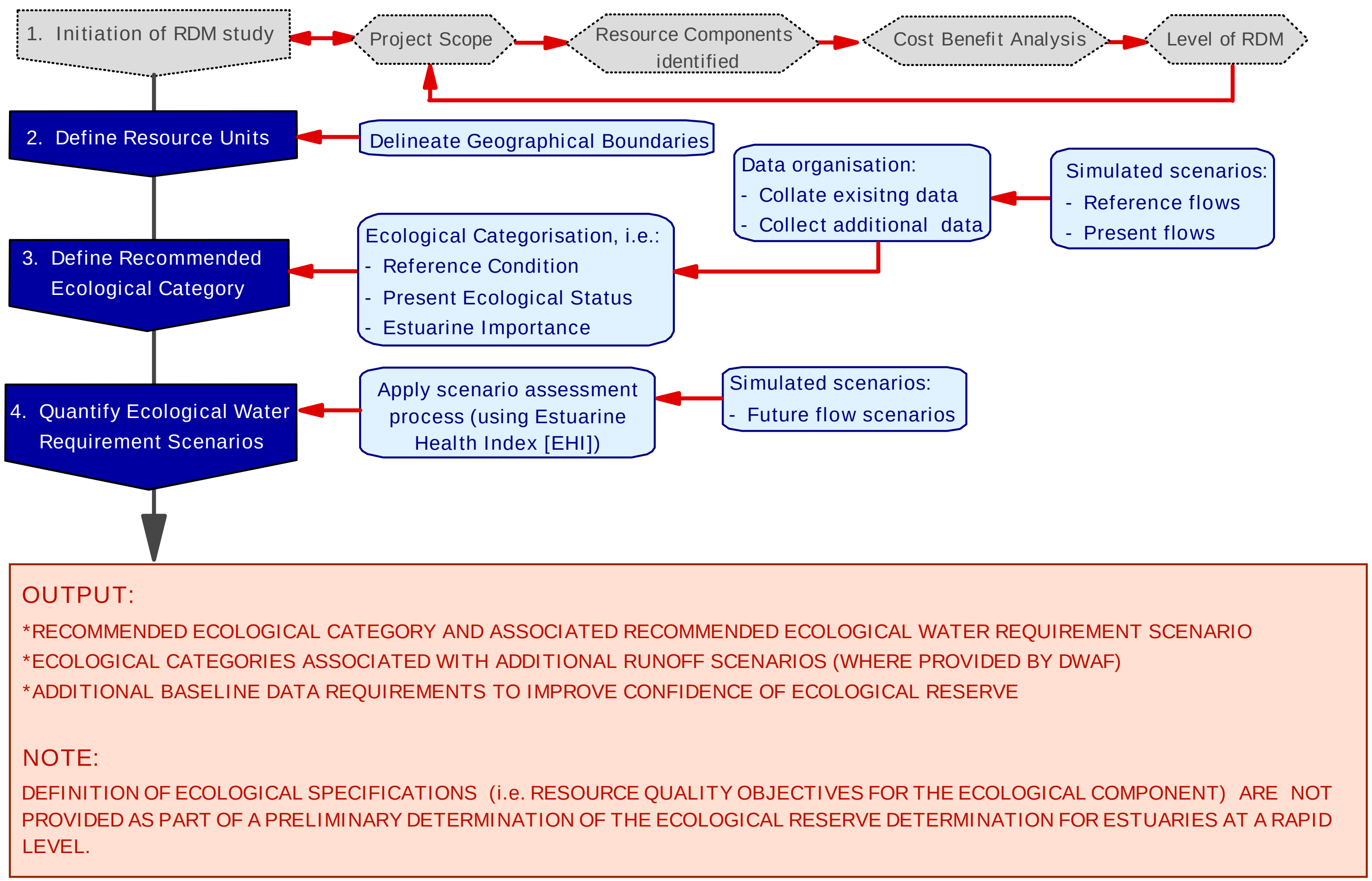


Figure 1.1: Procedures for a Rapid Ecological Reserve determination on estuaries in context of the broader RDM process (components not addressed as part of the Ecological Reserve determination process are indicated by non-solid line boxes)

2. DEFINITION OF RESOURCE UNIT

For the purposes of the Rapid Ecological Reserve determination on the Siyaya Estuary, the geographical boundaries are estimated as follows (WGS 84):

- **Downstream boundary:** The estuary mouth (28°58.034’ S, 31°45.723’ E).
- **Upstream boundary:** Head of tidal influence, approximately 2.5 km from the mouth (28°58.785 S, 31°44.453 E)
- **Lateral boundaries:** 5 m contour above MSL along the banks.

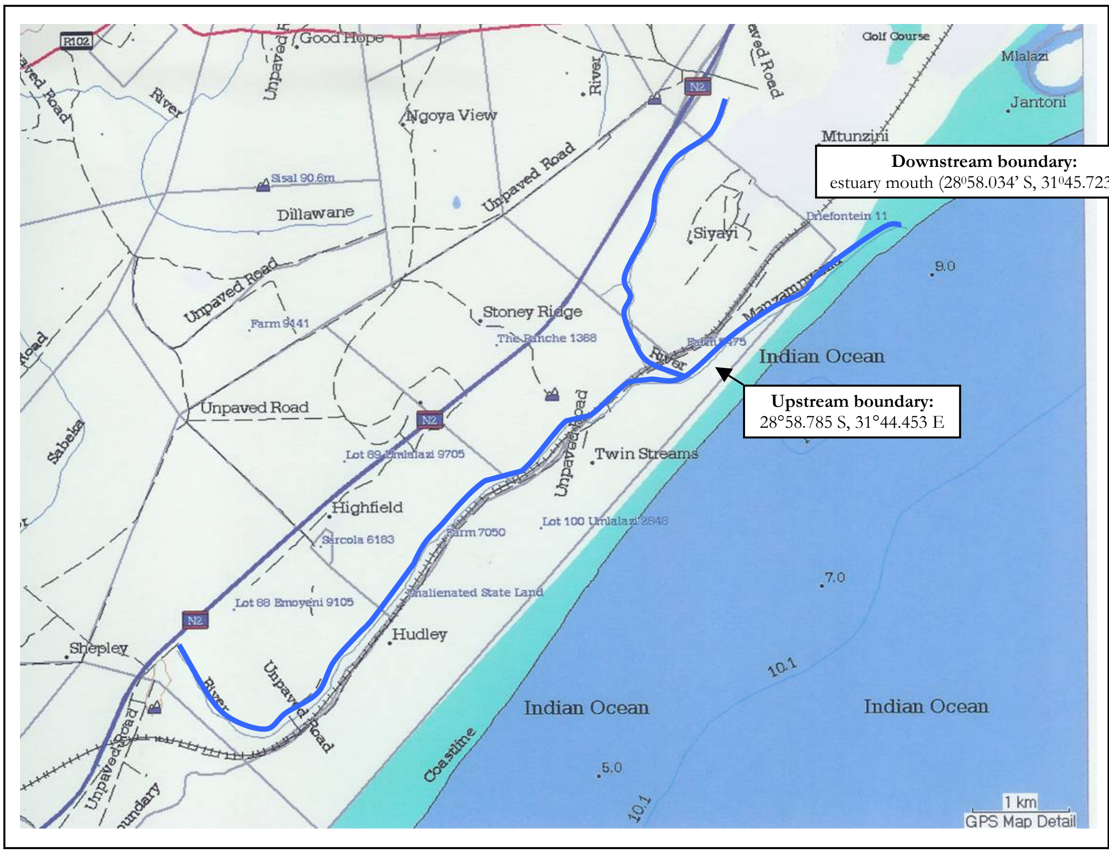


***Figure 2.1**: Position of the Siyaya Estuary on the KZN coast*

3. Ecological Categorisation

3.1. Typical Abiotic States

Three states were identified for the Siyaya Estuary:

State 1: Open Mouth (1 – 3 days at a time)	> 0.3 m^3/s
State 2: Closed Mouth, high water levels	0.025 – 0.3 m^3/s
State 3: Closed Mouth, low water levels	0 – 0.025 m^3/s

The transitions between the different states will not be instantaneous, as the resultant mouth conditions and salinity distribution are both dependent on the flow rate and its duration.

During months in which State 1 occurs, open mouth conditions only persist for a few days at a time, i.e. the Siyaya Estuary follows a rapid mouth open/closed regime depending on the size of the freshette/flood that breached the mouth and follow up high flow conditions. Semi-closed conditions may occur shortly after closure in State 1 and perhaps also in State 2. This means that a channel with outflow may still be present but this is in a perched position on the berm and tidal inflow will hardly occur. High waves, especially at spring tides, may cause overwash of the berm at all three states, depending on the height of the berm.

ABIOTIC STATE 1: OPEN MOUTH
Typical flow patterns: Flow ranges > 0.3 m^3/s represent months were open mouth conditions occur for short periods at a time. *Confidence: Low*
State of the mouth: The mouth is open for short periods at a time (1-3 days). Semi-closed mouth conditions could occur shortly after closure. Thereafter overwash of the berm could occur with high waves during springtides. *Confidence: Low*
Flood plain inundation patterns: This state does not result in inundation of the flood plain. *Confidence: High*
Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide): Very little tidal variation occurs during the open state. *Confidence: Low*
Retention times of water masses: During the open state most of the estuary drains and retention time is low. *Confidence: Low*
Total volume: Less than 10 000 m^3 *Confidence: Medium*
Salinity distributions in the estuary: During the open state the salinity depends on the extent to which the estuary mouth has been flushed open. The salinity distribution tends to be very homogenous, with limited saline penetration in the lower 500 m. The upper to middle reaches tend to be below 5 ppt, while the lower reaches generally tend to be less than 10 ppt. Right after a flood/freshette salinity values of more than 25 ppt have been recorded throughout the system for short periods at a time (i.e. a few weeks). *Confidence: Low*
System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen): Temperature variable due to mixing of river and sea water. pH reduced relative to sea water, suspended solids, turbidity and dissolved oxygen relatively high due to water movement and turbulence. *Confidence: Low*
Nutrients: Relatively low due to rapid run-off and no retention. *Confidence: Low*

ABIOTIC STATE 2: CLOSED MOUTH, HIGH WATER LEVELS

Typical flow patterns: Flow ranges 0.025 - 0.3 m^3/s

Confidence: Low

State of the mouth: The mouth is closed with water levels between 1. 3 m and 2.65 m.

Confidence: Low

Flood plain inundation patterns: Floodplain inundation can occur in this state. However the area of the flood plain is limited.

Confidence: High

Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide): No tidal variation occurs during this state. Variations in flow result in variations in water levels related to the balance between river inflow and seepage through the berm.

Confidence: Low

Retention times of water masses: The retention time will last as long as the mouth stays closed.

Confidence: Low

Total volume: The volume of water in the estuary will vary between 60 000 m^3 and 160 000 m^3 dependent on the water level.

Confidence: Medium

Salinity distributions in the estuary: Low with little horizontal or vertical variation.

Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen): Some temperature layering possible, low suspended solids and turbidity, dissolved oxygen dependent on amount of organic debris and vegetation growth, layering effects possible under calm conditions. No extreme pH levels.

Confidence: Low

Nutrients: High water levels would be associated with consistent run-off and possible accumulated nutrient input from catchment. Would expect uptake by macrophytes and possibly phyto-plankton.

Confidence: Low

ABIOTIC STATE 3: CLOSED MOUTH, LOW WATER LEVELS

Typical flow patterns: Flow ranges 0.0 - 0.025 m^3/s.

Confidence: Low

State of the mouth: The mouth is closed with water levels between 0.6 m and 1. 3 m. Overwash only occurs at springtide when the waves are very high

Confidence: Low

Flood plain inundation patterns: This state does not result in inundation of the flood plain.

Confidence: High

Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide): No tidal variation occurs during this state. Variations in flow result in variations in water levels related to the balance between river inflow, water levels and seepage through the berm.

Confidence: Low

Retention times of water masses: The retention time will last as long as the mouth stays closed.

Confidence: Low

Total volume: Between 10 000 m^3 and 60 000 m^3 dependent on the water level.

Confidence: Medium

Salinity distributions in the estuary: Predominantly fresh and horizontally uniform.

Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen): Possible temperature layering due to emergent vegetation reducing wind turn over effects, possible reduced pH and oxygen in deeper water due to organic decay, suspended solids and turbidity low due to settling and low input

Confidence: Low

Nutrients: Possibly low due to low input but this may be compensated by groundwater flow.

Confidence: Low

3.2. Description of Present State

3.2.1. Abiotic Components

a) Seasonal variability in river inflow

Monthly simulated runoff data for the Present State are provided in Table 1. A summary of the occurrences of flow distributions (mean monthly flows in m^3/s) for the Present State of the Siyaya Estuary, derived from the 85-year simulated data set, is provided below:

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	0.995	0.942	**2.605**	**1.296**	**1.913**	**2.755**	**2.158**	**1.516**	**1.484**	**1.156**	0.374	**1.514**
90%ile	0.284	0.355	0.351	0.493	**1.146**	0.618	0.404	0.202	0.104	0.149	0.070	0.314
80%ile	0.135	0.181	0.176	0.284	0.555	0.329	0.133	0.102	0.046	0.051	0.045	0.102
70%ile	0.080	0.133	0.096	0.179	0.357	0.137	0.052	0.057	0.031	0.031	0.033	0.054
60%ile	0.060	0.082	0.068	0.111	0.130	0.077	0.034	0.024	0.021	0.027	0.022	0.036
50%ile	0.027	0.046	0.048	0.048	0.053	0.037	0.019	0.013	0.016	0.017	0.014	0.019
40%ile	0.008	0.021	0.018	0.009	0.021	0.012	0.009	0.003	0.011	0.009	0.008	0.009
30%ile	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20%ile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10%ile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1th%ile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

b) Present flood regime

The flood regime is judged to be very similar to that under reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than 1 m^3/s. This is to be expected as there is no large dam development in the catchment.

Confidence: ***Medium***

c) Present sedimentary processes

The current shallowness of the lower estuary is to a large extent related to the decrease in water levels because of the reduction in base flow.

Significant sedimentation occurred in the estuary in the past because of the development of sugarcane farming in the catchment. More recently the cane has been largely replaced by forestry and erosion may have been reduced. Although sedimentation has been reduced the river is not able to easily move previous deposits as evidenced by recent floods which were not strong enough to flush the estuary and reset it to its reference conditions.

Confidence: ***Low***

d) Occurrence and duration of Abiotic states during the Present State

The occurrence of the different states is for easier analysis illustrated in three different ways:

- Firstly by the indicated colour coding in Table 1, which includes the full simulated monthly runoff dataset for this scenario.
- Secondly the same data are summarized in the occurrence table under (a) above, in which the same colour coding is used.
- Thirdly, to obtain a quick overview, the median (50 %) and drought (10 %) data are plotted in the figure below.

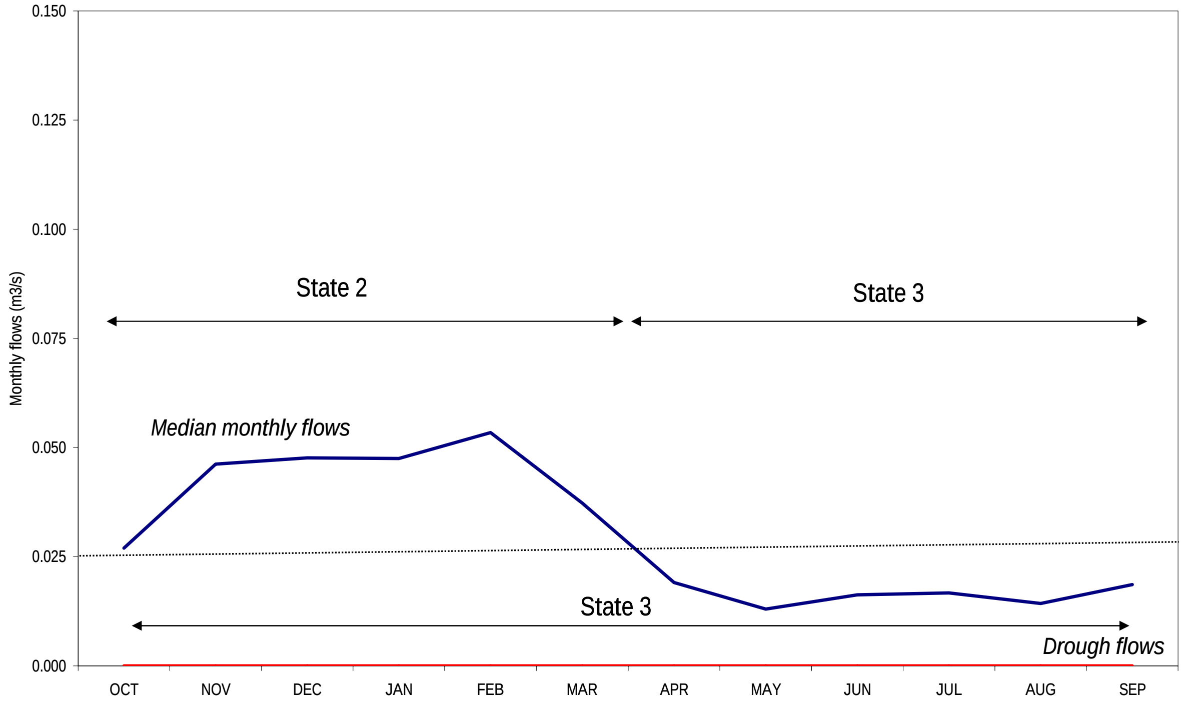


Table 1. Present State: Simulated runoff data for the Siyaya estuary in m³/s

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1920	0.007	0.000	0.094	0.143	0.000	0.103	0.000	0.000	0.000	0.000	0.000	0.088	0.037
1921	0.114	0.613	0.553	0.008	0.007	0.111	0.000	0.057	0.003	0.000	0.044	0.000	0.126
1922	0.007	0.175	0.000	0.991	0.086	0.000	0.007	0.023	0.000	0.000	0.000	0.000	0.108
1923	0.000	0.000	0.142	0.097	0.012	0.532	0.091	0.022	0.079	0.030	0.021	0.158	0.099
1924	0.104	0.538	0.396	0.045	0.744	**3.774**	0.951	0.415	0.046	0.110	0.034	0.031	0.600
1925	0.005	0.000	0.075	0.004	0.000	0.000	0.000	0.000	0.003	0.001	0.000	0.073	0.013
1926	0.107	0.046	0.159	0.006	0.049	0.578	0.039	0.085	0.021	0.030	0.016	0.007	0.096
1927	0.001	0.000	0.000	0.449	0.020	0.012	0.068	0.096	0.019	0.009	0.047	0.000	0.061
1928	0.000	0.000	0.000	0.000	0.000	**1.717**	0.102	0.000	0.018	0.037	0.058	0.017	0.165
1929	0.014	0.005	0.000	0.232	0.000	0.000	0.007	0.000	0.048	0.009	0.003	0.038	0.030
1930	0.000	0.041	0.071	0.000	0.000	0.065	0.013	0.000	0.000	0.014	0.000	0.000	0.017
1931	0.000	0.000	0.053	0.000	**1.746**	0.112	0.369	0.501	0.065	0.028	0.018	0.005	0.230
1932	0.000	0.000	0.093	0.038	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.011
1933	0.000	0.000	0.250	0.322	0.097	0.004	0.018	0.139	0.134	0.132	0.045	0.017	0.097
1934	0.000	0.000	0.599	0.008	0.004	0.000	0.000	0.546	**3.405**	0.645	0.571	0.055	0.486
1935	0.006	0.000	0.000	0.149	**1.233**	0.089	0.002	0.196	0.036	0.027	0.014	0.025	0.141
1936	0.059	0.392	0.007	0.000	0.152	0.057	0.052	0.004	0.092	0.048	0.032	0.010	0.074
1937	0.000	0.000	0.175	0.071	0.546	0.006	0.000	0.000	0.021	0.411	0.050	0.005	0.105
1938	0.022	0.000	0.000	0.000	0.409	0.064	0.001	0.105	0.040	0.097	0.028	**1.015**	0.145
1939	0.074	0.557	0.044	0.004	0.000	0.037	0.142	**1.302**	0.820	0.076	0.065	0.020	0.262
1940	0.008	0.583	0.212	0.013	0.000	0.097	0.016	0.000	0.018	0.012	0.001	0.022	0.082
1941	0.000	0.102	0.036	0.653	0.021	0.313	0.022	0.026	0.018	0.025	0.021	0.011	0.105
1942	0.000	0.215	0.462	0.009	0.031	0.776	0.571	0.069	0.041	0.349	0.336	0.044	0.244
1943	0.134	0.020	0.047	0.000	0.115	0.059	0.000	0.000	0.197	0.033	0.013	0.544	0.095
1944	0.033	0.041	0.000	0.000	0.850	0.624	0.039	0.003	0.000	0.000	0.002	0.000	0.128
1945	0.000	0.000	0.000	0.000	0.000	0.012	0.061	0.000	0.000	0.000	0.000	0.000	0.006
1946	0.034	0.000	0.048	0.000	0.644	0.152	0.019	0.007	0.022	0.023	0.014	0.035	0.079
1947	0.055	0.002	0.107	0.077	0.000	0.000	0.012	0.002	0.000	0.000	0.000	0.000	0.022
1948	0.000	0.004	0.000	0.000	0.371	0.000	0.369	0.013	0.013	0.006	0.000	0.000	0.062
1949	0.190	0.036	0.336	0.001	0.367	0.012	0.000	0.005	0.006	0.002	0.000	0.000	0.078
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.213	0.101	0.026
1951	0.067	0.000	0.089	0.037	0.000	0.052	0.003	0.083	0.014	0.028	0.007	0.000	0.032
1952	0.000	0.079	0.000	0.000	0.161	0.001	0.000	0.000	0.000	0.000	0.000	0.049	0.023
1953	0.022	0.196	0.048	0.174	**1.020**	0.069	0.170	0.131	0.050	0.028	0.009	0.136	0.164
1954	0.625	0.032	0.012	0.282	0.021	0.533	0.031	0.002	0.000	0.000	0.000	0.002	0.130
1955	0.150	0.162	0.223	0.000	**1.294**	0.119	0.030	0.013	0.111	0.039	0.106	0.105	0.188
1956	0.057	0.101	**3.482**	0.317	0.384	0.237	0.526	0.057	0.029	0.052	0.034	0.619	0.494
1957	0.975	0.085	0.020	0.186	0.682	0.030	0.329	0.032	0.024	0.018	0.006	0.515	0.238
1958	0.062	0.000	0.000	0.074	0.007	0.000	0.000	0.016	0.000	0.000	0.000	0.372	0.044
1959	0.141	0.000	0.290	0.000	**1.524**	0.160	0.849	0.257	0.045	0.022	0.014	0.039	0.269
1960	0.000	0.683	**2.438**	0.422	**1.571**	0.098	**3.304**	0.207	0.989	0.201	0.038	0.078	0.824
1961	0.151	0.137	0.018	0.058	0.025	0.055	0.019	0.018	0.003	0.004	0.035	0.012	0.045
1962	0.090	0.099	0.067	0.312	0.023	0.160	0.037	0.004	**1.118**	**1.088**	0.096	0.011	0.260
1963	0.076	0.059	0.007	0.578	0.070	0.001	0.223	0.024	0.011	0.030	0.024	0.019	0.094
1964	0.593	0.169	0.041	0.000	0.000	0.000	0.089	0.018	0.090	0.072	0.180	0.161	0.118
1965	0.672	0.144	0.013	0.303	0.082	0.000	0.011	0.003	0.029	0.013	0.095	0.031	0.117
1966	0.006	0.022	0.000	0.181	0.053	**1.334**	**1.939**	0.127	0.019	0.062	0.033	0.007	0.315
1967	0.061	0.056	0.000	0.127	0.063	0.439	0.030	0.001	0.019	0.009	0.064	0.016	0.074
1968	0.027	0.189	0.151	0.000	0.000	**1.624**	0.130	0.133	0.044	0.031	0.026	0.228	0.218
1969	0.250	0.031	0.179	0.027	0.000	0.000	0.001	0.074	0.020	0.023	0.020	0.022	0.055
1970	0.413	0.650	0.036	0.294	0.188	0.359	0.335	**2.640**	0.185	0.586	0.066	0.083	0.490
1971	0.179	0.074	0.136	0.201	**2.326**	0.162	0.041	0.736	0.079	0.044	0.026	0.001	0.320
1972	0.000	0.107	0.365	0.115	0.258	0.001	0.347	0.036	0.013	0.028	0.010	0.823	0.173
1973	0.061	0.100	0.006	0.523	0.077	0.000	0.021	0.101	0.035	0.030	0.021	0.000	0.082
1974	0.000	0.215	0.000	0.127	0.544	0.030	0.012	0.006	0.004	0.008	0.007	0.204	0.092
1975	0.033	0.045	0.055	0.732	0.409	**2.561**	**1.114**	0.152	0.035	0.051	0.042	0.120	0.447
1976	0.208	0.087	0.361	0.268	**1.834**	0.527	0.042	0.025	0.015	0.017	0.014	0.110	0.282
1977	0.065	0.149	0.057	**1.191**	0.215	0.079	0.427	0.047	0.031	0.032	0.025	0.058	0.198
1978	0.527	0.058	0.001	0.033	0.000	0.000	0.000	0.096	0.016	0.009	0.009	0.051	0.068
1979	0.008	0.222	0.096	0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	0.094

Table 1 (cont.) Present State: Simulated runoff data for the Siyaya estuary in m³/s

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1980	0.021	0.036	0.000	0.000	0.593	0.036	0.023	0.400	0.083	0.034	0.034	0.063	0.107
1981	0.013	0.179	0.016	0.014	0.022	0.076	0.003	0.094	0.015	0.011	0.001	0.000	0.037
1982	0.133	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048	0.000	0.015
1983	0.081	0.146	0.038	**1.845**	**1.223**	0.158	0.052	0.020	0.010	0.066	0.025	0.000	0.300
1984	0.000	0.000	0.000	0.212	0.934	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.092
1985	**1.102**	0.021	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.107
1986	0.000	0.000	0.056	0.108	0.000	0.620	0.023	0.000	0.144	0.021	0.033	**4.134**	0.424
1987	0.307	0.073	0.064	0.000	**1.288**	0.399	0.029	0.006	0.011	0.012	0.014	0.003	0.177
1988	0.039	0.257	0.161	0.000	0.348	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.065
1989	0.000	**2.050**	0.091	0.000	0.000	0.614	0.039	0.000	0.000	0.000	0.072	0.000	0.237
1990	0.107	0.000	0.297	0.240	0.050	0.723	0.040	0.043	0.009	0.018	0.014	0.023	0.132
1991	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.004
1992	0.000	0.301	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025
1993	0.133	0.000	0.128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022
1994	0.216	0.000	0.000	0.000	0.000	0.034	0.472	0.030	0.029	0.008	0.000	0.000	0.066
1995	0.030	0.118	0.655	0.532	**1.031**	0.142	0.014	0.005	0.000	0.165	0.020	0.000	0.221
1996	0.000	0.000	0.000	0.229	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.020
1997	0.000	0.731	0.018	0.000	0.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.096
1998	0.000	0.000	0.096	0.303	0.360	0.000	0.000	0.000	0.000	0.000	0.006	0.037	0.065
1999	0.420	0.003	0.090	0.164	0.006	0.321	0.070	0.118	0.021	0.015	0.000	0.005	0.104
2000	0.025	0.063	0.323	0.048	0.207	0.004	0.000	0.001	0.000	0.000	0.000	0.372	0.086
2001	0.070	0.144	0.066	0.067	0.044	0.000	0.000	0.000	0.000	**1.514**	0.256	0.037	0.186
2002	0.025	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.000	0.000	0.017	0.007
2003	0.000	0.050	0.000	0.589	0.158	0.000	0.063	0.000	0.000	0.161	0.023	0.061	0.092
2004	0.000	0.211	0.000	0.009	0.095	0.034	0.000	0.000	0.011	0.000	0.000	0.000	0.029

	<0.025		0.025-	1.4	>0.3

e) Anthropogenic influences, other than modification of river inflow, that are presently affecting the abiotic characteristics in the estuary:

Structures (e.g. weirs, bridges, mouth stabilization): There is a footbridge across the estuary about 1.5 km from the mouth. Its impact on flows is probably very limited.

Confidence: ***High***

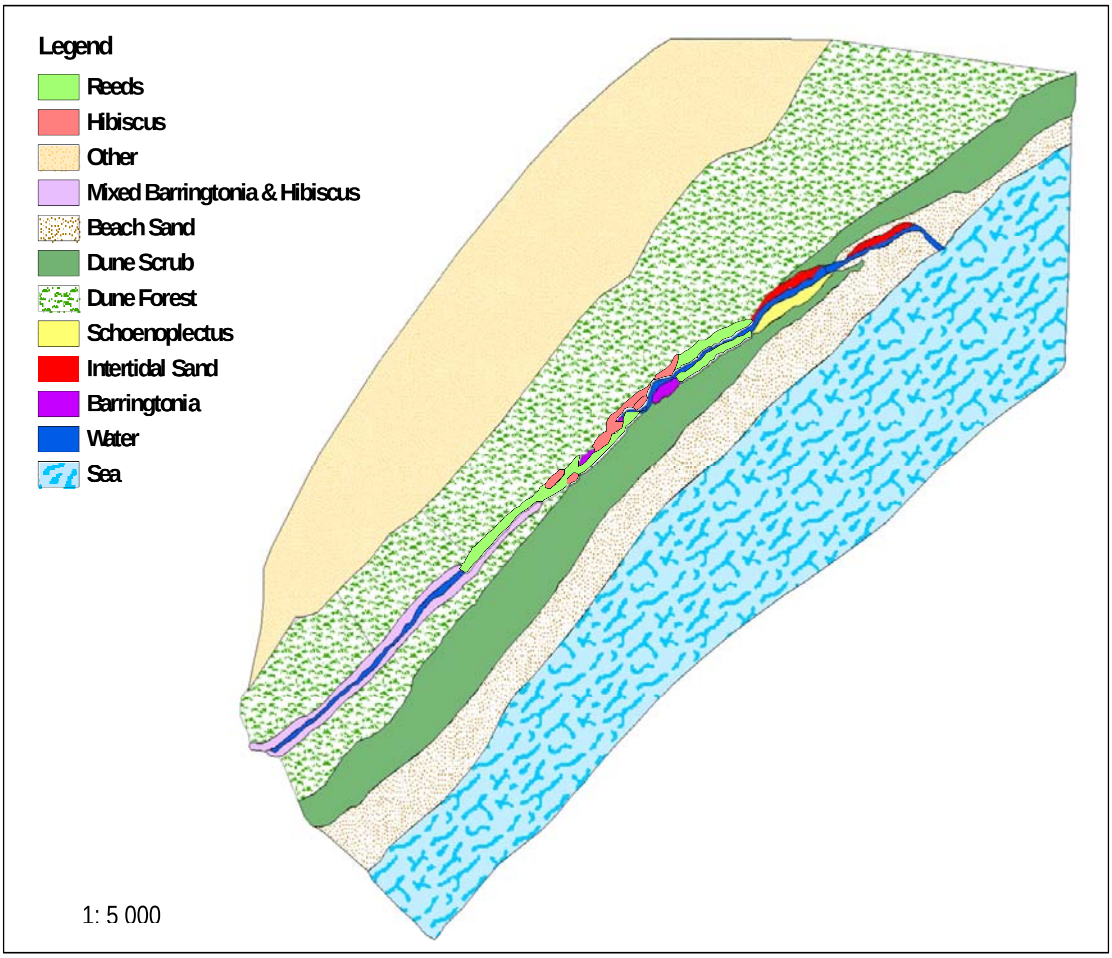
***Discharges into estuary affecting water quality*:** No known point sources but diffuse runoff from canefields, *Eucalyptus* plantations and local village may occur

Confidence: ***Low***

3.2.2. Biotic Components

MACROPHYTES

The present state of vegetation cover in the Siyaya has been digitised from field data and this is represented in the figure below.



Vegetation in the Siyaya Estuary

It is clear from this map that the categories reeds+sedges and lagoon swamp forest (*Barringtonia racemosa* and *Hibiscus tiliaceus*) form the major cover in this estuary. In the mid and lower sections of the estuary reeds have covered the entire channel. The upper part of the estuary has a swamp forest fringe where shading limits reed encroachment. The area designated intertidal area may not necessarily represent true intertidal area for most of the time but wet sand possibly due to seepage into this area has the capacity to support microphytobenthos and has been labelled as such for calculation of functional importance.

The areas covered by each category were obtained from the GIS map and this was used to obtain a comparative functional botanical importance score for the Siyaya. Functional importance considers the coverage of each plant community type and its overall contribution to productivity in the estuary and is detailed in the table below

When compared to large estuaries the small Siyaya estuary has a very low score in terms of functional botanical importance. In addition there are no rare higher plant communities or species present in the system. To provide perspective the Siyaya was compared to a smaller estuary such as the Tongati. If this estuary is given a score of 100 then the Siyaya would score 34. It is considered prudent to make this more appropriate comparison since the majority of estuaries in the region are small systems. The collective value of these small systems becomes important in terms of the total estuarine resources in the region.

Functional Botanical Importance of the Siyaya

Category	Coverage (Ha)	Productivity Value g/m²/yr	Sub-score
Lagoon Swamp Forest	3.7227	1890	7036
Reeds and Sedges	2.6790	1384	3708
Water (phytoplankton)	2.1870	163	356
Intertidal Areas (phytobenthos)	0.6421	124	80
Botanical Score = 11180			
Normalized against large estuary (St Lucia) = **0.56**			
Normalized against small estuary (Tongati) = **34**			

Confidence: ***High***

INVERTEBRATES

Benthic invertebrates

The degradation of the estuary continued until the early 1980's, when the Siyaya and surrounding catchment became the focus of a demonstration project. All previous benthic invertebrate studies on the system were related to the Siyaya Catchment Demonstration Project (SCDP). Since the inception of the SCDP 25 years ago, no long term monitoring of the estuarine benthos has taken place other than by the Coastal Research Unit of Zululand (CRUZ), University of Zululand.

CRUZ monitored the abiotic and biotic responses of the estuary to catchment restoration over a three year period from 1992-1994 and then continued subsequent to the reopening of the mouth in April 1995 until October 2003, to investigate changes in benthic biota in response to alternate dry and wet climatic cycles. Thus, for the earlier portion of this study, recruitment from the marine environment was limited to only those periods of overwash of the sandbar at the mouth. Subsequent to breaching in April 1995, conditions within the system changed to represent a more typical estuarine fauna. Data post 1996 are unpublished and have not been fully analysed, but reference to these will be made to describe the present state of the system and evaluate the response of the benthos to future abiotic scenarios.

A more recent study (twice annually since 2005) has been undertaken by Marine and Estuarine Research cc for the purposes of biomonitoring for Ticor South Africa. Reference to this study was by way of *pers comm*. with the study leaders.

The only quantitative data collected pre-1990 for benthic invertebrates were by:

National Institute for Water Research , Durban	September 1979	dredged samples
South African National Committee for Oceanographic Research	1983-1984 4x quarterly samples	cored samples

(Oceanographic Research Institute 1991, 1999)

All CRUZ data (post 1991) are summarised by MacKay 1996, MacKay and Cyrus 1996, MacKay and Cyrus 2001, CRUZ Unpublished Data).

A mean of 9,874 invertebrates m^{-2} per site and season and 85 taxa were sampled from 1992 to 1994. The mean density of benthos sampled over four seasons in the Siyaya was 14,433 m^{-2} in 1992, 8,340 m^{-2} in 1993 and 6,850 m^{-2} in 1994. Subsequent to mouth breaching, numbers were on a trajectory of decline (<6,500 m^{-2}) until early 1996, when numbers increased substantially from comparative periods in the previous study years. This reflected the change in state of the system to a more estuarine/marine dominated community, with high levels of productivity from the lower to middle reaches. From 2000 onwards, samples again showed a rapid decline in number and diversity as the system showed the effects of significantly reduced baseflows attributed to afforestation in the catchment and the compounding effect of the prevailing drought.

During 1992, 50 taxa were recorded and distributed across Cumacea, Tanaidacea, two Gastropoda species, eight Polychaeta taxa, five Isopoda genera, six Amphipoda and four Mysidacea taxa. During 1993, 45 taxa were identified with representatives from the phyla Platyhelminthes, Nematoda, Annelida, Mollusca, Crustacea and Insecta. Polychaeta, Isopoda and Amphipoda were still well represented, but there was an increase in the ingression of freshwater insects. During 1994, 59 taxa were recorded over four seasons; the majority (40 taxa) were primarily freshwater affiliated. Despite large numbers of insects, other faunal groups were still present under these fresh conditions, notably Amphipoda, Isopoda, Polychaeta, Oligochaeta and Nematoda.

A highly significant relationship was found between benthic numerical abundance and sample site ($P < 0.001$). Abundance was also influenced by Season and Year ($P < 0.05$). Maximum productivity in the system changes according to the amount of freshwater inflow to the system. In a normal, wet year (e.g. annual runoff >0.150 m^3/s) benthic invertebrates are most abundant in Summer (1995/6 mean of ~19,000 m^{-2} over five sites). During dry years when there is little direct connection with the marine environment (annual runoff <0.150 m^3/s) benthic invertebrates are most abundant in winter (estuary mean of ~10,500 m^{-2} over five sites in 1993 and ~9,800 m^{-2} over five sites in 1994). This pattern appeared to be consistent from 1997 to 2003.

The benthos at Site 3 (mean density of 20,386 m^{-2}; SE 5,242) was the most abundant in 1992. Upper and lower reaches of the estuary were the least abundant (Site 1 mean density = 11,690 m^{-2}, SE 4,341; Site 5 8,902 m^{-2}, SE 2,628) and the overall trend in abundance was to increase from the upper and lower reaches towards the middle of the estuary. In 1992, the mean density over all five sampling sites was 19,446 m^{-2} (SE 4,962) in Summer, 10,394 m^{-2} (SE 2,030), 11,641 m^{-2} (SE 2,556) and 16,249 m^{-2} (SE 1,862) in Autumn, Winter and Spring, respectively.

During 1993, Site 1 was the most impoverished area every season. Benthic densities decreased from Sites 2 to 3 except during Autumn, when Site 3 was the most abundant sampling site (10,185 m^{-2}). During Summer, Autumn, Winter and Spring of 1992 the mean density per season exceeded those for the same period during 1993 by 12,870 m^{-2}, 4,071 m^{-2}, 849 m^{-2} and 6,582 m^{-2}.

Throughout 1994, Site 2 generally was more abundant, while the most impoverished areas fluctuated between Sites 1, 3 and 4. The mean density per site showed that Sites 1, 3 and 5 were similar throughout the year (7,852 m^{-2}, SE 3,635; 6,731 m^{-2}, SE 2,618; 7,072 m^{-2}, SE 1385, respectively). Sites 2 and 4 had the highest and lowest mean density per site during 1994 (9,857 m^{-2}, SE 2,294 and 2,739 m^{-2}, SE 742). The abundance of benthos at Site 1 showed the most marked decrease compared with other seasons. 1994 benthos showed decreases from 1993 equivalent samples of 2,094 m^{-2}, 536 m^{-2}, 901 m^{-2} and 2,425 m^{-2}, for Summer, Autumn, Winter and Spring.

Although the middle reaches (Sites 2 and 3) were on average, more numerically abundant, it was the numbers of individual taxa that reflected the pattern of changing salinity and increase or decrease or marine dominance in the system. In the reported and published studies post 1990, the greatest numbers of estuarine benthic taxa occurred during 1992. In 1994, the greatest proportions of estuarine benthic taxa occurred closer to the lower reaches of the estuary at Site 1 and overall, freshwater benthos was more dominant. Of the mean 14,433 individuals m^{-2} collected in 1992, 97% were estuarine. In 1993, 85% were estuarine and by 1994 only 46% were estuarine. There was a corresponding increase in the number of freshwater taxa colonizing the estuary from 1992 to 1994. Despite the change in species composition to a freshwater dominated assemblage with the length of time the mouth is closed, a fauna that are typically estuarine are always numerically abundant even if it is restricted to the lower reaches. The distribution of species and relative abundance is such that the system is dominated by a small number of highly abundant species and a large number of poorly represented/rare species.

The results of these studies indicated that the past catchment restoration efforts had some positive effect on the state of the Siyaya Estuary, with particular reference to the macrobenthic component. There was an increase in both the number of taxa and the density of benthos since the first survey was conducted in 1988 (37 in 1988, 59 in 1994, 52 in 1996, 58 in 2000). Many benthic species that are found in both small, generally closed KwaZulu-Natal estuaries and large systems open to the sea, were also found in this study. This implies that past habitat changes did not necessarily exclude many species, but did limit populations.

Currently, the benthos of the Siyaya Estuary is in yet another degraded state (CRUZ and MER unpublished data). arguably worse than that prior to the SCDP. Conditions within the catchment are responsible for reduced flows to the estuary, resulting in longer periods of isolation from the marine environment and general degradation of the macrobenthic habitat in the system. The current drought is exacerbating all of these effects.

As was the case during 1992-1994, by the end of 2003, freshwater taxa dominated the species list but numerical abundance belonged to the estuarine crustaceans *Grandidierella lignorum*, *Corophium triaenonyx*, *Apseudes digitalis* and *Iphinoe truncata* and the polychaete *Ceratonereis keiskama*. Marine and Estuarine Research cc data show this system to be in severely degraded state as of 2005, with almost complete loss of suitable habitat and biodiversity in some areas.

Confidence: **High**

Larger invertebrates (Macrocrustacea)

Begg (1978) noted that early records from the system included *Macrobrachium* spp., *Callianassa kraussi,* the mollusc *Neritina natalensis* and a large penaeid prawn possibly *Penaeus monodon.* Subsequent surveys of the system were undertaken by the University of Natal during 1979 and 1980 (van der Elst *et. al.* 1999). The checklist contained in van der Elst *et. al.* (1999) contains 14 species of macrocrustacea and 8 species of mollusc. Freshwater macrocrustacea dominated the upper reaches with fresh to brackish water species in the middle and lower reaches. Short term 'invasions' of the lower reaches by post-larval stages of marine/estuarine species occurred when a connection to the sea was present. *Varuna litterata,* an exceptionally euryhaline crab was the most successful species of this group and penetrated upper and lower reaches of the system.

The most intensive sampling of the system to date was undertaken by the Coastal Research Unit of Zululand (CRUZ) who first sampled the system in August 1991 and then during the period 1992 to 1994 sampled the macrocrustacea fauna, using baited traps (Cyrus & Martin, 1996). The monitoring programme set up for this project was run by CRUZ for a further nine years after the WWF programme ended and was suspended in November 2003. To date the bulk of the collected macrocrustacean material has only been data based and no further analysis has been undertaken. All records from April 1992 to November 2003 have been extracted from the field records and were accessed as part of this review.

A scan of the CRUZ data indicates that a total of 18 species of macrocrustacea were recorded during the study period indicating the presence of a fairly diverse fauna. Nine of these species were not recorded by van der Elst *et. al.* (1999) and no data are available on molluscs or other larger invertebrates. The data indicate that the freshwater *Macrobrachium* spp. dominated the catch throughout the period with *M.equidens* and *M.rude* being most commonly caught. This group is well known for being extremely difficult to identify if the specimens are not adult males. In addition the taxonomy continues to be in a state of flux. This is evident from the number of unidentified species listed in the CRUZ data and also by the fact that a total of eight species have been reported from the Siyaya system. Of these two species were not recorded by CRUZ and four were not recorded by van der Elst *et. al* (1999). Time was not available to investigate if any synonyms are present.

It should be noted that brackish water (>8‰) is critical for successful larval development in this genus (Cort, 1983). The data appear to indicate that numbers of juveniles and adults being trapped declined over the study period and this may reflect a shift in the system from brackish to freshwater conditions throughout as appeared to have occurred from January 2001 onwards.

In terms of the typical estuarine/marine species the data show only limited influxes of *Penaeus monodon* in 1992 and *P.indicus* in 1998. It appears that there was much less recruitment during the period April 1992 to November 2003 than is reported by van der Elst *et. al.* (1999) for the period 1979-80 (see above). This may be directly related to the frequency of mouth opening and length of time a connection to the sea was present. The presence of *Varuna litterata* in the system and the existence of records of movement of this species out of the system to sea to spawn (Bickerton & Sapsford, 1981) coupled with the mass inward migrations that megalope larvae of this species undertake, would tend to indicate that it is an integral component of the ecosystem and is probably present throughout the Siyaya catchment as an adult.

Since the onset of the drought in late 2002 the system has deteriorated significantly (pers obs 2006). Negligible flows, low water and salinity levels in the estuary and lack of any contact with the marine environment has severely degraded the system and would undoubtedly have affected the macrocrustacea fauna. However, no data on this are currently available.

Confidence: **Medium**

FISH

Begg (1978) indicated that a list of fish species caught in the Siyaya in 1950 numbered 16 species 'excluding barbell and eels'. Subsequent surveys of the system were undertaken by the University of Natal (1979-80) and the NIWR (van der Elst *et. al*, 1999). These produced some 25 species and it was considered that the system had a 'modest Ichthyofauna with relatively few species'.

The most intensive sampling of the system to date was undertaken by the Coastal Research Unit of Zululand (CRUZ) who first sampled the system in August 1991 when 15 species were netted in the estuary (Cyrus & Martin, 1991). Monitoring was resumed during the period 1992 to 1994 (MacKay & Cyrus, 1996) and continued for a further nine years terminating in November 2003. To date the bulk of the collected material has only been databased and no analysis has been undertaken. All records from August 1991 to February 2000 have been extracted and were accessed as part of this review. Time limitations have dictated that only accessing and scanning the raw data was possible. However information from the extracted records (August 1991 to February 2000) does provide a background considered to be more than suitable for use in a Rapid reserve determination.

The CRUZ data base lists 16,508 individual records comprising 57 species and 20 families. This represents 52% of the fish recorded in Lake St Lucia, the largest estuarine system in South Africa. The fish species present represent a diverse fauna in terms of estuarine dependence and feeding habits. Analysis of the 58 species recorded using the estuarine association categories of Whitfield (1998), revealed the following:-

1.	Estuarine residents **(12 Species; 21% of Fauna)**	
a.	Breeding only in estuaries	4 species
b.	Breeding mainly in estuaries	8 species
2.	Marine migrants **(25 Species; 43% of Fauna)**	
a.	Juveniles wholly estuarine dependent	9 species
b.	Juveniles mainly estuarine dependent	10 species
c.	Juveniles weakly estuarine dependent	6 species
3.	Marine stragglers **(10 Species; 17% of Fauna)**	
4.	Freshwater migrants **(8 Species; 14% of Fauna)**	
5.	Catadromous migrants **(3 Species; 5% of Fauna)**	
	a. Obligate freshwater phase	1 species
	b. Facultative freshwater phase	2 species

It is clear from the species data, physical conditions (Huizinga & van Niekerk 2006 Appendix B) and many years personal experience of the system, that the oscillation across a number of states in terms of estuarine volume and mouth condition results in the ichthyofauna of the Siyaya changing dramatically. The main drivers determining the fish species and the nursery role of the estuary are essentially related to three conditions: fresh with low water levels, full with fresh to low salinities and temporary open/closed estuarine.

Under typically temporary open/closed estuarine conditions, when the salinities can range from 0 to 35‰ but probably averages 5 to 15‰, the fish fauna is dominated by species belonging to Category 2. These comprise juveniles of marine species which utilise the system as a nursery ground. At these times it appears that diversity and densities can be relatively high with up to 500 or more fish per set having been caught during seine and gill netting. Although most individuals were < 200mm Standard Length (SL) reasonable numbers were larger than this reaching up to 300mm SL. This phase appeared to dominate throughout the period August 1991 through to February 2000. Recruitment from the marine environment into the system takes place when the mouth is open and during high tide periods by way of wave overtopping. MacKay & Cyrus (1996) recorded 13 species recruiting into the Siyaya estuary during overtopping events.

At times during the above period, when the system moved towards the full with fresh to low salinities condition the typically estuarine species (Whitfield, 1998 - Category 1) start to show dominance. These are mostly small sized species which are capable of withstanding a wide range of salinity and which breed within the system.

Under extreme low flow/drought conditions such as are currently present (2003-2006) virtually no water reaches the estuary, the levels are extremely low and the entire system is fresh. During such time the freshwater species (Whitfield, 1998 - Category 4) dominate the system. Although only a limited scan of the fish data for the Siyaya Estuary has been undertaken it is clear that under 'normal' conditions the system is very much a functional nursery area for juvenile marine species while at the same time having a well developed estuarine resident fauna. It is considered that the Siyaya is, in terms of its fish fauna, one of the most important Temporary Open/Closed Estuaries on the entire Zululand Coast.

No Red Data list exists for estuarine species, however, *Croilia mossambica*, *Redigobius dewaali, Silhouettea sibayi* and *Myxus capensis* are all listed as Rare by Skelton (1993).

Since the onset of the drought in late 2002 the system has deteriorated significantly (pers obs 2006). Negligible flows, low water and salinity levels in the estuary and lack of any contact with the marine environment has severely degraded the system and would undoubtedly have affected the fish fauna. However, no data on this are currently available.

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Confidence: ***Medium***

BIRDS

This description is based on species records compiled in 1979, discussions with other observers and personal experience of the system over a 20 year period.

The diversity and particularly the abundance of the avifauna of the Siyaya estuary would certainly have been historically limited by the small size and generally non–tidal nature of the system. The latter would have excluded particularly the migratory wading species which are dependent on tidal environments for feeding on invertebrate prey and left piscivorous types as the main avian users of the system. The small size of the system would have restricted the numbers of individuals although the records indicate a variety of species including plunging or diving/swimming types such as African fish eagle *Haliaetus vocifer,* giant *Megaceryle maxima,* pied *Ceryle rudis* and malachite kingfisher *Alcedo cristata*, as well as darter *Anhinga rufa,* white breasted *Phalacrocorax carbo,* African *P.africanus* and occasional Cape cormorant *P.capensis*. Purple heron *Ardea purpurea* were resident with occasional squacco *Ardeola ralloides* and black *Egretta ardesiaca* as well as white backed night heron *Gorsachius leuconotus*. Spurwing goose *Plectropterus gambensis* as well as black duck *Anas sparsa* were common with seasonal visits from yellow-billed duck *Anas undulata*. Black crake *Amaurornis flavirostris*, moorhen *Gallinula chloropus*, African jacana *Actophilornis africanus* and finfoot *Podica senegalensis* were breeding residents. Osprey *Pandion haliaetus* and fishing owl *Scotopelia peli* were rare visitors. While some of these species such as the purple heron and black crake require reed or vegetation cover most of those mentioned require open water to feed. With decreasing water levels and hypoxic conditions and following the extended period of mouth closure culminating in the conditions existing in early 2006, where virtually the entire surface of the estuary was covered by reeds *Phragmites australis* or other aquatic macrophytes, the fish fauna has become depauperate and any survivors inaccessible to piscivorous birds resulting in the loss of virtually all of the above species.

Confidence: ***High***

f) Effect of abiotic characteristics and processes, as well as other biotic components on estuarine biota:

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
Mouth condition (provide temporal implications where applicable)	**Macrophytes:** During open mouth conditions (state 1) there could be some increase in salinity especially with high waves and spring tides in the lower to mid reaches of the estuary. As this condition occurs over relatively short periods and the vegetation (mainly *Phragmites, Schoenoplectus* and *Hibiscus*) in this area is tolerant of salinity there should not be significant changes. There may also be some temporary increase in intertidal area but this is not considered to be very significant over a short period. Under state 2 there should not be very significant changes other than a possible increase in open water area (phytoplankton) and a possible die back of reeds in the central sections of the channel where reed encroachment has occurred. Under state 2 any significant increase in reed growth on the landward margins is prevented by the limited floodplain and shading. During state 3 which appears to be the predominant condition in recent years, reed encroachment into the channel will be at a maximum. *Confidence:* ***Medium/high***
	Invertebrates: *Macrobenthos:* Mouth condition has a direct relationship with ambient salinity levels in the lower reaches of the estuary and saline penetration into the system. In Abiotic State 1, the mouth may open completely for short periods or remain semi-closed for a short while thereafter. The Siyaya benthos responds to these conditions by initially showing a decline in numerical abundance, particularly in the lower reaches. Later as newly recruited marine/estuarine fauna become established (Abiotic State 2), abundance increases significantly in a relatively short time period (within three months). Given that the peak period of production occurs in Summer in a wet year, if mouth opening is during that period, overall abundance will increase dramatically, particularly if new marine/estuarine taxa become established. Data from the CRUZ study in 1995, 1997 and 1998 reflect this biotic state. Abundance is not spread evenly across all taxa. The distribution of species and relative abundance is such that the system is dominated by a small number of highly abundant estuarine species and a large number of rare marine and freshwater species. From 1991 to 2003, the system has for the majority of the time reflected a fauna that is indicative of State 3. Marine influence is restricted to intermittent overwash (not always at every high spring tide). The system is generally fresh to brackish (0-5ppt). However, if the system was recently open, partially open or had large overwash, salinity is recorded in the system, even as far as the middle reaches and in the deeper areas (>1.5m). The fauna is initially more species rich than in either State 1 or 2, but this is due to the influx of freshwater taxa into the upper and middle reaches. Estuarine taxa are numerically dominant in the estuary only if this state does not persist for more than six months at a time. Peak productivity is during Winter if the Siyaya has a year dominated by Abiotic State 3. If State 3 persists over a number of consecutive seasons the fauna becomes impoverished as species disappear under these inhospitable conditions. The middle reaches are most abundant during years dominated by Abiotic States 1 and 2 and middle to lower reaches during a dry year (primarily Abiotic State 3). Relative abundance of the major estuarine species *Grandidierella lignorum*, *Corophium triaenonyx*, *Apseudes digitalis*, *Iphinoe truncata* and *Ceratonereis keiskama* will fluctuate according to abiotic state. *Confidence:* ***High***

	Larger Invertebrates (Macrocrustacea) Abiotic State 1 provides the optimal conditions for the system to be utilized by estuarine/marine or species that require estuarine/marine linkages in their life cycle. Species diversity and density are at their highest during this period due to the presence of a salinity gradient. Abiotic State 2 still provides suitable estuarine conditions for the bulk of species provided that salinities do not fall much below 5‰. Once this occurs numerous species are unable to cope and experience osmoregulatory problems. The negative consequences of this state are that the connection between the estuarine system and the sea is limited. This results in the bulk of species not being able to recruit into or out of the system. Brackish and freshwater breeding species tend to become dominant. Abiotic State 3 has major negative consequences for the estuarine and marine associated species due to the low salinities that prevail. In addition prolonged periods with the system totally fresh may also have a negative impact on the *Macrobrachium* spp. which require brackish water (>8‰) for successful larval development. Low water levels also impact on the fauna present as their available habitat is reduced. In all cases it is preferable that the mouth is open for adult emigration of *Varuna* in around February/March and when megalopae return in April/May (some times also in October). The commonest penaeid recruits into the system during the autumn-spring period. *Confidence:* ***Medium***
	Fish: Abiotic State 1 provides the optimal conditions for the system to be utilized by species of marine origin and typical estuarine species. Species diversity and density are at their highest. Abiotic State 2 still provides suitable conditions for the bulk of species provided that salinities do not fall below 5‰. Once this occurs numerous species are unable to cope and experience osmoregulatory problems. The negative consequences of this state are that the connection between the estuarine system and the sea is cut. This results in the bulk of fish, which on reaching first maturity migrate to the sea to spawn, being unable to undertake this migration. Estuarine breeding species tend to become dominant. Abiotic State 3 has major negative consequences for the estuarine and marine associated species due to the low salinities that prevail. Low water levels also impact on the fauna and small individuals of freshwater species tend to dominate. *Confidence:* ***Medium***
	Birds: The perched nature of the system and the generally closed mouth means that even during open mouth periods there would be very little development of an intertidal fauna, the avifauna would be dominated by piscivorous species and their diversity and abundance would track fish population dynamics. Birds would therefore be favoured by Abiotic States 1 and 2. *Confidence:* ***High***
Exposure of inter-tidal areas during low tide	**Macrophytes:** Only under open mouth conditions is there a possibility of a small increase in intertidal area near the mouth. The short duration of open mouth conditions makes this relatively insignificant in terms of the productivity from benthic algal communities during this period. The area indicated on the map as an intertidal area on the west of the channel adjacent to the dunes may not always represent a true intertidal area but rather a wet area due to seepage. It has however been indicated as such because of the capacity to support microphytobenthos. *Confidence:* ***High***

	<u>Invertebrates</u>: *Macrobenthos* The intermittently open Siyaya is typically not a tidal system. It is only tidal for a few hours or at most days during Abiotic State 1. Given this, the benthos will not be unduly affected by tidal exposure as it is of short duration and burrowing fauna are able to create micro-habitats within sediments. Larger fauna such as molluscs on the sediment surface are more likely to show effects such as bivalves closing valves during low tide and gastropods either moving to subtidal areas or closing opercula. *Confidence:* ***High*** *Larger Invertebrates (Macrocrustacea)* The nature of the Siyaya Estuary is such that there are only limited intertidal areas and these are only functional when the mouth is open. It is considered that the exposure of these would have a limited or no impact on the larger invertebrates present. However, a decrease in water level would have significant impacts due to the shallow nature and size of the system. This occurred pre-1999, however after this date large numbers of molluscs were present, *Hiatula lunulata* in brackish conditions during and just subsequent to mouth closure and *Melanoides tuberculata* under fresh conditions. This fauna made a significant contribution to the invertebrate biomass of the system during this period. *Confidence:* ***Medium***
	<u>Fish</u>: The nature of the Siyaya Estuary is such that there are only limited intertidal areas and these are only functional when the mouth is open. It is considered that the exposure of these would have virtually no impact on the fish present. However, a decrease in water level would have significant impacts on the fish fauna due to the shallow nature and size of the system. *Confidence:* ***Medium***
	<u>Birds</u>: This would be of little relevance to the bird fauna as there is minimal development of any invertebrate intertidal fauna. *Confidence:* ***High***
Sediment processes and characteristics	**<u>Macrophytes</u>:** The present state of the macrophyte communities has been determined, in part, by siltation due to poor practices in sugar cane farming since the late 1940s. The reduction in erosion since then has stabilised the sediment levels and characteristics and the macrophyte community is in turn relatively stable. *Confidence:* ***High***

<u>Invertebrates</u>:

Macrobenthos:

The system was previously described (pre-1940s) as fairly deep and characterised by clean marine sands. Since that time large volumes of silt are reported to have been deposited in the system.

The upper reaches are muddy (< 0.063 mm) overlain with a fairly deep layer (20-50cm) of detritus in various states of decay. This resulted in water column oxygen of < 2mg/l. The middle reaches are variable but usually fine to medium grained sands that may be muddy in the summer months, particularly after high rainfall. The lower reaches are characterised by medium grained sands that are usually detritus free, particularly near the mouth. Benthic assemblages in the Siyaya are strongly correlated to sediment grain size, particularly % silt and % organic content of substrate (MacKay 1996).

The upper reaches are characterised by primarily freshwater taxa, particularly when the system is in Abiotic State 2 or 3. *Apseudes digitalis* was the dominant estuarine crustacean in the upper and middle reaches. *Grandidierella lignorum*, *Ceratonereis keiskama* and *Iphinoe truncata* showed a preference for medium grained sand in areas that were brackish to saline. Numerical abundance was at a maximum in a range of fine to medium sand, with little mud in salinities of 5-15ppt (MacKay 1996; MacKay & Cyrus, 2001).

Confidence: ***High***

Larger Invertebrates (Macrocrustacea)

Little or no scouring occurs when the system is open, particularly in the middle and upper reaches. The sediments in the upper reaches have, for the past 15 years, been characterised by detrital rich fine sand and mud. In some areas this is anoxic with bottom oxygen levels <2mg/l. Any substrate or other habitat preference post larvae and juvenile macrocrustaceans have for these areas may be affected by this.

Confidence: ***Medium***

<u>Fish</u>:

Sediment stability is associated with high benthic production during Abiotic States 1 and 2, thus promoting food resource availability to fish. Rapid sediment scour during flooding has not been a feature of recent conditions and this has resulted in expansion of the *Phragmites* beds and build up of the sediment load in the estuary. Under Abiotic State 3 sediments and *Phragmities* beds have become more stabilized. All this has potential negative impacts on the fish fauna.

Confidence: ***Low***

<u>Birds</u>:

If sediment stability favours benthic production this will translate into a higher carrying capacity for fish and greater food availability for piscivorous birds.

Confidence: ***Medium***

Retention times of water masses	**<u>Macrophytes</u>:** States 2 and 3 predominate in the estuary and resulted in prolific reed growth. Water level in state 2 maximizes reed encroachment. The relatively long retention times (due to limited mouth opening) would mean that catchment derived nutrients would also promote reed growth. While nutrient data are unavailable it can be safely deduced that agricultural practices will provide some nutrient input into downstream estuaries. *Confidence:* ***Medium***

	<u>Invertebrates</u>: *Macrobenthos* Exceptionally long retention times in this system may lead to negative consequences for the macrobenthos. There is evidence that occasionally there are high levels of nutrients in the system (particularly during prolonged Abiotic State 3). With time aquatic macrophytes (aside from *Phragmites australis)* proliferate along with submerged *Ceratophyllum* and *Lemna minor* on the water surface. Flushing would alleviate this to some degree. The build up of silt and detritus in the upper reaches would not be flushed out with a shorter retention time. No scouring of the substrate has taken place in the upper reaches of the system, even during large flood events such as those in 1984 and 1987 floods. The impact of the accumulation of detritus in the system would be mitigated by a shorter retention time resulting in flushing of anoxic water out of the system. The balance of retention time promoting primary and secondary production and creating a stable environment for *k*-selected macroinvertebrate species and a diverse community should be considered against retention time creating large stagnant areas with an anoxic substrate. ***Confidence: Medium*** *Larger Invertebrates (Macrocrustacea)* Increased retention time of water masses could lead to increased retention of detrital components in the estuary. This in turn could result in greater food availability for the Macrocrustacea. However as there are already large amounts of rotting detritus in the system, what would be more beneficial would be the flushing of some of this to prevent the anoxic conditions, described under Sediment Process above, from occurring. *Confidence:* ***Low***
	<u>Fish</u> In terms of the estuary, increased retention time of water masses could lead to increased planktonic production although nothing is known of the plankton of this small system. This would benefit newly recruited marine fish post larvae as well as resident and migratory zooplanktivorous species. Low water retention times in the estuary would lead to reduced planktonic production and poor survival of newly recruited marine post larvae and the larvae of certain estuarine resident species. *Confidence:* ***Low***
	<u>Birds</u>: Longer retention times at high water levels in the medium term that favour fish populations would also favour piscivorous birds. *Confidence:* ***Medium***
Flow velocities	**<u>Macrophytes</u>:** Probably due to size of the catchment even the high flow velocities do not seem to cause any significant scouring of the estuary bed and thus slightly increased velocities are not expected to have any major impact on the vegetation cover. It is however possible that a **major** flood could have an adequate scouring capacity and could result in clearing the channel of reeds ultimately creating larger open water surface area. *Confidence:* ***Medium***

	<u>Invertebrates</u>: *Macrobenthos:* The benthos studied in Siyaya was collected in the top 5 cm of substrate. This is the area that would most likely be affected by scouring and disruption to the sediment-water interface under high flow conditions. Those species with a larval phase of reproduction and requiring stable substrata for settlement would be greatly affected by faster flowing water. If flows were to increase substantially in the more muddy areas in the upper reaches of the system, this sediment type would be more likely to be suspended and transported elsewhere. *Confidence:* ***Medium*** *Larger Invertebrates (Macrocrustacea)* Most of the macrocrustacean species found within the estuary would avoid areas where high flow velocities occur. Not all species have larvae that are able to regulate their position within an estuary under high flow conditions. The system however is seldom exposed to velocities that could potentially impact on the macrocrustacean fauna and in any case they would take refuge in the reed beds. *Confidence:* ***Low***
	<u>Fish</u>: Most of the fish species found within the estuary would avoid areas where high flow velocities occur. Not all species have larvae that are able to regulate their position within an estuary under high flow conditions. The system however is seldom exposed to velocities that could potentially impact on the fish fauna. *Confidence:* ***Low***
	<u>Birds</u>: Conditions inimical to fish as described above would be disadvantageous to piscivorous birds. *Confidence:* ***Medium***
Volume of water in estuary	**<u>Macrophytes</u>:** The roughly equal occurrence of states 2 and 3 do not seem to alter the vegetation to any significant degree. The lagoon swamp forest species will be tolerant of greater inundation during state 2. If under certain conditions state 2 is prolonged, there could be a reduction of reed cover *Confidence:* ***Medium/high***
	<u>Invertebrates</u>: *Macrobenthos*: The bathymetry of the Siyaya is such that if water volume is high, only a limited increase in the subtidal area will occur. This is in the lower reaches to the mouth, which are sandy and support the richest estuarine/marine fauna. Given that numerical dominance is higher in the middle reaches, the lower reaches would only contribute to overall benthic abundance if large water volumes were sustained but with frequent overwash of the sandbar. The opposite (low water volume) creates a significant change and detrimental effect on the benthos. Total colonisation area is substantially reduced and there is the possibility that certain habitats may be significantly reduced such as sand at the mouth and fine sand and muddy sand in the middle regions. The volume of water is reduced in two scenarios: if the mouth is open for a prolonged period in this perched system or baseflow is reduced. Both have overall long term negative consequences and are not conducive to supporting a flourishing benthic community. *Confidence*: ***Medium*** *Larger Invertebrates (Macrocrustacea)* If the estuary is merely a conduit for freshwater (*i.e.* it is open for a large amount of time) and given its perched nature, a large amount of suitable subtidal habitat will be lost (Abiotic State 3) *Confidence:* ***Low***

Fish:
Water depth and size limits the penetration of large fish into the system. During Abiotic Stages 1 & 2, increased volumes and water depth would favour the colonization of the system by fish growing to a larger size.

Mouth closure usually leads to reduced volumes of water due to seepage and evaporation. Under extreme drought conditions, loss of water volume can lead to virtually no standing water being present in the system.

Confidence: ***Low***

Birds:
If a larger volume of water in the estuary is beneficial to the fish fauna this would benefit any piscivorous birds.

Confidence: ***Medium***

Salinities

Macrophytes:

Under present conditions there are no expected drastic changes in salinity. The vegetation present is tolerant of the range of salinities that may occur and as such the vegetation (diversity and cover) will remain stable.

Confidence: ***High***:

Invertebrates:
Macrobenthos:
Although salinity fluctuations are part of the normal environment of estuarine benthic invertebrates, the mechanisms and responses they have evolved to deal with such fluctuations are in many cases only effective for relatively short periods (hours to days). If the period of adverse salinity (extremely low in the case of the Siyaya) exceeds the functional period of the avoidance mechanisms used, the fitness of the animal could be impaired, even resulting in death. Most of the fauna is estuarine with a wide salinity tolerance and appears comfortable for sustained periods even at < 5ppt. Certain benthic assemblages characterise each abiotic state of the system. For instance:

State 1. A core of several estuarine species present under all salinity conditions of which one or two are important numerically as salinity increases e.g. *Grandidierella lignorum* and *Iphinoe truncata*
State 2 An assemblage of larger numbers of estuarine taxa that penetrate to the middle reaches of the system and dominate species richness and abundance. This fauna tolerates lower salinity for long periods (<5ppt)
State 3 Taxa that are present, are at low abundance and species richness is dominated by Insecta

Confidence: ***High***

Larger Invertebrates (Macrocrustacea)
The species composition of macrocrustacea in the Siyaya Estuary is to a large degree determined by the salinity regime and water volume present at the time. Salinity ranges that occur in Abiotic Stages 1 & 2 are optimum for development of a diverse fauna of marine and estuarine origins. The presence of Abiotic Stage 3 results in a dominance of fresh to brackish water species.

Confidence: ***Medium***

Fish:
The species composition of fish in the Siyaya Estuary is to a large degree determined by the salinity regime and water volume present at the time. Salinity ranges that occur in Abiotic Stages 1 & 2 are optimum for development of a diverse fish fauna of marine and estuarine origins. The presence of Abiotic Stage 3 results in a dominance of smaller individuals of freshwater species.

Confidence: ***Medium***

	<u>Birds</u>: More fish benefit piscivorous birds. They would therefore benefit from States 1 and 2 as referred to in the paragraph above. *Confidence:* ***Medium***
Other water quality variables	**<u>Macrophytes</u>:** No information of nutrients or toxic chemicals is available. However the present state may be sustained through nutrient inputs from the agricultural areas upstream *Confidence:* ***Low***
	<u>Invertebrates</u>: *Macrobenthos:* Any increase in nutrients that promotes microalgal growth would ultimately benefit benthic invertebrates. However, if this should be extreme and anoxic or hypoxic conditions occur at the sediment-water interface only species able to tolerate low oxygen levels would remain. This is the case in the upper reaches of the Siyaya that are typically anoxic due to detritus decay. Many benthic invertebrates are filter feeders and as such, are not tolerant of highly turbid water with high levels of suspended solids. If turbid conditions persist, then deposit feeders such as the tanaid *Apseudes digitalis* would then become numerically dominant. This is the case in the middle reaches of the system. Any process or point source of effluent that alters ambient pH has a large effect on estuarine organisms. Even relatively small-scale increases (rapid changes by <2 pH units) can result in large-scale effects to these biota (MacKay 1996, MacKay & Cyrus 2001). *Confidence:* ***High*** *Larger Invertebrates (Macrocrustacea)* Data has shown that nutrients do increase particularly in the middle reaches during low flows. This leads to the further proliferation of aquatic macrophytes which are already reducing the open water areas of the system. *Confidence:* ***Low***
	<u>Fish</u>: Although reduced oxygen levels do arise during any of the abiotic stages and at times it appears that anoxic conditions may exist in some parts of the system these have not been known to have any major impacts on the fauna. *Confidence:* ***Low***
	<u>Birds</u>: Birds are unlikely to be influenced by water quality except in terms of the influence of the water quality on food, *i.e.* fish availability. *Confidence:* ***Medium***

g) Anthropogenic influences, other than modification of river inflow, that are presently directly affecting biotic characteristics in the estuary:

ANTHROPOGENIC INFLUENCES	*BIOLOGICAL RESPONSE*
Structures (e.g. weirs, bridges, jetties, causeway)	**<u>Macrophytes</u>:** The narrow walkway across the estuary does not have any significant impact on the vegetation *Confidence:* ***Medium***

<table>
<tr><th>ANTHROPOGENIC INFLUENCES</th><th>BIOLOGICAL RESPONSE</th></tr>
<tr><td></td><td><u>Invertebrates</u>:
Macrobenthos:
The wooden bridge in the middle section of the Siyaya has no discernible effect on the benthos. As these fauna are not migratory, the gauging station upstream also has no discernible effect.

Confidence: High

Larger Invertebrates (Macrocrustacea)
Only one small wooden bridge is present in the estuary and this has no impact on the larger invertebrates.

Confidence: High</td></tr>
<tr><td></td><td><u>Fish</u>:
Only one small wooden bridge is present in the estuary and this has no impact on the fish fauna.

Confidence: High</td></tr>
<tr><td></td><td><u>Birds</u>:
No apparent impact under present conditions.

Confidence: High</td></tr>
<tr><td rowspan="4">Human exploitation (consumptive and non-consumptive)</td><td><u>Macrophytes</u>:
None known

Confidence: Low</td></tr>
<tr><td><u>Invertebrates</u>:
Macrobenthos:
Negative anthropogenic influences on the system have not been direct to the estuary itself, other than possible nutrient increases and microbial contamination from an adjacent resort. Drastic changes have taken place to the small catchment that included removal of riparian vegetation for cane farming, poor cane farming practices resulting in large amounts of silt transported to the estuary, the subsequent invasion of Phragmites australis and proliferation to cover the majority of open water areas and more recently afforestation of the catchment with an associated dramatic decrease in baseflow to the estuary. Ultimately these have completely changed the habitat and functioning of this small estuary and influenced the nature of the current zoobenthos, particularly in the middle and upper reaches.

Confidence: Medium

Larger Invertebrates (Macrocrustacea)
Human exploitation of macrocrustacea in this system is virtually unheard of and it is considered that there are no real anthropogenic influences on the fauna. In the recent past it was suspected that seepage from septic tanks at the tourist location next to the estuary could have potentially been having an impact. However, no information relating to this was available.

Confidence: Medium</td></tr>
<tr><td><u>Fish</u>:
Although illegal gill netting has taken place from time to time in the Siyaya, the fact that it is inside a game reserve means that this is not a frequent occurrence. Due to the size of the system, any such sustained operations would rapidly impact on the fauna.

Confidence: Medium</td></tr>
<tr><td><u>Birds</u>:
Human access to the bulk of the estuary is restricted by the fringing vegetation and boating is impossible because of the proliferation of the reeds and other aquatic macrophytes. Direct human influence is therefore minimal.

Confidence: High</td></tr>
</table>

3.3. Reference Condition

3.3.1. Abiotic Components

a) Seasonal variability in river inflow:

Monthly simulated runoff data for the Siyaya Estuary Reference (or natural) Condition are provided in Table 2. A summary of flow distribution (mean monthly flows in m^3/s) for the Reference Condition, derived from the 85-year simulated data set, is provided below:

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	**1.085**	**1.092**	**2.756**	**1.436**	**1.997**	**2.912**	**2.368**	**1.682**	**1.645**	**1.293**	0.447	**1.739**
90%ile	0.393	0.493	0.464	0.626	**1.312**	0.748	0.533	0.263	0.181	0.228	0.122	0.416
80%ile	0.226	0.296	0.274	0.401	0.688	0.446	0.188	0.162	0.087	0.082	0.077	0.177
70%ile	0.161	0.239	0.187	0.289	0.480	0.218	0.105	0.100	0.069	0.061	0.059	0.106
60%ile	0.121	0.163	0.149	0.208	0.218	0.149	0.077	0.063	0.054	0.054	0.051	0.077
50%ile	0.087	0.134	0.126	0.126	0.123	0.109	0.066	0.047	0.052	0.041	0.043	0.063
40%ile	0.064	0.095	0.078	0.081	0.078	0.075	0.055	0.036	0.041	0.036	0.037	0.045
30%ile	0.051	0.075	0.061	0.069	0.058	0.055	0.042	0.034	0.032	0.027	0.029	0.038
20%ile	0.044	0.043	0.051	0.052	0.042	0.048	0.035	0.027	0.026	0.021	0.021	0.029
10%ile	0.031	0.031	0.037	0.033	0.031	0.029	0.023	0.018	0.019	0.015	0.018	0.021
1%ile	0.016	0.012	0.020	0.019	0.017	0.013	0.013	0.009	0.010	0.009	0.011	0.014

b) Flood regime for the reference condition:

All floods reached the estuary, from freshettes to major floods. This leads to resetting of the salinity profile and perhaps scouring from especially the middle and lower reaches during very large floods.

Confidence: ***Low***

c) Differences in sediment processes under reference compared with present:

The estuary was probably significantly deeper under the reference conditions than at present.

Confidence: ***Medium***

d) Occurrence and duration of different Annual Abiotic states during the Reference Condition

The occurrence of the different states is for easier analysis illustrated in three different ways:

- Firstly by the indicated colour coding in Table 2, which includes the full simulated monthly runoff dataset for this scenario.
- Secondly the same data are summarized in the occurrence table above, in which the same colour coding is used.
- Thirdly, to obtain a quick overview, the median (50 %) and drought (10 %) data are plotted in the figure below.

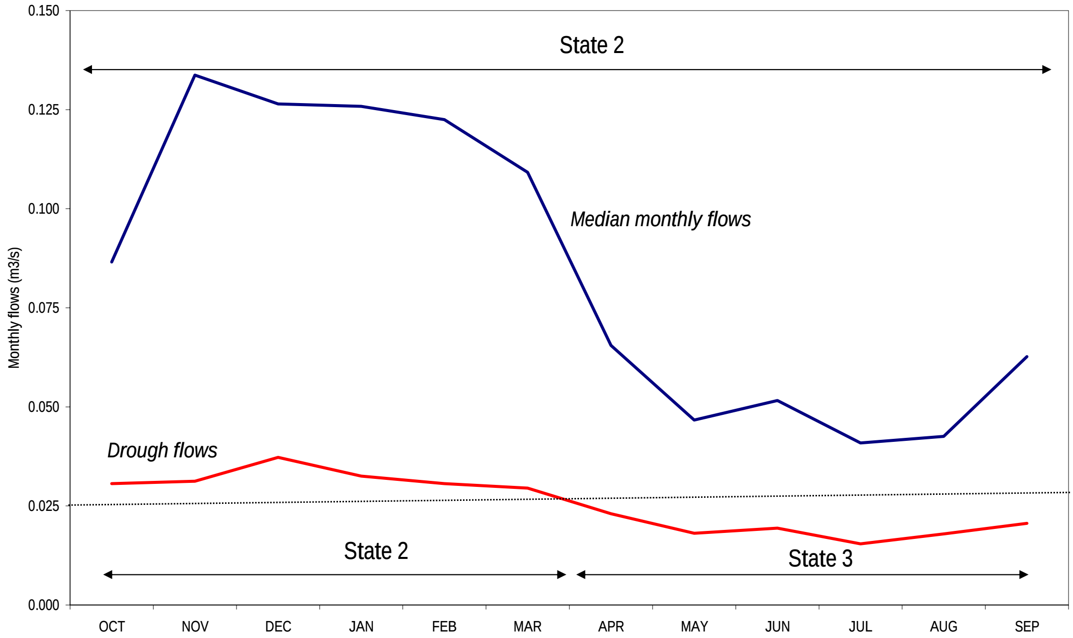


Table 2. *Reference conditions: Simulated monthly runoff data for the Siyaya Estuary in m^3/s*

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1920	0.068	0.020	0.186	0.251	0.033	0.194	0.036	0.025	0.016	0.023	0.018	0.157	0.086
1921	0.202	0.780	0.716	0.072	0.066	0.199	0.034	0.108	0.036	0.021	0.086	0.028	0.196
1922	0.065	0.291	0.032	**1.130**	0.154	0.024	0.055	0.066	0.031	0.021	0.019	0.015	0.159
1923	0.013	0.012	0.241	0.195	0.078	0.662	0.157	0.065	0.175	0.062	0.053	0.259	0.165
1924	0.201	0.725	0.524	0.111	0.875	**3.841**	**1.013**	0.474	0.073	0.158	0.058	0.068	0.677
1925	0.051	0.069	0.154	0.072	0.031	0.031	0.036	0.021	0.038	0.028	0.028	0.135	0.058
1926	0.192	0.137	0.261	0.076	0.121	0.707	0.081	0.140	0.054	0.060	0.045	0.045	0.161
1927	0.054	0.027	0.064	0.581	0.078	0.078	0.132	0.175	0.054	0.036	0.088	0.036	0.118
1928	0.039	0.022	0.020	0.057	0.018	**1.851**	0.151	0.030	0.059	0.077	0.124	0.063	0.212
1929	0.073	0.084	0.032	0.349	0.049	0.016	0.055	0.022	0.097	0.039	0.035	0.093	0.079
1930	0.038	0.133	0.156	0.033	0.041	0.146	0.062	0.034	0.035	0.046	0.027	0.031	0.065
1931	0.049	0.024	0.135	0.074	**1.890**	0.184	0.526	0.731	0.096	0.050	0.043	0.039	0.308
1932	0.049	0.057	0.179	0.118	0.057	0.063	0.030	0.018	0.015	0.013	0.019	0.011	0.053
1933	0.016	0.042	0.364	0.450	0.181	0.068	0.069	0.236	0.268	0.236	0.076	0.053	0.172
1934	0.046	0.036	0.728	0.070	0.063	0.036	0.035	0.654	**3.728**	0.688	0.624	0.088	0.566
1935	0.052	0.040	0.033	0.252	**1.372**	0.155	0.041	0.273	0.070	0.054	0.042	0.068	0.196
1936	0.127	0.534	0.062	0.066	0.245	0.130	0.107	0.037	0.148	0.088	0.064	0.048	0.136
1937	0.039	0.045	0.277	0.159	0.678	0.059	0.025	0.034	0.060	0.557	0.081	0.042	0.169
1938	0.080	0.032	0.054	0.027	0.533	0.139	0.044	0.170	0.090	0.195	0.059	**1.214**	0.216
1939	0.122	0.702	0.100	0.069	0.026	0.107	0.218	**1.490**	0.927	0.098	0.099	0.053	0.335
1940	0.057	0.723	0.309	0.077	0.042	0.179	0.057	0.030	0.053	0.037	0.028	0.068	0.138
1941	0.031	0.205	0.110	0.793	0.074	0.426	0.064	0.067	0.053	0.055	0.053	0.052	0.167
1942	0.051	0.336	0.590	0.072	0.097	0.907	0.760	0.103	0.070	0.444	0.389	0.077	0.326
1943	0.211	0.088	0.115	0.033	0.199	0.131	0.037	0.027	0.274	0.061	0.041	0.666	0.155
1944	0.084	0.125	0.051	0.032	0.986	0.752	0.080	0.034	0.030	0.023	0.030	0.023	0.182
1945	0.028	0.023	0.054	0.057	0.033	0.080	0.126	0.035	0.024	0.015	0.019	0.016	0.042
1946	0.103	0.033	0.130	0.023	0.780	0.247	0.070	0.046	0.064	0.057	0.048	0.087	0.136
1947	0.126	0.079	0.198	0.167	0.049	0.055	0.059	0.037	0.026	0.018	0.022	0.019	0.072
1948	0.050	0.085	0.036	0.037	0.495	0.045	0.478	0.050	0.052	0.035	0.026	0.030	0.115
1949	0.288	0.123	0.458	0.068	0.489	0.070	0.042	0.040	0.039	0.028	0.025	0.018	0.139
1950	0.018	0.011	0.041	0.020	0.028	0.042	0.012	0.017	0.031	0.028	0.296	0.203	0.062
1951	0.157	0.037	0.178	0.120	0.043	0.129	0.048	0.144	0.052	0.062	0.038	0.028	0.087
1952	0.023	0.179	0.050	0.027	0.261	0.063	0.022	0.027	0.017	0.016	0.017	0.107	0.066
1953	0.087	0.318	0.126	0.286	**1.174**	0.134	0.284	0.239	0.086	0.051	0.033	0.205	0.245
1954	0.765	0.097	0.073	0.399	0.075	0.657	0.069	0.032	0.029	0.019	0.018	0.042	0.192
1955	0.241	0.275	0.332	0.053	**1.433**	0.192	0.077	0.047	0.186	0.067	0.191	0.189	0.265
1956	0.116	0.196	**3.607**	0.410	0.485	0.331	0.601	0.086	0.057	0.081	0.059	0.760	0.568
1957	**1.058**	0.158	0.079	0.290	0.813	0.080	0.425	0.062	0.053	0.040	0.030	0.623	0.305
1958	0.120	0.050	0.033	0.164	0.066	0.020	0.014	0.057	0.021	0.015	0.017	0.476	0.087
1959	0.229	0.075	0.408	0.058	**1.666**	0.241	**1.065**	0.357	0.072	0.042	0.037	0.083	0.351

Table 2 (cont.) Reference conditions: Simulated monthly runoff data for the Siyaya Estuary in m³/s

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1960	0.041	0.826	2.594	0.551	1.671	0.151	3.393	0.236	1.062	0.247	0.061	0.127	0.902
1961	0.250	0.242	0.073	0.137	0.082	0.125	0.061	0.052	0.033	0.027	0.071	0.052	0.101
1962	0.167	0.198	0.145	0.434	0.078	0.255	0.084	0.036	1.249	1.229	0.120	0.043	0.338
1963	0.143	0.144	0.066	0.712	0.132	0.056	0.311	0.057	0.041	0.059	0.054	0.059	0.153
1964	0.731	0.293	0.106	0.045	0.026	0.050	0.156	0.055	0.159	0.142	0.314	0.272	0.197
1965	0.759	0.243	0.066	0.419	0.148	0.051	0.050	0.034	0.065	0.037	0.147	0.074	0.175
1966	0.057	0.102	0.053	0.290	0.123	1.468	2.173	0.157	0.045	0.095	0.059	0.041	0.388
1967	0.127	0.143	0.043	0.226	0.134	0.561	0.070	0.033	0.054	0.034	0.108	0.056	0.133
1968	0.087	0.305	0.247	0.053	0.056	1.757	0.180	0.247	0.077	0.056	0.053	0.329	0.290
1969	0.393	0.100	0.273	0.093	0.048	0.040	0.041	0.127	0.053	0.051	0.050	0.065	0.112
1970	0.549	0.850	0.090	0.410	0.278	0.485	0.404	2.685	0.213	0.649	0.090	0.134	0.574
1971	0.286	0.156	0.221	0.304	2.427	0.222	0.082	0.831	0.107	0.068	0.049	0.033	0.385
1972	0.044	0.207	0.483	0.207	0.364	0.052	0.448	0.069	0.043	0.056	0.036	0.939	0.243
1973	0.114	0.196	0.064	0.655	0.143	0.054	0.066	0.160	0.069	0.058	0.049	0.033	0.139
1974	0.020	0.333	0.045	0.229	0.676	0.092	0.057	0.041	0.036	0.034	0.036	0.291	0.153
1975	0.093	0.134	0.133	0.872	0.552	2.735	1.186	0.210	0.062	0.078	0.068	0.201	0.528
1976	0.304	0.171	0.468	0.378	1.915	0.618	0.077	0.055	0.043	0.039	0.039	0.174	0.347
1977	0.131	0.261	0.128	1.330	0.313	0.148	0.538	0.076	0.060	0.054	0.050	0.106	0.266
1978	0.684	0.131	0.055	0.107	0.035	0.028	0.024	0.156	0.051	0.037	0.038	0.105	0.122
1979	0.064	0.344	0.181	0.148	0.040	0.021	0.036	0.017	0.017	0.015	0.019	0.868	0.146
1980	0.072	0.126	0.061	0.028	0.728	0.102	0.075	0.556	0.158	0.062	0.065	0.116	0.175
1981	0.064	0.291	0.076	0.086	0.083	0.155	0.044	0.153	0.048	0.037	0.028	0.038	0.092
1982	0.220	0.064	0.040	0.030	0.030	0.013	0.025	0.017	0.015	0.023	0.094	0.038	0.051
1983	0.162	0.261	0.115	1.992	1.454	0.252	0.098	0.051	0.039	0.103	0.052	0.032	0.378
1984	0.048	0.038	0.056	0.326	1.074	0.078	0.021	0.013	0.019	0.013	0.011	0.015	0.136
1985	1.229	0.089	0.039	0.250	0.056	0.064	0.046	0.023	0.023	0.015	0.011	0.021	0.157
1986	0.031	0.047	0.140	0.210	0.032	0.751	0.067	0.024	0.218	0.053	0.074	4.495	0.508
1987	0.394	0.156	0.134	0.042	1.424	0.511	0.066	0.035	0.041	0.036	0.042	0.040	0.235
1988	0.103	0.380	0.257	0.066	0.466	0.051	0.021	0.042	0.025	0.018	0.013	0.016	0.119
1989	0.037	2.200	0.153	0.042	0.025	0.743	0.086	0.027	0.024	0.016	0.123	0.029	0.291
1990	0.191	0.036	0.415	0.358	0.120	0.856	0.082	0.089	0.042	0.047	0.044	0.068	0.198
1991	0.038	0.092	0.049	0.024	0.012	0.012	0.013	0.005	0.005	0.006	0.020	0.092	0.031
1992	0.022	0.433	0.051	0.087	0.039	0.048	0.018	0.012	0.011	0.009	0.018	0.022	0.064
1993	0.225	0.044	0.227	0.052	0.022	0.043	0.014	0.016	0.013	0.014	0.030	0.015	0.060
1994	0.319	0.070	0.024	0.010	0.061	0.109	0.589	0.073	0.077	0.041	0.029	0.020	0.118
1995	0.096	0.226	0.792	0.670	1.223	0.231	0.052	0.035	0.028	0.227	0.047	0.027	0.299
1996	0.034	0.026	0.017	0.345	0.053	0.014	0.057	0.025	0.027	0.024	0.019	0.042	0.057
1997	0.059	0.881	0.080	0.071	0.580	0.054	0.042	0.027	0.021	0.020	0.015	0.024	0.152
1998	0.058	0.030	0.188	0.429	0.484	0.055	0.033	0.036	0.027	0.023	0.038	0.091	0.122
1999	0.544	0.075	0.178	0.272	0.062	0.436	0.126	0.226	0.053	0.039	0.025	0.044	0.175
2000	0.085	0.156	0.441	0.126	0.310	0.059	0.037	0.034	0.022	0.014	0.010	0.474	0.146
2001	0.140	0.255	0.147	0.156	0.113	0.045	0.033	0.018	0.030	1.627	0.414	0.077	0.257
2002	0.079	0.089	0.055	0.044	0.023	0.018	0.021	0.009	0.071	0.025	0.014	0.066	0.043
2003	0.018	0.144	0.026	0.727	0.253	0.045	0.127	0.037	0.023	0.228	0.057	0.119	0.150
2004	0.051	0.332	0.046	0.084	0.180	0.104	0.030	0.029	0.048	0.025	0.021	0.027	0.080

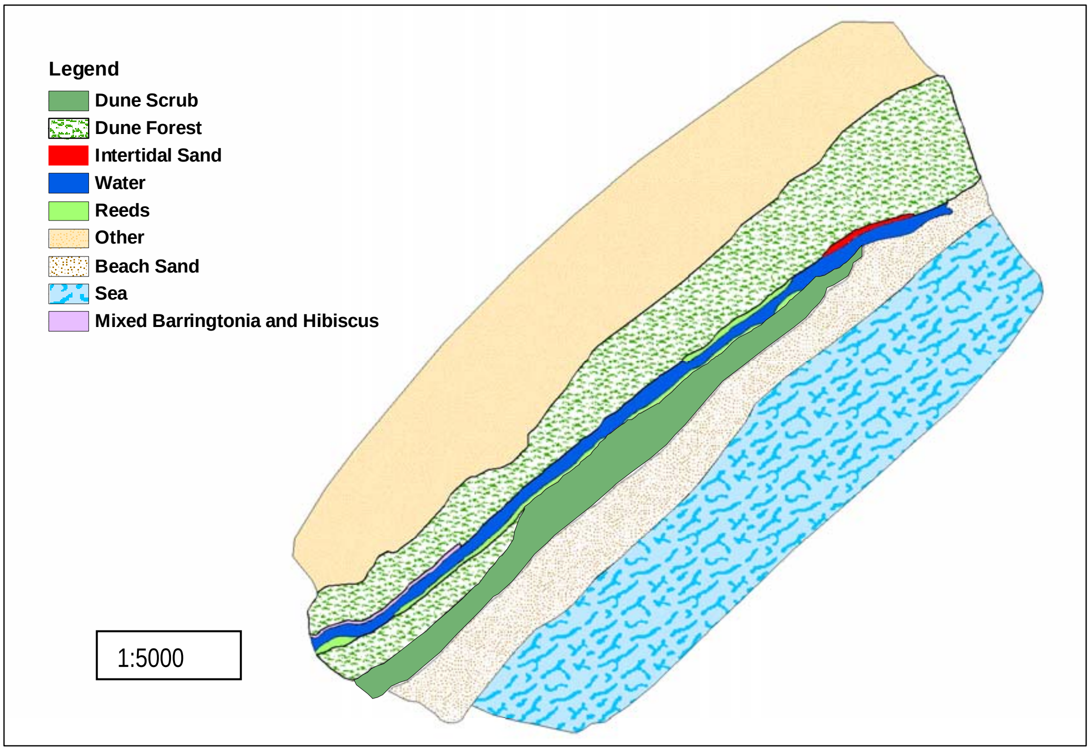
	<0.025		0.025-	1.4	>0.3

3.3.2. Biotic Components

a) Change in biotic characteristics from the Reference Condition to the Present State:

MACROPHYTES

The condition of the estuary based on the 1937 aerial photograph is assumed for the purposes of this study to represent the pristine or near pristine condition and the coverage is represented in the figure below



Vegetation of the Siyaya estuary based on 1937 aerial photography

As with the majority of estuaries along the KZN coast, envisaging a pristine state is made difficult by the fact that the earliest aerial photographs are those from 1937 by which time agriculture, in particular sugar cane farming, was well established in the majority of the catchments. Nonetheless according to Begg (1978), major perturbations in the farming areas of the catchment only began around 1948 when practices such as ploughing downhill along steep slopes, planting on river banks and major drainage of upstream wetlands and swamps occurred. According to the landowner of the farm Twin Streams (Begg, 1978) this led to serious erosion and frequent flooding of the system. In time such erosion resulted in severe siltation and changes in the bed height of the estuary and lagoon. Initially the catchment area was dominated by sugar cane farming but later the development of forestry has arguably resulted in significant flow reductions. These factors obviously played a significant role in determining the present state of the vegetation communities of the system.

If the condition of system in 1937 is assumed to be near pristine then there have been very significant changes in the distribution of vegetation since then. The differences in cover are shown in the table below.

Differences in vegetation coverage between 1937 and 2001

Category	Area in 2001 Ha	Area in 1937 Ha
Lagoon Swamp Forest	3.72	0.6
Reeds and Sedges	2.68	2.7
Water (phytoplankton)	2.19	7.5
Intertidal Areas (phytobenthos)	0.64	0.4
Total area	9.23	11.1

The most obvious difference between the early condition and the present state is the extent of water surface area. According to Begg (1978) the estuary and lagoon would have been a deep clear water system. The map drawn from the 1937 aerial photograph indeed shows a channel (open water) some 30-40 meters wide with narrow patches of fringing reeds. It is possible that the upper reaches of the estuary, which would have been freshwater dominated, may have had submerged macrophytes but this is not discernible in the photograph. It is also likely that there was a fringe of lagoon swamp forest species (*Barringtonia racemosa* and *Hibiscus tiliaceus*) along the west bank but this cannot be distinguished from the surrounding dune forest. Such a fringe of swamp forest species was identified by Begg in the 1978 study and was observed by the author at about the same time. As these were relatively large and old trees this condition was probably characteristic of pristine conditions. This community has thus been represented along the west bank in the upper reaches of the estuary

Since at least the mid 1940s the siltation described above would have initially encouraged the inward spread of reeds into the channel area especially in the lower section of the estuary and with time the establishment of lagoon swamp forest species landward of these. These changes have now resulted in very significant reduction of open water areas. The mid and lower sections of the estuary are presently dominated by the reed *Phragmites australis* which almost covers the entire channel in the area behind the dunes. Presently the upper section of the estuary is fringed by a mixture of tall (older) trees of *Barringtonia* and *Hibiscus* where shading from these trees limits reed growth. The estuary most likely did not support any rare or endangered plant communities or individual species.

It would seem that the major influences on the distribution of estuarine vegetation since pristine conditions are changes in flow and sedimentation. The consequent change to water depth has resulted in extensive reed encroachment and significant reduction in open water areas. There seems to be slight contradiction in some of the data in that high flows were reported in the late 1940s due to poor catchment practices including removal of swamps in the catchment. Such flows should have resulted in scouring of the estuary bed yet this did not seem to occur since sedimentation has actually raised the bed height. It can be speculated that that the flows were not high enough for significant scouring and that erosion in the catchment resulted in sediment deposition which is largely the cause of reed proliferation in this estuary. The later introduction of forestry into the catchment has reduced flows (and water depth) and thus supported reed encroachment.

As the functional botanical importance rating is based on productivity of various plant communities the existence of large open water areas (which has a low productivity value) under pristine conditions will result in a lower botanical importance score than was achieved under present conditions.

Confidence: ***Medium***

INVERTEBRATES

Macrobenthos:

Under Reference Conditions, the system was typically more estuarine in nature given the frequency of occurrence of Abiotic State 2 and limited Abiotic State 3. Even in dry years the system would have functioned reasonably well.

In the Reference Condition, the estuary would have opened more frequently and sustained a salinity profile for longer and penetrated into the upper reaches. Sediments would have been dramatically different. Upper and middle reaches would have been sandier and less anoxic as *Phragmites* reeds would not have dominated the open water areas. In this environment, the benthos would be more stable, more prolific and more diverse. Although it is envisaged that taxa represented in Abiotic States 1 and 2 of the Present State were comparable under reference conditions, it is estimated that more taxa were in the Siyaya in the past, at higher densities and distributed in different areas within the system. Estuarine taxa would have dominated throughout in terms of species richness and numerical abundance. Insects and other freshwater species would be limited to the extreme upper reaches. The estuarine fauna present would reflect the nature of the sediments as well as water quality conditions, for instance a range of feeding guilds from deposit feeders to filter feeders. It is estimated that many taxa have been lost from this system with degradation of the estuarine habitat and that in the past a healthy River-Estuary Interface occurred approximately 1.5-2.0 km upstream of the mouth.

Confidence: ***Medium***

Larger Invertebrates (Macrocrustacea)
Under the Reference Condition the system would have been able to retain and sustain a more stable estuarine fauna than at present. This would have been dominated by marine and estuarine species in the lower and middle reaches whilst fresh to brackish water species would have dominated the upper reaches. Densities (and possibly diversity) of this fauna would have been greater in the past. This would have been largely due to the fact that the mouth would have opened more frequently. In addition it can be considered that there would have been more opportunities for overtopping events to take place due to the bar being breached more frequently and therefore not having as much time to stabilize at greater heights. Under such Reference Conditions water volumes under closed mouth situations would have been greater and increased benthic food sources would be sustained for greater lengths of time. Although the Present State of the system, based on 1991-2003 data, indicated a 60% similarity to the Reference Condition, the impact of the past four years of increased afforestation and the drought, has arguably caused further deviation from the Reference Condition.

Confidence: ***Low***

FISH

Under the Reference Condition the system would have retained a more stable estuarine fish fauna dominated by juvenile marine species and estuarine residents. Densities and possibly diversity of this fauna would have been greater. This would have been largely due to the fact that the mouth would have opened more frequently. In addition it can be considered that there would have been more opportunities for overtopping events to take place due to the bar being breached more frequently and therefore not having as much time to stabilize at greater heights. Under such Reference Conditions water volumes under closed mouth situations would have been greater, benthic food sources would also have been greater due to estuarine conditions being persistent for greater lengths of time. Although the Present State of the system, based on 1991-2000 data, indicates a 60% similarity to the Reference Condition, the impact of the past four years of drought, indicates a substantial move away from the Reference Condition.

Confidence: ***Low***

BIRDS

Following on from the above comments on the invertebrates and fish, the combination of deeper and more open water plus a greater diversity and abundance of invertebrate and fish prey species would have supported a variety of water birds as opposed to the present situation where observations indicated a virtual absence of these species.

Confidence: ***Medium***

3.4. Present Ecological Status of the Siyaya Estuary

The Present Ecological Status is determined using the Estuarine Health Index (EHI) described in detail in Appendix E3 of the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods of which the documentation is currently in preparation (DWAF 2004). Details regarding the individual scoring systems are included in those reports.

The EHI is sub-divided into:

- The Habitat Health score determined by Abiotic variables (*hydrology, hydrodynamics and mouth condition, water quality, physical habitat alteration and human disturbance of habitat and biota*)
- The Biological Health score determined by Biotic variables (*microalgae, macrophytes, invertebrates, fish and birds – due to budgetary constraints, microalgae and zooplankton were not included in this assessment*)

The scores are 'percentage deviation' of the Present State from the Reference Condition, *e.g.* if the Present State is still the same as the Reference Condition, then the score is 100.

3.4.1. *Abiotic Components*

Hydrology			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	30	For the Siyaya River Estuary low flows are defined as flows associated with the *State 3: Closed, with low water levels* (i.e. <0.025 m^3/s). Months with median low flows of less than 0.025 m^3/s never occurred under the median flow condition in the Reference conditions. Under the Present state they occur for 6 months of the year (April - September) under the median flow conditions. In addition, these flows are currently overall for the 85-year period occurring for 51% of the time under the Present state versus 13 % under the Reference conditions. This drastic increase in the occurrence of very low flows has resulted in a drop of 1 to 2 m in water levels.	M
b. % similarity in mean annual frequency of floods	95	The reduction in high flows is deemed to be very little based on the very limited reduction in monthly flows of higher than $1m^3/s$.	M
Hydrology score	**56**		**M**

Hydrodynamics and mouth condition			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
Change in mean duration of closure, e.g. over a 5 or 10 year period	95	The occurrence of high flows, which are at the Siyaya associated with State 1 : Open mouth conditions, has only changed in a limited way between reference and present conditions (from 16 % under the reference conditions to 13% under the present state)	M
Hydrodynamics & mouth condition score	**95**		**M**

Water quality				
VARIABLE		**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1.	Change in the longitudinal salinity gradient (%) and vertical salinity stratification	80	The salinity distribution is very homogenous for the Siyaya Estuary. Some small changes are expected due to decrease in the amount of inflowing water during the closed state (from State 2 to State 3) that would have assisted in lowering the over all salinity values in the system. To counteract the above mentioned process, there may have been some reduction in salinity penetration due to the infilling of the subtidal area which reduces the ability of seawater to penetrate the system after a breaching.	L
2a.	Nitrate/phosphate (inorganic nutrient) concentration in the estuary	30	Agriculture in catchment, use of fertilisers resulting in nutrient enrichment from local run-off	M
2b.	Suspended solids (turbidity) in the estuary	30	Accelerated erosion as a result of poor land management and the removal of riparian and wetland habitats.	M
2c.	Dissolved oxygen in the estuary	15	High levels of decaying plant matter – exacerbated by high retention times and little flushing	H
2d.	Levels of toxins	60	Local run-off – agricultural application of herbicides and pesticides and urban runoff from the village of Mtunzini	M
Water Quality score		**41**		**M**

Physical habitat alteration				
VARIABLE		**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	70	Some infilling is reputed to have occurred due to sedimentation related to change in land-use in the catchment, particularly agricultural and forestry activities.	M
1b	% similarity in sand fraction relative to total sand and mud	30	The estuary has become considerably muddier from the reference conditions due to increased erosion related to changes in the land-use in the catchment.	M
	Mean of 1a and 1 b	50		
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	30	A major difference is that the average depth in the estuary is drastically reduced because of the increase in State 3. A score of 40% would be given for changes in the subtidal area due to a decrease in water levels. In addition sedimentation has occurred due to change in land-use in the catchment, particularly agricultural and forestry. Therefore 30% is allocated for both these changes.	L
Anthropogenic influence:				
	Percentage of overall change in intertidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	30	Considerable sedimentation has occurred due to change in land-use in the catchment, particularly agricultural and forestry activities.	M
	Percentage of overall change in subtidal habitat caused by **anthro-pogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	30	Considerable sedimentation has occurred as a result in agriculture and forestry in the catchment.	M
Physical habitat score		**58**		**L**

3.4.2. Biotic Components

Macrophytes			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Species richness	65	No change in the diversity of higher plants. Change in algal diversity unknown and an estimate of 20% difference is proposed i.e. 80% similarity	M
2a. Abundance/Biomass	100	Very significant increase in reeds and lagoon swamp forest. Decrease in phytoplankton (open water surface)	H
2b. Community composition	30	Significant change in cover in channel/floodplain	H
Macrophytes health score	**30**		**M**

Invertebrates			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
Macroinvertebrates (Benthos)			
1. Species richness	10	Approximately 30% of the original species remain. Species losses are primarily associated with anthropogenic manipulation of the catchment and secondary effects to the estuary. It is estimated that more estuarine species occurred in the past when estuarine benthic habitat was more favourable (less mud and anoxic detritus) and that freshwater fauna did not penetrate as far into the system.	M
2a. Abundance	40	Salinity penetration into the system is not common and the sediment has been radically altered by deposition of silt and mud. Rotting detritus in the upper reaches causes anoxic conditions. Overall benthic habitat has decreased (most recent study by MER, where mouth lower reaches have decreased substantially in area) and declined in suitability.	M
2b. Community composition	40	The reduction in the number of estuarine taxa and the increase in freshwater taxa particularly during the extended periods of Abiotic State 3 have altered the community composition from the Reference. More hardy species such as *Capitella capitata* and *Prionospio sexoculata* are now common in the system..	M
Macrocrustacea			
1. Species richness	17	Overall species richness recorded recently is high, however some estuarine species have not been recorded. This would tend to indicate that some losses may have occurred. Current state of the system indicates a large move away from the Reference Condition.	M
2a. Abundance	20	Mouth opens less frequently, water volumes do not remain high for as long as in the past. Overall estuarine habitat availability is reduced due to 30% reduction in flows. Current state of the system indicates a large move away from the Reference Condition.	M
2b. Community composition	10	Absence of some typically estuarine species indicates change in community composition. Current state of the system indicates a large move away from the Reference Condition.	M
Invertebrates score	**10**		**M**

Fish			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Species richness	10	Species richness recorded recently is high, however some obvious estuarine species have not been recorded. This would tend to indicate that some losses may have occurred. Current state of the system indicates a large move away from the Reference Condition.	M

2a. Abundance	30	Mouth opens less frequently, water volumes do not remain high for as long as in the past. Overall estuarine availability is reduced due to 30% reduction in flows. Current state of the system indicates a large move away from the Reference Condition.	M
2b. Community composition	40	Absence of certain typically estuarine species indicates change in community composition. The absence of any typical zooplanktivorous species further indicates a change in the community composition. Current state of the system indicates a large move away from the Reference Condition.	M
Fish score	**10**		**M**

Birds			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Species richness	10	Habitat loss through reed and submerged or floating macrophyte proliferation plus collapse of food supply	M
2a. Abundance	10	As above	M
2b. Community composition	10	As above	M
Bird score	**10**		**M**

To establish the change in Present State (compared with Reference Conditions) that has occurred in the system which is not flow related the specialists estimated the percentage of overall change that can be attributed directly to anthropogenic activities.

COMPONENT	% CHANGE DUE TO NON-FLOW RELATED ACTIVITIES	MOTIVATION	CONFI-DENCE
Macrophytes	60	Sedimentation due to poor catchment practices (and possible nutrient inputs from farming areas) is believed to have had major contribution to change in cover in the adjacent wetlands, riparian areas, river channel and floodplain.	M
Invertebrates	30	Extensive infilling of the estuary due to silt deposition in the past has completely transformed the upper reaches of this system, combined with a dramatic decrease in water level particularly during Abiotic State 3.	M
Fish	20	Habitat loss through sedimentation and nutrient inputs (related to loss of wetlands and riparian corridors) with the consequent proliferation of aquatic macrophytes.	M
Birds	10		M

The individual scores for each of the components (*i.e.* overall score listed) are incorporated into a Habitat health score and a Biological health score. This allows for the determination of the Estuarine Health Index (EHI) Score as illustrated in Section 4

3.5. Importance of Siyaya Estuary

Estuarine importance is an expression of the value of a specific estuary in maintaining ecological diversity and the functioning of estuarine systems on local and wider scales. The variables selected for the estuarine importance rating index were:

- Estuary size
- Zonal type rarity
- Habitat diversity
- Biodiversity importance
- Functional importance

Each of the above can be categorised as measures of rarity, abundance or ecological function. The rationale for selecting these variables, as well as further details on the estuarine importance index are discussed in detail in Appendix E4 of the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods (DWAF 2004).

For this study, the Ecological importance determination of the Siyaya Estuary was obtained from the *Estuarine Prioritisation for RDM* project (Turpie *et al.* 2002). The *Functional Importance* score, however, was derived at the Specialist Workshop held in Mtunzini in May 2006.

The Estuarine Importance Index scores allocated to the Siyaya Estuary (after Turpie *et al.* 2002), were as follows:

	SCORE	MOTIVATION
Estuary Size	**40**	Estuary size is defined as the total area (ha) within the geographical boundaries of the estuarine resource unit. Size is then converted to a measure of importance using scoring guidelines, which is based on 10% rank percentiles of estuaries of known size. With an area between 8.6 and 12.5 ha the Siyaya Estuary is assigned a score of 40.
Zonal Type Rarity	**10**	The estuary is one of 94 temporarily closed estuaries within the Subtropical biogeographical zone. The Zonal Type Rarity index is thus 1 - the score assigned is 10.
Habitat Diversity	**60**	This score is calculated on the basis of the amount of each habitat type present in the estuary in relation to the total area of this habitat in South African estuaries.
Biodiversity score	**70**	Data such as species richness; species rarity or endemism; and abundance (numbers, area or biomass) on estuarine plants, invertebrates, fish and birds are used to calculate this score.

Functional Importance		
SUB-COMPONENTS	**SCORE**	**SCORING GUIDELINES**
a. Estuary: Input of detritus and nutrients generated in estuary	60	None = 0 Little = 20 Some = 40 Important = 60 Very important = 80 Extremely important =100
b. Nursery function for marine-living fish and crustaceans	50	
c. Movement corridor for river invertebrates and fish breeding in sea	60	
d. Roosting area for marine or coastal birds	20	
e. Catchment detritus, nutrients and sediments to sea	10	
Functional score	**60***	

*** Using the maximum score of the above**

The individual scores obtained above are incorporated into the final Estuarine Importance Score (Table 3.51).

Table 3.51: Estuarine Importance scores for the Siyaya Estuary

CRITERION	SCORE	WEIGHT	WEIGHTED SCORE
Estuary Size	40	15	6
Zonal Rarity Type	10	10	1
Habitat Diversity	60	25	15
Biodiversity Importance	70	25	18
Functional Importance	60	25	15
ESTUARINE IMPORTANCE SCORE			**55**

The Estuarine Importance Score for the Siyaya Estuary, based on its Present State, is **55**, placing the estuary at the upper end of the "low to average importance" category on a national scale (Table 3.52). However, it was emphasized by the specialists at the workshop that the Siyaya estuary **is extremely important on a regional scale** as the **only** temporarily open / closed system north of the Thukela river. This was a key factor influencing the recommended ecological category for the Siyaya estuary.

Table 3.52: Interpretation of Estuarine Importance scores for estuaries

IMPORTANCE SCORE	DESCRIPTION
81 – 100	Highly important
61 – 80	Important
0 – 60	**Low to average importance**

3.6. Recommended Ecological Category for the Siyaya Estuary

The recommended Ecological Category represents the level of protection assigned to an estuary. In turn, it is again used to determine the Ecological Water Requirement Flow Scenario.

For estuaries the first step is to determine the 'minimum' EC of an estuary, equivalent to Present Ecological Status (PES). The relationship between Estuarine Health Index Score, Present Ecological Status and Ecological Category is set out in Table 3.61.

Table 3.61: Relationship between Present Ecological Status and minimum Ecological Category

<table>
<tr><th>ESTUARINE HEALTH INDEX SCORE</th><th>PRESENT ECOLOGICAL STATUS</th><th>DESCRIPTION</th><th>ECOLOGICAL CATEGORY</th><th>CORRESPONDING MANAGEMENT CLASS</th></tr>
<tr><td>91 – 100</td><td>A</td><td>Unmodified, natural</td><td>A-/A+</td><td>Natural
(Class I)</td></tr>
<tr><td>76 – 90</td><td>B</td><td>Largely natural with few modifications</td><td>B-/B+</td><td>Good
(Class II)</td></tr>
<tr><td>61 – 75</td><td>C</td><td>Moderately modified</td><td>C-/C+</td><td rowspan="2">Fair
(Class III)</td></tr>
<tr><td>41 – 60</td><td>D</td><td>Largely modified</td><td>D-/D+</td></tr>
<tr><td>21 – 40</td><td>E</td><td>Highly degraded</td><td>E</td><td rowspan="2">Poor
(unacceptable)</td></tr>
<tr><td>0 – 20</td><td>F</td><td>Extremely degraded</td><td>F</td></tr>
</table>

NOTE: Should the present ecological status of an estuary be either a Category E or F, recommendations must be made as to how the status can be elevated to at least achieve a Category D (as indicated above).

The degree to which the 'minimum' Ecological Category (based on its Present Ecological Status) needs to be modified to assign a recommended EC depends on:

- Importance of the estuary (determined in Section 3.5 above).
- Modifying determinants, i.e. protected area status and desired protected area status - a status of 'area requiring high protection' should be assigned to estuaries that are identified as vital for the full and most efficient representation of estuarine biodiversity.

The proposed rules for allocation of the recommended Ecological Category are set out in Table 3.62.

Table 3.62: Rules for allocation of recommended Ecological Category

CURRENT/DESIRED PROTECTION STATUS AND ESTUARINE IMPORTANCE	ECOLOGICAL CATEGORY	POLICY BASIS
Protected area	A or BAS	Protected and desired protected areas should be restored to and maintained in the best possible state of health.
Desired Protected Area (based on complementarity)	A or BAS	
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B class.
Important	PES + 1, min C	Important estuaries should be in an A, B or C class.
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D class.

During the workshop there was great emphasis placed on the Siyaya Estuary as a 'regionally important' system and is furthermore a protected area under the jurisdiction of Ezemvelo KZN Wildlife. Following the rules listed above it is recommended that the Ecological Category be raised to an **A or the Best Attainable Status.**

The achievability of the recommended Ecological Category for the Siyaya Estuary was assessed by evaluating the reversibility of present anthropogenic influences that have resulted in a Category E. At the estuarine specialist workshop it was concluded that the main reason for the estuary being in a Category E was the reduction in river flows (although there are also other anthropogenic influences such as flood plain development, sedimentation and other human disturbances). This has decreased flow through the mouth, resulting in decreased in mouth openings compared to the Reference Condition. The sedimentation of the system coupled with this reduction in river flows has resulted in accelerated encroachment of the reed *Phragmites australis*. Discussions around a reduction in forestry in the catchment as well as a reed removal programme were considered viable options to 'reverse' present anthropogenic influences on the estuary and to improve the Ecological Category to a Category B.

Thus, the recommended Ecological Category for the Siyaya Estuary is estimated as Category B. (Confidence = Low)

NOTE:

Other factors, such as the socio-economic and financial implications of removing or reducing significantly forestry in the catchment, would need to be discussed with the DWAF and other stakeholders.

It is also important to confirm through measurements whether sedimentation in the system is still a major issue and appropriate actions taken if this is shown to be the case.

4. Quantification of Ecological Water Requirement Scenarios

4.1 Simulated Future Runoff Scenarios

Simulated Monthly Runoff were supplied to the estuarine team by SRK Consulting Engineers. A summary of the mean annual runoffs (MAR) of the various Simulated Monthly Runoff Scenarios is provided below.

Name	Description	MAR	%
Reference	Reference	6,489,326	100
Present	Present Flows	4,598,805	70.9
Scenario 1	Mining scenario	4,796,561	73.9
Scenario 2	Post - mining scenario	5,742,903	88.5

The overall confidence in the hydrology is medium as limited accurate runoff data were available to provide a base for the hydrological assessment.

4.2 Ecological Water Requirement Assessment Process

4.2.1 Future Scenario 1

a) Seasonal variability in river inflow

Monthly simulated runoff data for the Future Scenario 1 are provided in Table 3. A summary of flow distributions (mean monthly flows in m³/s) for the Future Scenario 1, derived from the 85-year simulated data set, is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	0.872	0.851	**2.251**	**1.144**	**1.631**	**2.393**	**1.942**	**1.374**	**1.346**	**1.064**	0.358	**1.409**
90%ile	0.300	0.354	0.343	0.469	**1.047**	0.582	0.416	0.204	0.137	0.178	0.093	0.322
80%ile	0.154	0.194	0.188	0.285	0.529	0.333	0.140	0.125	0.064	0.063	0.058	0.129
70%ile	0.102	0.148	0.116	0.193	0.358	0.155	0.069	0.073	0.048	0.045	0.043	0.072
60%ile	0.073	0.090	0.087	0.128	0.144	0.094	0.047	0.042	0.036	0.040	0.036	0.050
50%ile	0.043	0.064	0.068	0.063	0.069	0.059	0.037	0.028	0.034	0.029	0.030	0.037
40%ile	0.026	0.035	0.030	0.027	0.033	0.033	0.027	0.019	0.026	0.025	0.025	0.023
30%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018	0.018
20%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018
10%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018
1%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018

b) Predicted Flood regime for the Future Scenario 1

Relatively small differences are expected in the floods reaching the estuary under Future Scenario 1 compared to those under reference conditions, based on the fact that the simulated monthly runoff data indicate very little change in months with flows higher than 1 m³/s. This is especially true for major floods.

Confidence: ***Medium***

c) Predicted sediment processes under Future Scenario 1 compared with Reference State:

The current shallowness of the estuary is to a large extent related to the decrease in water levels because of the reduction in base flow reaching the estuary under state 3.

The increase in base flow (increase in State 2 from State 3) compared to the Present should result in some limited increase in water levels and depths. The increased occurrence of State 2 will still be significantly less than under the reference condition, therefore the water levels and depths under base flow conditions will also still be significantly lower compared to reference conditions.

Significant sedimentation has occurred in the estuary in the past as a result of sugarcane farming in the catchment. More recently, this has largely been replaced by forestry and the erosion has possibly strongly been reduced. Sedimentation rates under Future Scenario 1 will probably be similar to present day conditions, provided current land-use is maintained. As mentioned under present state the recent floods which passed through the system were not strong enough to flush sediments accumulated in the estuary and reset it to reference conditions.

Confidence: ***Medium***

d) Occurrence and duration of the abiotic states during Future Scenario 1

The occurrence of the different states is for easier analysis illustrated in three different ways:

- Firstly by the indicated colour coding in Table 3, which includes the full simulated monthly runoff dataset for this scenario.
- Secondly the same data is summarized in the occurrence table under (i) above, in which also the same colour coding is used.
- Thirdly, to obtain a quick overview, the median (50 %) and drought (10 %) data are plotted in the figure below.

Confidence: ***Low***

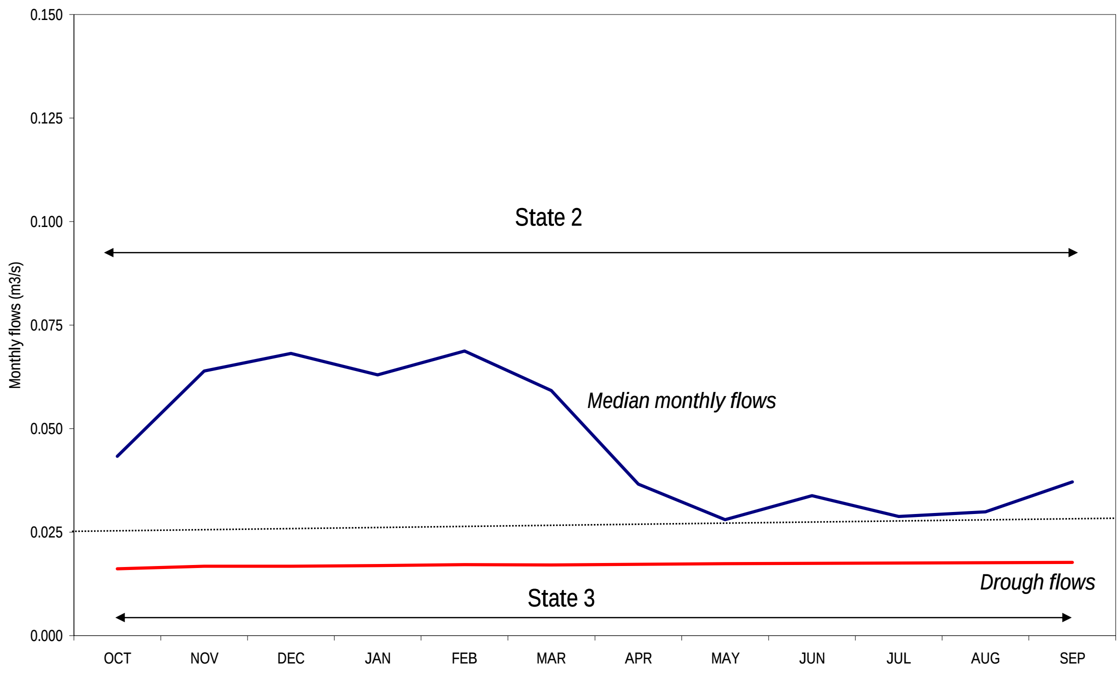


Table 3. Future Scenario 1: Simulated runoff data for the Siyaya Estuary in m³/s

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1920	0.028	0.017	0.116	0.162	0.017	0.127	0.017	0.017	0.017	0.018	0.018	0.112	0.056
1921	0.135	0.589	0.548	0.021	0.024	0.132	0.017	0.077	0.021	0.018	0.064	0.018	0.139
1922	0.026	0.189	0.017	0.889	0.098	0.017	0.027	0.043	0.017	0.018	0.018	0.018	0.115
1923	0.016	0.017	0.160	0.117	0.032	0.510	0.111	0.043	0.131	0.046	0.038	0.194	0.119
1924	0.135	0.540	0.399	0.053	0.685	**3.177**	0.835	0.381	0.053	0.124	0.042	0.043	0.540
1925	0.016	0.017	0.091	0.019	0.017	0.017	0.017	0.017	0.023	0.018	0.018	0.095	0.030
1926	0.127	0.065	0.176	0.022	0.067	0.548	0.051	0.102	0.036	0.044	0.031	0.024	0.109
1927	0.017	0.017	0.018	0.432	0.034	0.035	0.089	0.129	0.036	0.024	0.065	0.018	0.077
1928	0.016	0.017	0.017	0.017	0.017	**1.501**	0.112	0.017	0.040	0.057	0.094	0.037	0.164
1929	0.033	0.023	0.017	0.242	0.017	0.017	0.027	0.017	0.070	0.027	0.022	0.061	0.048
1930	0.016	0.062	0.091	0.017	0.017	0.089	0.033	0.017	0.020	0.032	0.018	0.018	0.036
1931	0.016	0.017	0.074	0.020	**1.530**	0.126	0.405	0.573	0.072	0.037	0.030	0.018	0.234
1932	0.016	0.017	0.110	0.055	0.017	0.023	0.017	0.017	0.017	0.018	0.018	0.018	0.029
1933	0.016	0.017	0.260	0.324	0.116	0.027	0.039	0.178	0.204	0.180	0.057	0.030	0.121
1934	0.016	0.017	0.560	0.020	0.020	0.017	0.017	0.522	**3.074**	0.574	0.511	0.061	0.451
1935	0.016	0.017	0.017	0.163	**1.098**	0.101	0.017	0.210	0.050	0.040	0.029	0.042	0.143
1936	0.076	0.387	0.018	0.017	0.167	0.077	0.070	0.020	0.111	0.066	0.047	0.025	0.089
1937	0.016	0.017	0.189	0.088	0.521	0.021	0.017	0.018	0.040	0.443	0.062	0.021	0.119
1938	0.039	0.017	0.017	0.017	0.401	0.085	0.019	0.126	0.065	0.150	0.043	0.973	0.159
1939	0.077	0.529	0.050	0.017	0.017	0.058	0.159	**1.211**	0.760	0.079	0.075	0.030	0.256
1940	0.020	0.544	0.218	0.024	0.017	0.116	0.030	0.017	0.035	0.026	0.018	0.041	0.092
1941	0.016	0.120	0.055	0.608	0.032	0.317	0.036	0.044	0.035	0.040	0.038	0.028	0.115
1942	0.016	0.225	0.446	0.020	0.048	0.714	0.599	0.076	0.051	0.360	0.314	0.051	0.245
1943	0.144	0.028	0.060	0.017	0.130	0.078	0.017	0.017	0.212	0.046	0.028	0.527	0.108
1944	0.043	0.057	0.017	0.017	0.777	0.587	0.050	0.018	0.017	0.018	0.019	0.018	0.132
1945	0.016	0.017	0.017	0.017	0.017	0.036	0.084	0.018	0.017	0.018	0.018	0.018	0.024
1946	0.056	0.017	0.070	0.017	0.605	0.172	0.040	0.027	0.044	0.041	0.033	0.056	0.095
1947	0.075	0.019	0.126	0.095	0.017	0.017	0.030	0.020	0.017	0.018	0.018	0.018	0.040
1948	0.016	0.024	0.017	0.017	0.369	0.017	0.369	0.031	0.034	0.023	0.018	0.018	0.077
1949	0.205	0.054	0.336	0.017	0.365	0.030	0.017	0.022	0.024	0.018	0.018	0.018	0.092
1950	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.232	0.147	0.046
1951	0.099	0.017	0.109	0.057	0.017	0.075	0.022	0.105	0.034	0.045	0.025	0.018	0.053
1952	0.016	0.098	0.017	0.017	0.178	0.023	0.017	0.017	0.017	0.018	0.018	0.072	0.041
1953	0.043	0.211	0.068	0.191	0.932	0.084	0.210	0.180	0.063	0.038	0.022	0.151	0.177
1954	0.596	0.037	0.026	0.283	0.032	0.507	0.041	0.017	0.017	0.018	0.018	0.021	0.136
1955	0.167	0.177	0.234	0.017	**1.149**	0.131	0.046	0.028	0.141	0.051	0.147	0.138	0.195
1956	0.068	0.114	**2.962**	0.306	0.365	0.241	0.478	0.062	0.040	0.062	0.044	0.604	0.448
1957	0.850	0.088	0.031	0.194	0.633	0.039	0.327	0.041	0.036	0.029	0.020	0.493	0.228
1958	0.072	0.017	0.017	0.092	0.023	0.017	0.017	0.036	0.017	0.018	0.018	0.371	0.059
1959	0.158	0.017	0.296	0.017	**1.343**	0.172	0.848	0.287	0.052	0.031	0.025	0.054	0.267

Table 3 (cont.): Future Scenario 1: Simulated runoff data for the Siyaya Estuary in m³/s

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1960	0.016	0.630	**2.115**	0.419	**1.356**	0.101	**2.807**	0.196	0.871	0.199	0.046	0.090	0.728
1961	0.174	0.151	0.027	0.071	0.037	0.073	0.033	0.033	0.019	0.018	0.052	0.029	0.060
1962	0.108	0.115	0.083	0.312	0.034	0.177	0.052	0.019	**1.017**	**1.012**	0.097	0.022	0.255
1963	0.089	0.072	0.020	0.541	0.078	0.018	0.234	0.036	0.026	0.043	0.039	0.035	0.103
1964	0.568	0.193	0.053	0.017	0.017	0.017	0.108	0.035	0.119	0.108	0.242	0.200	0.141
1965	0.602	0.155	0.021	0.300	0.090	0.017	0.025	0.018	0.045	0.026	0.112	0.047	0.122
1966	0.020	0.038	0.017	0.193	0.069	**1.181**	**1.778**	0.125	0.030	0.073	0.044	0.020	0.299
1967	0.076	0.071	0.017	0.142	0.078	0.427	0.041	0.017	0.036	0.023	0.081	0.032	0.087
1968	0.044	0.201	0.166	0.017	0.017	**1.423**	0.136	0.187	0.055	0.042	0.038	0.251	0.217
1969	0.289	0.037	0.187	0.037	0.017	0.017	0.017	0.092	0.036	0.037	0.035	0.040	0.071
1970	0.417	0.645	0.042	0.293	0.195	0.364	0.319	**2.229**	0.178	0.530	0.071	0.095	0.452
1971	0.203	0.082	0.145	0.207	**1.989**	0.162	0.051	0.671	0.083	0.052	0.036	0.018	0.297
1972	0.016	0.122	0.358	0.128	0.264	0.017	0.346	0.047	0.028	0.041	0.024	0.755	0.177
1973	0.069	0.114	0.019	0.494	0.087	0.017	0.037	0.118	0.049	0.043	0.035	0.018	0.092
1974	0.016	0.224	0.017	0.144	0.519	0.047	0.029	0.023	0.022	0.023	0.024	0.220	0.106
1975	0.049	0.063	0.073	0.673	0.418	**2.243**	0.973	0.162	0.044	0.059	0.051	0.148	0.414
1976	0.218	0.095	0.347	0.268	**1.563**	0.485	0.048	0.036	0.027	0.028	0.027	0.127	0.264
1977	0.080	0.165	0.071	**1.056**	0.227	0.092	0.422	0.054	0.042	0.040	0.036	0.072	0.196
1978	0.527	0.064	0.017	0.048	0.017	0.017	0.017	0.115	0.034	0.025	0.026	0.071	0.082
1979	0.025	0.232	0.112	0.080	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.696	0.105
1980	0.034	0.056	0.017	0.017	0.562	0.055	0.044	0.436	0.120	0.046	0.048	0.080	0.123
1981	0.026	0.190	0.029	0.031	0.037	0.096	0.019	0.113	0.032	0.026	0.018	0.018	0.053
1982	0.150	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.070	0.018	0.033
1983	0.103	0.164	0.059	**1.607**	**1.163**	0.178	0.064	0.032	0.024	0.079	0.037	0.018	0.289
1984	0.016	0.017	0.017	0.223	0.849	0.038	0.017	0.017	0.017	0.018	0.018	0.018	0.100
1985	0.984	0.031	0.017	0.161	0.017	0.024	0.020	0.017	0.017	0.018	0.018	0.018	0.114
1986	0.016	0.017	0.078	0.129	0.017	0.584	0.039	0.017	0.166	0.038	0.054	**3.698**	0.401
1987	0.307	0.082	0.076	0.017	**1.142**	0.390	0.038	0.019	0.026	0.025	0.029	0.019	0.174
1988	0.056	0.262	0.174	0.017	0.346	0.017	0.017	0.024	0.017	0.018	0.018	0.018	0.080
1989	0.016	**1.776**	0.098	0.017	0.017	0.578	0.055	0.017	0.017	0.018	0.093	0.018	0.226
1990	0.127	0.017	0.301	0.250	0.067	0.672	0.052	0.061	0.026	0.033	0.031	0.042	0.142
1991	0.016	0.029	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.060	0.022
1992	0.016	0.304	0.017	0.030	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018	0.042
1993	0.153	0.017	0.148	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018	0.040
1994	0.229	0.017	0.017	0.017	0.018	0.059	0.461	0.050	0.054	0.028	0.018	0.018	0.082
1995	0.050	0.137	0.612	0.507	0.970	0.161	0.027	0.019	0.017	0.178	0.033	0.018	0.223
1996	0.016	0.017	0.017	0.238	0.017	0.017	0.029	0.017	0.017	0.018	0.018	0.020	0.037
1997	0.021	0.675	0.033	0.018	0.439	0.017	0.017	0.017	0.017	0.018	0.018	0.018	0.105
1998	0.020	0.017	0.117	0.307	0.361	0.017	0.017	0.019	0.017	0.018	0.025	0.060	0.081
1999	0.414	0.017	0.109	0.179	0.020	0.325	0.086	0.169	0.036	0.027	0.018	0.022	0.120
2000	0.042	0.081	0.323	0.063	0.219	0.020	0.017	0.017	0.017	0.018	0.018	0.369	0.099
2001	0.087	0.160	0.085	0.086	0.061	0.017	0.017	0.017	0.017	**1.337**	0.329	0.050	0.191
2002	0.038	0.028	0.017	0.017	0.017	0.017	0.017	0.017	0.049	0.018	0.018	0.039	0.024
2003	0.016	0.070	0.017	0.553	0.174	0.017	0.085	0.020	0.017	0.178	0.041	0.082	0.106
2004	0.016	0.223	0.017	0.028	0.114	0.056	0.017	0.017	0.031	0.018	0.018	0.018	0.047

(red)	**<0.025**	(yellow)	**0.025-0.3**	1.4	**>0.3**

e) EHI for the Future Scenario 1 - Abiotic

Hydrology			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	50	For the Siyaya River Estuary low flows are defined as flows associated with the *State 3: Closed, with low water levels* (i.e. <0.025 m^3/s) Months with flows of less than 0.025 m^3/s occurred 13% of the time under the Reference conditions. Under Future scenario 1 State 3 occurs for 39% of the time. While the base flow has increased compared to present conditions, it is still significantly lower than at reference conditions resulting also in a significant drop of 0.5 to 1.0 m in water levels under these conditions.	M
b. % similarity in mean annual frequency of floods	90	The reduction in high flows is slightly more than under present conditions but is probably still very limited based on the reduction in monthly flows of less than 1 m^3/s.	M
Hydrology score	**66**		**M**

Hydrodynamics and mouth condition			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
Change in mean duration of closure, e.g. over a 5 or 10 year period	95	The occurrence of high flows, which are associated with State 1: Open mouth conditions, has only changed in a limited way between reference and Future Scenario 1 (from 16 % under the reference conditions to 13% under Future Scenario 1). Occasional prolonged periods of mouth closure are probably more related to dry cycles in the climate than to changes in runoff conditions between the scenarios	M
Hydrodynamics and mouth conditions score	**95**		**M**

Water quality			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	85	The salinity distribution is very homogenous in the Siyaya Estuary. Some small changes are expected due to a decrease in the amount of inflowing water during the closed states (from State 2 to State 3) that would have assisted in lowering the overall salinity values in the system. To counteract the above mentioned process, there may have been some reduction in salinity penetration due to the infilling of the subtidal area which reduces the ability of seawater to penetrate the system after a breaching.	L
2a. Nitrate/ phosphate (inorganic nutrients) concentration in the estuary	45	Slight improvement with lower concentrations in catchment runoff.	L
2b. Suspended solids in present in inflowing freshwater	25	Possibly more control of catchment erosion	L
2c. Dissolved oxygen in the estuary	25	Less nutrification means less organic production and decay and possibly less oxygen demand	L
2d. Levels of toxins	65	Possible slight increase due to heavy plant in mining area	L
Water Quality score	**49**		**L**

Physical habitat alteration			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Resemblance of intertidal sediment structure and distribution to reference condition			
1a % similarity in intertidal area exposed	70	Some infilling has occurred due to sedimentation related to change in land-use in the catchment, *viz*.. agricultural and forestry activities.	L
1b % similarity in sand fraction relative to total sand and mud	40	The estuary has become considerably muddier compared to the reference conditions due to increased erosion related to changes in the land-use in the catchment.	L
2 Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	40	A major difference is that the average depth in the estuary is drastically reduced because of the increase in State 3. However, compared to Present conditions the minimum base flow has increased for significant periods from zero flow to flows of 0.017 m^3/s. A score of 50 % would be given for changes in the subtidal area due to a decrease in water levels. In addition sedimentation has occurred due to change in land-use in the catchment, e.g. agricultural and forestry, resulting in the estuary being shallower than under Reference Conditions. Therefore 40% is allocated for both these changes.	L
Physical habitat	**48**		**L**

f) Predicted change in biotic characteristics under future Scenario 1 compared with the Reference Condition, as well as the causes of these changes:

MACROPHYTES

The very small increase in flow in future scenario 1 compared to present condition is unlikely to cause any significant change in vegetation distribution or species composition. Thus the major changes that have occurred from pristine to present conditions are likely to remain. There is however a very small possibility of decreased reed growth in the central areas of the channel with the predicted increase in state 2.

Confidence: ***Medium***

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macrocrustaceans)

Macrobenthos:
This scenario represents a very slight improvement to the physical conditions reported for the Present State (73.9% of Reference State MAR). Although the increase in baseflow from the present should result in slight increases in water level, this is nonetheless significantly less than the Reference State. Abiotic State 3 occurs 39% of the time, compared with 13% under Reference Conditions and 51% in the Present State. Prolonged Abiotic State 3 is associated with poor species richness and a depauperate community. Although sedimentation rates are estimated to be similar to the Reference, deposited sediments will remain in the system and as such this scenario is marginally improved in terms of the benthic fauna to the Present State. Slight improvements to the physical condition will be reflected as slight improvements to the species richness and abundance of this fauna.

Confidence: ***Medium***

Larger Invertebrates (Macrocrustacea)
Future Scenario 1 indicates a reduction of 26.1% in Mean Annual Runoff from the Reference Condition. This is only 3% less than what it is under the Present Condition (prior to the current drought conditions). However, given the perceived impact (no data available) of the current drought over the past four years it is considered that the macrocrustacean fauna will only undergo a minor recovery.

Confidence: ***Low***

FISH
Future Scenario 1 indicates a reduction of 26.1% in Mean Annual Runoff from the Reference Condition. This is only 3% less than what it is under the Present Condition (prior to the current drought conditions). However, given the perceived impact (no data available) of the drought over the past four years it is considered that the fish fauna will only undergo a minor recovery. *Confidence:* ***Medium***
BIRDS
The minor recovery in the fish fauna referred to above will provide little or no benefit to the piscivorous birds. Unless there is a significant reduction in water coverage by emergent and submerged macrophytes, there is unlikely to be any benefit at all. *Confidence:* ***High***

g) EHI for the future Scenario 1 - Biotic

Macrophytes			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Species richness	65	No change in the diversity (compared to present conditions) of higher plants is expected with the slight increase in occurrence of state 2. Change in algal diversity from reference to present condition is unknown and an estimate of a 20% change was proposed earlier for present conditions. The estimated score for change from reference conditions to future scenario 1 thus remains the same as proposed for the change to present conditions	M
2a. Abundance	100	As there is not expected to be a significant change from present conditions with the exception of a small possibility of a decrease in reed area due to somewhat increased occurrence of state 2 under future scenario 1. The change in abundance from reference conditions is thus slightly less than under present condition and is given a score of 35% for future scenario 1. This is because there is a very significant increase in reeds and lagoon swamp forest and decrease in phytoplankton (open water surface) since reference conditions	H
2b. Community composition	30	Significant change in cover in channel/floodplain has presently occurred and no major changes are expected under future scenario 1. Thus, the change from reference condition is still high	H
Macrophyte score	**30**		**M**
Invertebrates			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
Macroinvertebrates			
1. Species richness	35	Approximately 60% of the original species remain. Species losses are primarily associated with anthropogenic manipulation of the catchment and secondary effects to the estuary. It is estimated that more estuarine species occurred in the past when estuarine benthic habitat was more favourable and that freshwater fauna did not penetrate as far into the system.	L
2a. Abundance	60	Salinity penetration into the system is not common and the sediment has been radically altered by deposition of silt and mud. Rotting detritus in the upper reaches causes anoxic conditions. Overall benthic habitat has decreased and declined in suitability. The slight increase in abundance from Present State (40%) is due to the decrease in occurrence of Abiotic State 3 from 51% to 39% in Future Scenario 1.	L
2b.Com-munity composition	50	The reduction in the number of estuarine taxa and the increase in freshwater taxa particularly during Future Scenario 1: Abiotic State 3 has altered the community composition from the Reference. Now, more hardy species are common in the system such as *Capitella capitata* and *Prionospio sexoculata*. Given that this scenario is slightly improved from the Present State, the community is closer to the Reference (Present State score 40)	L

Macrocrustacea			
1. Species richness	35	Species richness would increase from the current condition due to the increased base flow, but it would not reach the same state as recorded during 1992 - 1994	L
2a. Abundance	60	Abundance would increase from the currently perceived (drought) condition due to the increased base flow but it would not reach the same state as recorded during 1992 - 1994	L
2b. Community composition	60	Community Composition would increase from the currently perceived (drought) condition due to the increased base flow, but it would not reach the same state as recorded during 1992 - 1994	L
Invertebrate score	**35**		**L**

Fish			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1.Species richness	35	Species richness would increase from the currently perceived (drought) condition due to the increased base flow, but it would not reach the same state as recorded during 1992 - 1994	L
2a. Abundance	50	Abundance would increase from the currently perceived (drought) condition due to the increased base flow, but it would not reach the same state as recorded during 1992 - 1994	L
2b.Community composition	50	Community Composition would diversify from the currently perceived (drought) condition due to the increased base flow, but it would not reach the same state as recorded during 1992 - 1994	L
Fish score	**35**		**L**

Birds			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Species richness	35	An improvement on the present condition is possible but the amount of vegetation in the estuary remains a major obstacle to the recovery of the system as a water bird habitat.	L
2a. Abundance	40	As above	L
2b. Community composition	50	As above	L
Bird score	**35**		**L**

4.2.2 Future Scenario 2: Post Mining development – short term

a) Seasonal variability in river inflow under scenario 2

Monthly simulated runoff data for the Future Scenario 2 are provided in Table 4. A summary of flow distribution (mean monthly flows in m^3/s) for the Future Scenario 2, derived from the 85-year simulated data set, is provided below:

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	**1.050**	**1.034**	**2.711**	**1.385**	**1.955**	**2.874**	**2.344**	**1.665**	**1.631**	**1.283**	0.437	**1.718**
90%ile	0.358	0.435	0.419	0.574	**1.271**	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.048	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.047	0.040	0.044	0.040	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.041	0.030	0.037	0.031	0.032	0.042
40%ile	0.029	0.037	0.033	0.030	0.036	0.037	0.031	0.019	0.026	0.026	0.026	0.024
30%ile	0.016	0.017	0.017	0.018	0.018	0.017	0.017	0.017	0.018	0.018	0.018	0.018
20%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018
10%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018
1%ile	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018

b) Predicted Flood regime for the Future Scenario 2

Relatively small differences are expected on the floods reaching the estuary under Future Scenario 2 compared to those under reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than $1m^3/s$. This is especially the case for major floods.

Confidence: ***Medium***

c) Predicted sediment processes under Future Scenario 2 compared with Reference State:

The current shallowness of the estuary is to a large extent related to the decrease in water levels because of the reduction in base flow reaching the estuary under state 3.

The increase in base flow (increase in State 2 from State 3) compared to the Present should result in some limited increase in water levels and depths. The increased occurrence of State 2 will still be significantly less than under the reference condition, therefore the water levels and depths under base flow conditions will also still be significantly lower compared to reference conditions.

Significant sedimentation occurred in the estuary in the past because of the development of sugarcane farming in the catchment. More recently this has largely been replaced by forestry and the erosion in the catchment has possible been reduced. Sedimentation rates under Future Scenario 1 are probably similar to what they were under reference conditions, provided current land-use is maintained. However, recent floods were not strong enough to flush sediments accumulated in the past from the estuary and to reset it to what it was under reference conditions.

Confidence: Low

d) Occurrence and duration of the abiotic states during Future Scenario 2

- The occurrence of the different states is for easier analysis illustrated in three different ways:

- Firstly by the indicated colour coding in Table 4, which includes the full simulated monthly runoff dataset for this scenario.
- Secondly the same data is summarized in the occurrence table under (i) above, in which the same colour coding is used.
- Thirdly, to obtain a quick overview, the median (50 %) and drought (10 %) data are plotted in the figure below.

Confidence: Low

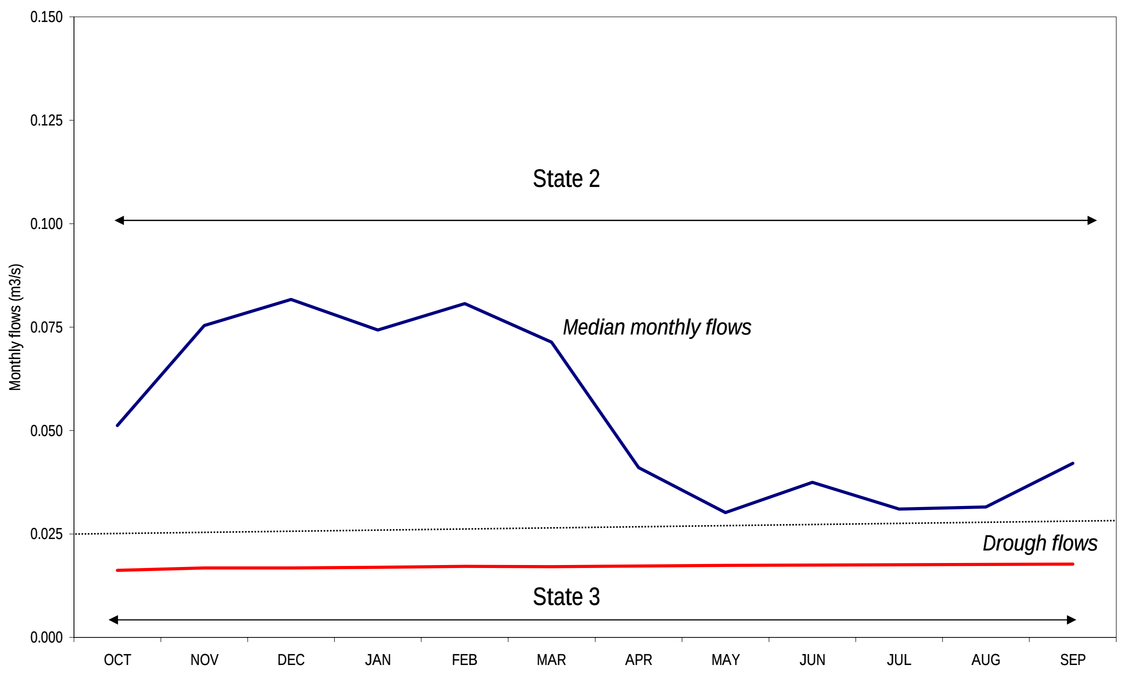


Table 4. Future Scenario 2: Simulated runoff data for the Siyaya Estuary in m³/s

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1920	0.032	0.017	0.142	0.200	0.017	0.156	0.017	0.017	0.017	0.018	0.018	0.136	0.066
1921	0.167	0.722	0.671	0.020	0.024	0.161	0.017	0.092	0.022	0.018	0.075	0.018	0.168
1922	0.029	0.233	0.017	**1.079**	0.113	0.017	0.030	0.050	0.017	0.018	0.018	0.018	0.137
1923	0.016	0.017	0.197	0.144	0.036	0.625	0.133	0.049	0.161	0.052	0.042	0.239	0.143
1924	0.166	0.667	0.480	0.060	0.833	**3.803**	0.989	0.458	0.059	0.149	0.047	0.048	0.647
1925	0.016	0.017	0.110	0.021	0.017	0.017	0.017	0.017	0.024	0.018	0.018	0.115	0.034
1926	0.156	0.078	0.216	0.024	0.079	0.669	0.057	0.123	0.040	0.050	0.034	0.025	0.131
1927	0.019	0.017	0.019	0.529	0.036	0.040	0.107	0.158	0.040	0.026	0.077	0.018	0.091
1928	0.016	0.017	0.017	0.017	0.017	**1.813**	0.127	0.017	0.045	0.068	0.113	0.042	0.195
1929	0.038	0.025	0.017	0.298	0.017	0.017	0.031	0.017	0.083	0.029	0.024	0.072	0.056
1930	0.016	0.075	0.111	0.017	0.017	0.109	0.037	0.018	0.021	0.036	0.018	0.018	0.041
1931	0.016	0.017	0.090	0.023	**1.848**	0.146	0.501	0.714	0.082	0.040	0.032	0.018	0.283
1932	0.016	0.017	0.135	0.066	0.017	0.026	0.017	0.017	0.017	0.018	0.018	0.018	0.032
1933	0.016	0.017	0.319	0.398	0.140	0.030	0.045	0.220	0.254	0.226	0.065	0.032	0.148
1934	0.016	0.017	0.683	0.019	0.021	0.017	0.017	0.638	**3.713**	0.678	0.613	0.067	0.541
1935	0.016	0.017	0.017	0.201	**1.330**	0.117	0.017	0.257	0.056	0.045	0.031	0.047	0.171
1936	0.091	0.475	0.017	0.017	0.203	0.092	0.083	0.021	0.134	0.078	0.053	0.027	0.106
1937	0.016	0.017	0.233	0.107	0.636	0.022	0.017	0.018	0.046	0.547	0.071	0.021	0.143
1938	0.045	0.017	0.017	0.017	0.491	0.101	0.020	0.153	0.076	0.185	0.048	**1.193**	0.193
1939	0.087	0.643	0.055	0.017	0.017	0.069	0.194	**1.474**	0.913	0.088	0.088	0.032	0.307
1940	0.021	0.664	0.264	0.026	0.017	0.141	0.033	0.017	0.038	0.027	0.018	0.047	0.109
1941	0.016	0.146	0.065	0.741	0.032	0.389	0.040	0.051	0.039	0.045	0.042	0.031	0.138
1942	0.016	0.277	0.545	0.020	0.055	0.869	0.736	0.086	0.056	0.434	0.378	0.057	0.296
1943	0.176	0.030	0.070	0.017	0.157	0.094	0.017	0.017	0.260	0.052	0.030	0.645	0.129
1944	0.048	0.067	0.017	0.017	0.945	0.715	0.055	0.018	0.017	0.018	0.019	0.018	0.158
1945	0.016	0.017	0.017	0.017	0.017	0.042	0.101	0.019	0.017	0.018	0.018	0.018	0.026
1946	0.067	0.017	0.085	0.017	0.739	0.209	0.046	0.030	0.050	0.047	0.037	0.066	0.113
1947	0.091	0.021	0.154	0.116	0.017	0.017	0.034	0.021	0.017	0.018	0.018	0.018	0.045
1948	0.016	0.027	0.017	0.017	0.453	0.017	0.453	0.034	0.037	0.025	0.018	0.018	0.091
1949	0.253	0.064	0.413	0.017	0.447	0.032	0.017	0.023	0.025	0.018	0.018	0.018	0.110
1950	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.285	0.182	0.053
1951	0.122	0.017	0.134	0.069	0.017	0.091	0.024	0.127	0.037	0.052	0.027	0.018	0.062
1952	0.016	0.120	0.017	0.017	0.219	0.025	0.017	0.017	0.017	0.018	0.018	0.086	0.047
1953	0.051	0.260	0.082	0.235	**1.132**	0.096	0.260	0.222	0.072	0.041	0.022	0.184	0.214
1954	0.730	0.039	0.028	0.347	0.033	0.620	0.045	0.017	0.017	0.018	0.018	0.022	0.164
1955	0.205	0.217	0.287	0.017	**1.391**	0.154	0.052	0.030	0.172	0.057	0.180	0.169	0.236
1956	0.080	0.137	**3.562**	0.358	0.443	0.293	0.577	0.069	0.043	0.071	0.048	0.739	0.538
1957	**1.023**	0.099	0.034	0.238	0.771	0.042	0.400	0.045	0.039	0.031	0.019	0.602	0.275
1958	0.085	0.017	0.017	0.112	0.024	0.017	0.017	0.041	0.017	0.018	0.018	0.455	0.070
1959	0.194	0.017	0.364	0.017	1.624	0.204	1.041	0.340	0.057	0.032	0.026	0.063	0.321
1960	0.016	0.768	**2.549**	0.499	**1.629**	0.113	**3.369**	0.220	**1.048**	0.237	0.050	0.106	0.873
1961	0.214	0.183	0.028	0.085	0.041	0.087	0.036	0.036	0.019	0.018	0.060	0.031	0.070
1962	0.132	0.140	0.100	0.383	0.036	0.217	0.059	0.019	**1.235**	**1.219**	0.109	0.022	0.308
1963	0.108	0.086	0.021	0.660	0.090	0.019	0.287	0.040	0.027	0.049	0.043	0.038	0.123
1964	0.695	0.235	0.061	0.017	0.017	0.017	0.131	0.039	0.145	0.132	0.303	0.251	0.171
1965	0.723	0.185	0.021	0.367	0.106	0.017	0.026	0.017	0.051	0.027	0.136	0.053	0.145
1966	0.022	0.044	0.017	0.238	0.081	**1.430**	**2.149**	0.140	0.031	0.085	0.048	0.020	0.359
1967	0.091	0.084	0.017	0.175	0.092	0.523	0.045	0.017	0.040	0.024	0.097	0.035	0.104
1968	0.052	0.247	0.202	0.017	0.017	**1.719**	0.156	0.231	0.062	0.046	0.042	0.308	0.261
1969	0.358	0.041	0.228	0.042	0.017	0.017	0.017	0.111	0.039	0.041	0.039	0.045	0.084
1970	0.513	0.792	0.045	0.359	0.236	0.447	0.379	**2.669**	0.198	0.639	0.079	0.113	0.543
1971	0.251	0.097	0.176	0.253	**2.385**	0.185	0.058	0.814	0.093	0.058	0.038	0.018	0.356
1972	0.016	0.149	0.439	0.155	0.322	0.017	0.423	0.052	0.029	0.046	0.025	0.918	0.213
1973	0.079	0.138	0.019	0.604	0.101	0.017	0.041	0.143	0.055	0.048	0.038	0.018	0.109
1974	0.016	0.275	0.017	0.177	0.634	0.054	0.032	0.025	0.022	0.024	0.025	0.270	0.127
1975	0.058	0.075	0.088	0.820	0.510	**2.697**	**1.161**	0.194	0.048	0.068	0.057	0.180	0.498
1976	0.269	0.113	0.423	0.327	**1.873**	0.581	0.053	0.039	0.029	0.029	0.028	0.154	0.316
1977	0.096	0.202	0.084	**1.279**	0.271	0.110	0.513	0.060	0.046	0.044	0.039	0.085	0.236
1978	0.649	0.073	0.017	0.056	0.017	0.017	0.017	0.140	0.037	0.027	0.027	0.085	0.098
1979	0.028	0.285	0.136	0.096	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.848	0.125
1980	0.037	0.068	0.017	0.017	0.686	0.064	0.051	0.540	0.144	0.052	0.054	0.095	0.148
1981	0.029	0.233	0.032	0.035	0.042	0.117	0.019	0.136	0.034	0.027	0.018	0.018	0.062
1982	0.185	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.083	0.018	0.037
1983	0.127	0.202	0.070	**1.940**	**1.412**	0.214	0.073	0.034	0.025	0.094	0.041	0.018	0.348
1984	0.016	0.017	0.017	0.274	**1.032**	0.040	0.017	0.017	0.017	0.018	0.018	0.018	0.119
1985	**1.194**	0.031	0.017	0.198	0.017	0.026	0.022	0.017	0.017	0.018	0.018	0.018	0.135
1986	0.016	0.017	0.095	0.158	0.017	0.713	0.042	0.017	0.203	0.043	0.063	**4.475**	0.485
1987	0.358	0.098	0.089	0.017	**1.382**	0.473	0.041	0.019	0.026	0.026	0.031	0.019	0.207
1988	0.068	0.322	0.212	0.017	0.424	0.017	0.017	0.026	0.017	0.018	0.018	0.018	0.095
1989	0.016	**2.142**	0.108	0.017	0.017	0.706	0.061	0.017	0.017	0.018	0.112	0.018	0.270

Table 4 (cont.): Future Scenario 2: Simulated runoff data for the Siyaya Estuary in m^3/s

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1990	0.156	0.017	0.370	0.306	0.078	0.819	0.058	0.072	0.028	0.037	0.033	0.048	0.171
1991	0.016	0.033	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.072	0.023
1992	0.016	0.374	0.017	0.035	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018	0.048
1993	0.190	0.017	0.183	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.019	0.018	0.046
1994	0.283	0.017	0.017	0.017	0.019	0.071	0.565	0.057	0.063	0.031	0.018	0.018	0.098
1995	0.061	0.168	0.747	0.619	**1.181**	0.193	0.028	0.019	0.017	0.217	0.036	0.018	0.270
1996	0.016	0.017	0.017	0.293	0.017	0.017	0.033	0.017	0.017	0.018	0.018	0.022	0.042
1997	0.024	0.823	0.035	0.020	0.538	0.017	0.018	0.017	0.017	0.018	0.018	0.018	0.126
1998	0.023	0.017	0.143	0.378	0.442	0.017	0.017	0.020	0.017	0.018	0.027	0.071	0.097
1999	0.509	0.017	0.133	0.221	0.020	0.399	0.101	0.209	0.039	0.029	0.018	0.023	0.145
2000	0.050	0.098	0.397	0.074	0.268	0.021	0.017	0.017	0.017	0.018	0.018	0.453	0.119
2001	0.105	0.196	0.102	0.104	0.072	0.017	0.017	0.017	0.017	**1.617**	0.403	0.056	0.230
2002	0.044	0.030	0.017	0.017	0.017	0.017	0.017	0.017	0.057	0.018	0.018	0.045	0.026
2003	0.016	0.086	0.017	0.675	0.211	0.017	0.103	0.021	0.017	0.219	0.046	0.099	0.127
2004	0.016	0.274	0.017	0.033	0.138	0.066	0.017	0.017	0.034	0.018	0.018	0.018	0.054

(red)	**<0.025**	(yellow)	**0.025-**	1.4	**>0.3**

e) EHI for the Future Scenario 2 - abiotic

Hydrology			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	55	For the Siyaya River Estuary low flows are defined as flows associated with the *State 3: Closed, with low water levels* (i.e. <0.025 m^3/s) Months with flows of less than 0.025 m^3/s occurred 13% of the time under the Reference conditions. Under Future scenario 2 State 3 occurs for 38% of the time. While the base flow has increased compared to present conditions, it is still significantly lower than at reference conditions resulting also in a significant drop of 0.5 to 1.0 m in water levels and depths under these conditions.	M
b. % similarity in mean annual frequency of floods	98	The reduction in high flows is expected to be very little based on the reduction in monthly flows of less than 1 m^3/s.	M
Hydrology score	**72**		**M**

Hydrodynamics and mouth condition			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
Change in mean duration of closure, e.g. over a 5 or 10 year period	95	The occurrence of high flows, which are at the Siyaya associated with State 1 : Open mouth conditions, has only changed in a limited way between reference and Future Scenario 2 (from 16 % under the reference conditions to 14% under Future Scenario 2). Occasional prolonged periods of mouth closure are probably more related to dry cycles in the climate than to changes in runoff conditions between the scenarios.	M
Hydrodynamics and mouth conditions Score	**95**		**M**

Water quality			
VARIABLE	**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	85	The salinity distribution is very homogenous in the Siyaya Estuary. Some small changes are expected due to a decrease in the amount of inflowing water during the closed states (from State 2 to State 3) that would have assisted in lowering the over all salinity values in the system. To counteract the above mentioned process, there may have been some reduction in salinity penetration due to the infilling of the subtidal area which reduces the ability of seawater to penetrate the system after a breaching.	L
2a.Nitrate/phosphate (inorganic nutrients) concentration in the estuary	45	No improvement on scenario 1 (mining); some improvement on present condition	L
2b. Suspended solids in present in inflowing freshwater	30	Slight improvement on scenario 1 (mining); no improvement on present condition	L
2c. Dissolved oxygen in the estuary	25	Sllght improvement on present condition; no improvement on scenario 1 (mining)	L
2d. Levels of toxins	65	No improvement on scenario 1 (mining) some improvement on present condition	L
Water Quality score	**49**		**L**

Physical habitat alteration				
VARIABLE		**SCORE**	**MOTIVATION**	**CONFI-DENCE**
1. Resemblance of <u>intertidal sediment</u> structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	70	Some infilling is reputed to have occurred due to sedimentation related to change in land-use in the catchment, *viz.* agricultural and forestry activities.	L
1b	% similarity in sand fraction relative to total sand and mud	40	The estuary has become considerably muddier compared to the reference conditions due to increased erosion related to changes in the land-use in the catchment.	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	40	A major difference is that the average depth in the estuary is drastically reduced because of the increase in State 3. However, compared to Present conditions the minimum base flow has increased for significant periods from zero flow to flows of 0.017 m^3/s. A score of 50% would be given for changes in the subtidal area due to the decrease in water levels. In addition some sedimentation has occurred due to change in land-use in the catchment, *viz* agricultural and forestry. Therefore 40% is allocated for both these changes.	L
Physical habitat		**48**		**L**

f) Predicted change in biotic characteristics of the future Scenario 2 compared with the Reference Condition, as well as the <u>causes</u> of these changes:

MACROPHYTES

The more significant increase in state 2 in future scenario 2 as compared to future scenario 1 will result in a greater possibility of reduction in reed growth in the central channel area due to increased flows and higher water levels. This will result in concurrent increase in open water surface (phytoplankton). While this will shift the present condition towards a more pristine condition the overall change will still be a long way from this. This is because the flows will not be sufficient to significantly alter the bed morphology *i.e.* serious scouring will be required to clear the channel of reeds and sediments that have accumulated

Confidence: ***Medium***

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macrocrustaceans)

Macroinvertebrates:

Future Scenario 2: Post Mining is closer to the Reference (88.5% of Reference State MAR) than either the Present State or Future Scenario 1. However, the changes to the predicted sediment processes, water levels and depths and occurrence and duration of abiotic states show only slight improvement to the physical conditions reported for the Present State. This state is highly comparable to Future Scenario 1 in terms of hydrology, hydrodynamics and mouth condition, water quality and physical habitat alteration with an insignificant reduction in the occurrence of Abiotic State 3 (39% to 38%) and % similarity in mean annual frequency of floods from 90 to 98. Although sedimentation rates are estimated to be similar to the Reference, deposited sediments will remain in the system and as such this scenario is little different in terms of the benthic fauna to the Future Scenario 1. Slight improvements to the physical condition will not be reflected in any discernible change to either species richness or abundance of this fauna.

Confidence: ***Medium***

Larger Invertebrates (Macrocrustacea)

Despite the fact that the reduction in MAR from the Reference Condition to Future Scenario 2 indicates only an 11.5% decrease, the predicted flow scenarios indicate a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition. It is therefore considered that the changes from Reference will be similar to that of the Mining Scenario. In addition this is a short term scenario which is only considered to last some two years.

Confidence: ***Low***

FISH

Despite the fact that the reduction in MAR from the Reference Condition to Future Scenario 2 indicates only 11.5% decrease, the predicted flow scenarios indicate a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition. It is therefore considered that the changes from Reference will be similar to that of the Mining Scenario. In addition this is only a short term scenario which is considered to last some two years.

Confidence: **Low**

BIRDS

Following on from the comments relating to the invertebrates and fish, no significant long term improvement in the bird fauna would be expected.

Confidence: ***Low***

g) EHI for the Future Scenario 2:

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	65	No change in the diversity (compared to present conditions) of higher plants is expected with the slight increase in occurrence of state 2. Change in algal diversity from reference to present condition is unknown and an estimate of 20% was proposed earlier for present conditions. The estimated score for change from reference conditions to future scenario 2 thus remains the same as proposed for the change to present conditions	M

2a. Abundance	100	As there is not expected to be a significant change from present conditions with the exception of a relatively small possibility of a decrease in reed area due to somewhat increased occurrence of state 2 under future scenario 2. The change in abundance form reference conditions is thus slightly less than under present conditions and is given a score of 40% for future scenario 2. This is because there is nonetheless a very significant increase in reeds and lagoon swamp forest and a decrease in phytoplankton (open water surface) relative to reference conditions	H
2b. Community composition	30	Significant change in cover in channel/floodplain has presently occurred and no major changes are expected under future scenario 2. Thus the change from reference condition is still high	H
Macrophytes score	**30**		**H**

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Macroinvertebrates			
1. Species richness	35	Approximately 60% of the original species remain. Species losses are primarily associated with anthropogenic manipulation of the catchment and secondary effects to the estuary. It is estimated that more estuarine species occurred in the past when estuarine benthic habitat was more favourable and that freshwater fauna did not penetrate as far into the system.	L
2a. Abundance	60	Salinity penetration into the system is not common and the sediment has been radically altered by deposition of silt and mud. Rotting detritus in the upper reaches causes anoxic conditions. Overall benthic habitat has decreased and declined in suitability. The slight increase in abundance from Present State (40%) is due to the decrease in occurrence of Abiotic State 3 from 51% to 39% in Future Scenario 2.	L
2b. Community composition	50	The reduction in the number of estuarine taxa and the increase in freshwater taxa particularly during Future Scenario 2: Abiotic State 3 has altered the community composition from the Reference. Now, more hardy species are common in the system such as *Capitella capitata* and *Prionospio sexoculata*. Given that this scenario is slightly improved from the Present State, the community is closer to the Reference (Present State score 40)	L
Macrocrustacea			
1. Species richness	35	Species Richness would increase from the currently perceived (drought) condition Present State due to the increased base flow. However, due to there still being a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition, it is considered that the Species Richness would be much as for Scenario 1 - Mining.	L
2a. Abundance	60	Abundance would increase from the currently perceived (drought) condition Present State due to the increased base flow. However, due to there still being a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition, it is considered that Abundance would be much as for Scenario 1 - Mining.	L
2b. Community composition	60	Community Composition would diversify from the currently perceived (drought) condition Present State due to the increased base flow. However, due to there still being a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition, it is considered that the Community Composition would be much as for Scenario 1 - Mining.	L
Invertebrates score	**35**		**L**

Fish

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	35	Species richness would increase from the currently perceived (drought) condition Present State due to the increased base flow. However, due to there still being a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition, it is considered that the changes would be much as for Scenario 1 - Mining.	L
2a. Abundance	50	Abundance would increase from the currently perceived (drought) condition Present State due to the increased base flow. However, due to there still being a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition, it is considered that Abundance would be much as for Scenario 1 - Mining.	L
2b. Community composition	50	Community Composition would diversify from the currently perceived (drought) condition Present State due to the increased base flow. However, due to there still being a significant drop of 0.5 to 1.0 m in water levels and depths when compared to the Reference Condition, it is considered that the Community Composition would be much as for Scenario 1 - Mining.	L
Fish score	**35**		**L**

Birds

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	35	Possible improvement on present conditions but not on scenario 1 (mining). Vegetation proliferation remains a major problem.	L
2a. Abundance	40	As above	L
2b. Community composition	50	As above	L
Bird score	**35**		**L**

5. QUANTIFICATION OF ECOLOGICAL RESERVE SCENARIOS - ADDITIONAL FUTURE RUNOFF SCENARIOS

5.1. Additional future runoff Scenarios

After the analysis at the workshop of Future Scenario 1 (Mining Scenario) and Future Scenario 2 (Post Mining Scenario), it was decided to analyse 3 further future scenarios:

- Future Scenario 3: Post Mining Scenario, but with base flow as at Present Day Scenario.
- Future Scenario 4: Post Mining Scenario, but with base flow at 0.05 m^3/s or as at Reference Conditions, whichever is the lowest.
- Future Scenario 5: As for Future Scenario 4, but including management interventions

5.2. Future Scenario 3: Post Mining Scenario, but with base flow as at the Present Day Scenario

Discussions at the workshop appeared to suggest that, it was possible with careful control of developments in the catchment, that the base flow in the long-term could return to a situation similar to present day condititions. It was therefore decided that such a future post mining scenario should also be analysed.

Simulated runoff data were not available for such a scenario and it was therefore scored similar to Future Scenario 2 (Post Mining Scenario) for the higher flows and for the base flows scored similar to the Present Day Scenario.

5.3. Future Scenario 3: Post Mining Scenario, but with base flow as at the Present Day Scenario

a) Seasonal variability in river inflow:

The occurrences of monthly flows for this new Future Scenario 3 are displayed in the occurrences table below. This occurrences table was obtained from that of Future Scenario 2 for the flows with occurrences of 50 % and higher and from that for Present Conditions for the flows with occurrences less than 50 %.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	**1.050**	**1.034**	**2.711**	**1.385**	**1.955**	**2.874**	**2.344**	**1.665**	**1.631**	**1.283**	0.437	**1.718**
90%ile	0.358	0.435	0.419	0.574	**1.271**	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.048	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.047	0.040	0.044	0.040	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.041	0.030	0.037	0.031	0.032	0.042
40%ile	0.008	0.021	0.018	0.009	0.021	0.012	0.009	0.003	0.011	0.009	0.008	0.009
30%ile	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20%ile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10%ile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1%ile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

b) Predicted Flood regime for the Future Scenario 3

Relatively small differences are expected in the floods reaching the estuary under Future Scenario 3 compared to those under reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months of flows higher than 1 m^3/s. This is especially the case for major floods.

Confidence: Medium

c) Predicted sediment processes under Future Scenario 3 compared with Reference State:

The current shallowness of the estuary is to a large extent related to the decrease in water levels because of the reduction in base flow reaching the estuary at present under state 3. Significant sedimentation occurred in the estuary in the past as a result of sugarcane farming in the catchment. More recently this has been largely replaced by forestry and the erosion in the catchment has possibly been reduced. Sedimentation rates may at present be similar to what they were under reference conditions. However, recent floods were not strong enough to flush accumulated sediments from the estuary and reset it to its reference conditions.

Confidence: Low

d) EHI for the Future Scenario 3 - abiotic

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	30	For the Siyaya River Estuary low flows are defined as flows associated with the *State 3: Closed, with low water levels* (i.e. <0.025 m^3/s) Months with median low flows of less than 0.025 m^3/s never occurred under the median flow condition in the Reference conditions. Under the Present state they occur for 6 months of the year (April - September) under the median flow conditions. In addition, these flows are currently overall for the 85-year period occurring for 51% of the time under the Present state versus 13 % under the Reference conditions. This drastic increase in the occurrence of very low flows has resulted in a drop of 1 to 2 m in water levels at these lower flows.	M
b. % similarity in mean annual frequency of floods	95	The reduction in high flows is expected to be very little based on the limited reduction in monthly flows of less than 1 m^3/s.	M
Hydrology score	**56**		**M**

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	95	The occurrence of high flows, which are at the Siyaya associated with State 1 : Open mouth conditions, will only change in a limited way between reference and Future Scenario 3 (from 16 % under the reference conditions to 13% under Future Scenario 3, similarly to the Present conditions)	M
Hydrodynamics and mouth conditions Score	**95**		**M**

Water quality

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	80	The salinity distribution is very homogenous in the Siyaya Estuary. Some small changes are expected due to a decrease in the amount of inflowing water during the closed states (from State 2 to State 3) that would have assisted in lowering the over all salinity values in the system. There may have been some reduction in salinity penetration due to the infilling of the subtidal area which reduces the ability of seawater to penetrate the system after a breaching.	L
2a.Nitrate/phosphate (inorganic nutrients) concentration in the estuary	30	No change	L
2b. Suspended solids in present in inflowing freshwater	30	No change	L
2c. Dissolved oxygen in the estuary	15	No change	L
2d. Levels of toxins	60	No change	L
Water Quality score	**41**		**L**

Physical habitat alteration

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Resemblance of <u>intertidal sediment</u> structure and distribution to reference condition			
1a % similarity in intertidal area exposed	70	Some infilling is reputed to have occurred due to sedimentation related to change in land-use in the catchment, *viz* agricultural and forestry activities.	L
1b % similarity in sand fraction relative to total sand and mud	30	The estuary has become considerably muddier compared to the reference conditions due to increased erosion related to changes in the land-use in the catchment.	L
2 Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	30	A major difference is that the average depth in the estuary is drastically reduced because of the increase in State 3. A score of 40% would be given for changes in the subtidal area due to the decrease in water levels. In addition sedimentation has occurred due to change in land-use in the catchment, *viz* agriculture and forestry. Therefore 30% is allocated for both these changes.	L
Physical habitat	**40**		**L**

e) Predicted change in biotic characteristics of the future Scenario 3 compared with the Reference Condition, as well as the causes of these changes:

MACROPHYTES

No change from present conditions in terms of distribution and abundance is expected.

Confidence: high

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Macroinvertebrates:

Habitat health scores for Future Scenario 3 are exactly the same as the Present State in terms of hydrology, hydrodynamics and mouth condition, water quality and physical habitat alteration. Thus, the biological health scores should be comparable, if not the same. Given that it is envisaged that the system will be subject to elevated baseflows (0.017 m^3/s) for a short duration and a resultant increase in water level to 0.5m under Scenario 2, the fauna present will have recovered to be more representative of historical conditions under Scenario 2, before the decline in baseline flows (as is the case with the Present State) under Scenario 3.

Thus overall biotic health scores will be slightly improved from the Present State.

Confidence: ***Medium***

Larger Invertebrates (Macrocrustacea)

The drastic increase in the occurrence of very low flows, as predicted for this scenario, would result in a drop of 1 to 2 m in water levels at these lower flows and this would result in the macrocrustacean fauna present under this scenario being quite different from that of the Reference Condition.

Although the Present State of the system, based on 1991-2003 data, indicates a 60% similarity to the Reference Condition, the impact of the past four years of drought, indicates a substantial move away from the Reference Condition.

Confidence: ***Medium***

FISH

The increase in the occurrence of very low flows, as predicted by this scenario, would result in a drop of 1 to 2 m in water levels and this would result in the fish fauna present under this scenario being quite different from that of the Reference Condition.

Although the Present State of the system, based on 1991-2000 data, indicates a 60% similarity to the Reference Condition, the impact of forestry and the past four years of drought, indicates a substantial move away from the Reference Condition.

Confidence: ***Medium***

BIRDS

Adverse effects on the fish in combination with the loss of bird habitat through aquatic vegetation growth minimise any benefits to the birds

Confidence: ***Medium***

f) EHI for the Future Scenario 3: Biotic

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Macrophytes			
1. Species richness	65	No change from present conditions is expected and scores will remain unchanged from those for present condition compared to perceived pristine conditions	L
2a. Abundance	100	No change from present conditions is expected and scores will remain unchanged from those for present condition compared to perceived pristine conditions	L

2b. Community composition	30	No change from present conditions is expected and scores will remain unchanged from those for present condition compared to perceived pristine conditions	L
Macrophytes score	**30**		**L**

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Macroinvertebrates			
1. Species richness	17	Approximately 40% of the original species remain. Species losses are primarily associated with anthropogenic manipulation of the catchment and secondary effects to the estuary. It is estimated that more estuarine species occurred in the past when estuarine benthic habitat was more favourable (less mud and anoxic detritus) and that freshwater fauna did not penetrate as far into the system.	L
2a. Abundance	50	Salinity penetration into the system is not common and the sediment has been radically altered by deposition of silt and mud. Rotting detritus in the upper reaches causes anoxic conditions. Overall benthic habitat has decreased (most recent study by MER, where mouth lower reaches have decreased substantially in area) and declined in suitability.	L
2b. Community composition	50	The reduction in the number of estuarine taxa and the increase in freshwater taxa particularly during the extended periods of Abiotic State 3 have altered the community composition from the Reference. Now, more hardy species are common in the system such as *Capitella capitata* and *Prionospio sexoculata*.	L
Macrocrustacea			
1. Species richness	17	Species richness will be much the same as it is under the Present State due to the base flows predicted being much the same.	L
2a. Abundance	50	Abundance will be much the same as it is under the Present State due to the base flows predicted being much the same.	L
2b. Community composition	50	Community diversity will be much the same as it is under the Present State due to the base flows predicted being much the same.	L
Invertebrates score	**17**		**L**

Fish

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	25	Species richness will be much the same as it is under the Present State due to the base flows predicted being much the same.	L
2a. Abundance	35	Abundance will be much the same as it is under the Present State due to the base flows predicted being much the same.	L
2b. Community compositi on	45	Community diversity will be much the same as it is under the Present State due to the base flows predicted being much the same.	L
Fish score	**25**		**L**

Birds

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	17	Possible slight improvement on present conditions as suggested above for the fish.	L
2a. Abundance	20	Possible slight improvement on present conditions as suggested above for the fish.	L
2b. Community composition	30	Possible slight improvement on present conditions as suggested above for the fish.	L
Bird score	**17**		**L**

5.4. Future Scenario 4: Post Mining Scenario, but with base flow at 0.05 m^3/s or as at the Reference Conditions, which ever is the lowest, but with the current state of sedimentation in the estuary

At the discussions at the workshop it appeared that, dependent on the developments in the catchment, the base flow in the long-term could return to that under present day conditions. It was therefore decided that such a future post mining scenario should also be analysed.

Simulated runoff data were not available for such a scenario and it was therefore scored similar to Future Scenario 2 (Post Mining Scenario) for the higher flows and for the base flows scored similar to the Present Day Scenario.

a) Seasonal variability in river inflow:

The occurrences of monthly flows under Future Scenario 4 are displayed in the occurrences table below. This occurrences table was obtained from that of Future Scenario 2 for the flows higher than 0.050 m^3/s and from that of the Reference Conditions Scenario for flows less than 0.050 m^3/s. Flows of 0.050 m^3/s were assumed for the monthly occurrences that were in between these obtained from Future Scenario 4 and the Reference Conditions Scenario.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.050	1.034	2.711	1.385	1.955	2.874	2.344	1.665	1.631	1.283	0.437	1.718
90%ile	0.358	0.435	0.419	0.574	1.271	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.050	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.050	0.050	0.050	0.050	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.050	0.047	0.050	0.041	0.043	0.050
40%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.036	0.041	0.036	0.037	0.045
30%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.042	0.034	0.032	0.027	0.029	0.038
20%ile	0.044	0.043	0.050	0.050	0.042	0.048	0.035	0.027	0.026	0.021	0.021	0.029
10%ile	0.031	0.031	0.037	0.033	0.031	0.029	0.023	0.018	0.019	0.015	0.018	0.021
1%ile	0.016	0.012	0.020	0.019	0.017	0.013	0.013	0.009	0.010	0.009	0.011	0.014

b) Predicted Flood regime for the Future Scenario 4

Relatively small differences are expected in the floods reaching the estuary under Future Scenario 4 compared to those under reference conditions based on the fact that the simulated monthly runoff data for Future Scenario 2, which is similar for high flows to that of Future Scenario 4, indicate very little change for months of flows higher than 1 m^3/s. This is especially true for major floods.

Confidence: ***Medium***

3. Predicted sediment processes under Future Scenario 4 compared with Reference State:

The base flow will be 0.05 m^3/s or similar to that under Reference Conditions, which ever is the lowest. The water levels in the estuary will therefore at base flow conditions again increase to those under reference conditions and the reduction in the depths will only be due to sedimentation.

Significant sedimentation occurred in the estuary in the past because of the development of sugarcane farming in the catchment. More recently this has been largely replaced by forestry and the erosion in the catchment has possibly been reduced. The sedimentation rates have therefore possibly also been reduced. However, recent floods were not and future floods will probably not be strong enough to flush accumulated sediments from the estuary and reset it to its reference conditions.

Confidence: ***Low***

4. EHI for the Future Scenario 4 - abiotic

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	90	For this Scenario it is assumed that low flows will again be similar to what they used to be under Reference Conditions. The MAR (and high flows) will be slightly lower than under Reference Conditions	M
b. % similarity in mean annual frequency of floods	95	The reduction in high flows is expected to be very little based on the limited reduction in monthly flows of less than 1 m^3/s.	M
Hydrology score	**92**		**M**

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	98	This is slightly less than under Reference Conditions	M
Hydrodynamics and mouth conditions Score	**92**		**M**

Water quality

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	90	The effects of base flows on salinity distributions would be similar to those under Reference Conditions. However, the sedimentation which occurred in the past will probably result in some reduction in salinity penetration due to the infilling of the subtidal area which reduces the ability of seawater to penetrate the system after a breach.	L
2a.Nitrate/phosphate (inorganic nutrients) concentration in the estuary	65	Possible slight improvement on present conditions.	L
2b. Suspended solids in present in inflowing freshwater	30	No improvement in catchment erosion control	L

2c. Dissolved oxygen in the estuary	35	Possible improvement based on less nutrophication	L
2d. Levels of toxins	70	No improvement	L
Water Quality score	**54**		**L**

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFI-DENCE
1. Resemblance of <u>intertidal sediment</u> structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	70	Some infilling is reputed to have occurred due to sedimentation related to change in land-use in the catchment, *viz* agricultural and forestry activities.	L
1b	% similarity in sand fraction relative to total sand and mud	40	The estuary has become considerably muddier compared to the reference conditions due to increased erosion related to changes in the land-use in the catchment.	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	70	The water levels under base flow conditions will return to what they were under reference conditions. This will result in a significant increase in depths, but because of the sedimentation which occurred in the past these depths and the subtidal area will still be less than under the Reference Conditions.	L
Physical habitat		**63**		**L**

c) Predicted change in biotic characteristics of the future Scenario 4 compared with the Reference Condition, as well as the <u>causes</u> of these changes:

MACROPHYTES

Improved flows will increase the volume of water in the estuary, thereby increasing the water column habitat. However without removal of sediments and in-channel reeds there would not be a significant return of the macrophytes community towards the reference condition. The upper reaches of the estuary where the original reed fringe was replaced by lagoon swamp forest species (*Barringtonia* and *Hibiscus*) will remain unchanged as this succession will be permanent. Only a slight positive change from present conditions in terms of distribution and abundance is expected

Confidence: ***Medium***:

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macrocrustaceans)

*Macroinvertebrates***:**

Future Scenario 4: Post Mining with baseflow close to Reference is closer to the Reference ecological Condition than the Present State and Scenarios 1-3. Although the abiotic components are expected to simulate historical conditions (seasonal variability in river inflow, floods, hydrodynamics and mouth condition and water quality - all scores >=90%), the physical habitat alteration is still relatively high due to years of extensive mud and silt deposition in the estuary that have never been scoured out. This is particularly in respect of the sand fraction relative to total sand and mud. The nature, distribution and abundance of benthic macroinvertebrates are governed primarily by the type of substrates in which they reside. Therefore with such gross alteration to the benthic environment biotic health scores, although improved from other flow scenarios and the Present State, will still reflect that the estuary is still largely different from its historical condition.

Confidence: ***Medium***

Larger Invertebrates (Macrocrustacea)

With MAR and high flows nearing that of the Reference Condition it can be expected that the characteristics of the macrocrustacean fauna under this Scenario will approach that of the Reference Condition.

Confidence: ***Low***

FISH
With MAR and high flows nearing that of the Reference Condition it can be expected that the characteristics of the macrocrustacean fauna under this Scenario will approach that of the Reference Condition. The will be more and greater depths of water for the fauna to utilize and typical Temporary Open/Closed Estuarine conditions will prevail. *Confidence:* **Low**
BIRDS
Habitat restoration and food availability would enhance the bird community and carrying capacity. Proliferation of vegetation remains a problem. *Confidence:* **Low**

d) EHI for the Future Scenario 4 - Biotic

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	65	Species richness is still expected to be similar to present day conditions which is 80% similar to pristine conditions	M
2a. Abundance	50	The higher flows and more frequent flushing could reduce nutrient availability and result in less prolific reed growth.	M
2b. Community composition	40	Increased flow could result in more open water area	M
Macrophytes score	**40**		**M**

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Macroinvertebrates			
1. Species richness	17	Approximately 40% of the original species remain. Species losses are primarily associated with anthropogenic manipulation of the catchment and secondary effects to the estuary. It is estimated that more estuarine species occurred in the past when estuarine benthic habitat was more favourable (less mud and anoxic detritus) and that freshwater fauna did not penetrate as far into the system.	L
2a. Abundance	50	Salinity penetration into the system is not common and the sediment has been radically altered by deposition of silt and mud. Rotting detritus in the upper reaches causes anoxic conditions. Overall benthic habitat has decreased (most recent study by MER, where mouth lower reaches have decreased substantially in area) and declined in suitability.	L
2b. Community composition	50	The reduction in the number of estuarine taxa and the increase in freshwater taxa particularly during the extended periods of Abiotic State 3 have altered the community composition from the Reference. Now, more hardy species are common in the system such as *Capitella capitata* and *Prionospio sexoculata*.	L
Macrocrustacea			
1. Species richness	50	With MAR and high flows nearing that of the Reference Condition, Species Richness under Scenario 4 will increase towards that of the Reference Condition.	L
2a. Abundance	80	With MAR and high flows nearing that of the Reference Condition, Abundance under Scenario 4 will increase towards that of the Reference Condition.	L
2b. Community composition	65	With MAR and high flows nearing that of the Reference Condition, Community Composition under Scenario 4 will increase towards that of the Reference Condition.	L
Invertebrates score	**65**		**L**

Fish

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	50	With MAR and high flows nearing that of the Reference Condition, Species Richness under Scenario 4 will tend towards that of the Reference Condition, as more water will be available and connections to the sea will be more regular than under the Present State.	L
2a. Abundance	70	With MAR and high flows nearing that of the Reference Condition, Abundance under Scenario 4 will tend towards that of the Reference Condition, as more water will be available and connections to the sea will be more regular than under the Present State.	L
2b. Community composition	65	With MAR and high flows nearing that of the Reference Condition, Community Composition under Scenario 4 will tend towards that of the Reference Condition, as more water will be available and connections to the sea will be more regular than under the Present State.	L
Fish score	**50**		**L**

Birds

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	50	Marked improvement on present conditions	L
2a. Abundance	60	Marked improvement on present conditions	L
2b. Community composition	60	Marked improvement on present conditions	L
Bird score	**50**		**L**

5.5. Future Scenario 5: Post Mining Scenario, but with base flow at 0.05 m³/s or as at the Reference Conditions, which ever is the lowest and with the accumulated sediments having been removed from the estuary

The analysis of Future Scenario 4, with increased base flows as under the Reference Conditions, but without the removal of sediments would not result in the desired ecological conditions, which were hoped for. This additional Future Scenario 5 was therefore added at which it was assumed that the accumulated sediments would also be removed from the estuary.

Simulated runoff data was not available for such a scenario and it was therefore scored similar to Scenario 4 for the flow related aspects and the scores were adapted for the effects of the removal of the accumulated sediments.

a) Seasonal variability in river inflow:

The occurrences of monthly flows under this new Future Scenario 5, which are similar to those of Future Scenario 4, are displayed in the occurrences table below. This occurrences table was obtained from that of Future Scenario 2 for the flows higher than 0.050 m^3/s and from that of the Reference Conditions Scenario for flows less than 0.050 m^3/s. Flows of 0.050 m^3/s were assumed for the monthly occurrences that were in between these obtained from Future Scenario 4 and the Reference Conditions Scenario.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.050	1.034	2.711	1.385	1.955	2.874	2.344	1.665	1.631	1.283	0.437	1.718
90%ile	0.358	0.435	0.419	0.574	1.271	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.050	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.050	0.050	0.050	0.050	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.050	0.047	0.050	0.041	0.043	0.050
40%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.036	0.041	0.036	0.037	0.045
30%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.042	0.034	0.032	0.027	0.029	0.038
20%ile	0.044	0.043	0.050	0.050	0.042	0.048	0.035	0.027	0.026	0.021	0.021	0.029
10%ile	0.031	0.031	0.037	0.033	0.031	0.029	0.023	0.018	0.019	0.015	0.018	0.021
1%ile	0.016	0.012	0.020	0.019	0.017	0.013	0.013	0.009	0.010	0.009	0.011	0.014

b) Predicted Flood regime for the Future Scenario 5

Relatively small differences are expected in the floods reaching the estuary under Future Scenario 5 compared to those under reference conditions based on the fact that the simulated monthly runoff data for Future Scenario 2, which is similar for high flows to that of Future Scenario 5, indicate very little change for months of flows higher than 1 m^3/s. This is especially the case for major floods.

Confidence: ***Medium***

c) Predicted sediment processes under Future Scenario 5 compared with Reference State:

The base flow will be 0.05 m^3/s or similar to that under Reference Conditions, which ever is the lowest. The water levels in the estuary will therefore again increase to those under reference conditions and additionally it is assumed that the sediments, which have accumulated in the estuary will be removed.

Confidence: ***Medium***

d) EHI for the Future Scenario 5 - Abiotic

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	90	For this Scenario it is assumed that low flows will again be similar to what they used to be under Reference Conditions. The MAR (and high flows) will be similar to those under Future Scenario 4 and will still be slightly lower than under Reference Conditions	M
b. % similarity in mean annual frequency of floods	95	The reduction in high flows is expected to be very little based on the limited reduction in monthly flows of less than 1 m^3/s.	M
Hydrology score	**92**		**M**

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	98	This is similar to Future Scenario 4.	M
Hydrodynamics and mouth conditions Score	**98**		**M**

Water quality

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	95	The effects of base flows on salinity distributions would be almost similar to those under Reference Conditions.	L
2a.Nitrate/phosphate (inorganic nutrients) concentration in the estuary	75	Improvement but some nutrient input remains	L
2b. Suspended solids in present in inflowing freshwater	80	Reduced due to improved catchment management	L
2c. Dissolved oxygen in the estuary	90	Improved due to greater water turnover and exchange	L
2d. Levels of toxins	75	Reduced due to improved catchment management	L
Water Quality score	**83**		**L**

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFI-DENCE
1. Resemblance of <u>intertidal sediment</u> structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	90	The intertidal area will be closely similar to what it was under Reference Conditions	L
1b	% similarity in sand fraction relative to total sand and mud	80	The accumulated sediments are supposed to be removed. The sediments entering the estuary could be slightly muddier compared to the reference conditions.	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	80	The water levels under base flow conditions will return to reference conditions. Additionally the accumulated sediments will be removed. This will result in an increase in depths and a return to subtidal conditions approaching those under Reference Conditions.	L
Physical habitat		**83**		**L**

e) Predicted change in biotic characteristics of the future Scenario 5 compared with the Reference Condition, as well as the <u>causes</u> of these changes:

MACROPHYTES

Removal of sediments and in-channel reeds together with improved flows should result in the macrophytes community distribution more closely approaching that of pristine conditions. This intervention will create the desired channel morphology for increased open water areas and will in addition result in net removal of nutrients (reeds) from the system. However the upper reaches of the estuary where the original reed fringe was replaced by lagoon swamp forest species (*Barringtonia* and *Hibiscus*) will remain unchanged as this succession will be permanent unless these trees are removed as well.

Confidence: ***Medium***:

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Macroinvertebrates:

Future Scenario 5: Post Mining with baseflow close to Reference and accumulated sediments removed is as close to the Reference ecological Condition as is possible. The MAR is closer to the Reference high flows than any of the other four scenarios. The hydrodynamics and mouth condition are comparable to Scenario 4 but subtidal substrates will be similar Reference Condition with settled catchment silt and mud removed as well as layers of anoxic detritus. This removal of sediments will dramatically increase the depth of the system and therefore vastly improve the benthic habitat.

Biotic health scores will be slightly different from the Reference Condition given that catchment use will still influence the estuary to some degree.

Confidence: ***Medium***

MAR and the mean frequency of floods will be similar to that of the Reference Condition thus it can be expected that the characteristics of the macrocrustacean fauna under this scenario will be very similar to the Reference Condition. There will be more and greater depths of water for the fauna to utilize and typical Temporary Open/Closed Estuarine conditions will prevail.

Confidence: ***Low***

FISH

MAR and the mean frequency of floods will be similar to that of the Reference Condition thus it can be expected that the characteristics of the fish fauna under this Scenario will be very similar to that of the Reference Condition. The will be more and greater depths of water for the fauna to utilize and typical Temporary Open/Closed Estuarine conditions will prevail.

Confidence: ***Low***

BIRDS

Reversion to greater water depths and recovery of fish populations would greatly improve bird environment and carrying capacity. Level of vegetation cover remains a problem.

Confidence: ***Low***

f) EHI for Future Scenario 5:

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	80	The presence of more open water area could see a return of indigenous submerged macrophytes which may have been present under pristine conditions. Algal diversity could also improve under better water quality conditions that may be expected under these conditions	L
2a. Abundance	75	Loss of reeds in the lower part of the estuary would make this area similar to pristine conditions. However the lagoon swamp forest in the upper section is considered to be a permanent condition unless further interventions are made here.	M
2b.Community composition	80	Community distribution would approach more pristine conditions but the lagoon swamp forest will remain. Algal diversity is expected to improve.	M
Macrophytes score	**75**		**M**

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
Macroinvertebrates			
1. Species richness	17	Approximately 40% of the original species remain. Species losses are primarily associated with anthropogenic manipulation of the catchment and secondary effects to the estuary. It is estimated that more estuarine species occurred in the past when estuarine benthic habitat was more favourable (less mud and anoxic detritus) and that freshwater fauna did not penetrate as far into the system.	L

2a. Abundance	50	Salinity penetration into the system is not common and the sediment has been radically altered by deposition of silt and mud. Rotting detritus in the upper reaches causes anoxic conditions. Overall benthic habitat has decreased (most recent study by MER, where mouth lower reaches have decreased substantially in area) and declined in suitability.	L
2b. Community composition	50	The reduction in the number of estuarine taxa and the increase in freshwater taxa particularly during the extended periods of Abiotic State 3 have altered the community composition from the Reference. Now, more hardy species are common in the system such as *Capitella capitata* and *Prionospio sexoculata*.	L
Macrocrustacea			
1. Species richness	80	Species Richness will almost be that of the Reference Condition due to water availability, connectivity to the marine environment and the removal of sediments.	L
2a. Abundance	90	Abundance will almost be that of the Reference Condition due to water availability, connectivity to the marine environment and the removal of sediments.	L
2b. Community composition	90	Community Composition will almost be that of the Reference Condition due to water availability, connectivity to the marine environment and the removal of sediments.	L
Invertebrates score	**80**		**L**

Fish

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	80	Species Richness will almost be that of the Reference Condition due to water availability, connectivity to the marine environment and the removal of sediments.	L
2a. Abundance	90	Abundance will almost be that of the Reference Condition due to water availability, connectivity to the marine environment and the removal of sediments.	L
2b. Community composition	90	Community Composition will almost be that of the Reference Condition due to water availability, connectivity to the marine environment and the removal of sediments.	L
Fish score	**80**		**L**

Birds

VARIABLE	SCORE	MOTIVATION	CONFI-DENCE
1. Species richness	80	Assumes restoration of estuary volume and previous relative proportions of reeds and open water.	L
2a. Abundance	90	Assumes restoration of estuary volume and previous relative proportions of reeds and open water.	L
2b. Community composition	90	Assumes restoration of estuary volume and relative proportions of reeds and open water.	L
Bird score			

6. ECOLOGICAL CATEGORIES ASSOCIATED WITH DIFFERENT SCENARIOS

The individual EHI scores, as well as the corresponding EC for the different scenarios are provided in Table 6.1.

TABLE 6.1: Summary of Estuarine Health Index (EHI) scoring and Ecological Category (EC) associated with different Future Scenarios

VARIABLE	WEIGHT	Present State	Future Scenario 1	Future Scenario 2	Future Scenario 3	Future Scenario 4	Future Scenario 5
MAR (x 10^6 m^3)		**4.6**	**4.8**	**5.7**	**4.6**	**6.2**	**6.2**
Hydrology	*25*	56	66	72	56	92	92
Hydrodynamics	*25*	95	95	95	95	98	98
Water quality	*25*	41	49	49	41	54	83
Physical habitat alterations	*25*	40	48	48	40	63	83
Habitat Score	***50***	**58**	**64**	**66**	**58**	**77**	**89**
Macrophytes	*25*	30	30	30	30	40	75
Invertebrates	*25*	10	35	35	17	50	80
Fish	*25*	10	35	35	25	50	80
Birds	*25*	10	35	35	17	50	80
Biological Score	***50***	**15**	**34**	**34**	**22**	**48**	**79**
EHI INDEX SCORE		**37**	**49**	**50**	**40**	**62**	**84**
EC		**E**	**D**	**D**	**E**	**C**	**B**

To select the recommended 'Ecological Water Requirement Scenario', the general rule for estuaries states that the simulated runoff scenario representing the largest modification in flow, but that which would still keep the estuary in the recommended Ecological Category (in this case a **Category B)** should be the recommended 'Ecological Water Requirement Scenario'.

The only scenario evaluated as part of this Rapid determination that provided an Ecological Category B was the one in which flow was returned to 95% of the MAR, coupled with management interventions. The workshop concluded that this was the only way in which an Ecological Category of B could be attained. This was because the reduction in base flows coupled with the sedimentation and reed encroachment accounts for much of the degradation observed in this estuary. The recommended 'Ecological Water Requirement Scenario' for an Ecological Category of B would therefore require the liberation of water within this catchment as well as deliberate management actions such as the removal of sediment and reeds within the estuary and rehabilitation of wetlands and riparian zones within the greater catchment.

For the purposes of this rapid assessment, a conservative estimate of the **recommended 'Ecological Water Requirement Scenario'** for the Siyaya Estuary (to meet the recommended Ecological Category of B) is estimated at a MAR of 6.2 x 10^6 m^3, similar to the Reference Condition, with the following distribution:

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	**1.050**	**1.034**	**2.711**	**1.385**	**1.955**	**2.874**	**2.344**	**1.665**	**1.631**	**1.283**	0.437	**1.718**
90%ile	0.358	0.435	0.419	0.574	**1.271**	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.050	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.050	0.050	0.050	0.050	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.050	0.047	0.050	0.041	0.043	0.050
40%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.036	0.041	0.036	0.037	0.045
30%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.042	0.034	0.032	0.027	0.029	0.038
20%ile	0.044	0.043	0.050	0.050	0.042	0.048	0.035	0.027	0.026	0.021	0.021	0.029
10%ile	0.031	0.031	0.037	0.033	0.031	0.029	0.023	0.018	0.019	0.015	0.018	0.021
1%ile	0.016	0.012	0.020	0.019	0.017	0.013	0.013	0.009	0.010	0.009	0.011	0.014

NOTE:

- Although the recommended 'Ecological Water Requirement Scenario' provided in this Rapid assessment resembles the flows during the Reference Condition, the re-introduction of such a flow regime will on its own not be enough to lift the estuary to an Ecological Category B, due to the impact of other non-flow related anthropogenic activities on the estuary, such as sedimentation, reed encroachment and removal of supporting wetland and riparian habitats.
- The Present Ecological Status of the Siyaya Estuary (Ecological Category E) is considered to be on a negative trajectory rather than stable. Present flows are therefore insufficient to maintain the estuary in its present category.
- Increasing flows can marginally lift the system to an Ecological Category D but increases approaching 80% of the MAR are required to lift the system to a C and ultimately a B.

RECOMMENDATIONS ON ADDITIONAL MONITORING REQUIREMENTS

Data requirements to improve the confidence of the preliminary Ecological Reserve determination are set out in the method for Intermediate level determination (medium confidence), as well as for comprehensive level determinations (medium to high confidence). In particular, acquisition of the following data sets is required to improve the confidence of the preliminary determination of the Ecological Reserve on the Siyaya Estuary:

- Water level recordings as undertaken by DWAF to be continued. Continuous record of water level variation in the estuary near the mouth (for medium confidence as required for the Intermediate level at least a 5-year record is recommended).
- Continuous flow gauging of river inflow to the estuary (for medium confidence as required for the Intermediate level at least a 5-year record is recommended). This information would be required to

establish a relationship between flow and mouth condition, as well as to calibrate the simulated runoff data sets.

- Mouth observations as undertaken by Ezemvelo KZN Wildlife to be continued.

- A bathymetric survey of the estuary should be undertaken, including a detailed survey of the inlet and cross-sections upstream at the locations at which earlier cross-sections were surveyed by the CSIR (Van der Elst *et al.*, 1999).

- Monitoring of longitudinal and vertical salinity distributions.

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APPENDIX A

LIST OF AVAILABLE DATA AND INFORMATION AVAILABLE FOR THIS STUDY

Data availability on sediment dynamics, hydrodynamics and water quality

DATA REQUIRED	AVAILABILITY	COMMENT
Simulated monthly runoff data (at the head of the estuary) for present state, reference conditions and the selected future runoff scenarios over a 50 to 70 year period	Provided by SRK Consulting Engineers	Provided for 85-year period. Low confidence as runoff data is of low quality.
Simulated flood hydrographs for present state, reference conditions and future runoff scenarios: • 1:1, 1:2, 1:5 floods (influencing aspects such as floodplain inundation) • 1:20, 1:50, 1:100, 1:200 year floods (influencing sediment dynamics)	None	
Aerial photographs of estuary (earliest available year as well as most recent)	1937,1953,1957,1960, 1964,1965,1969,1973, 1975,1976,1979, 1981,1983,1984,1985, 1987, 1989, 1990	Collected for DEAT
Continuous water level recordings near mouth of the estuary	Water level data available from May 2002.	Collected by DWAF
Mouth observations (1)	Weekly mouth observations	KZNWildlife
Mouth observations (2)	Quarterly mouth observations for 1991 - 2003	CRUZ
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • end of low flow season (i.e. period of maximum seawater intrusion) • peak of high flow season (i.e. period of maximum flushing by river water)	Limited data sets of surface and bottom salinity measurements for 1991 – 2003 collected as part of CRUZ research study)	CRUZ
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Limited off data sets of surface and bottom measurements for 1991 – 2003 (collected as part of CRUZ research study)- Not worked up for this study	CRUZ
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	No data	Not considered to be a major concern in this estuary
Water quality (e.g. system variables, nutrients and toxic substances)measurements on river water entering at the head of the estuary Water quality (e.g. system variables, nutrients and toxic substances)measurements on near-shore seawater	No data received	

Data availability on invertebrates

DATA REQUIRED	AVAILABILITY	COMMENT
Compile a detailed sediment distribution map of the estuary Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates. During each survey, collect sediment samples for analysis of grain size [1] and organic content [2] at the six benthic sites. Surveys to determine salinity distribution pattern along the length of the estuary, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity) are required for different seasons and for different states of the tide [3] Seasonal (summer winter) physico-chemical data are also required for each of the six benthic sampling sites Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (summer winter) data sets for at least one year are required, preferably collected at spring tides.		
Collect two sets of beam trawl samples (i.e. mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (summer winter) data sets for at least one year are required, preferably collected at spring tides.	**Beam Trawls:** No data available **Baited Traps:** 1992-2002 – seasonal samples from three sites. Information databased but data still in raw form with no analysis having been done to date. **Shoreline Surveys:** No data	**CRUZ**
Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key species such as Varuna litterata, Callianassa and Upogebia which require a connection to the marine environment at specific times of the year. Collect three zooplankton samples, at night, one each from the upper, middle and lower reaches of the estuary. Seasonal (summer winter) data sets for at least one year are required, preferably collected at spring tides.	**No additional Data** on occurrence/recruitment and emigration of key species	

Data availability on fish

DATA REQUIRED	AVAILABILITY	COMMENT
In a small estuary (<5km) collect at minimum three sets of samples from the lower, middle and upper reaches of the estuary. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets need to be in the 0 to 10 ppt reach of the estuary. Sampling should be representative of small fish (seine nets) and large fish (gill nets). In a larger estuary (>5km) sampling can either be at fixed intervals (every 2km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system. Sampling should be representative of small fish (seine nets) and large fish (gill nets). Sampling should be done during both the low and the high flow season for the full extent of the system (as far as tidal variation) to allow for predictive capabilities.	**Small Estuary:** 1992-2002 - seasonal samples. Large & Small Seine netting at three sites. Gill netting at two sites. Information databased but data still in raw form with no analysis having been done to date.	**CRUZ**

Data availability on birds

DATA REQUIRED	AVAILABILITY	COMMENT
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. Seasonal (summer winter) data sets for at least one year are required. It this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally exposed areas).	Historical occurrence records (Garland & Frost 1979) for last 40 years; not quantitative and anecdotal to some degree but reliable.	Adequate record of changes.

APPENDIX B

SUMMARY SPECIALIST REPORTS

SIYAYA PHYSICAL CONDITIONS, SUMMARY REPORT

By

Piet Huizinga, private consultant
Lara van Niekerk, CSIR

The following physical aspects, relevant for the functioning of the estuary are briefly described:

* Water levels and depths in the estuary
* Open and closed mouth conditions
* Sedimentation
* Others

Information available:

* Literature
* CSIR aerial photographic records since 1937
* Water level recordings in the estuary since May 2002 from the Department of Water affairs and Forestry
* Weekly mouth observations by KZNWildlife from 1996
* Quarterly mouth observations by Cruz between August 1991 and September 2003
* Simulated monthly runoff data for 85 years for Reference (natural), Present, During mining and Post-mining conditions, provided by SRK Consulting Engineers

Water levels and depths in the estuary

Major reductions in water depths were probably a major reason why dramatic changes occurred in the ecology of the Siyaya Estuary. Historically these changes in depths were probably initially the result of sedimentation caused by erosion in the catchment. However, more recent drastic reductions in the depths were caused by a drop in water levels in the estuary due to reductions in baseflow. The analysis of water level recordings and flow data indicates that a strong correlation exists between baseflow, water levels in the estuary and seepage from the estuary through the berm. Based on simulated runoff data provided to the project team, it is estimated that significant baseflow existed most of the time under natural conditions, resulting in high water levels (and depths of up to a few meters) in the estuary. Largely because of the forestation in the catchment this baseflow has strongly been reduced at present and for prolonged periods the river flow is even reduced to zero. As a result the average water levels have dropped and the remaining depths are often only a few decimeters in most of the estuary. This probably was a major reason why almost the whole estuary has been colonized in recent years by reeds.

The shallowness of the estuary is highlighted by the fact that tidal variations are not observed when the mouth is open at the water level recordings collected at the footbridge across the estuary.

Open and closed mouth conditions

Normally the key drivers of the physical conditions in an estuary are the frequency and duration of open and closed mouth conditions. The limited information from the past indicates that the mouth only breached during high flow events and that it then only remained open for up to a few days (Begg, 1978). Shortly after the mouth had been open overwash of the berm often occurred, bringing additional seawater into the estuary. This was reduced as the berm grew higher until overwash only occurred when the waves at sea were very high.

As mentioned, the developments in the catchment resulted in a strong reduction in the baseflow, but the reduction in the occurrence of high flows was far less, because significant dams had not been constructed. The occurrence of high flow events causing mouth breachings has therefore not been reduced much either. Breachings therefore probably occur at present at a similar frequency, or slightly less frequent, as was the case under reference conditions. Periods of few breachings are probably mainly related to drought conditions and periods of more breachings to wet conditions.

The mouth of the Siyaya Estuary is on a high energy coast with a steep beach slope and a relatively narrow breakerzone. This means that the closing forces acting on the inlet are strong. The surface is estimated to be only 8 ha (Begg, 1978), which means that the tidal flows are very small and that they probably play an insignificant role in keeping the inlet open. Closure can even occur at a river flow of up to 10 m^3/s. Such a flow is very rare at the Siyaya and if it occurs, it will normally only be for a short period of a few days.

Breaching of the mouth will normally only occur when the water level in the estuary exceeds the height of the berm. This normally probably happens when the river flow is elevated to more than 0.3 m^3/s. This is also related to seepage losses through the long berm parallel to the estuary and will be discussed later.

As mentioned, the mouth normally only remains open for a few days after a breaching. After closure the berm will start building up, but when the river flow remains high enough it is possible that the increase in water level will be such that after a period of several hours the height of the berm will be exceeded again and the mouth will re-open. Shortly thereafter at high tide the mouth might close again because of the wave action. The same process can then repeat itself, if the river flow remains high enough. Observations have indeed been made that open and closed conditions of the mouth can follow each other in a matter of hours (Fiona Mackay, pers. comm.).

A special situation may also arise, namely that the inlet moves into a perched position above tidal influence and that outflow through the mouth is maintained because of continuous river flow. This is the so-called semi-closed condition, which can sometimes be observed at small estuaries such as the Siyaya. Future observations could confirm whether this is the case for this system.

Sedimentation

Considerable erosion in the catchment in the past, because of sugar cane farming, probably caused considerable sedimentation in the estuary, resulting in the estuary becoming shallower. However, more recently the sugar cane farming was replaced by commercial forestry and the rate of erosion in the catchment, and of sedimentation in the estuary, has probably drastically been reduced.

As discussed above, recent shallowing of the estuary is therefore probably more related to the reduction in water levels and depths in the estuary because of the reduction in baseflow than to ongoing sedimentation because of erosion in the catchment.

River flow, seepage and water levels in the Siyaya Estuary

A preliminary assessment was made of the correlation between river flow, seepage through the berm and water levels, based on the water level recordings from the Siyaya Estuary provided by DWAF.

An example of such a recording for December 2002 is included in Figure 1. The mouth was probably closed during this period and the downward slopes on this figure are probably related to seepage losses through the berm. River flow data are not available, but it is assumed that this was zero during the period, as was often observed in recent years.

The stretches of downward slopes are more or less parallel, except that the slopes are steeper at higher water levels and more gradual at lower levels. For stretches with only minor irregularities the drop in water levels was read from the graphs. For example during 2 and 3 December the water level dropped from 1.38 m to 1.34 m by 0.04 meter. Begg (1978) estimated that the surface area of the estuary was 8 hectares. Based on this it is estimated that 3200 m^3 of water was lost from the estuary through seepage during these two days, which is equivalent with 0.018 m^3/s. For the period May 2002 till December 2004 69 data points for seepage were obtained in this way. These data points are included in Table 1 and are also plotted in Figure 2, which gives an impression of the correlation between water levels and seepage.

It was then also assumed that when the mouth is closed, a constant water level would be maintained in the estuary if the seepage is equal to the river inflow and that Figure 2 also provides an estimate of the correlation of such constant water levels with river flow.

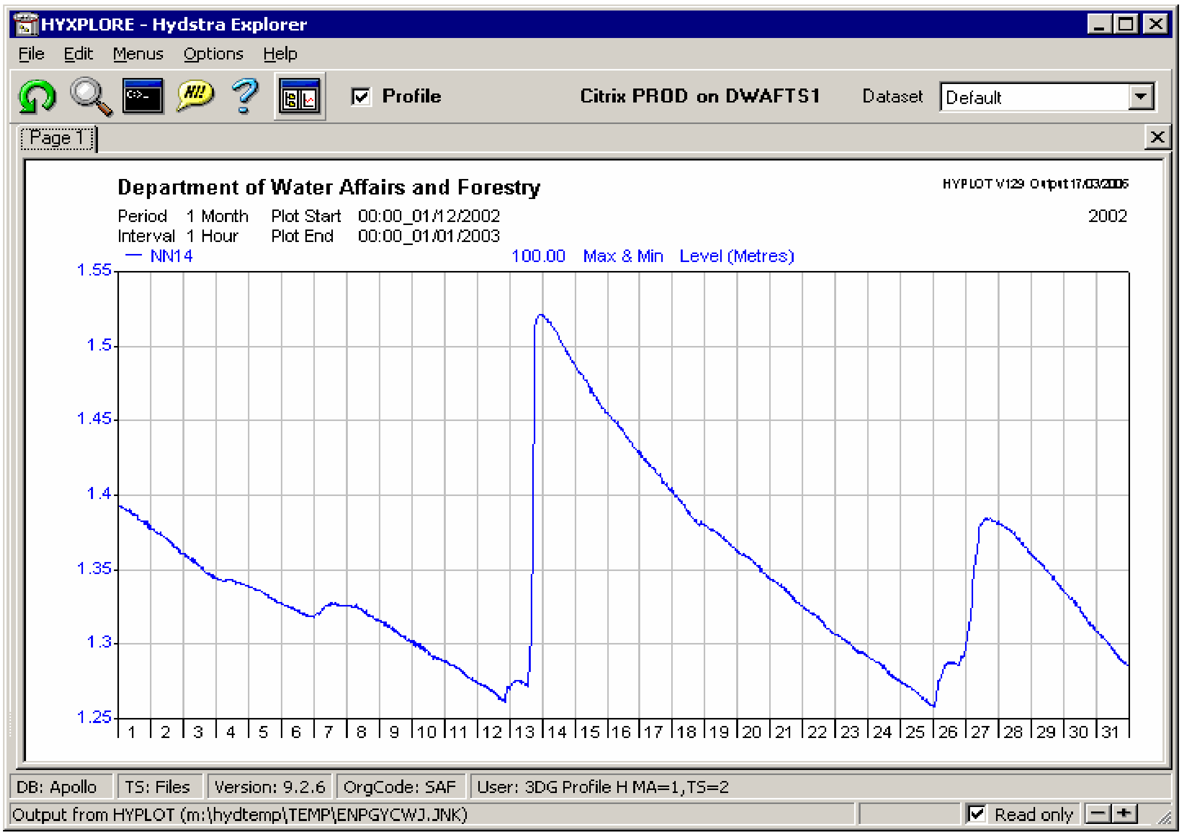

Figure 1. Water level recording in the Siyaya Estuary obtained from DWAF for December 2002

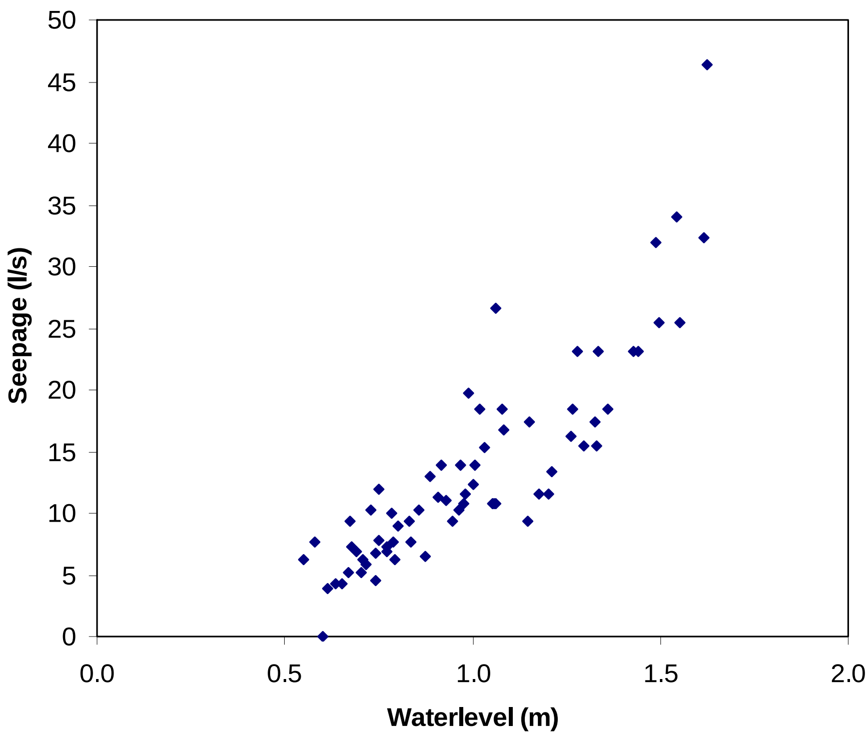

Figure 2. Correlation between water levels and seepage losses from the estuary

Water level (m)	Seepage (l/s)
0.550	6.2
0.580	7.7
0.600	0.0
0.613	3.9
0.637	4.3
0.654	4.3
0.671	5.2
0.675	9.3
0.678	7.3
0.693	6.9
0.704	5.2
0.710	6.2
0.717	5.9
0.728	10.2
0.741	6.8
0.741	4.6
0.749	12.0
0.751	7.8
0.773	6.9
0.773	7.3
0.787	10.0
0.788	7.7
0.795	6.2
0.800	9.0
0.830	9.3
0.835	7.7
0.856	10.2
0.875	6.5
0.886	13.0
0.910	11.3
0.918	13.9
0.930	11.1
0.945	9.3
0.965	10.2
0.968	13.9
0.978	10.8
0.983	11.6
0.988	19.7
1.000	12.3
1.005	13.9
1.020	18.5
1.032	15.3
1.055	10.8
1.058	10.8
1.063	10.8
1.063	26.6
1.080	18.5
1.085	16.7
1.145	9.3
1.153	17.4
1.178	11.6
1.203	11.6

Water level (m)	Seepage (l/s)
1.210	13.4
1.263	16.2
1.265	18.5
1.278	23.1
1.295	15.4
1.327	17.4
1.330	15.4
1.335	23.1
1.360	18.5
1.430	23.1
1.440	23.1
1.489	31.9
1.498	25.5
1.545	34.0
1.553	25.5
1.615	32.4
1.625	46.3

Table 1. Estimated losses from the estuary through seepage obtained from the water level recordings at different water levels

Other aspects

Some other physical aspects play an additional role at the Siyaya Estuary. These are:

- Migration of the mouth of the estuary to the north. However, it is not considered that this has major affects on the main physical aspects described above.
- Accretion of the beach. These could result in some reduction in seepage through the berm, but this could again be off-set by the increase in the length of the estuary because of the migration of the mouth.

Monitoring requirements

The monitoring requirements for the physical dynamic condition of the estuary are:

- Water level recordings as undertaken by DWAF to be continued.
- Flow gauging as undertaken by DWAF to be continued.
- Mouth observations as undertaken by KZNWildlife to be continued.
- A bathymetric survey of the estuary should be undertaken, including a detailed survey of the inlet and cross-sections upstream at the locations at which earlier cross-sections were surveyed by the CSIR (Van der Elst et al, 1999).
- Monitoring of longitudinal and vertical salinity distributions.

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SIYAYA ESTUARY RAPID RESERVE DETERMINATION

Summary Report: Macrophytes

April 2006

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Ref: D/Siyaya rdm/summary report

Siyaya Vegetation Summary Report for Rapid Reserve Determination

1. Background

As with the majority of estuaries along the KZN coast, envisaging a pristine state is made difficult by the fact that earliest aerial photographs are those from 1937 by which time agriculture, in particular sugar cane farming, was well established in the majority of the catchments. Nonetheless according to Begg (1978) major perturbations in the farming areas of the catchment only began around 1948 when bad practises such as ploughing downhill along steep slopes, planting on river banks and drainage of upstream swamps occurred. According to landowner of the farm Twin Streams (Begg, 1978) this led to serious erosion and frequent flooding of the system. In time such erosion has resulted in severe siltation and changes in the bed height of the estuary and lagoon. Initially the catchment area was dominated by sugar cane farming but later the development of forestry possibly resulted in significant flow reduction. These factors obviously played a significant role in determining the present state of the vegetation communities of the system.

2. Vegetation – Past and Present Condition

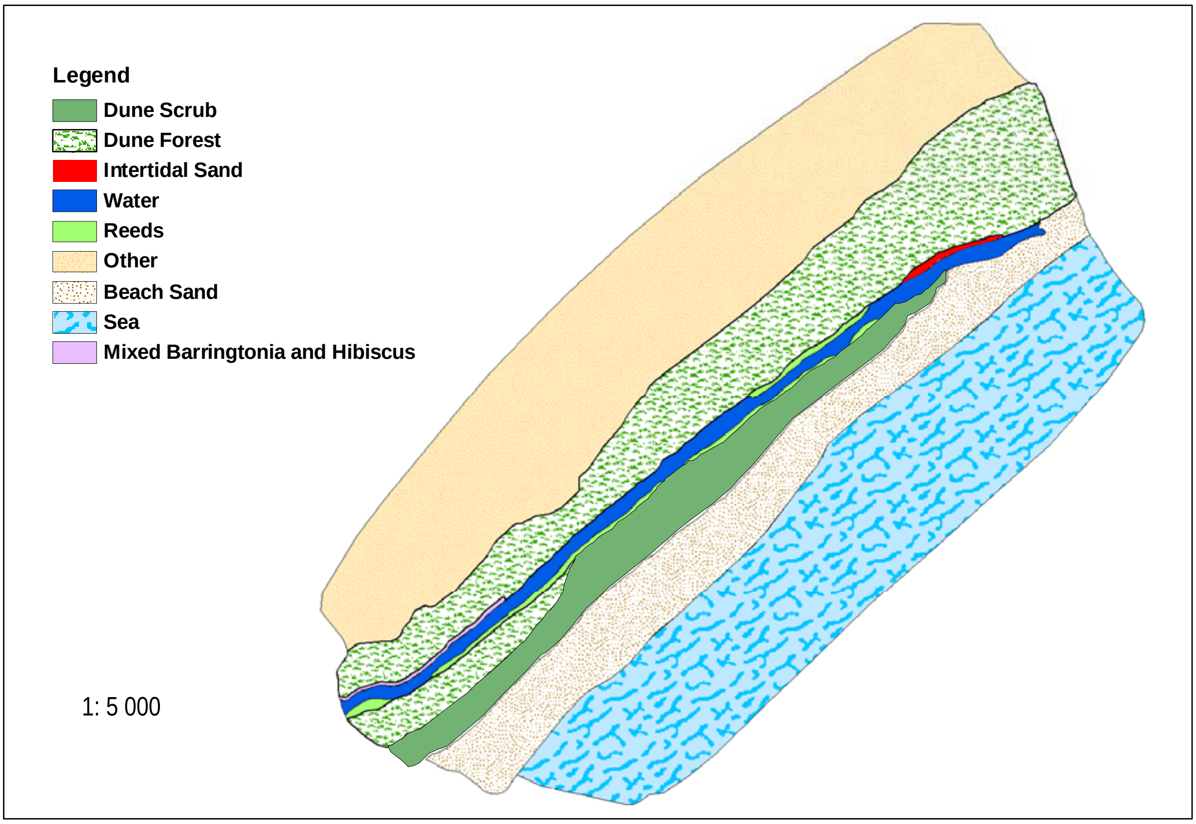
If the condition of system in 1937 is assumed to be near pristine then there have been very significant changes in the distribution of vegetation since then (fig1 and 2). The differences in cover are indicated in Table 1 and figures 1 and 2.

Table 1: Differences in coverage between 1937 and 2001

Category	**Area in 2001** Ha	**Area in 1937** Ha
Lagoon Swamp Forest	3.7227	0.5789
Reeds and Sedges	2.6790	2.6599
Water (phytoplankton)	2.1870	7.5104
Intertidal Areas (phytobenthos)	0.6421	0.3892
Total area	**9.2308**	**11.1384**

The most obvious difference between the early condition and the present state is the extent of water surface area. According to Begg (1978) the estuary and lagoon would have been a deep clear water system. The map drawn from the 1937 aerial photograph indeed shows a channel (open water) some 30-40 meters wide with narrow patches of fringing reeds (Fig 1. still to be inserted). It is possible that the upper reaches of the estuary, which would have been freshwater dominated, may have had submerged macrophytes but this is not discernable in the photograph. It is also likely that there might have been a narrow fringe of lagoon swamp forest species (*Barringtonia racemosa* and *Hibiscus tiliaceus*) along the west bank but this cannot be distinguished from the surrounding dune forest. Such a fringe of swamp forest species was identified by Begg in the 1978 study and was observed by the author at about the same time. As these were relatively large and old trees this condition was probably characteristic of pristine conditions.

Since at least the mid 1940s the siltation described above would have initially encouraged the inward spread of reeds into the channel area especially in the lower section of the estuary and with time the establishment of lagoon swamp forest species landward of these. These changes have now resulted in very significant reduction of open water areas. The mid and lower sections of the estuary are dominated by reeds which often almost covers the entire channel in the area behind the dunes. The upper section of the estuary is fringed by a mixture of tall (older) trees of *Barringtonia* and *Hibiscus* where shading from these trees limits reed growth. The estuary did not support any rare or endangered plant communities or individual species.



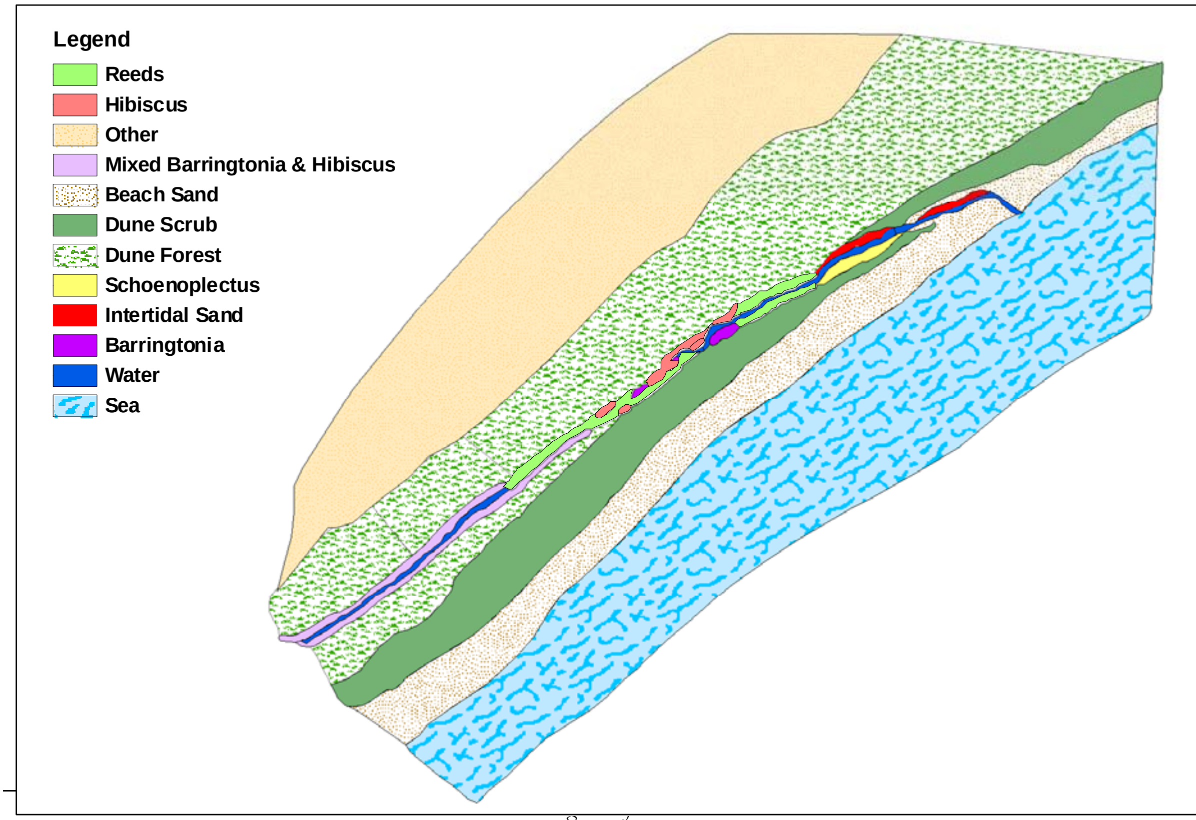


Fig 2. Coverage in the Siyaya Estuary in 2001

3. Botanical Importance Rating

The botanical importance rating (Coetzee et al.; Colloty, 2000) measures botanical importance by multiplying the area of each community type by a productivity value and adding these produce a score for each estuary. Estuaries are then compared by assigning a value of 100 to the highest scoring estuary and determining a percentage of this score for all other estuaries. A comparison of the botanical importance of the Siyaya based on the 1937 and 1996 states has been assessed by Riddin (1999). However the overall area of the estuary indicated for these two dates was vastly different in that analysis and there may have been a problem with the accuracy of measurement from the 1937 aerial photograph. Riddin did however develop a national botanical importance rating of the present condition for the Siyaya estuary based on a selection of national estuaries in which the Mhlathuze estuary scored 100. This resulted in an importance score of 1 for the Siyaya. This low score is not unexpected since the total area given in that study was only 8 hectares.

In the present study the mapping of the cover in the estuary produced the results indicated in Table 2. Due to the small total area of the Siyaya it would obviously produce a very low functional botanical importance score (0.56) when compared to large estuaries such as St Lucia. However it is considered more appropriate to compare the Siyaya with smaller estuaries since the majority of estuaries in KZN are smaller systems and these collectively contribute a significant proportion of the estuarine resources in the province. When compared to the Tongati estuary the Siyaya estuary scored 34.

Table 2. Functional Botanical Importance of the Siyaya

Category	**Coverage Ha**	**Productivity Value** g/m²/yr	**Sub-score**
Lagoon Swamp Forest	3.7227	1890	7036
Reeds and Sedges	2.6790	1384	3708
Water (phytoplankton)	2.1870	163	356
Intertidal Areas (phytobenthos)	0.6421	124	80
Botanical Score = 11180			
Normalized against large estuary (St Lucia) = **0.56**			
Normalized against small estuary (Tongati) = **34**			

4. Concluding Remarks

It would seem that the major influences on the distribution of estuarine vegetation since pristine conditions are changes in flow and sedimentation. The consequent change to water depth has resulted in extensive reed encroachment and significant reduction in open water areas. There seems to be slight paradox in some of data on flows in that high flows were reported in the late 1940s due to poor catchment practises including removal of swamps in the catchment. Such flows should have resulted in scouring of the estuary bed yet this did not seem to occur since sedimentation has actually increased the bed height. It can be speculated that that the flows were not high enough for significant scouring and that erosion in the catchment resulted in sediment deposition which is largely the cause of reed proliferation in this estuary. The later introduction of forestry into the catchment could have also reduced flows (and water depth) and thus supported reed encroachment.

From a botanical importance point of view the Siyaya estuary did not have a high importance. This is especially true since no rare or endangered communities or species were present in the system. Yet as a component of the ecosystem (primary producer) that supports other biota and its' functional role in water quality improvement (nutrient absorption, filtering capacity etc.) conservation of this component becomes vital to ecosystem sustainability. Certainly the fish community present in the system has already been identified as being diverse with some rare species also being present (Cyrus, 2006).

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SUMMARY REPORT
SIYAYA ESTUARY RAPID RESERVE DETERMINATION

Macroinvertebrates of the Siyaya Estuary

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1. CONTEXT OF STUDY

License applications have been received by the Department of Water Affairs from and Forestry from Ticor for their heavy mineral mining operation at Fairbreeze, in the vicinity of Mtunzini on the KwaZulu-Natal north coast. Future mining activities at Fairbreeze may result in flow alteration to the Siyaya and Amanzimnyama Rivers in the Siyaya catchment and ultimately, could alter flow and impact on the ecology of the Siyaya Estuary.

Ticor has appointed Marine and Estuarine Research as independent consultants to co-ordinate a rapid reserve determination on the estuary. The terms of reference stipulate that the Reserve should be carried out "based on available information and using methodologies set out in Volume 5 (1999) and subsequent revisions" of the RDM methododology. It was also stated that "the base flow requirements during the low flow season must be investigated to provide sufficient detail so as to specify the needs of the estuary for different desired states. The base flow component would therefore require a higher than rapid confidence and would be dependent upon the input hydrology data that will be provided to the reserve determination team by the appointed hydrologist."

The summary report will fulfil the information requirements for the macrobenthic invertebrate component of a Rapid Reserve Determination.

2. INTRODUCTION

Many estuaries in KwaZulu-Natal are subject to reduced marine influence, partly through modifications to their catchments and repeated closure of their mouths. This is true of the Siyaya Estuary, which was categorised as part of a group of systems that had over 90% of their coastal lowland, riverine and swamp forests removed as a result of sugarcane cultivation (Oceanographic Research Institute 1991). The reduction of large belts of natural vegetation in coastal areas through the removal of indigenous and often endemic floristic species, has increased soil erosion and caused large amounts of silt to be deposited in estuaries like the Siyaya. The resulting damage within the Siyaya was manifested firstly in a reduction of the overall depth of the estuary (from ~2m mean depth pre-1946; Oceanographic Research Institute 1991) and secondly in the colonisation and proliferation of various aquatic macrophytes, particularly *Phragmites australis*, as result of agricultural nutrient leacheate. The uninhibited flow of nutrients was a consequence of the absence of the filtering function of thick riparian forests. In addition to a change in the morphology of the Siyaya Estuary, continued soil erosion and flow of pollutants into the stream bed, the general degradation was compounded by the modification of habitats within the system.

The Siyaya Estuary mouth dynamics have been extremely variable over the past decade. Floods in 1987 caused the sandbar to disappear, heavy rainfall in 1990 caused a small channel to open to the sea, and the drought from 1991 to 1995 permitted only limited exchange with the sea. This opening and closing of the estuary has resulted in a very great variability of physical conditions that have unsurprisingly had a measurable effect on the biology of the system.

2.1 Estuary Characteristics

The Siyaya is a temporarily open/closed estuary, behaving as a typical estuary when closed (Whitfield 1992). It is one of 33 estuaries in the country with protected area status. Although it is 20th on this list it does make some contribution to the representation of estuarine biodiversity in the country (Turpie *et al.* 2002). Of some 250 functional estuaries in South Africa, the Siyaya is number 132 in conservation importance. This classification is based on estuary size, zonal type rarity, habitat and biodiversity importance (Turpie *et al.* 2002).

The 2.6 km Siyaya Estuary (28° 58'S; 31° 45'45" E), has a surface area of approximately 8ha and is part of an 18km^2 catchment on the north coast of KwaZulu-Natal (Begg 1978). The catchment consists of two main subcatchments around the Siyaya and Amanzimnyama Streams. The former having a steeper gradient, often transported large volumes of silt as it moved through fewer patches of swamp forest and was characterised by less riverine vegetation (Siyaya Project Newsletter No. 1 1981).

2.2 Available Information

The continued degradation of the estuary, primarily due to the direct and indirect effects of farming in the catchment continued until the early 1980's, when the Siyaya and surrounding catchment became the focus of a demonstration project. Through altered management practises and collaboration of various sectors of the community and governing bodies, this project was to serve as a blueprint for the restoration of other similarly degraded estuaries in the province. A local farmer, Mr Ian Garland, initiated restoration of the Siyaya Catchment through bank stabilisation and re-establishment of riverine and swamp communities of that area within the boundaries of his farm. The introduction of improved sugarcane farming methods and regrowth of natural coastal vegetation were to theoretically retard estuarine degradation.

All biophysical studies related to the Siyaya Catchment Demonstration Project (SCDP) were summarised by an ORI publication in 1999 (Oceanographic Research Institute 1999). Since the inception of the SCDP, 25 years ago, no long term monitoring of the estuarine benthos have taken place other than by the Coastal Research Unit of Zululand, University of Zululand. The Coastal Research Unit of Zululand monitored the abiotic and biotic responses of the estuary to catchment restoration over a three year period from 1992-1994 and then continued subsequent to the reopening of the mouth in April 1995. At that time, the mouth had remained closed with little marine overtopping for over five years. The aim of continued monitoring was to investigate changes in the biota related to alternate dry and wet climatic cycles (CRUZ unpublished data).

The abiotic responses of the system were measured as certain physical and chemical components of the water chemistry, including a detailed ionic analysis over four successive seasons. The biotic components investigated were the zoobenthos and ichthyofauna. To complete the biological survey of the entire estuary, macrocrustacean fauna were also collected during each scheduled sampling trip.

For the duration of the survey, the Siyaya Estuary remained closed and recruitment of juveniles and new marine species was limited to those periods when overtopping of the sandbar at the mouth took place. Subsequent to breaching of the sandbarrier in April 1995, conditions within the system changed to reflect a more typical estuarine, rather than a freshwater aquatic system. The comprehensive aquatic report on the recovery of the Siyaya therefore covered an intensive, three year period and established a long-term database against which future changes could be measured (MacKay and Cyrus 1996). The macrobenthic survey and determination of physico-chemical and water quality variables were also presented as an MSc dissertation (MacKay 1996). Later, a comparison of the Siyaya and the Nhlabane Estuary, further north were made in terms of defining freshwater quality according to the macrobenthic biotic component (MacKay and Cyrus 2001). Data collected subsequent to these analyses are unpublished but reference to these data will be made in this summary report. Data collection continued in the system on a quarterly basis until 2003 (CRUZ unpublished data).

A more recent study (twice annually since 2004) has been undertaken by Marine and Estuarine Research cc for the purposes of biomonitoring for Ticor South Africa. Reference to this study was by way of *pers comm.* with the study leaders.

The following benthic macroinvertebrate surveys were the only quantitative data collected pre-1990 (Oceanographic Research Institute 1991, 1999):

• September 1979	dredged samples	National Institute for Water Research , Durban
• 1983-1984 4x quarterly samples	cored samples	South African National Committee for Oceanographic Research

3. MACROINVERTEBRATE PRESENT STATE

The Siyaya was divided into five areas for the purposes of all CRUZ studies (MacKay 1996, MacKay and Cyrus 1996, MacKay and Cyrus 2001, CRUZ Unpublished Data). A site was selected in each area to represent a progression from the upper to lower reaches of the estuary, thus producing a gradient of quantifiable characteristics. This was especially of substrate type, where there was detrital rich mud in the upper reaches changing gradually to coarse grained marine sand in the lower reaches. Approximate locations of the five sites are depicted in Figure 1.

Quarterly sampling was conducted from 1992 to 2003 at intervals of three months to reflect seasonal changes in biotic and abiotic parameters at these five sites. The macroinvertebrate sampling protocol used standard methodology of replication at each site, the collection of a quantifiable amount of substrate at each site and laboratory sorting, identification to species level and enumeration to reflect the number of animals per square metre over space and time.

A mean of 9,874 invertebrates m^{-2} representing 85 taxa per site and season were sampled from the Siyaya from 1992 to 1994. The mean density of benthos sampled over four seasons in the Siyaya was 14,433 m^{-2} in 1992, 8,340 m^{-2} in 1993 and 6,850 m^{-2} in 1994 (MacKay 1996, MacKay and Cyrus 1996, MacKay and Cyrus 2001). Subsequent to mouth breeching, initially numbers were still on a trajectory of decline (<6,500 m^{-2}) until Early 1996, when numbers of fauna increased substantially from comparative periods in the previous study years. This reflected the change in state of the system to a more estuarine/marine dominated community, with high levels of productivity from the lower to middle reaches (CRUZ unpublished data). From 2000 onwards, preliminary analysis of samples again show a rapid decline in number and diversity as the system showed the effects of significantly reduced baseflows from afforestation in the catchment and the compounding effect of the prevailing drought in Zululand.

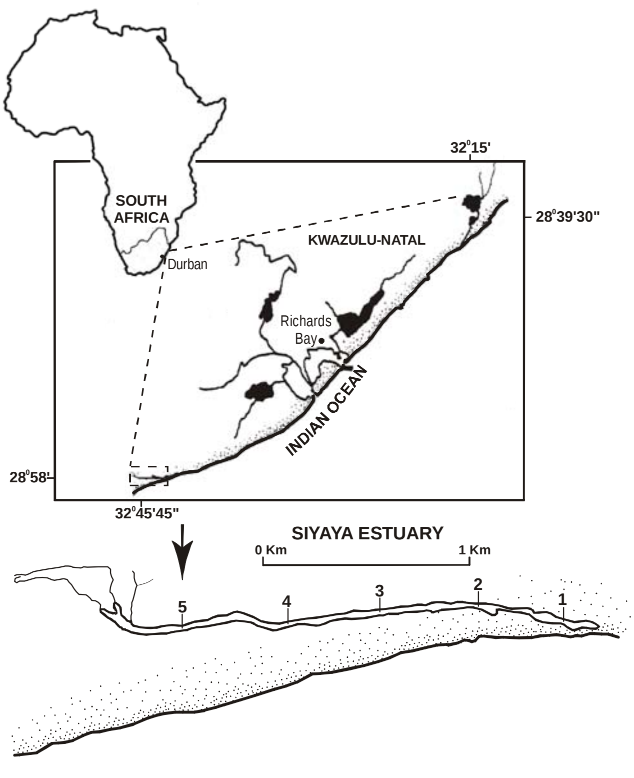

Figure 1. Location of biophysical sampling sites

During 1992, 50 taxa were recorded from the Siyaya Estuary. There was a wide faunal assemblage including Cumacea, Tanaidacea, two species of Gastropoda, eight Polychaeta taxa, five genera of Isopoda, six Amphipoda and four Mysidacea taxa. The few Decapoda sampled were mostly prawn post-larvae. During 1993, 45 taxa were identified with representatives from the phyla Platyhelminthes, Nematoda, Annelida, Arthropoda and Mollusca. Polychaeta, Isopoda and Amphipoda were still well represented, but a large number of the other taxa were aquatic insects from a wider range of families than encountered during 1992. During 1994, 59 taxa were recorded over four seasons, the majority (40 taxa) being freshwater related. Despite large numbers of insect fauna, other faunal groups were also present, notably Amphipoda, Isopoda, Polychaeta, Oligochaeta and Nematoda.

As faunal densities varied with season and site, differences between sampling years were further analysed using the model with effects 'Site', 'Season' and 'Sampling Year' on total benthic density (total density of 592,455 individuals m^{-2} over all 12 seasons (four per year). A highly significant relationship existed between benthic density and sampling site (P <0•001). The effects of year and of year v. season also yielded significant relationships (P <0•05). Thus, it was concluded that macrobenthic sites along the axial length of the estuary reflect a change in physico-chemical, sediment and botanical habitat related to distance from the marine environment. This changes according to season. Relative changes in baseflow as measured by decreasing MAR and reflected in differences per sampling year are also significant in this system (MacKay 1996, MacKay and Cyrus 2001).

Maximum productivity in the system changes according to the amount of freshwater inflow to the system. In a normal, wet year when baseflow is discernable, macroinvertebrates are at their maximum number in Summer (1995/6 mean of ~19,000 invertebrates m^{-2} over five sites; CRUZ unpublished data). During dry years when there is little connection with the marine environment, macroinvertebrates are at their maximum number during Winter (estuary mean of ~10,500 invertebrates m^{-2} over five sites in 1993 and ~9,800 invertebrates m^{-2} over five sites in 1994; MacKay 1996, MacKay and Cyrus 2001). This pattern appears to hold true for samples taken post 1996 to 2003 (CRUZ Unpublished data).

In terms of temporal and spatial changes in abundance, some trends were measurable during 1992. The benthos at Site 3 (mean density of 20,386 m^{-2}; SE 5,242) was the most abundant. Upper and lower reaches of the estuary tended to be less abundant (Site 1 mean density = 11,690 m^{-2}, SE 4,341; Site 5 8,902 m^{-2}, SE 2,628). The overall trend in abundance was to increase from the upper and lower reaches, towards the middle of the estuary. In 1992, the mean density over all five sampling sites was 19,446 m^{-2} (SE 4,962) in Summer, 10,394 m^{-2} (SE 2,030), 11,641 m^{-2} (SE 2,556) and 16,249 m^{-2} (SE 1,862) in Autumn, Winter and Spring, respectively. During 1992, the peak period of production of benthic invertebrates in the Siyaya Estuary, was during summer (MacKay 1996).

During 1993, throughout the system, total invertebrate densities were highest in Winter, followed by Spring, Summer and Autumn. The mean density during Summer was 6,576 m^{-2} (SE 2,280) and decreased slightly to 6,323 m^{-2} (SE 1,747) during Autumn. Invertebrate densities decreased slightly between Winter and Spring to 9,667 m^{-2} (SE 2,230). In 1993, peak abundance of benthic invertebrates was during Winter (10,792 m^{-2}; SE 2,672). Site 1 was the most impoverished area every season. Benthic densities decreased from Sites 2 to 3 except during Autumn, when Site 3 was the most abundant sampling site (10,185 m^{-2}). During Summer, Autumn, Winter and Spring of 1992 the mean density per season exceeded those for the same period during 1993 by 12,870 m^{-2}, 4,071 m^{-2}, 849 m^{-2} and 6,582 m^{-2}, respectively (MacKay 1996).

There was an increase in benthic abundance between Summer and Autumn, and a peak in abundance during Winter (peak = 9,891 m^{-2}, SE 2,548) of 1994. Throughout the year, Site 2 generally had the highest abundance, while the most impoverished areas fluctuated between Sites 1, 3 and 4. The mean density per site shows that Sites 1, 3 and 5 were similar throughout the year (7,852 m^{-2}, SE 3,635; 6,731 m^{-2}, SE 2,618; 7,072 m^{-2}, SE 1385, respectively). Sites 2 and 4 had the highest and lowest mean density per site during 1994 (9,857 m^{-2}, SE 2,294 and 2,739 m^{-2}, SE 742). The abundance of benthos at Site 1 showed the most marked decrease compared with other seasons. 1994 benthos showed decreases from 1993 equivalent samples of 2,094 m^{-2}, 536 m^{-2}, 901 m^{-2} and 2,425 m^{-2}, for Summer, Autumn, Winter and Spring (MacKay 1996).

Although the middle reaches (Sites 2 and 3) are on average, more numerically abundant, it is the numbers of individual taxa that reflect the pattern of changing salinity and increase or decrease or marine dominance in the system. In the original, reported and published studies the greatest numbers of estuarine benthic taxa occurred during 1992. In 1994, the greatest proportions of estuarine benthic taxa occurred closer to the lower reaches of the estuary at Site 1 and overall, freshwater benthos was more dominant.

Of the mean 14,433 individuals m^{-2} collected in 1992, 97% were estuarine. In 1993, 85% were estuarine and by 1994 only 46% were estuarine. Appendix 1 shows a steady increase in the number of freshwater taxa colonizing the Siyaya Estuary from 1992 to 1994 and the taxa sampled in the system. More recent data analysed have not indicated the addition of any new or significant taxa.

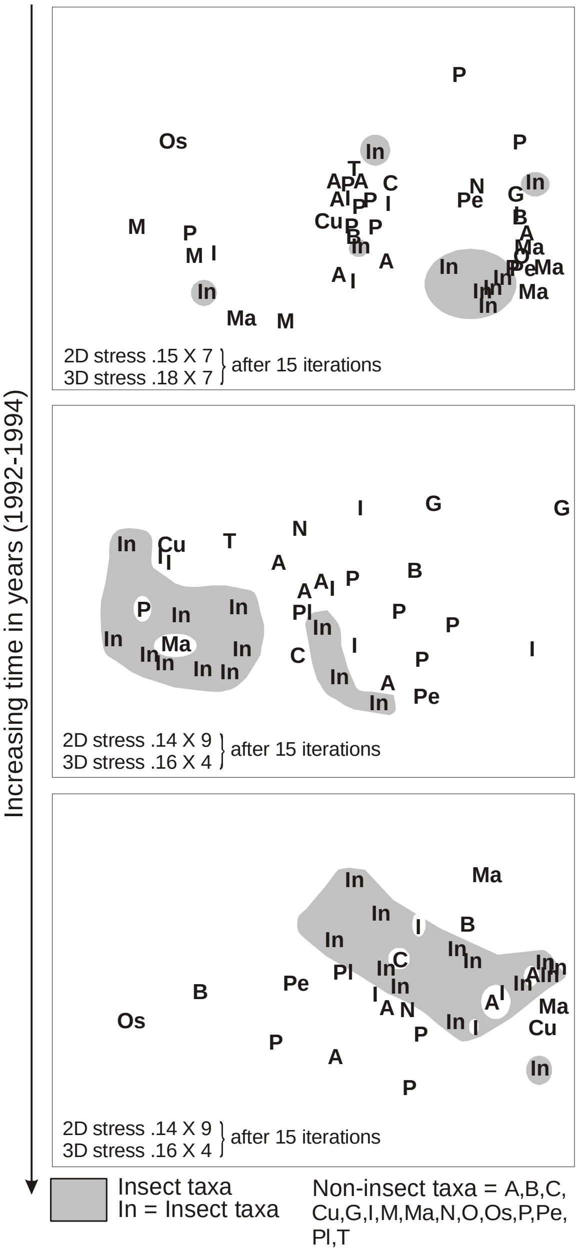

Figure 2. Ordination plots of all taxa collected in the Siyaya Estuary 1992-1993. Estuarine taxa are shaded

This change in the species richness to a more freshwater dominated assemblage with the length of time the mouth is closed is depicted in Figures 2 and 3. Despite the change in the types of fauna that colonise the system from the upper reaches into the lower reaches, fauna that are typically estuarine (refer to Appendix 1), are always numerically abundant even if they are restricted to the lower reaches around Site 1.

The distribution of species and relative abundance is such that the system is dominated by a small number of highly abundant species and a large number of poorly represented / rare species.

The results of these studies indicated that catchment restoration efforts had some effect on the state of the Siyaya Estuary, with particular reference to the macrobenthic component. This effect seems to be positive, as there has been an increase in both the number of taxa and density of zoobenthos since the first survey was conducted in 1988 (37 in 1988, 59 in 1994, 52 in 1996, 58 in 2000). Many benthic species that are found in both small, generally closed KwaZulu-Natal estuaries and large systems open to the sea, were also found in this study. This implies that past habitat changes did not necessarily exclude many species, but did limit populations.

Figure 4 represents the ordination of all temporal and spatial data collected from 1992 to 1996. With time samples collected after the breeching of the system tended to group closer to those collected at the beginning of the drought. Samples collected in 1992 were more abundant and species rich than any comparative samples collected in the early 1980s at the beginning of the catchment demonstration project.

Currently, the benthos of the Siyaya Estuary is in yet another degraded state (CRUZ and MER unpublished data). Again, it is conditions within the catchment that are responsible for reduced flows to the estuary, longer periods of isolation from the marine environment and general degradation of macrobenthic habitat in the system. Added to this, is the current drought which is exacerbating all of these effects. As was the case during the 1992-1994 study, numbers of freshwater taxa dominate species richness but numerical abundance belongs to the estuarine crustaceans *Grandidierella lignorum*, *Corophium triaenonyx*, *Apseudes digitalis* and *Iphinoe truncata* and the polychaete *Ceratonereis keiskama*). Marine and Estuarine Research cc data show this system to be in severely degraded state as of 2005, with almost complete loss of appropriate habitat and biodiversity in some areas.

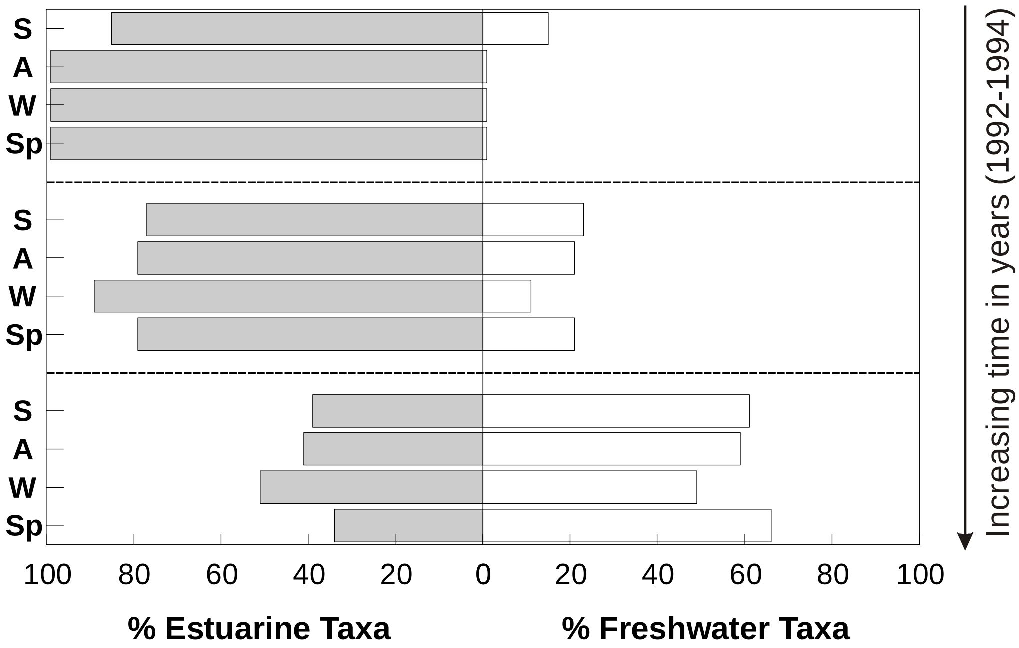

Figure 3. Seasonal percentage contribution of estuarine and freshwater taxon densities (m^{-2}) 1992-1994

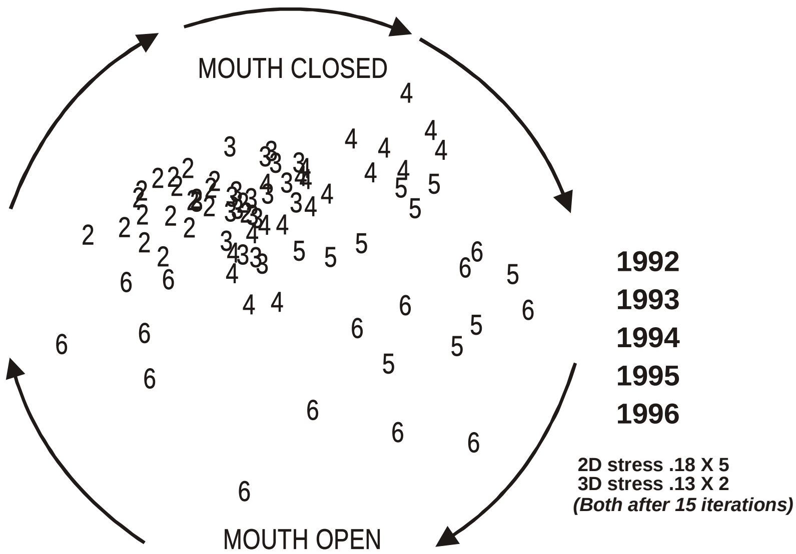

Figure 4. Two dimensional NMDS ordination results of macroinvertebrate samples collected in the Siyaya Estuary 1992-1996

4. POSSIBLE EFFECTS OF CHANGES TO FRESHWATER INFLOW ON MACROINVERTEBRATES

The major factors known to determine macrobenthic community structure are divided into environmental and non-environmental. Physical and chemical environmental factors that may affect estuarine macrobenthos are salinity gradients, shelter from wave action, fluctuations in temperature and oxygen levels, the nature of the substratum and the input of detritus (Nichols 1970; Barnes 1974; Metzeling 1993).

Physico-chemical variables are direct factors influencing benthic organisms, as far as they affect the physiological processes of any life stage of an organism (Boesch *et al.* 1976). The components of estuarine fauna are separated by means of their tolerance to salinity, although they are also affected by the aforementioned factors. In tolerable salinity and temperature ranges, it is substratum type that becomes the determining factor in benthic distribution (Day 1981). Cooper *et al.* (1995), reason that in our local estuaries the fauna are influenced by the salinity characteristics, period of connection with the sea, turbidity (controlled by catchment geology and flow), substrate and availability of nutrients (controlled to a large extent by cycles of breaching and flushing). The substrates within estuaries are usually different from adjacent marine coasts, in that they usually have sandy and muddy components. This is typical of most southern African estuaries (Blaber 1980). Although nutritionally rich, these muds are difficult areas to colonise, as locomotion both through and over the substrate may be difficult. In addition, fine silt in suspension can clog the filtering mechanisms of many of the animals that use this as their method of feeding. Gray (1981), maintains that grain size and organic content are important for estuarine macrobenthos. Marine sediments and muds provide inhospitable habitats, thus medium and fine sands usually have an abundant benthic faunal assemblage. Almost all bottom-dwelling animals will live only on specific substrates, and depending on the grain size of the sediment, this may play a role in determining the dominant feeding type (Nichols 1970) and the formation of burrows, as the latter is dependant on whether the substrate is sand or mud (Blaber 1980). The nature of the substrata in any estuary is dependent on:

1. The dominant water mass (fresh or seawater)
2. The nature of offshore deposits
3. The nature of the catchment drained by inflowing rivers

In addition, anthropogenic activities may directly or indirectly affect the distribution of macrobenthos, in that one, more or a combination of the above factors may be altered through catchment activities such as to increase or reduce freshwater inflow to an estuary. Any activity that alters the manner in which an estuary fluctuates on a normal seasonal and interannual basis should be considered as negatively influencing its conservation value and inherent worth as a nursery area.

Stream flows in the Siyaya and Amanzimnyama systems have decreased substantially, particularly since the catchment use was changed from sugarcane cultivation to commercial forestry. This has obviously visibly and measurably impacted on the flow regime of the Siyaya Estuary. Sugarcane cultivation and the period of changeover from cane to *Eucalyptus* resulted in large quantities of silt settling in the system. This has never been scoured out, even during large-scale events such as the Demoina and 1987 floods (Oceanographic Research Institute 1991, 1999).

If restoration of flow to the system is to have a positive effect on the macrobenthic ecology it is critical that it is managed and mimics the normal conditions of the system. It is also critical that a programme to remove the *Phragmites* reeds that have taken over almost the entire middle and upper reaches of the system, is implemented. The estuary is perched and flows that sustain an open mouth condition for prolonged periods will only impoverish the fauna of the system as they are constantly eroded away in the top centimetres of sediment, particular in the lower reaches where the abundant estuarine fauna occur.

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Appendix 1. List of taxa sampled in the Siyaya Estuary 1992-1994. Shading represents estuarine taxa

		1992	1993	1994
	NEMATODA			
1	Nematode spp.	X	X	X
	PLATYHELMINTHES			
2	Platyhelminthes spp.		X	X
	ANNELIDA			
3	Oligochaete spp.	X	X	X
	Polychaeta			
4	*Mercierella enigmata*	X		
5	*Ceratonereis keiskama*	X	X	X
6	*Desdemona ornata*	X	X	X
7	*Polydora sp.* T1	X	X	
8	*Prionospio sexoculata*	X	X	
9	*Dendronereis arborifera*	X		
10	Polychaete T1	X		
11	Polychaete T2	X		
	MOLLUSCA			
	Gastropoda			
12	*Melanoides tuberculatus*	X	X	X
13	*Assiminea bifasciata*	X	X	
	Bivalvia			
14	*Musculus virgiliae*	X		
15	*Pittaria kochii*		X	
	ARTHROPODA			
	Crustacea			
16	Cladocera spp.	X	X	X
17	Ostracoda spp.	X	X	X
	Isopoda			
18	*Dies monodi*	X		X
19	*Leptanthura laevigata*	X	X	X
20	*Munna sheltoni*	X	X	X
21	*Eurydice longicornis*	X	X	
22	*Excirollana natalensis*	X	X	
23	*Corollana africana*		X	
	Amphipoda			
24	*Corophium triaenonyx*	X	X	X
25	*Grandidierella lignorum*	X	X	X
26	*Melita zeylanica*	X		
27	*Orchestia ancheidos*	X	X	X
28	*Bolttsia minuta*	X	X	
29	*Urothoe tumorosa*	X		
	Tanaidacea			
30	*Apseudes digitalis*	X	X	X

	Cumacea			
31	*Iphinoe truncata*	X	X	
	Mysidacea			
32	*Mesopodopsis africanus*	X	X	X
33	*Rhopalophthalmus terrantalis*	X		
34	*Gastrosaccus brevifissura*	X		
35	Mysidopsis sp. T1	X		
	Decapoda			
	Brachyura			
36	Branchyura larvae	X		
37	*Hymenosoma orbiculaire*		X	X
	Macrura			
38	*Caridina nilotica*	X		X
39	*Lucifer pencillifer*	X		
40	*Callianassa kraussi*	X		
	Insecta			
41	Insecta AT1			X
42	Insecta NT1			X
43	Insecta NT2			X
44	Insecta NT3			X
45	Insecta NT5			X
46	Insecta NT5			X
47	Insecta LT1	X		
	Hemiptera			
48	Tridactylidae LT1		X	
49	Corixidae NT1	X	X	X
	Coleoptera			
50	Coleoptera NT1	X		X
51	Coleoptera PT1			X
52	Coleoptera AT1			X
53	Coleoptera LT1		X	
	Hymenoptera			
54	Hymenoptera NT1			X
55	Hymenoptera NT2			X
56	Hymenoptera NT3			X
	Diptera			
57	Diptera PT1			X
58	Diptera PT2			X
59	Diptera LT1	X		X
60	Diptera LT2			X
61	Diptera LT3			X
62	Diptera LT5		X	
63	Diptera LT5			X
64	Diptera LT6			X

65	Diptera AT1			**X**
66	Diptera AT3			**X**
67	Diptera AT5			**X**
68	Psychodidae LT1		**X**	**X**
69	Ceratopogonidae LT1	**X**	**X**	**X**
70	Chironomid spp. L	**X**	**X**	**X**
71	Chironomid spp. P	**X**	**X**	**X**
72	Chaoborus sp. LT1	**X**	**X**	**X**
73	Chaoborus sp. PT1	**X**	**X**	**X**
	Trichoptera			
74	Trichoptera LT1		**X**	**X**
75	Ecnomus sp. LT1			**X**
	Odonata			
76	Odonata NT1			**X**
77	Zygoptera LT1		**X**	
78	Gomphid T1	**X**		
79	Gomphidae NT1		**X**	**X**
80	Gomphidae NT2		**X**	**X**
71	Corduliidae NT1		**X**	
	Ephemeroptera			
82	Baetis LT1	**X**	**X**	**X**
83	Prosopistoma LT1		**X**	**X**
84	Hydrocarina sp. T1		**X**	**X**
85	Araneae sp. T1	**X**	**X**	**X**

SUMMARY REPORT

SIYAYA ESTUARY RAPID RESERVE DETERMINATION

LARGER INVERTEBRATES

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Coastal Research Unit of Zululand
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&
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Begg (1978) noted that early records from the system included *Macrobrachium* spp., *Callianassa kraussi* the mollusc *Neritina natalensis* and a large penaeid prawn (possibly *Penaeus monodon*).

Initial surveys of the system were undertaken by the University of Natal during 1979 and 1980 (van der Elst *et. al*, 1999). The checklist contained in van der Elst *et. al.* (1999) contains 14 species of macrocrustacea and 8 species of mollusc. In relation to the macrocrustacea it was considered that freshwater species dominated the upper reaches with fresh to brackish water species in the middle and lower reaches. Only short term 'invasions' of the lower reaches by post-larval stages of marine/estuarine species occurred when a connection to the sea was present. *Varuna litterata* an exceptionally euryhaline tolerant crab was considered to be the most successful species of this group and penetrated upper and lower reaches of the system. The macrocrustaceans sampled from July 1979 to August 1980 are summarised in Appendix 1.

The most intensive sampling of the system to date has been that undertaken by the Coastal Research Unit of Zululand (CRUZ) who first sampled the system in August 1991 (Cyrus & Martin, 1991). Subsequently during the period 1992 to 1994 sampling the macrocrustacea fauna took place on a quarterly basis, using baited traps, as part of a World Wildlife Fund (WWF) Programme on the system (MacKay & Cyrus, 1996). The monitoring programme set up for this project was run by CRUZ for a further nine years after the WWF programme ended and was suspended in November 2003. To date, the bulk of the collected macrocrustacean material (all components sampled) has only been data based and no further analysis has been undertaken. All records from April 1992 to November 2003 have been extracted and were accessed as part of this review.

A scan of the CRUZ data indicates that a total of 20 species of macrocrustacea were recorded during the study period indicating the presence of a fairly diverse fauna (see Appendix 1). Ten of these species were not recorded by van der Elst *et. al.* (1999). Only three species of mollusc were recorded in the CRUZ data base.

The data indicates that the freshwater *Macrobrachium* spp. dominated the catch throughout the period with *M.equidens* and *M.rude* being most commonly caught. This group is well known for being extremely difficult to identify if the specimens are not adult males. In addition, the taxonomy continues to be in a state of flux. This is evident from the number of unidentified species listed in the CRUZ data and also by the fact that a total of eight species have been reported from the Siyaya system. Of these, two species were not recorded by CRUZ and four were not recorded by van der Elst *et. al.*(1999). Time was not available to investigate if any synonyms are present.

It should be noted that brackish water (>8‰) is critical for successful larval development in this genus (Cort, 1983). The data appear to indicate that numbers of juveniles and adults being trapped declined over the study period and this may reflect a shift in the system from brackish to freshwater conditions throughout as appeared to have occurred from January 2001 onwards.

In terms of the typical estuarine/marine species, the data show only limited influxes of *Penaeus monodon* in 1992 and *P.indicus* in 1998. It appears that there was much less recruitment during the period April 1992 to November 2003 than is reported by van der Elst *et. al.* (1999) for the period 1979-80 (see above). This may be directly related to the frequency of mouth opening and length of time a connection to the sea was present.

The presence of *Varuna litterata* in the system and the existence of records of movement of this species out of the system to sea to spawn (Bickerton & Sapsford, 1981) coupled with the mass inward migrations that megalope larvae of this species undertake, would tend to indicate that it is an integral component of the ecosystem and is probably present throughout the Siyaya catchment as an adult.

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Appendix 1

Siyaya Estuary - Larger Invertebrates			
A. Macrocrustacea			
No.	Taxa	CRUZ	Other
1	*Acetes erythraeus*	1	
2	*Callianassa kraussi*	1	1
3	*Caridina africana*		1
4	*Caridina nilotica*	1	1
5	*Hymenosoma orbiculare*	1	
6	*Macrobrachium equidens*	1	1
7	*Macrobrachium idea*	1	
8	*Macrobrachium idella*	1	
9	*Macrobrachium lar*		1
10	*Macrobrachium lepidatylus*	1	1
11	*Macrobrachium petersii*		1
12	*Macrobrachium rude*	1	
13	*Macrobrachium vollenhoveni*	1	
14	*Metapenaeus monoceros*	1	1
15	*Palaemon conicinnus*	1	1
16	*Paratylodiplax blephariskios*	1	
17	*Penaeus indicus*	1	1
18	*Penaeus monodon*	1	1
19	*Potomon sidneyi*		1
20	*Rhynchoplax bavis*	1	
21	*Sesarma eulimene*	1	
22	*Sesarma meinerti*	1	
23	*Scylla serrata*	1	1
24	*Varuna litterata*	1	1
	Total	20	14
B. Other Species			
No.	Taxa	CRUZ	Other
1	*Hiatula lunulata*	1	1
2	*Lymnaea* sp.		1
3	Melanoides tuberculata	1	1
4	*Musculus virgiliae*		1
5	*Nassarius kraussianus*	1	
6	Neritina auriculata		1
7	*Neritina natalensis*		1
8	*Septaria* sp.		1
9	*Thiara vouamica*		1
	Total	3	8
33	Grand Totals	23	22

SUMMARY REPORT

SIYAYA ESTUARY RAPID RESERVE DETERMINATION

ICHTHYOFAUNA

Prof Digby Cyrus
Coastal Research Unit of Zululand
University of Zululand

Begg (1978) indicated that a list of fish species caught in the Siyaya in 1950 numbered 16 species 'excluding barbell and eels'.

Initial surveys of the system were undertaken by the University of Natal (1979-80) and subsequently the NIWR (van der Elst *et. al*, 1999). This indicated the presence of some 25 species and it was consisted that the system had a 'modest Ichthyofauna with relatively few species'.

The most intensive sampling of the system to date has been that undertaken by the Coastal Research Unit of Zululand (CRUZ) who first sampled the system in August 1991 when 4,059 individuals comprising 15 species were netted in the estuary (Cyrus & Martin, 1991). Subsequently during the period 1992 to 1994 sampling of the fish fauna took place as part of a World Wildlife Fund (WWF) Programme on the system (MacKay & Cyrus, 1996). The monitoring programme set up for this project was run by CRUZ for a further nine years after the WWF programme stopped and was terminated in November 2003. To date however the bulk of the collected material (all components sampled) has only been data based and no analysis has been undertaken. **In terms of the fish all records from August 1991 to February 2000 have been extracted from the field records and were accessed as part of this review.**

For this Rapid Assessment of the Siyaya Estuary time has only been available for accessing and scanning the raw material relating to the fish component. It has not been possible to undertake any annual or seasonal analysis of the data due to time constraints. However information from the extracted records (August 1991 to February 2000) does provide a background considered to be more than suitable for use in a Rapid Assessment of the System.

The CRUZ data base comprises a total of 16,508 individual records collected quarterly over the period August 1991 to February 2000. A scan of this data reviled that despite it's small a total of 57 species have been recorded in the Siyaya Estuary to date (CRUZ unpublished data). These comprise some 20 families of fish. This represents 52% of the fish fauna that has been recorded in Lake St Lucia, the largest estuarine system in South Africa.

The fish species present represent a diverse fauna in terms of estuarine type and feeding habits. An analysis of the 58 species recorded was undertaken using the estuarine association categories of Whitfield (1998), it revealed the following:-

1. Estuarine residents **(12 Species; 21% of Fauna)**
    c. Breeding only in estuaries 4 species
    d. Breeding mainly in estuaries 8 species

2. Marine migrants **(25 Species; 43% of Fauna)**
    d. Juveniles wholly estuarine dependant 9 species
    e. Juveniles mainly estuarine dependant 10 species
    f. Juveniles weakly estuarine dependant 6 species

3. Marine stragglers **(10 Species; 17% of Fauna)**

4. Freshwater migrants **(8 Species; 14% of Fauna)**

5. Catadromus migrants **(3 Species; 5% of Fauna)**
    a. Obligate freshwater phase 1 species
    b. Facultative freshwater phase 2 species

It is clear, from the species data, physical conditions report (Huizinga & van Niekerk) and many years personal experience of the system, that the oscillation across a number of states in terms of estuarine volume and mouth condition results in the Ichthyofauna of the Siyaya changing dramatically dependant on condition. The main drivers determining the role it plays and the fish species that present are essentially related to three conditions Fresh with Low Water Levels, Full with Fresh to Low Salinities and Temporary Open/Closed Estuarine.

Under typically Temporary Open/Closed Estuarine conditions, when the salinities can range from 0 to 35‰ but probably averages 5 to 15‰, the fish fauna is dominated by species belonging to Whitfield (1998) Category 2. These comprised juveniles of marine species which were utilizing the system as a nursery ground. At these times it appears that diversity and densities can be relatively high with up to 500 or more fish per set having been caught during seine and gill netting. Although most individuals were <200mm Standard Length (SL) reasonable numbers where larger than this reaching up to 300mm SL. This phase appeared to dominate throughout the period August 1991 through to February 2000. Recruitment from the marine environment into the system takes place when the mouth is open and during high tide periods by way of wave overtopping. MacKay & Cyrus (1996) recorded 13 species recruiting into the Siyaya estuary during overtopping events.

At times during the above period, the system moved towards the Full with Fresh to Low Salinities condition then the typically estuarine species (Whitfield, 1998 - Category 1) start to show dominance. These are mostly small sized species which are capable of withstanding a wide range of salinity and which breed within the system.

Under extreme low flow/drought conditions such as are currently present (2003-2006) virtually no water reaches the estuary and the levels are extremely low and the entire system is fresh. During such time the freshwater species (Whitfield, 1998 - Category 4) dominate the system. However due to it's shallow nature, smaller individuals tend to dominate.

Although only a limited scan of the un-assessed fish data for the Siyaya Estuary has been undertaken it is clear that under 'normal' conditions the system is very much a functional nursery area for juvenile marine species while at the same time having a well developed estuarine resident fauna. It is considered that the Siyaya is, interms of its fish fauna, one of the most important Temporary Open/Closed Estuaries on the entire Zululand Coast (if not the most important).

No Red Data list exists for estuarine species, however, *Crolia mossambica*, *Redigobius dewaali, Silhouettea sibayi* and *Myxus capensis* are all listed as Rare by Skelton (1993).

References

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Cyrus DP and Martin TJ (1991). Current status of the Siyaya Estuary: Fish and Malacostracan Fauna and Estuarine Function. Coastal Research Unit of Zululand Investigational Report No. 40, University of Zululand. 18pp.

MacKay CF and Cyrus DP (1996). Final Report to the World Wide Fund for Nature on the Survey of the Zoobenthos and Ichthyofauna of the Siyaya Estuary. Coastal Research Unit of Zululand Investigational Report No. 40, University of Zululand. 44pp.

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van der Elst RP, Birnie SL and Everett BI (Eds) (1999). Siyaya Catchment Demonstration Project: An experiment in estuarine rehabilitation. ORI Special Publication No. 6. South African Association for Marine Biological Research, South Africa. 99pp.

Whitfield AK (1998). Biology and Ecology of Fishes in Southern African Estuaries. *Ichthyological Monographs of the J.L.B.Smith Instutute of Ichthyology, No. 2, 223pp.*

Siyaya Estuary - Total Fish List All Data but mainly based on 1991-2000					
		Whitfield Category			Whitfield Category
1	*Ambassis gymnocephalus*	1b	31	*Lisa tricuspidens*	2b
2	*Ambassis natalensis*	1b	32	*Lutjanus argentimaculatus*	2c
3	*Ambassis ambassis*	1a	33	*Megalops cyprinoides*	5b
4	*Amblyrhynchotes honckenii*	3	34	*Monodactylus falciformis*	2a
5	*Anguilla marmorata*	5a	35	*Monodactylus argenteus*	2b
6	*Arothron immaculatus*	3	36	*Mugil cephalus*	2a
7	*Arothron hispidus*	3	37	*Myxus capensis*	5b
8	*Awaous aeneofuscus*	4	38	*Oligolepis keiensis*	1a
9	*Barbus paludinosus*	4	39	*Oreochromis mossambicus*	4
10	*Caffrogobius cafer*	1b	40	**POLYDACTYLUS INDICUS**	3
11	*Caranx papuensis*	2c	41	*Polydactylus plebius*	3
12	*Caranx sem*	3	42	*Pomadasys commersonnii*	2a
13	*Caranx sexfaciatus*	2b	43	*Pseudocrenilabrus philander*	4
14	*Chanos chanos*	2c	44	*Pseudorhombus arsius*	3
15	*Chelonodon laticeps*	3	45	*Redigobius dewaali*	1b
16	*Clarias gariepinus*	4	46	*Rhabdosargus holubi*	2a
17	*Clarias theodorae*	4	47	*Rhabdosargus sarba*	2b
18	*Croilia mossambica*	1b	48	*Rhabdosargus thorpei*	2b
19	*Diplodus sargus capensis*	2c	49	*Silhouettea sibayi*	1b
20	*Eleotris fusca*	1a	50	*Solea bleekeri*	2b
21	*Elops machnata*	2a	51	*Terapon jarbua*	2a
22	*Favonigobius reichei*	1b	52	*Tilapia sparrmmanii*	4
23	*Gerres acinaces*	2b	53	*Trachinotus blochii*	3
24	*Gerres methueni*	2b	54	*Trachinotus africanus*	3
25	*Gilchristella aestuaria*	1a	55	*Valamugil buchanani*	2c
26	*Glossogobius callidus*	1b	56	*Valamugil cunnesius*	2a
27	*Glossogobius giuris*	4	57	*Valamugil robustus*	2a
28	*Liza alata*	2b	58	*Valamugil seheli*	2c
29	*Liza dumerili*	2b			
30	*Liza macrolepis*	2a			

WATER ASSOCIATED BIRDS IN THE SIYAYA ESTUARY:

PROF A.T.FORBES
Marine and Estuarine Research

1. Introduction

The Siyaya estuary is a small, perched system, historically closed for much of the time and with a minimal intertidal area even when the mouth is open. This combination would have limited the use of the system by migratory waders. Steeply sloping banks would have restricted the abundance of wading but not necessarily those piscivores catching their prey by diving or stooping.

2. Methods

The following assessment is based on an unpublished list of 305 species collated by Ian Garland & Peter Frost in 1979 as part of the original Siyaya Catchment Development Project and reflects Frost's observations in 1978 and 1979 as well as Garland's records covering the previous 30 odd years. I have attempted to extract from the records those species associated specifically with the Siyaya estuary as opposed to those more strongly linked to the wetlands associated with the upstream reaches of the Amanzimnyama. These have then been combined with recent records to provide an assessment of present conditions.

3. Results

No actual counts are available but the size of the system would always have precluded large numbers of any water associated or dependent species being present. The early records included longtailed cormorants *Phalacrocorax africanus* and darters *Anhinga rufa* with occasional winter occurrences of Cape cormorant *Phalacrocorax capensis*. Purple heron *Ardea purpurea* were resident with occasional squacco *Ardeola ralloides* and rarely black heron *Egretta ardesiaca* as well as white-backed night heron *Gorsachius leuconotus*. Spurwinged goose *Plectropterus gambensis* were common as well as African black duck *Anas sparsa* and seasonal yellow-billed duck *Anas undulata*. Osprey *Pandion haliaetus* and Pel's fishing owl *Scotopelia peli* occurred although rarely. Malachite *Alcedo cristata* and giant kingfishers *Megaceryle maxima* were resident with occasional pied *Ceryle rudis*. Black crake *Amaurornis flavirostra*, moorhen *Gallinula chloropus*, African jacana *Actophilornis africanus* and finfoot *Podica senegalensis* were breeding residents.

4. Discussion and Conclusion

The major changes that have occurred in the estuary date back, according to Garland's records, to the early 70's, a particularly wet period which followed dry years in the late 60's. By the end of the 60's most of the wetlands and swamp forests in the catchment had been cleared or drained and the higher than normal rainfall in the early 70's resulted in major sediment deposition in the upper reaches of the estuary. The sedimentation in combination with agricultural run-off arguably accelerated growth of the reed *Phragmites australis* and Benfield (1985), based on an estimate of 0.1473 $ha.a^{-1}$, forecast complete coverage of the estuary in 18 years. This has proven remarkably and distressingly accurate. The net physical effect has been to minimise the area of open water and also the interface between reeds or sand and open water which are the areas where water birds tend to forage. It this comes as no surprise that records of the species mentioned above in recent years are virtually non-existent.

5. References

Benfield M.C. 1985 Management of *Phragmites* in the Siyaya Lagoon.Working document 13/B submitted to the Siyaya Catchment Demonstration Project. Unpublished.

Garland I. 1985 A short history of the Siyaya Lagoon and catchment area. Working document 1/G submitted to the Siyaya Catchment Demonstration Project. Unpublished.

APPENDIX C

Template for Presentation of Results as Required by the DWAF

1. Description of the River

<u>River</u>:	Siyaya River
<u>Drainage Region (monitoring point for Reserve)</u>:	Head of tidal influence, approximately 2.5 km from the mouth (28°58.785 S, 31°44.453 E)
Water Management Area:	Usutu to Mhlathuze

2. Preliminary determination of the recommended Ecological Flow Requirement Scenario - Section 17(1)

MAR of 6.5 million cubic meters, 95% of the natural MAR (6.2 million cubic meters)

NOTE: This amount accounts for the Ecological Requirements only

3. Preliminary determination of the Ecological Requirements for Water Quality - Section 17(1)

Not determined as part of a Preliminary Determination of the Ecological Reserve on a Rapid level.

4. Preliminary determination of recommended Ecological Category

Recommended Ecological Category is **Category B**

Category B represents *'largely natural with few modifications'*

NOTE:

Other factors, such as the socio-economic and financial implications of removing or at least significantly reducting forestry from the catchment, would need to be discussed by the DWAF and other stakeholders.

It is also important to confirm through measurements whether sedimentation in the system is still a major issue and appropriate actions taken if this is shown to be the case.

5. Applicability

5.1 This preliminary determination of the Reserve in terms of section(1)(a) is applicable to the following water resources or part of the resource:

<u>Siyaya Estuary</u> within the following geographical boundaries (WSG 84)

- **Downstream boundary:** The estuary mouth (28⁰58.034' S, 31⁰45.723' E).
- **Upstream boundary:** Head of tidal influence, approximately 2.5 km from the mouth (28°58.785 S, 31°44.453 E)
- **Lateral boundaries:** 5 m contour above MSL along the banks.

5.2 This preliminary determination of the Reserve in terms of section 17(1)(b) is applicable to the authorising of following water use:

- Section 21(a) - taking water from a water resource
- Section 21 (b) - storing water
- Section 21 (c) - impeding or diverting the flow of water in a watercourse

- Section 21 (e) – engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1)
- Section 21(f) – discharging water into a water resource through a pipe, canal, sewer, sea outfall or other conduit
- Section 21(g) - disposing of waste in a manner which may detrimentally impact on a water resource
- Section 21(h) - disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process
- Section 21 (i) - altering the bed, banks, course or characteristics of a watercourse

6. Supporting Documentation

Supporting documentation is provided in the following Annexures:

Annexure A: Preliminary Ecological Flow Requirement – Water Quantity	X
Annexure B: Preliminary Ecological Requirement – Water Quality	
Annexure C: Preliminary Basic Human Needs	
Annexure D: Resource Quality Objectives	
Annexure E: Special conditions and limitations	
Annexure F: Background and record of decision	X
Annexure G: Methodology	
Annexure H: Specialist reports (see Appendix B)	X
Annexure I: Map of study area	

ANNEXURE A
PRELIMINARY ECOLOGICAL RESERVE – WATER QUANTITY

1) Level of confidence of the determination: Low (i.e. < 40%)

2) The flow requirement is based on the natural flow contribution of the catchments upstream of the head of the Siyaya Estuary, (28°58.785 S, 31°44.453 E approximately 2.5 km upstream of the mouth) (The position of the head of the estuary, however, needs to be confirmed with tidal variation recordings).

3) Table 1 provides a summary of flow distribution (mean monthly flows in m^3/s) of the recommended Ecological Flow Requirement Scenario for the Siyaya Estuary to meet the recommended Ecological Category of B.

4) Table 2 provides a simulated monthly runoff (in mean monthly m^3/s) of the recommended Ecological Flow Requirement Scenario to meet the recommended Ecological Category of B.

Category B (recommended Ecological Category)

The **recommended Ecological Flow Requirement Scenario for Siyaya Estuary** is estimated at an MAR of 6.2 million cubic meters distributed as set out in Tables 1

TABLE 1: Siyaya Estuary: Summary of flow distribution (in mean monthly m^3/s) of the recommended Ecological Flow Requirement Scenario to meet the recommended Ecological Category of B

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	**1.050**	**1.034**	**2.711**	**1.385**	**1.955**	**2.874**	**2.344**	**1.665**	**1.631**	**1.283**	0.437	**1.718**
90%ile	0.358	0.435	0.419	0.574	**1.271**	0.710	0.508	0.246	0.167	0.218	0.111	0.395
80%ile	0.190	0.237	0.229	0.350	0.646	0.408	0.163	0.145	0.073	0.072	0.066	0.157
70%ile	0.126	0.180	0.143	0.237	0.438	0.180	0.081	0.083	0.054	0.051	0.050	0.085
60%ile	0.086	0.105	0.104	0.156	0.176	0.111	0.052	0.050	0.050	0.050	0.050	0.056
50%ile	0.051	0.075	0.082	0.074	0.081	0.071	0.050	0.047	0.050	0.041	0.043	0.050
40%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.036	0.041	0.036	0.037	0.045
30%ile	0.050	0.050	0.050	0.050	0.050	0.050	0.042	0.034	0.032	0.027	0.029	0.038
20%ile	0.044	0.043	0.050	0.050	0.042	0.048	0.035	0.027	0.026	0.021	0.021	0.029
10%ile	0.031	0.031	0.037	0.033	0.031	0.029	0.023	0.018	0.019	0.015	0.018	0.021
1%ile	0.016	0.012	0.020	0.019	0.017	0.013	0.013	0.009	0.010	0.009	0.011	0.014

NOTE:

- Although the recommended 'Ecological Water Requirement Scenario' provided in this Rapid assessment resembles the flows during the Reference Condition, the re-introduction of such a flow regime will on its own not be enough to lift the estuary to an Ecological Category B, due to the impact of other non-flow related anthropogenic activities on the estuary, such as sedimentation, reed encroachment and removal of supporting wetland and riparian habitats.
- The Present Ecological Status of the Siyaya Estuary (Ecological Category E) is considered to be on a negative trajectory rather than stable. Present flows are therefore insufficient to maintain the estuary in its present category.
- Increasing flows can marginally lift the system to an Ecological Category D but increases approaching 80% of the MAR are required to lift the system to a C and ultimately a B.

ANNEXURE F
BACKGROUND AND RECORD OF DECISION

1. Project Management

Marine & Estuarine Research: Ms N.T. Demetriades

2. Compilation of Rapid RDM Specialist Report

Marine & Estuarine Research: Ms N.T. Demetriades

3. Consultants conducting the Ecological Reserve:

TEAM MEMBER	CONTACT DETAILS
Nicolette Demetriades	Marine & Estuarine Research (nicolette@mer.co.za)
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Fiona McKay	Oceanographic Research Institute (fmackay@ori.org.za)
Prof Digby Cyrus	CRUZ, University of Zululand (dcyrus@pan.uzulu.ac.za)
Prof Ticky Forbes	Marine & Estuarine Research (ticky@mer.co.za)

4. Motivation for the preliminary Ecological Reserve determination study on a Rapid level

The Regional office of the Department of Water Affairs and Forestry (DWAF) has received licence applications in the Siyaya and Manzimnyama catchments which could alter the flow and/or impact upon the Siyaya estuary. In order to comply with the National Water Act 36 of 1998 a Rapid Ecological Reserve Determination for the Siyaya Estuary is required.

5. Scope of Study

Conduct a preliminary determination of the Ecological Reserve on a Rapid level, based on the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods of which the documentation in currently in draft form (DWAF 2004).