DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES

MATJIES ESTUARY

RAPID RESERVE DETERMINATION STUDY

TECHNICAL COMPONENT

October 2007

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Executive summary

Introduction

The findings of the preliminary Ecological Water Requirement study on the Matjies Estuary (rapid level) are presented in this report. The study was commissioned by Chris Mulder and Associates Incorporated and the Directorate: Resource Directed Measures of the Department of Water Affairs and Forestry (DWAF) to asses the ecological flow requirements from the Matjies catchment.

The Matjies Estuary is a small Temporarily Open/Closed Estuary situated approximately 1 km east of Keurboomsstrand in Formosa Bay. The estuary is flanked by two permanently open estuaries, i.e. the large Keurbooms Estuary to the west and the Sout Estuary to the East. The Matjies Estuary is a small black water system of about 0.6 km long with a maximum width of 0.1 km at the mouth. The upper section of the estuary comprises steep slopes, which opens up about 300 m from the mouth. The highly dynamic lower reaches of the estuary meanders within the constraint of rocky headlands about 100 m apart.

Data reports prepared as part of this study is provided as appendixes to the main report:

- Appendix A Inventory of data available for Ecological Reserve Determination on the Matjies Estuary
- Appendix B Hydrological report
- Appendix C Summery of additional information and data collected
- Appendix D Proposed changes to RDM methodology for estuaries
- Appendix E Data requirements for future RDM Studies on the Matjies Estuary

Project Team

The specialist team responsible for this study was as follows:

:Role/Expertise	Lead specialists	Contact details
Workshop coordination, Report preparation and Hydrodynamics	**Dr Thomas Bornman**	Nelson Mandela Metropolitan University, tom.bornman@nmmu.ac.za
Hydrodynamics	**Ms Lara van Niekerk**	CSIR, Stellenbosch, lvnieker@csir.co.za
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Invertebrates & birds	**Prof Tris Wooldridge**	Nelson Mandela Metropolitan University, tris.wooldridge@nmmu.ac.za
Fish	**Dr Alan Whitfield**	South African Institute of Aquatic Biodiversity A.Whitfield@ru.ac.za

Other parties present at the Estuarine Specialist Workshop, held in Port Elizabeth on 29 August 2007 were:

Person	Affiliation/role	Contact details
Ms Retha Stassen	Overall Project Leader	
Mr Elliot Weni	DWAF, East London	wenie@dwaf.gov.za
Ms Tembela Bushula	DWAF, East London	bushulat@dwaf.gov.za
Ms Potrait Tshatshu	DWAF, Port Elizabeth	tshatshup@dwaf.gov.za
Ms Ntsikelelo Macozoma	DWAF, Port Elizabeth	0738944897 (Trainee)
Ms Nuette Gordon	Botany Department, NMMU	nuette.gordon@nmmu.ac.za

Assumptions and Limitations

The following assumptions and limitations must be taken into account:

- The overall confidence in the hydrological data provided to the estuarine team by Estelle van Niekerk, BKS Consulting Engineers was medium to low as runoff data were not available for calibration of the simulated runoff scenarios.

- The accuracy of predicted Abiotic States for the Matjies Estuary and the distribution of these states under Reference Conditions, Present State and Future Scenarios depend largely on the accuracy of the simulated runoff data and measured flow data recorded during the study.

- Criteria for confidence limits attached to statements in this study 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 this preliminary determination of the Ecological Reserve on the Matjies Estuary, the geographical boundaries are defined as follows (Google Earth, WGS 1984):

- **Downstream boundary:** Estuary mouth (23°28'11.09"E; 34°0'10.02"S) (indicated by the number 1 in Plate 2)

- **Upstream boundary:** Approximately 0.6 km upstream of the mouth (23°28'12.38"E; 33°59'55.47"S) (indicated by the number 2 in Plate 2)

- **Lateral boundaries:** 5 m contour above MSL along the banks, a delineation that could be readily referenced from an ortho-photograph of the area.

Plate 1. Regional study area

Plate 2. Geographical boundaries

Present Ecological Status (PES)

The Estuarine Health Index (EHI) scores allocated to the Matjies Estuary (Present State) were as follows:

Variable	Weight	Score	Weighted score
Hydrology	25	92	23
Hydrodynamics and mouth condition	25	75	19
Water quality	25	83	21
Physical habitat alteration	25	95	24
Habitat health score			**86**
Microalgae	20	85	17
Macrophytes	20	90	18
Invertebrates	20	90	18
Fish	20	95	19
Birds	20	90	18
Biotic Health Score			**90**
Estuarine Health Score			**89**

The Estuarine Health Index score for the Matjies Estuary, based on its Present State, is **89**, translating into a **Present Ecological Status** of a **B,** i.e. largely natural with few modifications as indicated below:

Estuarine Health Index	Present Ecological Status	General description
91 – 100	A	Unmodified, natural
76 – 90	**B**	**Largely natural with few modifications**
61 – 75	C	Moderately modified
41 – 60	D	Largely modified
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

The **Estuarine Importance** scores allocated to the Matjies Estuary were as follows:

Criterion	Weight	Score	Weighted score
Estuary Size	15	10	2
Zonal Rarity Type	10	10	1
Habitat Diversity	25	10	3
Biodiversity Importance	25	63.5	16
Functional Importance	25	20	5
Estuarine Importance Score			**26**

The overall **Estuarine Importance Score** for the Matjies Estuary, based on its Present State, is **26**, signifying that the estuary is of low to average importance, as indicated below:

Importance Score	Description
81 – 100	Highly important
61 – 80	Important
0 – 60	**Of low to average importance**

Recommended Ecological Category for Matjies Estuary

The recommended Ecological Reserve Category (ERC) represents the proposed level of protection assigned to an estuary which, in turn, is used to determine the Ecological Reserve.

For estuaries the first step is to determine the 'minimum' Ecological Reserve Category of an estuary, based on its Present Ecological Status (PES). The relationship between Estuarine Health Index Score, Present Ecological Status and Ecological Reserve Category is set out below:

Estuarine Health Index	Present Ecological Status	Description	Ecological Reserve Category
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

Note: Should the Present Status category of an estuary be either an 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 minimum Ecological Reserve Category is determined by the Present Ecological Status. The degree to which the Ecological Category needs to be elevated above the Present Ecological Status depends on the level of importance and the level of protection or desired protection of a particular estuary.

The Matjies Estuary does not fall within a protected area nor was it listed as a Desired Protected Area in the C.A.P.E. Estuaries Conservation Plan for the temperate areas of South Africa. According to the guidelines for assigning a recommended Ecological Reserve Category, the Matjies Estuary should therefore be classified as a Category B based on its Present Ecological Status (PES).

Current/desired protection status and estuary importance	Recommended Ecological Reserve 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		
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.**

* BAS = Best Attainable State

At the specialist workshop it was concluded that the pressures currently contributing to the Present State of the estuary are human disturbance in and around the estuary and flow reduction from the catchments.

Quantification of Ecological Reserve Scenarios

Simulated Monthly Runoff was supplied to the estuarine team by Estelle van Niekerk from BKS Consulting Engineers. A summary of the mean annual runoffs (MAR) of the various Simulated Monthly Runoff Scenarios used for this Rapid level determination is provided below.

NAME	DESCRIPTION	MAR (10^6 m^3/annum)	PERCENTAGE MAR REMAINING
Reference	Reference Condition	5.10	100 %
Present	Present State	4.27	83.6 %
Future Scenario 1	Reference conditions – 0.05 m^3/s abstraction	3.65	71.6 %
Future Scenario 2	Reference conditions – 0.10 m^3/s abstraction	2.59	50.7 %
Future Scenario 3	Reference conditions – 0.20 m^3/s abstraction	1.36	26.6 %
Future Scenario 4	River Class C/D	1.22	23.9 %

The hydrology is based on the following assumptions and limitations (Appendix B):

- There are no measured flow data available for the Matjies Rivers. All flow data was simulated with the WRSM2000 model.
- The simulation parameters used in this study were transferred from the Bloukrans River.
- Very little rainfall data exist in the mountainous areas.
- The confidence in the flow data is therefore of a medium level with low confidence in the low flows.
- There are approximately 14km^2 of indigenous forest, 0.3 km^2 of afforestation (cultivated) and 1.4km^2 of irrigation in the catchment.
- The Matjies River receives a small amount of water from the Sout River and some treated effluent is returned to this river. The amounts are negligible.
- There is a dam of 0.25 million m^3 just upstream of the Estuary. The dam was modelled with no abstractions from it. It was assumed that abstractions from this dam are negligible, but that the dam contribute to evaporative losses from the system.
- In the past water was abstracted just before the estuary for Keurboomsstrand. Since 2002, Keurboomstrand receives their domestic water from other sources.
- The natural MAR has decreased from a natural MAR of 5.10 million m^3 to 4.27 million m^3 in its present state.

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

Variable	Weight	Present	Runoff scenario			
			1	2	3	4
Hydrology	25	92	84	74	58	35
Hydrodynamics/mouth condition	25	75	60	40	25	60
Water quality	25	83	70	50	23	27
Physical habitat alteration	25	95	90	80	55	10
Habitat Health Score (weighted)		**86**	**76**	**61**	**32**	**18**
Microalgae	20	85	70	50	25	25
Macrophytes	20	90	75	55	30	40
Invertebrates	20	90	65	35	17	10
Fish	20	95	90	60	35	17
Birds	20	90	80	35	10	10
Biotic Health Score (weighted)		**90**	**76**	**47**	**18**	**10**
Estuarine Health Index Score		**89**	**76**	**54**	**25**	**14**
Ecological Reserve Category (ERC)		**B**	**B**	**D**	**E**	**F**

Recommended ecological flow requirement for the Matjies Estuary

The evaluation of the simulated runoff scenarios was used to derive the recommended Ecological Flow Requirement. The recommended Ecological Flow Requirement is defined as the runoff 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 ERC.

In evaluating Future Scenarios 1 to 4 it was assumed that only river inflow from the Matjies catchment will be reduced and that all other related anthropogenic activities (e.g. human disturbance) will remain at present levels.

Scenario 1 will maintain the Matjies Estuary in the recommended ERC as it differs very little in reduction of runoff from the Present State. **Scenario 1 was selected as the Recommended Ecological Flow Requirement.**

Matjies Estuary: Summary of flow distributions under Future Scenario 1

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.65	0.56	0.21	0.25	0.36	0.37	0.31	0.56	0.29	0.22	0.64	0.39
90%ile	0.50	0.45	0.20	0.23	0.27	0.30	0.25	0.28	0.17	0.17	0.33	0.33
80%ile	0.33	0.30	0.16	0.15	0.19	0.16	0.17	0.20	0.11	0.11	0.21	0.26
70%ile	0.18	0.19	0.12	0.13	0.11	0.14	0.11	0.10	0.07	0.07	0.13	0.20
60%ile	0.14	0.13	0.07	0.06	0.08	0.11	0.07	0.06	0.05	0.05	0.08	0.14
50%ile	0.11	0.10	0.06	0.05	0.07	0.08	0.04	0.02	0.03	0.03	0.05	0.12
40%ile	0.10	0.08	0.04	0.03	0.05	0.05	0.03	0.01	0.02	0.02	0.04	0.09
30%ile	0.08	0.04	0.02	0.01	0.03	0.02	0.02	0.00	0.00	0.00	0.02	0.05
20%ile	0.05	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
10%ile	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

It is expected that River Class B/C (not investigated as part of this study) will keep the Matjies Estuary in a higher ERC B than the Scenario 1 investigated in this study, as long as all baseflows and floods are allowed through.

The following recommendations should be implemented before abstraction may be considered:

- Improved flow data is required
- The exact amount of water that will be abstracted must be quantified
- Capping flows need to be investigated
- No effluent may be pumped back into the river

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Terminology and acronyms

CSIR	Council for Scientific and Industrial Research
DWAF	Department of Water Affairs and Forestry
EHI	Estuarine Health Index
ERC	Ecological Reserve Category
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Marine and Coastal Management
MSL	Mean Sea Level
NMMU	Nelson Mandela Metropolitan University
PES	Present Ecological Status
PPT	Parts Per Thousand
RDM	Resource Directed Measures
REI	River Estuary Interface
RQO	Resource Quality Objectives
SAIAB	South African Institute of Aquatic Biodiversity

1 Introduction

1.1 Background

The findings of the preliminary Ecological Water Requirement study on the Matjies Estuary (rapid level) are presented in this report. The study was commissioned by Chris Mulder and Associates Incorporated and the Directorate: Resource Directed Measures of the Department of Water Affairs and Forestry (DWAF) to asses the ecological flow requirements from the Matjies catchment.

1.2 Project Team

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Workshop coordination, Report preparation and Hydrodynamics	**Dr Thomas Bornman**	Nelson Mandela Metropolitan University, tom.bornman@nmmu.ac.za
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Ms Ntsikelelo Macozoma	DWAF, Port Elizabeth	0738944897 (Trainee)
Ms Nuette Gordon	Botany Department, NMMU	nuette.gordon@nmmu.ac.za

1.3 Overview of Determination of Ecological Reserve for Estuaries: Process

The preliminary determination of the Ecological Water Requirements for estuaries can be conducted on different levels, namely:

- Comprehensive;
- Intermediate; and
- Rapid.

The procedures are discussed in detail in *Resource directed measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004). A summary of the procedures used for the Rapid level determination for estuaries are illustrated in the Figures 1 and 2 below:

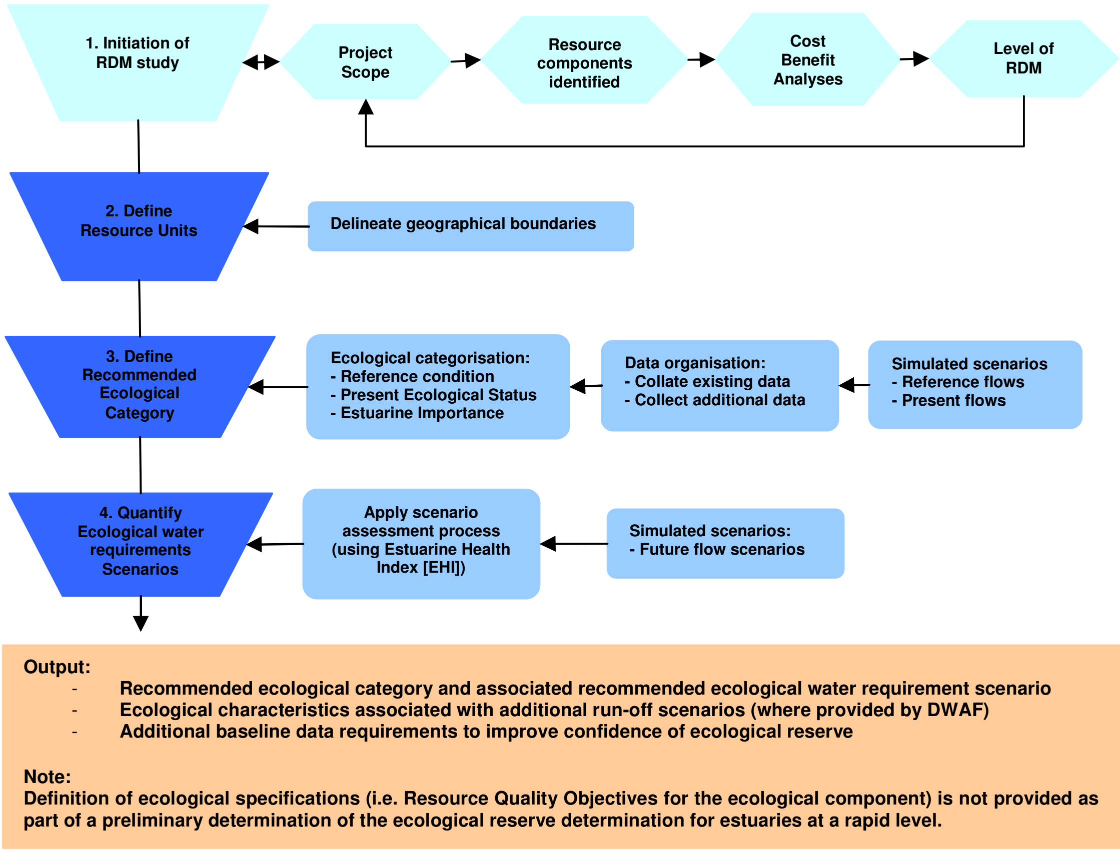


Figure 1. *Procedures for a Rapid Ecological Reserve Determination on estuaries, in context of the broader RDM process) (modified from DWAF, 2004)*

A summary of the human resource requirements to conduct a Rapid level determination are illustrated in Figure 2.

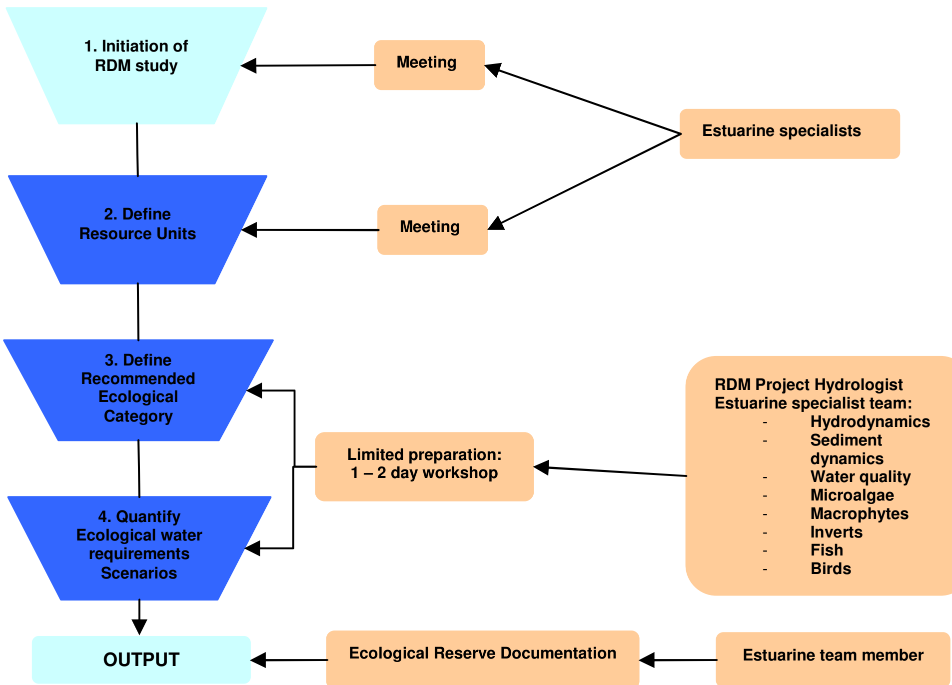


Figure 2. *Indication of human resource requirements for a Rapid Ecological Reserve determination on estuaries (modified after DWAF, 2004).*

1.4 Assumptions and limitations

The following assumptions and limitation must be taken into account:

- The overall confidence in the hydrological data provided to the estuarine team by Estelle van Niekerk, BKS Consulting Engineers was medium to low as runoff data were not available for calibration of the simulated runoff scenarios.

- The accuracy of predicted Abiotic States for the Matjies Estuary and the distribution of these states under Reference Conditions, Present State and Future Scenarios depend largely on the accuracy of the simulated runoff data and measured flow data recorded during the study.

- Criteria for confidence limits attached to statements in this study 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%)

2 Definition of Resource Unit

2.1 Introduction

The Matjies River is a small coastal river with its catchment lying to the north and east of Keurbooomstrand. The catchment area is 24 km^2. The total river length is 13.4 km, with the major tributary the Buffels River. The Mean Annual Runoff is estimated at 5.1 x 10^6 m^3 (van Niekerk 2007, Appendix B). The natural MAR has decreased to 4.27 million m^3 in its present state.

This region exhibits neither a summer nor a winter rainfall characteristic. Rain is experienced throughout the year with the highest precipitation during spring (September to November) and again during late summer (February and March). Rainfall higher than 1000 mm can be expected in the mountain areas. The rainfall decreases from east to west. The Matjies River receives a small amount of water from the Sout River and some treated effluent is returned to this river. The amounts are negligible.

The Matjies Estuary is a small black water system of about 0.6 km long with a maximum width of 0.1 km at the mouth. The upper section of the estuary comprises steep slopes, which opens up about 300 m from the mouth. The highly dynamics lower reaches of the estuary meanders within the constraint of rocky headlands about 100 m apart.

2.2 Geographical Boundaries

For the purposes of this preliminary determination of the Ecological Reserve on the Matjies Estuary, the geographical boundaries are defined as follows (Google Earth, WGS 1984):

- **Downstream boundary:** Estuary mouth (23°28'11.09"E; 34°0'10.02"S)
- **Upstream boundary:** Approximately 0.6 km upstream of the mouth (23°28'12.38"E; 33°59'55.47"S).
- **Lateral boundaries:** 5 m contour above MSL along the banks, a delineation that could be readily referenced from an ortho-photograph of the area.

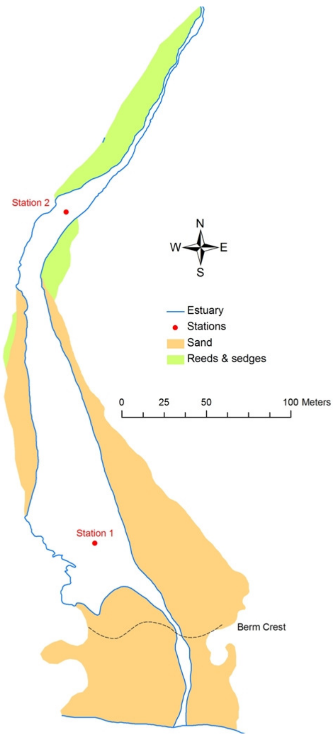


Plate 3. Geographical boundaries and size of the Matjies Estuary

3 Ecological Reserve Categorisation

3.1 Typical Abiotic States

Based on very little data three Abiotic States were identified for the Matjies Estuary, of which the occurrence and duration varies depending on river inflow rate. These states are:

State	Flows ($m^3.s^{-1}$)
State 1: Mouth Open	> 0.1
State 2: Intermitted Mouth Closure (<1 day)	0.1-0.03
State 3: Mouth Closure (> week)	< 0.03

As very little reliable data were available on the river inflow into the estuary a conceptual model was developed for the abiotic states based on the surface areas measured during this study. The assumptions and limitation of the Matjies Estuary's conceptual model are the following:

- The simulated average monthly flows are of medium confidence, with the baseflows judged to be of low confidence as there were no inflow data available to calibrate the data set. As baseflow drives mouth behaviour, the overall confidences in the study are low and the hydrology could not be used to assist in determining the Abiotic states.

- No data were available for seepage through the sand berm at the mouth. This could be highly variable depending on the width of the berm and the head of water behind the berm.

- No data was available on berm and water level relative to mean sea level (MSL).

- Most aerial photographs and observations shows that the mouth of the Matjies Estuary is predominantly open.

- The mouth of the Matjies Estuary was closed in April 2007 during high wave conditions.

- Surface data collected during this study indicated that the surface area of the Matjies Estuary varies significantly, depending on the water level, infilling of marine sediment and berm height. More detailed information is needed on relative water levels and surface area variability to accurately determine flow requirements of the Matjies Estuary.

Date	Surface area (m^2)
06-Dec-06	4565.81
11-Apr-07	6936.13
01-May-07	3919.01
Average	**5140.31**

- The Matjies Estuary comprises a relatively small volume as evident by its surface area. It can therefore fill up relatively easily after a mouth closure event and breach through overtopping.

- Based on the surface area of 5100 m^2 and following a precautionary approach it is estimated that the Matjies Estuary requires a flow of more than 0.1 $m^3.s^{-1}$ to facilitate mouth breaching within about a day of mouth closure. This flow will compensate for evaporative and seepage losses and cater for increases in water level (> 1 m) and surface areas not investigated in detail during this study.

- It is estimated that at flows less than 0.03 $m^3.s^{-1}$ the system would remain closed for a week or more depending on evaporative seepage and losses, rate of berm build-up, height of the sand berm, volume of water retained in the system at mouth closure and surface area of the system.

- For the purpose of scoring the future scenarios it is assumed that all off-take of flows occurs through off-channel developments. Any in-channel development could have an impact on the sediment balance of the system.

Abiotic State 1: Mouth Open

Typical flow patterns:

Average monthly flows greater than 0.1 $m^3.s^{-1}$.

Confidence: Low

State of the mouth:

The mouth is open.

Confidence: High

Floodplain inundation patterns:

This state results in inundation of the flood plain under flood conditions for short periods at a time (days) during the peak flood event.

Confidence: Low

Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide):

As the system is perched tidal variation is constricted. There are no data available but tidal variation on average should be < 1 m for a spring tide and < 0.3 m for a neap tide.

Tidal damping will occur during peak flood events.

Confidence: Low

Retention times of water masses:

Retention time is very short (less than 1 week).

Confidence: Low

Salinity distributions in the estuary:

During high flow events the system will be freshwater dominated for the duration of the event, lasting a few days at a time.

After the high flow event, saline water will penetrate the system on the high tide (> 50 % water column marine dominated) but be eroded on the low tide resulting in a highly stratified estuary, with bottom waters > 15 ppt and the surface waters less than 10 ppt.

As flow decreases towards the lower flow ranges, bottom waters will be more than 20 ppt in the deeper areas, while surface water will be between 20 ppt and 10 ppt depending on the inflow and state of the tide.

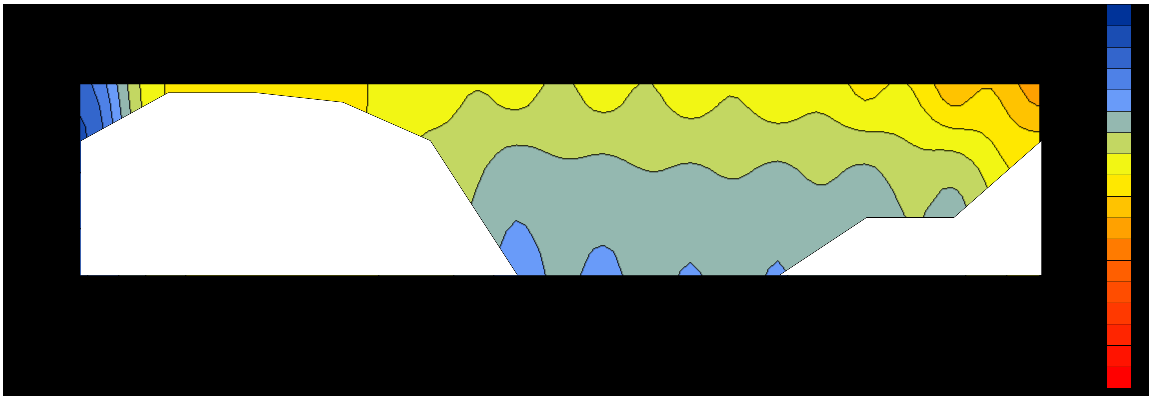


Figure 3. *Salinity profile of the Matjies Estuary*

Confidence: Medium

System variables (Temperature, pH, dissolved oxygen and turbidity):

Temperature: Temperatures in the Matjies Estuary are expected to show a strong seasonal pattern, with summer temperature ranging between 20 – 25°C and winter temperature between 13 and 16°C.

pH: pH in the Matjies Estuary is expected to remain within the range 7.0 to 8.5. The lower ranges being associated with the fresher (upper) reaches and higher ranges with the more saline (lower) reaches.

Dissolved oxygen: The Matjies Estuary should generally be well-oxygenated (>7 $mg.l^{-1}$) because the estuary is shallow, does not appear to carry a heavy load of organic matter and is flushed rapidly during the fresh phase.

Turbidity: Turbidity in the Matjies Estuary is generally expected to be low. However, during periods of higher freshwater inflow, turbidity levels can be expected to increase throughout the estuary. Results from December 2006 suggest that secchi depth should decrease to <40 cm during high flow events.

Confidence: Medium

Nutrients:

Dissolved Inorganic Nitrogen-N (DIN): The estuary will be dominated by freshwater during a high flow event or stratified at lower flows. DIN is likely to be <700 $\mu g.l^{-1}$ (50 µM) throughout the estuary.

Dissolved reactive phosphorus-P: The estuary will be dominated by freshwater during a high flow event. Dissolved reactive phosphorus is likely to be <40 $\mu g.l^{-1}$ (1.3 µM) throughout the estuary.

Dissolved reactive silicate-Si: The estuary will be dominated by freshwater during a high flow event. Dissolved reactive silicate is likely to be <6000 $\mu g.l^{-1}$ (214 µM) throughout the estuary.

Confidence: Medium/Low

State 2: Intermitted Mouth Closure (< 1 day)

Typical flow patterns:

Average monthly flows between 0.03 and 0.10 $m^3.s^{-1}$.

Confidence: Low

***State of the mouth*:**

The mouth is open, but can close for about a day during high wave conditions before breaching due to overtopping.

Confidence: Low

***Floodplain inundation patterns*:**

This state does not result in inundation of the flood plain. Some back flooding may occur at low levels due to intermittent mouth closure

Confidence: Low

***Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide)*:**

As the system is perched tidal variation is constricted. There are no data available but tidal variation on average should be < 1 m for a spring tide and < 0.3 m for a neap tide.

During the brief mouth closure events their will be no tidal variation.

Confidence: Low

Retention times of water masses:

Retention time is less than a week, with some deeper areas taking up to two weeks.

Confidence: Low

***Salinity distributions in the estuary*:**

Saline water will penetrate the system on the high tide (> 80 % water column marine dominated), but be somewhat eroded on the low tide as the system is very shallow.

The estuary will become stratified, with bottom waters >25 ppt in the deeper areas 0.3 - 0.4 km from the mouth. Surface water will be between 20 ppt and 10 ppt depending on the inflow and state of the tide.

Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen):

Temperature: Temperatures in the Matjies Estuary are expected to show a strong seasonal pattern, with summer temperature ranging between 20 – 25°C and winter temperature between 13 and 16°C.

pH: pH in the Matjies Estuary is expected to remain within the range 7.0 to 8.5. The lower ranges being associated with the fresher (upper) reaches and higher ranges with the more saline (lower) reaches.

Dissolved oxygen: The Matjies Estuary should generally be well-oxygenated (>7 $mg.l^{-1}$) because the estuary is shallow and does not appear to carry a heavy load of organic matter. Well-oxygenated marine water is likely to replenish water in deeper pools (~2 m deep) due to tidal exchange.

Turbidity: Turbidity in the Matjies Estuary is expected to be low; secchi depth > water column depth. However, during periods of higher freshwater inflow, turbidity levels can be expected to increase throughout the estuary. Results from December 2006 suggest that secchi depth could decrease to <40 cm in the upper reaches during periods of elevated river flow (flows approaching 1.0 $m^3.s^{-1}$).

Confidence: Medium

Nutrients

Dissolved Inorganic Nitrogen-N (DIN): The estuary will be strongly stratified. DIN is likely to be <700 $\mu g.l^{-1}$ (50 µM) throughout the estuary.

Dissolved reactive phosphorus-P: The estuary will be strongly stratified. Dissolved reactive phosphorus is likely to be <40 $\mu g.l^{-1}$ (1.3 µM) throughout the estuary.

Dissolved reactive silicate-Si: The estuary will be strongly stratified. Dissolved reactive silicate is likely to be <6000 $\mu g.l^{-1}$ (214 µM) throughout the estuary.

Confidence: Medium/Low

Abiotic State 3: Mouth Closure (> 1 week)

Typical flow patterns:

Average monthly flows less than 0.03 $m^3.s^{-1}$.

Confidence: Low

State of the mouth:

The mouth is closed for more than a week depending on the inflow.

Confidence: Low

Flood plain inundation patterns:

This state can cause inundation of the flood plain during period of prolonged closure.

Confidence: Low

Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide):

As the system is very perched during this state tidal variation is constricted. There are no data available but tidal variation on average should be < 0.5 m for a spring tide and < 0.2 m for a neap tide.

Confidence: Low

Retention times of water masses:

Retention time is more than a week, with some deeper areas taking up to month or more depending on duration of mouth closure.

Confidence: Low

Salinity distributions in the estuary:

In the initial phase of this state the estuary is highly stratified, with bottom waters ~ 30 ppt in the deeper areas 0.3 - 0.4 km from the mouth. Surface water will be brackish (between 25 ppt and 10 ppt) depending on the inflow and state of the tide. During period of prolonged closure with no river inflow the stratification will break down to a relatively homogenous brackish system (between 15 and 25 ppt).

If there is river inflow during period of prolonged closed mouth conditions, the estuary will become fresher as the increase in berm height would restrict interaction with the sea, while seepage losses would decrease the salinity in the system. Some overwash during very high tides will replenish the salinity in the estuary and assist in maintaining the brackish conditions in the system (10 – 15 ppt).

Confidence: Low

System variables (Temperature, pH, dissolved oxygen and turbidity):

Temperature: Temperatures in the Matjies Estuary are expected to show a strong seasonal pattern, with summer temperature ranging between 20 – 25°C and winter temperature between 13 and 16°C.

pH: pH in the Matjies Estuary is expected to remain within the range 7.0 to 8.5. The lower ranges being associated with the fresher (upper) reaches and higher ranges with the more saline (lower) reaches.

Dissolved oxygen: The Matjies Estuary should generally be well-oxygenated (>7 $mg.l^{-1}$) because the estuary is shallow and does not appear to carry a heavy load of organic matter. Well-oxygenated marine water is likely to replenish water in deeper pools (~2 m deep) due to tidal exchange.

Turbidity: Turbidity in the Matjies Estuary is expected to be low; secchi depth > water column depth. However, during periods of higher freshwater inflow, turbidity levels can be expected to increase throughout the estuary. Results from December 2006 suggest that secchi depth could decrease to <40 cm in the upper reaches during periods of elevated river flow (flows approaching 1.0 $m^3.s^{-1}$).

Confidence: Medium

Nutrients:

Dissolved Inorganic Nitrogen-N (DIN): The estuary likely to be strongly stratified to brackish. DIN is likely to be <700 $\mu g.l^{-1}$ (50 µM) throughout the estuary.

Dissolved reactive phosphorus-P: The estuary will be strongly stratified. Dissolved reactive phosphorus is likely to be <40 $\mu g.l^{-1}$ (1.3 µM) throughout the estuary.

Dissolved reactive silicate-Si: The estuary will be strongly stratified. Dissolved reactive silicate is likely to be <3000 $\mu g.l^{-1}$ (107 µM) throughout the estuary.

Confidence: Low

3.2 Description of Present State

3.2.1 Abiotic Components

Seasonal variability in river inflow

Monthly simulated runoff data for the Present State is provided in Table 1. A summary of the occurrences of flow distributions (average monthly flows in $m^3.s^{-1}$) for the Present State of the Matjies Estuary, derived from the 60-year simulated data set, is provided in Table 1 below:

Table 1. *Summary of flow distributions for the Present State*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.70	0.61	0.22	0.26	0.41	0.41	0.35	0.61	0.32	0.27	0.69	0.42
90%ile	0.55	0.50	0.21	0.25	0.31	0.35	0.28	0.32	0.22	0.21	0.38	0.36
80%ile	0.34	0.31	0.15	0.16	0.21	0.19	0.20	0.24	0.14	0.16	0.25	0.28
70%ile	0.20	0.22	0.11	0.13	0.12	0.17	0.14	0.14	0.12	0.12	0.18	0.23
60%ile	0.16	0.14	0.07	0.06	0.09	0.13	0.10	0.09	0.10	0.09	0.12	0.17
50%ile	0.13	0.11	0.05	0.04	0.08	0.10	0.07	0.05	0.07	0.07	0.08	0.14
40%ile	0.11	0.09	0.03	0.02	0.06	0.07	0.05	0.04	0.05	0.06	0.07	0.12
30%ile	0.10	0.04	0.02	0.00	0.03	0.04	0.03	0.03	0.03	0.03	0.05	0.07
20%ile	0.07	0.02	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.04	0.04
10%ile	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
1%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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 1.0 $m^3.s^{-1}$. The 95%ile indicates that there is a 2.2 % decrease in the floods to the estuary.

Confidence: Low

Present sediment processes

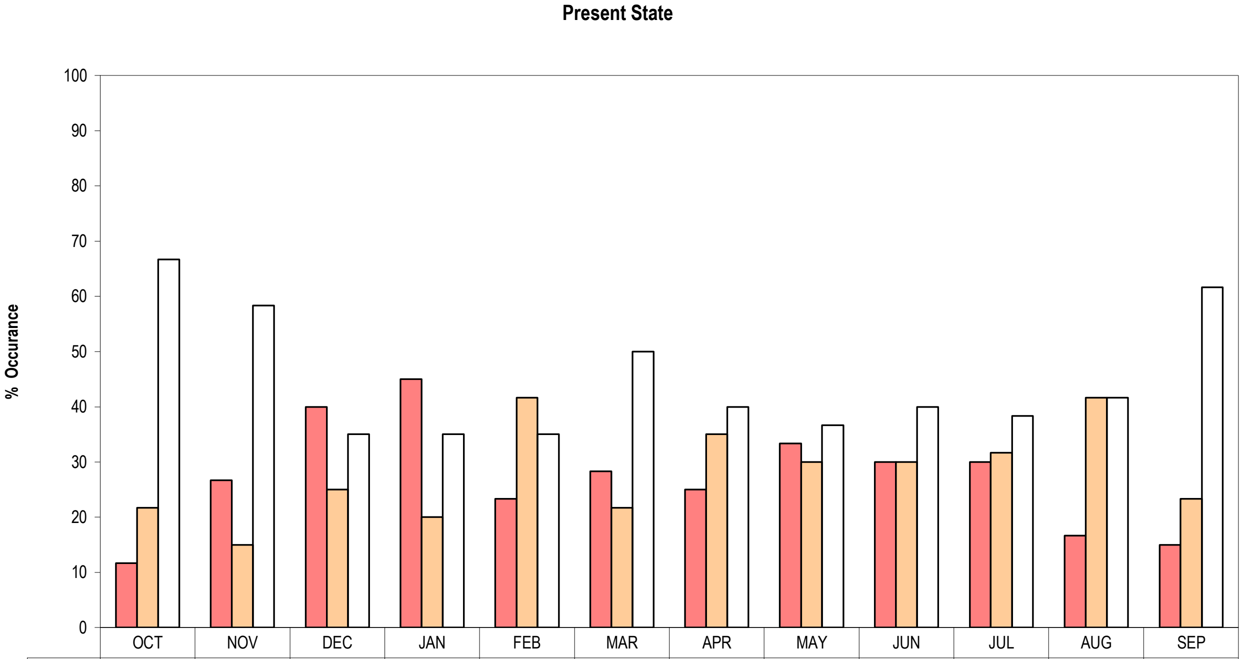
The hydrological data indicates that the magnitude and occurrence of major floods has hardly been reduced. This also means that the flushing of sediments during such floods has hardly been reduced. It is therefore likely that the sedimentation in the estuary is not much different from what it was under natural conditions.

Confidence: Low

Table 2. *Simulated monthly volumes in the Matjies Estuary for the Present State in* $m^3.s^{-1}$.

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.82	0.31	0.00	0.00	0.02	0.05	0.07	1.22	0.57	0.12	0.17	0.29	0.30
1935	0.31	0.26	0.15	0.04	0.06	0.13	0.05	0.20	0.08	0.26	0.09	0.18	0.15
1936	0.22	0.35	0.21	0.03	0.07	0.18	0.03	0.00	0.00	0.11	0.04	0.23	0.12
1937	0.13	0.04	0.18	0.18	0.01	0.07	0.07	0.01	0.00	0.00	0.02	0.05	0.06
1938	0.07	0.23	0.16	0.00	0.66	0.47	0.11	0.00	0.00	0.14	0.36	0.34	0.21
1939	0.13	0.08	0.04	0.14	0.21	0.11	0.03	0.01	0.00	0.07	0.01	0.08	0.08
1940	0.03	0.00	0.00	0.04	0.00	0.01	0.32	0.10	0.08	0.06	0.01	0.05	0.06
1941	0.37	0.18	0.21	0.25	0.07	0.04	0.00	0.33	0.15	0.06	0.04	0.03	0.14
1942	0.10	0.04	0.05	0.27	0.08	0.06	0.03	0.00	0.02	0.03	0.09	0.40	0.10
1943	0.19	0.53	0.38	0.03	0.05	0.04	0.01	0.81	0.32	0.17	0.07	0.16	0.23
1944	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.24	0.23	0.09	0.04	0.02	0.06
1945	0.03	0.00	0.02	0.06	0.08	0.36	0.11	0.00	0.00	0.03	0.06	0.03	0.07
1946	0.10	0.02	0.00	0.12	0.08	0.23	0.13	0.13	0.10	0.21	0.07	0.14	0.11
1947	0.09	0.13	0.01	0.06	0.06	0.03	0.20	0.05	0.00	0.00	0.00	0.08	0.06
1948	0.13	0.12	0.04	0.14	0.11	0.00	0.03	0.06	0.00	0.00	0.00	0.05	0.06
1949	0.00	0.50	0.11	0.00	0.00	0.00	0.00	0.02	0.00	0.12	0.21	0.16	0.09
1950	0.21	0.64	0.32	0.41	0.16	0.01	0.00	0.05	0.10	0.32	0.37	0.36	0.24
1951	0.09	0.00	0.00	0.24	0.19	0.01	0.06	0.03	0.03	0.04	0.25	0.59	0.13
1952	0.22	0.11	0.02	0.00	0.05	0.00	0.00	0.00	0.20	0.16	0.36	0.29	0.12
1953	0.76	0.42	0.09	0.00	0.00	0.05	0.05	0.30	0.16	0.22	0.70	0.33	0.26
1954	0.03	0.16	0.02	0.14	0.77	0.22	0.05	0.02	0.02	0.01	0.00	0.00	0.12
1955	0.13	0.67	0.15	0.00	0.09	0.20	0.06	0.34	0.13	0.01	0.01	0.28	0.17
1956	0.55	0.26	0.06	0.02	0.10	0.19	0.06	0.02	0.12	0.05	0.18	0.23	0.15
1957	0.10	0.00	0.03	0.01	0.00	0.25	0.16	0.21	0.10	0.01	0.16	0.09	0.09
1958	0.10	0.00	0.07	0.26	0.08	0.16	0.35	0.24	0.06	0.11	0.28	0.13	0.15
1959	0.17	0.05	0.00	0.16	0.03	0.10	0.24	0.14	0.08	0.18	0.07	0.17	0.12
1960	0.04	0.10	0.22	0.20	0.17	0.34	0.12	0.14	0.05	0.05	0.07	0.04	0.13
1961	0.10	0.02	0.01	0.09	0.06	0.37	0.19	0.03	0.01	0.00	0.80	0.30	0.17
1962	0.68	0.39	0.03	0.06	0.03	0.60	0.28	0.07	0.03	0.20	0.08	0.03	0.21
1963	0.07	0.00	0.10	0.16	0.10	0.08	0.10	0.02	0.19	0.07	0.18	0.53	0.13
1964	0.17	0.14	0.01	0.00	0.00	0.17	0.20	0.13	0.10	0.08	0.03	0.02	0.09
1965	0.41	0.61	0.15	0.23	0.14	0.00	0.02	0.03	0.01	0.00	0.28	0.18	0.17
1966	0.01	0.02	0.05	0.04	0.10	0.29	0.74	0.60	0.20	0.12	0.06	0.24	0.21
1967	0.07	0.10	0.06	0.00	0.04	0.17	0.08	0.06	0.36	0.12	0.08	0.24	0.12
1968	0.19	0.23	0.03	0.03	0.09	0.14	0.06	0.00	0.12	0.08	0.04	0.02	0.09
1969	0.13	0.04	0.00	0.01	0.33	0.08	0.00	0.00	0.00	0.01	0.42	0.17	0.10
1970	0.18	0.03	0.36	0.11	0.32	0.18	0.28	0.32	0.13	0.52	0.70	0.24	0.28
1971	0.07	0.33	0.11	0.05	0.41	0.16	0.02	0.03	0.07	0.12	0.18	0.06	0.13
1972	0.01	0.00	0.00	0.00	0.03	0.11	0.12	0.04	0.05	0.03	0.04	0.11	0.05
1973	0.04	0.21	0.03	0.21	0.14	0.19	0.07	0.21	0.08	0.01	0.22	0.14	0.13
1974	0.03	0.12	0.01	0.16	0.24	0.14	0.05	0.00	0.04	0.07	0.08	0.40	0.11
1975	0.12	0.10	0.21	0.04	0.06	0.18	0.03	0.06	0.04	0.19	0.08	0.08	0.10
1976	0.70	0.38	0.07	0.00	0.41	0.41	0.09	0.32	0.14	0.02	0.09	0.12	0.23
1977	0.13	0.20	0.06	0.00	0.00	0.00	0.02	0.03	0.10	0.03	0.12	0.06	0.06
1978	0.11	0.13	0.19	0.13	0.04	0.00	0.26	0.15	0.06	0.24	0.55	0.28	0.18
1979	0.05	0.00	0.00	0.04	0.00	0.00	0.04	0.01	0.12	0.04	0.06	0.15	0.04
1980	0.16	0.06	0.14	0.42	0.21	0.76	0.40	0.97	0.42	0.08	0.69	0.27	0.38
1981	0.43	0.18	0.06	0.00	0.03	0.11	0.80	0.25	0.04	0.11	0.05	0.17	0.19
1982	0.11	0.00	0.00	0.00	0.10	0.03	0.00	0.05	0.22	0.55	0.23	0.15	0.12
1983	0.15	0.11	0.08	0.00	0.03	0.09	0.01	0.00	0.01	0.01	0.00	0.02	0.04
1984	0.00	0.02	0.01	0.13	0.22	0.08	0.15	0.04	0.05	0.10	0.03	0.00	0.07
1985	0.45	0.27	0.11	0.26	0.04	0.00	0.00	0.00	0.00	0.00	0.24	0.13	0.13
1986	0.42	0.15	0.00	0.00	0.11	0.07	0.30	0.09	0.07	0.02	0.09	0.42	0.14
1987	0.13	0.00	0.00	0.00	0.00	0.01	0.23	0.25	0.14	0.06	0.12	0.07	0.08
1988	0.09	0.01	0.02	0.00	0.00	0.00	0.16	0.04	0.00	0.06	0.01	0.02	0.03
1989	0.56	0.73	0.14	0.00	0.30	0.07	0.17	0.12	0.22	0.08	0.07	0.04	0.21
1990	0.15	0.14	0.00	0.01	0.23	0.10	0.00	0.03	0.03	0.01	0.04	0.02	0.06
1991	0.25	0.06	0.13	0.02	0.25	0.16	0.05	0.10	0.07	0.15	0.35	0.13	0.14
1992	0.72	0.50	0.05	0.02	0.00	0.00	0.05	0.03	0.11	0.06	0.05	1.02	0.22
1993	0.33	0.11	0.13	0.07	0.09	0.11	0.08	0.08	0.07	0.08	0.12	0.15	0.12

1: Open	>0.1	2: Closed <1 day	0.03-0.1	3: Closed(> week)	< 0.03



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	11.7	26.7	40.0	45.0	23.3	28.3	25.0	33.3	30.0	30.0	16.7	15.0
State 2	21.7	15.0	25.0	20.0	41.7	21.7	35.0	30.0	30.0	31.7	41.7	23.3
State 1	66.7	58.3	35.0	35.0	35.0	50.0	40.0	36.7	40.0	38.3	41.7	61.7

Figure 4. *Occurrence of Abiotic states during the Present State*

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):

None

Confidence: High

***Discharges into estuary affecting water quality*:**

Small amounts of treated effluent are discharged in the Matjies River

Confidence: Medium

Human exploitation (consumptive or non-consumptive):

Disturbance

Confidence: Medium

Artificial mouth breachings:

None

Confidence: Low

3.2.2 Biotic Components

MICROALGAE

Phytoplankton

Seawater outside the estuary was dominated by flagellates (26% relative abundance) and diatoms (73%) and biomass (measured using chl-a as an index) ranged from 0.2 $\mu g.l^{-1}$ (Dec 06) to 6.5 $\mu g.l^{-1}$ (Apr 07). The phytoplankton in the estuary was dominated by flagellates (>80%; possibly a mixture of heterotrophic and autotrophic cells) with some diatoms (<16%) and dinoflagellates (<10%). During the open phase, based on Dec 06 data, phytoplankton chl-a was low and ranged from 0.3 to 4.8 $\mu g.l^{-1}$. In April 2007, which represents the intermittently open/closed phase, chl-a was slightly higher and ranged from 0.2 to 13.1 $\mu g.l^{-1}$. Phytoplankton cell density within the estuary was generally low (<1000 cells/ml). Phytoplankton biomass was consistently low in the river water (0.2 to 1.4 µg $chl\text{-}a.l^{-1}$) and was dominated by a small (<2 µm) chlorophyte that was present in high densities (>70000 $cells.ml^{-1}$). If chlorophyte numbers are ignored, then flagellates (69%), diatoms (3%) and cyanobacteria (27%) were present in the river water too.

Benthic microalgae

Average benthic chl-a was relatively low in the Matjies estuary. During the open phase (Dec 06) chl-a ranged from 0.4 to 10.0 $\mu g.g^{-1}$ sediment, reaching a maximum subtidally at site 2 (350 m from mouth). During the closed/intermittently open phase (April 2007), chl-a was slightly higher and ranged from 4.6 to 15.4 $\mu g.g^{-1}$ sediment. The estuary is generally dominated by coarse marine sediment episammic diatoms are likely to dominate the benthic microalgae.

Confidence: Medium

MACROPHYTES

The estuary is short (0.6 km) and characterised by steep slopes. There is limited intertidal area and the available habitat for macrophytes is thus small. Sediment movement and channel migration in the lower and mouth reaches of the estuary prevent the establishment of permanent macrophyte areas. Brakgras, *Sporobolus virginicus* occurs here as well as the sedge *Ficinia nodosa.* Brakgras is common along the margins of salt marshes or in dune slacks.

The dominant macrophyte in the Matjies Estuary is common reed, *Phragmites australis*. This is a cosmopolitan plant capable of growing quickly in favourable environments and producing large clumps of thick rhizomes. It has periods of die-back in winter or when under stress. Other plants present include sharp rush, *Juncus kraussii*, buffalo grass, *Stenotaphrum secundatum* and brassbuttons, *Cotula coronopifolia*. Most aerial photographs and observations shows that the mouth of the Matjies Estuary is predominantly open which indicates that the estuary is perched as the vegetation reflects a brackish (< 20 ppt) system.

Sediment movement and channel migration in the lower and mouth reaches of the estuary prevent the establishment of permanent submerged macrophyte beds. Filamentous macroalgae may be present during intermittently closed and closed phases.

Confidence: Medium

INVERTEBRATES

Zooplankton

There are no available data on the zooplankton and it was not possible to deploy zooplankton nets. However, because of the shallow nature of the system and frequent shift in salinity (because of the relatively small volume of water in the estuary and inflow patterns of fresh and saltwater), zooplankton biomass is likely to be low. The uppermost reaches are also likely to be colonized by freshwater associated species, different to those near the mouth.

Benthic invertebrates

The sandy substrata characterizing the Matjies Estuary is relatively mobile and observations suggest that the lower channel is constantly changing in shape and position. This is reflected in the benthic community which is composed of relatively few species (mostly amphipods) that are large and mobile. Chironomid larvae were also present, mostly in the upper reaches. Two species of *Grandidierella* commonly found in other South African estuaries were the most important species, but maximum densities were relatively low. Abundance levels between the two visits also differed significantly.

Larger invertebrates
None observed.

Confidence: Medium

FISH

A total of nine fish species from five families have been recorded from the Matjies Estuary. Two of these species are dependent on estuaries for breeding purposes, and include resident taxa such as the Knysna sandgoby *Psammogobius knysnaensis* and prison goby *Caffrogobius gilchristi*. A total of three marine species, including the Cape stumpnose *Rhabdosargus holubi* and Cape moony *Monodactylus falciformis*, are dependent on estuaries as nursery areas. A further two marine species (striped mullet *Liza tricuspidens* and southern mullet *Liza richardsonii*) are at least partially dependent on estuaries as nursery areas. One catadromous species, the freshwater mullet *Myxus capensis* was recorded throughout the estuary. The freshwater Eastern Cape redfin *Pseudobarbus afer* was found in the middle reaches of the system where salinities were <5 psu. No stenohaline marine species were recorded in the estuary due to the low salinities and lack of a permanent connection to the sea.

The Matjies Estuary supports an ichthyofauna dominated by 0+ juvenile mugilids (mullet) that utilize the system as a nursery area. Most of the fish species found in the estuary are associated with the benthos, either the microphytobenthos in the case of detritivorous mugilids or the zoobenthos in the case of carnivorous sparids and gobies. Poor planktonic food resources as a result of clear, nutrient poor river inflow have contributed to the apparent absence of planktivorous fish species within this estuary.

Confidence: Medium

BIRDS

Kelp gulls were the only species observed at the time of visiting the estuary (up to 24 at any one time). Observations suggest that they use the estuary as a roosting and bathing area. No waders were observed (although species such as White-fronted Sandplover are likely to spend time near the mouth). Upstream of the beach and in the gorge, other birds associated with the estuary are also likely to occur (e.g. Cape Wagtail, Pied and Giant Kingfishers).

Confidence: Medium

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)	**<u>Microalgae</u>:** Average microalgal biomass is likely to be lowest during the open phase when river flow and tidal exchange keeps water residence time within the estuary to a minimum. Confidence: Medium
	<u>Macrophytes</u>: An open mouth usually creates intertidal areas where salt marsh can establish. However the steep banks and perched nature of the Matjies Estuary limits the establishment of intertidal salt marsh. The open mouth condition is important as this ensures tidal flushing and introduces saline water maintaining brackish conditions in the estuary. Confidence: Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Invertebrates: An open mouth condition will reduce water volume and benthic area in the estuary, leading to a reduction in biomass. The open mouth will also increase lateral movement of the channel, favouring only larger motile organisms that are capable of relocation as the position of the mouth changes. Confidence: Medium
	Fish: An open mouth will facilitate recruitment of estuary-associated marine taxa but the limited water area and invertebrate food resources will restrict the diversity and biomass of fishes that can be supported by this small system. Confidence: Medium
	Birds: An open mouth will lead to a reduction in food resources (invertebrates and fish), that in turn lead to fewer birds utilizing the system. Confidence: Medium
Exposure of inter-tidal areas during low tide	**Microalgae:** The average chl-*a* content of the intertidal sediment (6.7 ± 1.6 $\mu g.g^{-1}$) was only slightly higher than that measured in the subtidal sediment (6.2 ± 1.0 $\mu g.g^{-1}$) during the study so no significant impact is expected. Confidence: Medium
	Macrophytes: This is usually essential to the functioning of intertidal salt marsh. However this habitat is absent from the Matjies Estuary. Confidence: Medium
	Invertebrates: The intertidal area is too dynamic, and organisms migrate to the subtidal as water levels change. No burrowing macrofauna was observed (e.g. sandprawns). Further upstream, the banks are relatively steep, and very little intertidal area becomes exposed. Confidence: Medium
	Fish: Exposure of intertidal areas during low tide is a natural phenomenon and one which fish species are well adapted to. The perched nature of the Matjies Estuary means that tidal fluctuations are limited. Confidence: Medium
	Birds: No change in terms of food availability likely to influence the avifauna, although a potentially larger roosting area becomes exposed. Confidence: Medium
Sediment processes and characteristics	**Microalgae:** Sediment processes are similar to the reference state so it is unlikely that there has been any change in the benthic microalgal community. Confidence: Low

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Macrophytes: A dynamic sediment environment prevents the establishment of macrophytes especially submerged macrophytes such as *Ruppia cirrhosa* and *Potamogeton pectinatus*. Sedimentation and shallowing of the estuary will promote reed expansion resulting in a loss of open water habitat. Floods are important in flushing out sediment and preventing reed encroachment in the main water channel. Confidence: Medium
	Invertebrates: Similar to the reference state and no likely change to the invertebrate community. Confidence: Medium
	Fish: Similar to the reference state and therefore little or no likely change to the fish community. Confidence: Medium
	Birds: Similar to the reference state and no likely change to the bird community. Confidence: Medium
Retention times of water masses	**Microalgae:** Microalgal biomass is determined by flow velocity and retention time. Retention time between the three states varies from <1 week (State 1) to 1 week/months (state 3). Microalgal biomass is likely to be lowest during state 1 and highest when a salinity gradient is present (State 2). Retention times are similar to the reference state so there is no impact. Confidence: Low
	Macrophytes: Because of its small surface area and volume the Matjies Estuary fills up rapidly after a mouth closure event and breaches through overtopping. When open water retention time is less than 1 week. This dynamic nature of the estuary prevents the development of submerged macrophyte beds. During prolonged closed mouth conditions detritus from fringing vegetation may accumulate in the estuary and lead to anoxia. Confidence: Medium
	Invertebrates: Similar to the reference state and no likely change to the invertebrate community. However, a longer retention time probably leads to anoxia on the bottom and this will negatively influence the invertebrates (leading to mortality. Since there is no change in the submerged macrophyte state, a change in the invertebrate community is unlikely. Confidence: Medium
	Fish: Similar to the reference state and therefore little or no likely change to the fish community. Confidence: Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Birds: Similar to the reference state and no likely change to the bird community. However, if anoxic conditions develop because of mouth closure, invertebrates as a source of food for foraging birds will decline and those species that feed on them will spend less time at the estuary. Overall, there is likely to be little change since the most abundant species (Kelp Gulls) spend most time roosting or bathing. Confidence: Medium
Flow velocities	**Microalgae**: Microalgal biomass is determined by flow velocity and retention time. There is a lack of information on flow so the flow-retention time relationship is poorly understood. However, if a flow in excess of 0.1 $m^3.s^{-1}$ were to occur, then residence time would be <1 week resulting in a relatively low phytoplankton biomass (chl-a <10 $\mu g.l^{-1}$). Flow is similar to the reference state so there is no impact. Confidence: Low
	Macrophytes: During floods flow velocity would be high, potentially removing and flushing out macrophytes from the estuary. High flow velocity during the open mouth condition would prevent the establishment of submerged macrophytes in the mouth and lower reaches of the estuary. Confidence: Medium
	Invertebrates: Small invertebrates such as the zooplankton are likely to be flushed from the estuary under greater flow velocities. If there is an accumulation of macrophyte material following higher flows, then some invertebrates will increase in abundance. Because of the small area, no significant change is likely. Confidence:
	Fish: Similar to the reference state and therefore little or no likely change to the fish community. Confidence: Medium
	Birds: Birds feeding on subtidal invertebrates are likely to spend more time at the estuary if there is an increase in invertebrate biomass (following the argument above). However, the change is unlikely to be significant since the estuary covers only a relatively small area. Confidence: Medium
Volume of water in estuary	**Microalgae**: The higher the volume of water in the estuary, the more habitat available for phytoplankton and, to a lesser extent, benthic microalgae. Confidence: High
	Macrophytes: The small surface area of the estuary results in a low but variable water volume. A greater volume of water would provide habitat for submerged macrophytes. Confidence: Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Invertebrates: A greater water volume in the estuary will increase the subtidal area and therefore lead to an increase in habitat for benthic animals. Benthic biomass is therefore likely to increase. Zooplankton will also increase in biomass since a greater water volume is linked to a greater residence time of the estuary water. Confidence: Medium
	Fish: Any increase in the volume of water within the estuary will be of benefit to both fish biodiversity and size. The present small size of fishes within the estuary is a function of the limited water volume and shallowness of the system. Confidence: Medium
	Birds: If there is an increase in water volume and a concomitant increase in invertebrate biomass (see above), then time spent at the estuary by foraging birds will increase. Confidence: Medium
Salinity	**Microalgae:** Phytoplankton responds significantly to nutrients in freshwater (particularly PO_4^{3+}, NO_3^{2-} and NH_4^+). The more fresh the estuary, the greater the load of nutrients entering the estuary. An optimal balance between river flow and retention time will support the highest phytoplankton biomass (likely to be flows between 0.03 and 0.1 $m^3.s^{-1}$) Confidence: Low
	Macrophytes: The macrophtyes in the estuary indicate a predominantly brackish (< 20 ppt) system due to the perched nature of the estuary. During both high (April 2007) and low flow (December 2006) surveys there was a salinity gradient in the estuary, 0.6 to 20.9 ppt and 3.2 to 10.9 ppt respectively. During persistent closed mouth conditions the estuary would become fresher which would encourage the growth and expansion of common reed, *Phragmites australis*. This plant dies back when exposed to salinity greater than 20 ppt for three months. Confidence: Medium
	Invertebrates: Invertebrate community structure is likely to shift in response to salinity changes. Higher salinity values will favour marine Associated forms and lower salinity values will favour those species linked to the upstream section. Confidence: Medium
	Fish: Fishes are tolerant of a wide range of salinities but marine fishes will temporarily leave the estuary when freshwater conditions prevail during high river flows. The perched nature and fluctuating salinities with the Matjies Estuary is likely to preclude the presence of marine stragglers, even under marine conditions. Confidence: Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	<u>Birds</u>: Changes in the structure of the foraging birds community will probably change marginally if there is a change in structure of the bentbic community. Confidence: Medium
Other water quality variables	**<u>Microalgae</u>:** Elevated nutrients, fine sediment and organic matter imported in river water generally support a higher microalgal biomass. Currently, levels of these variables, excl DIN, appear to be low and similar to the reference condition so there is no impact. DIN concentrations are high (up to 600 µg/l) but phytoplankton growth appears to be limited by low DIP concentrations (DIN:DIP >20). Confidence: Medium
	<u>Macrophytes</u>: Small amounts of treated effluent are discharged in the Matjies River. The nutrients in this effluent will increase the growth and expansion of macrophytes. Confidence: Medium
	<u>Invertebrates</u>: Increased nutrient loading will likely lead to an increase in filter feeders. Confidence: Medium
	<u>Fish</u>: Increased primary and secondary production within the estuary due to nutrient loading will increase the biomass and productivity of fish species within this system. Confidence: Medium
	<u>Birds</u>: No significant change likely since prey organisms are not likely to change in any significant way. Confidence: Medium

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>Microalgae</u>:** N/A Confidence:
	<u>Macrophytes</u>: N/A Confidence:
	<u>Invertebrates</u>: N/A Confidence: High

ANTHROPOGENIC INFLUENCES	BIOLOGICAL RESPONSE
	Fish: N/A Confidence: High
	Birds: N/A Confidence: High
Human exploitation (consumptive and non-consumptive)	**Microalgae**: Human exploitation is minimal, similar to reference condition. *Confidence: High*
	Macrophytes: No human exploitation was observed. Confidence: Medium
	Invertebrates: N/A Confidence: High
	Fish: No fishing activities were observed. Confidence: Medium
	Birds: Disturbance Confidence: High

3.3 Reference Conditions

3.3.1 Abiotic Components

Seasonal variability in river inflow:

Monthly simulated runoff data for the Matjies Estuary Reference (or natural) Condition is provided in Table 3. A summary of flow distribution (average monthly flows in $m^3.s^{-1}$) for the Reference Condition, derived from the 60-year simulated data set, is provided in Table 3 below:

Table 3. *Summary of flow distributions for the Reference Condition*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.70	0.61	0.26	0.30	0.41	0.42	0.36	0.61	0.34	0.27	0.69	0.43
90%ile	0.55	0.50	0.25	0.28	0.32	0.35	0.30	0.33	0.22	0.22	0.38	0.37
80%ile	0.38	0.35	0.21	0.20	0.24	0.21	0.22	0.25	0.16	0.16	0.26	0.30
70%ile	0.23	0.24	0.17	0.18	0.16	0.19	0.16	0.15	0.12	0.12	0.18	0.24
60%ile	0.19	0.18	0.12	0.11	0.13	0.16	0.12	0.11	0.10	0.10	0.13	0.19
50%ile	0.16	0.15	0.11	0.10	0.12	0.13	0.09	0.07	0.08	0.08	0.10	0.17
40%ile	0.15	0.13	0.09	0.08	0.10	0.10	0.08	0.06	0.07	0.07	0.09	0.14
30%ile	0.13	0.09	0.07	0.06	0.08	0.07	0.07	0.05	0.05	0.05	0.07	0.10
20%ile	0.10	0.06	0.06	0.04	0.07	0.05	0.05	0.04	0.03	0.04	0.06	0.07
10%ile	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.04	0.05
1%ile	0.04	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.03

Present flood regime

The flood regime is judged to be very similar to that of the Present State.

Confidence: Low

Present sediment processes

The hydrological data indicates that the magnitude and occurrence of major floods has hardly been reduced. This also means that the flushing of sediments during such floods has hardly been reduced. It is therefore likely that the sedimentation in the estuary is not much different from what it was under natural conditions.

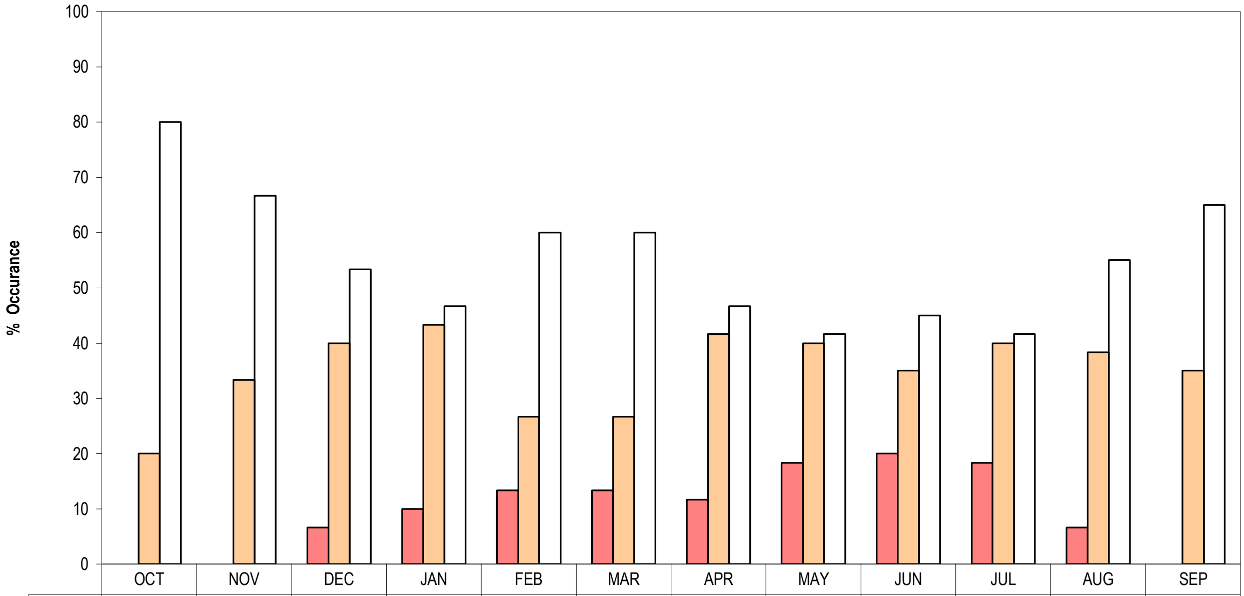
Confidence: Low

Table 4. *Simulated monthly flows ($m^3.s^{-1}$) to the Matjies Estuary for the Reference Conditions*

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.82	0.35	0.06	0.02	0.06	0.08	0.09	1.22	0.57	0.14	0.18	0.30	0.32
1935	0.32	0.29	0.20	0.10	0.10	0.15	0.07	0.21	0.10	0.27	0.13	0.19	0.18
1936	0.24	0.37	0.25	0.09	0.11	0.20	0.07	0.01	0.02	0.11	0.07	0.24	0.15
1937	0.16	0.08	0.22	0.23	0.07	0.09	0.09	0.03	0.02	0.01	0.04	0.07	0.09
1938	0.10	0.26	0.21	0.06	0.67	0.48	0.15	0.03	0.01	0.15	0.36	0.34	0.23
1939	0.17	0.12	0.09	0.19	0.24	0.14	0.06	0.03	0.02	0.07	0.04	0.09	0.11
1940	0.07	0.05	0.03	0.09	0.04	0.05	0.33	0.13	0.09	0.07	0.04	0.07	0.09
1941	0.37	0.23	0.25	0.29	0.12	0.07	0.03	0.33	0.17	0.07	0.06	0.06	0.17
1942	0.12	0.09	0.10	0.30	0.13	0.09	0.05	0.02	0.03	0.04	0.10	0.41	0.12
1943	0.22	0.53	0.42	0.10	0.09	0.07	0.04	0.81	0.34	0.17	0.10	0.17	0.26
1944	0.16	0.08	0.03	0.02	0.02	0.02	0.02	0.25	0.24	0.11	0.06	0.05	0.09
1945	0.07	0.03	0.07	0.11	0.12	0.37	0.15	0.02	0.02	0.04	0.07	0.06	0.10
1946	0.13	0.07	0.04	0.17	0.12	0.25	0.15	0.14	0.11	0.22	0.11	0.15	0.14
1947	0.12	0.17	0.07	0.11	0.10	0.06	0.20	0.08	0.02	0.02	0.03	0.10	0.09
1948	0.16	0.16	0.09	0.19	0.15	0.03	0.05	0.07	0.03	0.01	0.02	0.07	0.09
1949	0.04	0.50	0.18	0.03	0.03	0.02	0.02	0.04	0.02	0.12	0.21	0.18	0.12
1950	0.23	0.64	0.36	0.43	0.20	0.04	0.02	0.06	0.10	0.32	0.38	0.36	0.26
1951	0.15	0.03	0.01	0.28	0.23	0.05	0.08	0.05	0.05	0.06	0.25	0.59	0.15
1952	0.25	0.15	0.08	0.06	0.09	0.03	0.03	0.01	0.20	0.17	0.36	0.31	0.15
1953	0.77	0.45	0.15	0.04	0.01	0.08	0.07	0.30	0.18	0.22	0.70	0.35	0.28
1954	0.08	0.19	0.08	0.19	0.77	0.26	0.07	0.04	0.04	0.03	0.03	0.03	0.15
1955	0.15	0.68	0.22	0.05	0.12	0.22	0.09	0.35	0.16	0.04	0.03	0.29	0.20
1956	0.55	0.30	0.11	0.08	0.13	0.21	0.09	0.04	0.12	0.07	0.18	0.24	0.18
1957	0.14	0.04	0.08	0.07	0.03	0.26	0.18	0.21	0.12	0.04	0.16	0.11	0.12
1958	0.13	0.06	0.12	0.29	0.13	0.18	0.35	0.25	0.09	0.12	0.28	0.16	0.18
1959	0.20	0.10	0.04	0.21	0.09	0.12	0.25	0.15	0.09	0.18	0.10	0.19	0.14
1960	0.09	0.14	0.25	0.25	0.21	0.35	0.15	0.15	0.07	0.06	0.09	0.07	0.16
1961	0.13	0.07	0.07	0.14	0.10	0.37	0.22	0.06	0.03	0.02	0.80	0.33	0.20
1962	0.68	0.42	0.09	0.11	0.08	0.60	0.30	0.09	0.05	0.20	0.11	0.06	0.23
1963	0.10	0.05	0.15	0.20	0.14	0.11	0.12	0.05	0.19	0.09	0.18	0.53	0.16
1964	0.22	0.18	0.07	0.03	0.03	0.19	0.22	0.14	0.11	0.09	0.06	0.05	0.12
1965	0.41	0.61	0.21	0.27	0.18	0.04	0.04	0.05	0.03	0.02	0.28	0.20	0.20
1966	0.06	0.06	0.10	0.09	0.13	0.29	0.74	0.60	0.22	0.13	0.09	0.25	0.23
1967	0.12	0.14	0.11	0.04	0.08	0.19	0.10	0.07	0.36	0.15	0.09	0.24	0.14
1968	0.22	0.26	0.09	0.09	0.12	0.16	0.08	0.03	0.12	0.09	0.06	0.05	0.12
1969	0.16	0.09	0.02	0.07	0.35	0.13	0.02	0.01	0.01	0.02	0.42	0.20	0.12
1970	0.20	0.08	0.38	0.17	0.33	0.21	0.28	0.32	0.15	0.52	0.70	0.28	0.30
1971	0.10	0.35	0.17	0.10	0.41	0.19	0.05	0.04	0.08	0.12	0.19	0.10	0.16
1972	0.05	0.04	0.04	0.06	0.08	0.14	0.13	0.06	0.06	0.05	0.06	0.13	0.08
1973	0.09	0.24	0.09	0.25	0.19	0.21	0.10	0.21	0.10	0.03	0.22	0.17	0.16
1974	0.07	0.15	0.07	0.20	0.27	0.17	0.08	0.03	0.05	0.08	0.09	0.41	0.14
1975	0.17	0.14	0.25	0.10	0.10	0.19	0.07	0.07	0.05	0.19	0.11	0.10	0.13
1976	0.70	0.42	0.13	0.03	0.41	0.42	0.13	0.32	0.16	0.04	0.10	0.14	0.25
1977	0.16	0.23	0.11	0.04	0.02	0.02	0.05	0.05	0.10	0.05	0.13	0.09	0.09
1978	0.15	0.17	0.23	0.19	0.08	0.03	0.27	0.17	0.08	0.24	0.55	0.30	0.20
1979	0.10	0.04	0.06	0.09	0.05	0.02	0.06	0.04	0.12	0.06	0.07	0.16	0.07
1980	0.19	0.10	0.18	0.44	0.25	0.76	0.41	0.97	0.44	0.10	0.69	0.31	0.40
1981	0.43	0.23	0.11	0.06	0.07	0.14	0.80	0.28	0.05	0.12	0.07	0.19	0.21
1982	0.15	0.05	0.05	0.03	0.14	0.07	0.03	0.06	0.23	0.55	0.25	0.17	0.15
1983	0.18	0.15	0.13	0.06	0.08	0.11	0.05	0.01	0.02	0.03	0.02	0.05	0.08
1984	0.04	0.07	0.07	0.17	0.25	0.11	0.16	0.07	0.06	0.10	0.06	0.03	0.10
1985	0.45	0.30	0.16	0.30	0.10	0.01	0.01	0.01	0.02	0.02	0.25	0.16	0.15
1986	0.42	0.20	0.06	0.04	0.14	0.10	0.30	0.12	0.08	0.04	0.10	0.42	0.17
1987	0.18	0.04	0.05	0.03	0.02	0.05	0.24	0.25	0.15	0.08	0.13	0.10	0.11
1988	0.12	0.06	0.07	0.04	0.02	0.03	0.17	0.07	0.02	0.07	0.04	0.05	0.06
1989	0.56	0.73	0.21	0.03	0.32	0.12	0.18	0.14	0.22	0.10	0.08	0.07	0.23
1990	0.18	0.18	0.06	0.07	0.26	0.13	0.03	0.04	0.04	0.03	0.05	0.05	0.09
1991	0.27	0.11	0.18	0.09	0.27	0.19	0.08	0.10	0.08	0.16	0.35	0.17	0.17
1992	0.72	0.52	0.12	0.08	0.05	0.03	0.07	0.05	0.12	0.07	0.07	1.02	0.24
1993	0.38	0.15	0.18	0.12	0.12	0.14	0.10	0.09	0.08	0.09	0.13	0.17	0.15

1: Open	>0.1	2: Closed <1 day	0.03-0.1	3: Closed(> week)	< 0.03

Reference Conditions



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	0.0	0.0	6.7	10.0	13.3	13.3	11.7	18.3	20.0	18.3	6.7	0.0
State 2	20.0	33.3	40.0	43.3	26.7	26.7	41.7	40.0	35.0	40.0	38.3	35.0
State 1	80.0	66.7	53.3	46.7	60.0	60.0	46.7	41.7	45.0	41.7	55.0	65.0

Figure 5. *Occurrence of abiotic states under the Reference Condition*

3.3.2 Biotic Components

Predicted change in biotic characteristics from the Reference Condition to the Present State, as well as motivate the cause of such changes

MICROALGAE

There has been a 16% decrease in river flow from the natural MAR, which has resulted in slightly higher water residence times and more frequent mouth closures (state 3 has increased from 9.9% to 27.1%). This shift is likely to favour microalgal growth, particularly if the mouth does not close for long periods at a time (<1 week), there is overtopping or if there are still some river inputs of nutrients. There has been no decrease in the magnitude and frequency of floods so it is unlikely that there has been a change in the river inputs of suspended material or nutrients. Results suggest that the open phase (Dec 06) supports a lower average microalgal biomass (phytoplankton chl-a 2.0 µg/l and benthic chl-a 3.8 $\mu g.g^{-1}$) than the closed/intermittent phase (April 07) (phytoplankton chl-a 7.0 $\mu g.l^{-1}$ and benthic chl-a 8.5 $\mu g.g^{-1}$).

Confidence: Low

MACROPHYTES

The 16% decrease in river flow and increase in the closed mouth state from 9.9% to 27.1% would cause a slight increase in reed cover and abundance. However the floods remain close to natural which should keep the reed abundance close to natural.

Confidence: Medium

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Under present-day conditions, reduced river flow (16% reduction compared to natural) has lead to less frequent mouth opening and increase in mouth closure of more than 1 week (9.9% to 27.1%). Zooplankton biomass has probably increased slightly because of less frequent flushing from the system due to tidal action. The benthos is unlikely to have changed.

Confidence: Medium

FISH

Fish recruitment from the sea is unlikely to have been affected by the slight increase in closed mouth conditions. Overall the Present State fish community is likely to be very similar to that of the Reference Condition.

Confidence: Medium

BIRDS

Bird abundance is unlikely to have changed compared to natural.

Confidence: Medium

3.4 Present Ecological Status of the Matjies Estuary

3.4.1 Abiotic Components

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 the Matjies Estuary low flows are defined as flows less than 0.1 $m^3.s^{-1}$. As rainfall occurs throughout the year in this region, the hydrology scores were evaluated over the entire 60–year scenario sequence. Months with average flows of less than 0.1 $m^3.s^{-1}$ occurred under the Reference Conditions for 45% of the time. Under the Present State low flows occur for 55 % of the time.	L
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. (The 95%ile indicates that there is only a 2.2 % decrease in the floods to the estuary)	L
Hydrology score	**90**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	75	The occurrence of *State 3* increases from 10% under the Reference Conditions to 27% under the Present State. (Following a precautionary approach Mouth Conditions is scored conservatively as stated in Table 3.3b of the Estuarine RDM methods (DWAF 2004).)	L
Hydrodynamics and mouth conditions score	**75**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	80	There is a 10% decrease in State 1, leading to increased salinities under open mouth conditions. In addition there is a 17% increase in the occurrence of prolonged mouth closure events (State 3).	L
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	85	A 16% decrease in river flow will decrease the average concentrations of nutrients entering the estuary. Prolonged mouth closure and increased residence times will favour nutrient uptake.	L
2b. Suspended solids (turbidity) in the estuary	85	A 16% decrease in river flow will decrease the average concentrations of suspended solids entering the estuary. Prolonged mouth closure and increased residence times will favour the settling out of suspended solids and water should become slightly clearer.	L
2c. Dissolved oxygen in the estuary	85	A 17% increase in the occurrence of prolonged mouth closure will reduce water exchange, particularly in deeper reaches of the estuary causing a slight decrease in average DO. Occasional seawater overtopping will renew low DO water in deeper areas.	L
2d. Levels of toxins	-	-	
Water Quality score	**80**		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	95	Allow 5% change in the intertidal area due to changes in floods and land use.	L
1b	% similarity in sand fraction relative to total sand and mud	95	Allow 5% change in the intertidal area due to changes in floods and land use.	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	95	Allow 5% change in the intertidal area due to changes in floods and land use.	L
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
	Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
Physical habitat score		**95**		

3.4.2 Biotic Component

Estimated % of original species remaining
Scoring guideline: 100% = 100, 90% = 80; 80% = 65; 70% = 50, 60% = 35; 50% = 25; 40% = 17; 30% = 10; 20% = 5; 10% = 0

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	90	A 16% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
2a. Abundance	85	A 17% decrease in MAR will reduce the nutrient load into the estuary. However, residence time will increase, providing a more stable environment leading to an increase in phytoplankton biomass.	L
2b. Community composition	85	A 16% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
Benthic microalgae			
1. Species richness	90	The 17% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to estuarine (5 – 28 ppt) conditions.	L
2a. Abundance	85	There is likely to be an increase in benthic microalgal biomass in response to a 17% increase in the frequency of mouth closure.	L
2b. Community composition	85	The 17% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to brackish conditions.	L
Microalgae score	**85**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	99	The small increase in nutrients may promote the growth of weedy/ opportunistic species which would displace other slower growing species.	L
2a. Abundance/Biomass	90	The 16% decrease in river flow and increase in the closed mouth state from 10 to 27% would cause a slight increase in reed cover and abundance. Floods and sediment input remain close to natural which would prevent major reed encroachment. Although nutrient input is reduced because of lower river inflow, nutrients would still enter via floods. Prolonged mouth closure and increased residence times would favour nutrient uptake by the macrophytes which would increase biomass.	M
2b. Community composition	95	The small increase in nutrients may promote the growth of weedy species resulting in a small change in community composition.	L
Macrophytes score	**90**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	90	Because of the increase in salinity (in response to a reduction in MAR), species richness has probably increased slightly	L
2a. Abundance	90	Increased residence time and less frequent flushing (more frequent mouth closure) will lead to abundance levels increasing marginally.	L
2b. Community composition	90	Higher average salinity values has probably lead to an increase in euryhaline species and a reduction in freshwater associated species.	L
Macroinvertebrates (zoobenthos)			
1. Species richness	90	Because of the increase in salinity (in response to a reduction in MAR), species richness has probably increased slightly.	L
2a. Abundance	95	Higher average salinity values have probably resulted in a marginal increase in abundance.	L
2b. Community composition	90	Higher average salinity values have probably lead to an increase in euryhaline species and a reduction in freshwater associated species.	L
Macrocrustacea (hyperbenthos)			
1. Species richness	100	No change likely – estuary is small and not likely to support many species	L
2a. Abundance	95	Abundance of some species may have increased slightly because of more stable salinity values.	L
2b. Community composition	95	Higher average salinity values have probably lead to a slight increase in euryhaline species and a reduction in freshwater associated species.	L
Invertebrates score	**90**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	Unlikely to have changed from Reference Condition.	M
2a. Abundance	95	Very slight increase in abundance when compared to Reference Condition.	M
2b. Community composition	95	Minimal change in community composition when compared to Reference Condition. Slight increase in mouth closure and surface area of the estuary will result in an increase in zooplankton that may increase plankton feeding spp, e.g. *Monodactylus*.	M
Fish score	**95**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	Unlikely to have changed compared to natural	L
2a. Abundance	90	Small decrease in abundance because of human disturbance	L
2b. Community composition	90	Small decrease in community composition because of human disturbance. Some birds more sensitive to disturbance, e.g. egrets and herons (larger wading birds)	L
Bird score	**90**		

3.4.3 Anthropogenic activities

To establish the changes in Present State (compared with Reference Conditions) that are not as a result of changes in flow, but rather as a result of other anthropogenic activities, the Table below indicate the percentage of overall change predicted in particular components that are non-flow related:

COMPONENT	% CHANGE CAUSED BY NON-FLOW RELATED ACTIVITIES	MOTIVATION	CONFIDENCE
Microalgae	5%	Slight change in microalgae as a result of sedimentation due to a change in land use in the catchment.	M
Macrophytes	0%	There are currently no anthropogenic activities that would influence the macrophytes. The predicted changes in the macrophytes are all (100%) related to flow.	M
Invertebrates	0%	No current anthropogenic activities that would influence invertebrates	M
Fish	0%	No non-flow related activities identified that could cause changes in the fish assemblage.	M
Birds	100%	Increased human activity in the vicinity of the estuary likely to scare some birds away from the estuary, particularly in the mouth area.	M

4 Present Ecological Status (PES)

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 Table 5.

Table 5. *Estuarine Health Index (EHI) scores*

Variable	Weight	Score	Weighted score
Hydrology	25	92	23
Hydrodynamics and mouth condition	25	75	19
Water quality	25	83	21
Physical habitat alteration	25	95	24
Habitat health score			**86**
Microalgae	20	85	17
Macrophytes	20	90	18
Invertebrates	20	90	18
Fish	20	95	19
Birds	20	90	18
Biotic Health Score			**90**
Estuarine Health Score			**89**

The Estuarine Health Index score for the Matjies Estuary, based on its Present State, is **89**, translating into a **Present Ecological Status** of a **B,** i.e. largely natural with few modifications as indicated in Table 6 below:

Table 6. *Guidelines for the Present Ecological Status*

Estuarine Health Index	Present Ecological Status	General description
91 – 100	A	Unmodified, natural
76 – 90	**B**	**Largely natural with few modifications**
61 – 75	C	Moderately modified
41 – 60	D	Largely modified
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

5 Recommended Ecological Category for Matjies Estuary

The **Functional importance** of the Matjies Estuary on a regional scale is estimated to be **20,** as indicated in Table 7.

Table 7. *Functional importance scores*

Functional importance	Score
Export of organic material generated in the estuary (regional scale)	20
Nursery function for fish and crustaceans (marine /riverine)	20
Movement corridor for river invertebrates and fish breeding in sea	20
Roosting area for marine or coastal birds	20
Catchment detritus, nutrients and sediments to sea	20
Functional importance score (Maximum score)	**20**

The **Estuarine Importance scores** allocated to the Matjies Estuary were as follows (Table 8) (Turpie 2004 and Table 7 above):

Table 8. *Estuarine Importance scores*

Criterion	Weight	Score	Weighted score
Estuary Size	15	10	2
Zonal Rarity Type	10	10	1
Habitat Diversity	25	10	3
Biodiversity Importance	25	63.5	16
Functional Importance	25	20	5
Estuarine Importance Score			**26**

The overall **Estuarine Importance Score** for the Matjies Estuary, based on its Present State, is **26**, signifying that the estuary is of low to average importance, as indicated in Table 9.

Table 9. *Estuarine Importance description*

Importance Score	Description
81 – 100	Highly important
61 – 80	Important
0 – 60	**Of low to average importance**

The recommended Ecological Reserve Category (ERC) represents the proposed level of protection assigned to an estuary which, in turn, is used to determine the Ecological Reserve. For estuaries the first step is to determine the 'minimum' Ecological Reserve Category of an estuary, based on its Present Ecological Status (PES). The relationship between Estuarine Health Index Score, Present Ecological Status and Ecological Reserve Category is indicated in Table 10 below:

Table 10. *Ecological Reserve Category*

Estuarine Health Index	Present Ecological Status	Description	Ecological Reserve Category
91 – 100	A	Unmodified, natural	A
76 – 90	**B**	**Largely natural with few modifications**	**B**
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

Note: Should the Present Status category of an estuary be either an 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 minimum Ecological Reserve Category is determined by the Present Ecological Status. The degree to which the Ecological Category needs to be elevated above the Present Ecological Status depends on the level of **importance** and the level of **protection** or **desired protection** of a particular estuary.

The Matjies Estuary does not fall within a protected area nor was it listed as a Desired Protected Area in the C.A.P.E. Estuaries Conservation Plan for the temperate areas of South Africa. According to the guidelines for assigning a recommended Ecological Reserve Category, the Matjies Estuary should therefore be classified as a Category B based on its Present Ecological Status (PES) according to Table 11.

Table 11. *Guidelines for the Recommended Ecological Reserve Category*

Current/desired protection status and estuary importance	Recommended Ecological Reserve 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		
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.**

* BAS = Best Attainable State

At the specialist workshop it was concluded that the pressures currently contributing to the Present State of the estuary are human disturbance in and around the estuary and flow reduction from the catchments.

6 Quantification of Ecological Reserve Scenarios

6.1 Simulated runoff Scenarios

Simulated Monthly Runoff was supplied to the estuarine team by E Van Niekerk (Van Niekerk 2007; Appendix B), BKS Consulting Engineers. A summary of the mean annual runoffs (MAR) of the various Simulated Monthly Runoff Scenarios used for this Rapid RDM is provided in Table 12 below.

Table 12. *Summary of mean annual runoffs for the various simulated runoff scenarios*

Name	Description	MAR (million m^3/annum)	% remaining
Reference	Reference Condition	5.10	100
Present	Present State	4.27	83.6
Future Scenario 1	Reference Conditions – 0.05 m^3/s abstraction	3.65	71.6
Future Scenario 2	Reference Conditions – 0.10 m^3/s abstraction	2.59	50.7
Future Scenario 3	Reference Conditions – 0.20 m^3/s abstraction	1.36	26.6
Future Scenario 4	River Class C/D	1.22	23.9

The hydrology is based on the following assumptions and limitations (Van Niekerk 2007; Appendix B):

- There are no measured flow data available for the Matjies Rivers. All flow data was simulated with the WRSM2000 model.
- The simulation parameters used in this study were transferred from the Bloukrans River.
- Very little rainfall data exist in the mountainous areas.
- The confidence in the flow data is therefore of a medium level with low confidence in the low flows.
- There are approximately 14 km^2 of indigenous forest, 0.3 km^2 of afforestation (cultivated) and 1.4km^2 of irrigation in the catchment.
- The Matjies River receives a small amount of water from the Sout River and some treated effluent is returned to this river. The amounts are negligible.
- There is a dam of 0.25 million m^3 just upstream of the Estuary. The dam was modelled with no abstractions from it. It was assumed that abstractions from this dam are negligible, but that the dam contribute to evaporative losses from the system.
- In the past water was abstracted just before the estuary for Keurboomsstrand. Since 2002, Keurboomstrand receives their domestic water from other sources.
- The natural MAR has decreased from a natural MAR of 5.10 million m^3 to 4.27 million m^3 in its present state.

6.2 Future Scenario 1: Reference Condition – $0.05m^3.s^{-1}$

6.2.1 Abiotic Components

Seasonal variability in river inflow:

Monthly simulated runoff data for the Future Scenario 1 is provided in Table 14. A summary of flow distributions (average monthly flows in $m^3.s^{-1}$) for the Future Scenario 1, derived from the 60-year simulated data set, is provided in Table 13 below:

Table 13. *Summary of flow distributions for Future Scenario 1*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.65	0.56	0.21	0.25	0.36	0.37	0.31	0.56	0.29	0.22	0.64	0.39
90%ile	0.50	0.45	0.20	0.23	0.27	0.30	0.25	0.28	0.17	0.17	0.33	0.33
80%ile	0.33	0.30	0.16	0.15	0.19	0.16	0.17	0.20	0.11	0.11	0.21	0.26
70%ile	0.18	0.19	0.12	0.13	0.11	0.14	0.11	0.10	0.07	0.07	0.13	0.20
60%ile	0.14	0.13	0.07	0.06	0.08	0.11	0.07	0.06	0.05	0.05	0.08	0.14
50%ile	0.11	0.10	0.06	0.05	0.07	0.08	0.04	0.02	0.03	0.03	0.05	0.12
40%ile	0.10	0.08	0.04	0.03	0.05	0.05	0.03	0.01	0.02	0.02	0.04	0.09
30%ile	0.08	0.04	0.02	0.01	0.03	0.02	0.02	0.00	0.00	0.00	0.02	0.05
20%ile	0.05	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
10%ile	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Present flood regime

The flood regime is judged to be similar to that under reference conditions based on the fact that the simulated monthly runoff data indicate little change for higher flows months. The 95%ile indicates that there is an 11 % decrease in the floods to the estuary.

Confidence: Low

Present sediment processes

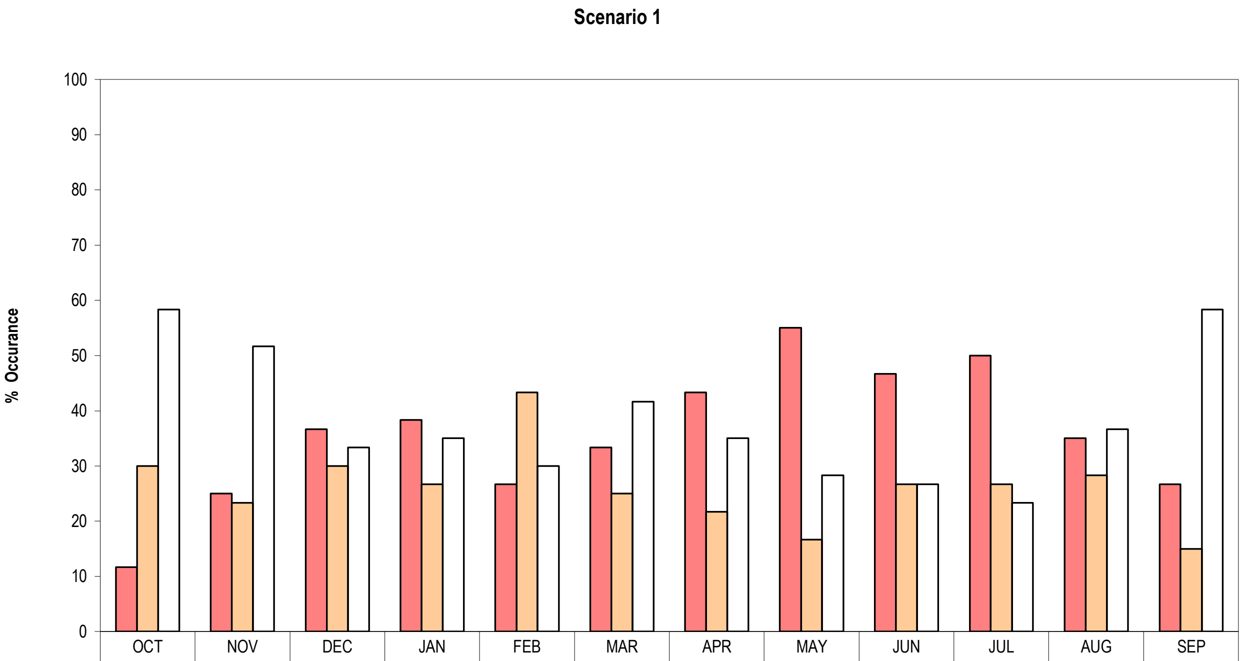
The hydrological data indicates that the magnitude and occurrence of major floods has been reduced slightly. This also means that the flushing of sediments during floods could have been somewhat reduced. It is therefore assumed that the sedimentation in the estuary can be somewhat affected by Future Scenario 1 from what it was under natural conditions. There may also be some increased erosion in the catchment.

Confidence: Low

Table 14. *Simulated monthly flows ($m^3.s^{-1}$) to the Matjies Estuary for the Future Scenario 1 (Reference Conditions – 0.05 $m^3.s^{-1}$)*

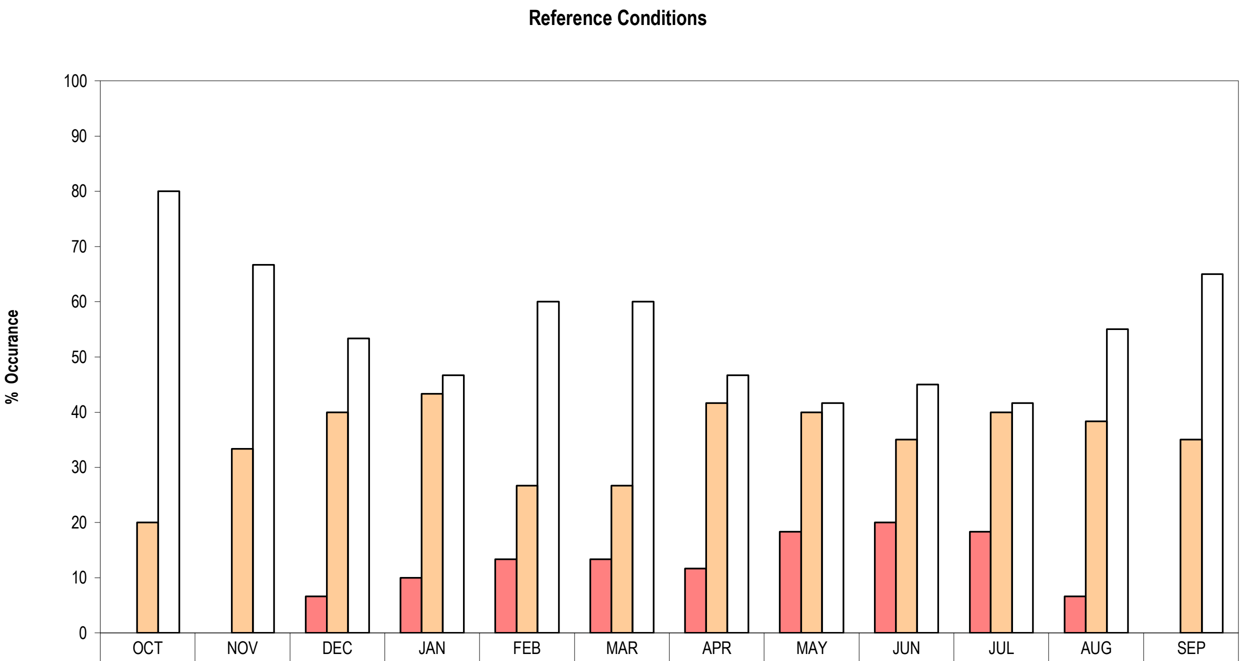
YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.77	0.30	0.01	0.00	0.01	0.03	0.04	1.17	0.52	0.09	0.13	0.26	0.28
1935	0.27	0.24	0.15	0.05	0.05	0.10	0.02	0.16	0.05	0.22	0.08	0.15	0.13
1936	0.19	0.32	0.20	0.04	0.06	0.15	0.02	0.00	0.00	0.06	0.02	0.19	0.10
1937	0.11	0.03	0.17	0.18	0.02	0.04	0.04	0.00	0.00	0.00	0.00	0.02	0.05
1938	0.05	0.21	0.16	0.01	0.62	0.43	0.10	0.00	0.00	0.10	0.31	0.30	0.19
1939	0.12	0.07	0.04	0.14	0.19	0.09	0.01	0.00	0.00	0.02	0.00	0.04	0.06
1940	0.02	0.00	0.00	0.04	0.00	0.00	0.28	0.08	0.04	0.02	0.00	0.02	0.04
1941	0.32	0.18	0.20	0.24	0.07	0.02	0.00	0.28	0.12	0.02	0.01	0.01	0.12
1942	0.07	0.04	0.05	0.25	0.08	0.04	0.00	0.00	0.00	0.00	0.05	0.37	0.08
1943	0.17	0.48	0.37	0.05	0.04	0.02	0.00	0.76	0.29	0.12	0.05	0.13	0.21
1944	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.20	0.19	0.06	0.01	0.00	0.05
1945	0.02	0.00	0.02	0.06	0.07	0.32	0.10	0.00	0.00	0.00	0.02	0.01	0.05
1946	0.08	0.02	0.00	0.12	0.07	0.20	0.10	0.09	0.06	0.17	0.06	0.11	0.09
1947	0.07	0.12	0.02	0.06	0.05	0.01	0.15	0.03	0.00	0.00	0.00	0.05	0.05
1948	0.11	0.11	0.04	0.14	0.10	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.05
1949	0.00	0.45	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.16	0.14	0.08
1950	0.18	0.59	0.31	0.38	0.15	0.00	0.00	0.01	0.05	0.27	0.33	0.32	0.22
1951	0.10	0.00	0.00	0.23	0.18	0.00	0.03	0.00	0.00	0.01	0.20	0.56	0.11
1952	0.20	0.10	0.03	0.01	0.04	0.00	0.00	0.00	0.15	0.12	0.31	0.27	0.10
1953	0.72	0.40	0.10	0.00	0.00	0.03	0.02	0.25	0.13	0.17	0.65	0.31	0.23
1954	0.03	0.14	0.03	0.14	0.72	0.21	0.02	0.00	0.00	0.00	0.00	0.00	0.11
1955	0.10	0.63	0.17	0.00	0.07	0.17	0.04	0.30	0.11	0.00	0.00	0.24	0.15
1956	0.50	0.25	0.06	0.03	0.08	0.16	0.04	0.00	0.07	0.02	0.13	0.20	0.13
1957	0.09	0.00	0.03	0.02	0.00	0.21	0.13	0.16	0.07	0.00	0.11	0.06	0.07
1958	0.08	0.01	0.07	0.24	0.08	0.13	0.30	0.20	0.04	0.07	0.23	0.12	0.13
1959	0.15	0.05	0.00	0.16	0.04	0.07	0.20	0.10	0.04	0.13	0.05	0.14	0.09
1960	0.04	0.09	0.20	0.20	0.16	0.30	0.10	0.10	0.02	0.01	0.04	0.02	0.11
1961	0.08	0.02	0.02	0.09	0.05	0.32	0.17	0.01	0.00	0.00	0.75	0.29	0.15
1962	0.63	0.37	0.04	0.06	0.03	0.55	0.25	0.04	0.00	0.15	0.06	0.01	0.18
1963	0.05	0.00	0.10	0.15	0.09	0.06	0.07	0.00	0.14	0.04	0.13	0.49	0.11
1964	0.17	0.13	0.02	0.00	0.00	0.14	0.17	0.09	0.06	0.04	0.01	0.00	0.07
1965	0.36	0.56	0.16	0.22	0.13	0.00	0.00	0.00	0.00	0.00	0.23	0.16	0.15
1966	0.01	0.01	0.05	0.04	0.08	0.24	0.69	0.55	0.17	0.08	0.04	0.20	0.18
1967	0.07	0.09	0.06	0.00	0.03	0.14	0.05	0.02	0.31	0.10	0.04	0.20	0.09
1968	0.17	0.21	0.04	0.04	0.07	0.11	0.03	0.00	0.07	0.04	0.01	0.00	0.07
1969	0.11	0.04	0.00	0.02	0.30	0.08	0.00	0.00	0.00	0.00	0.37	0.16	0.09
1970	0.15	0.03	0.33	0.12	0.28	0.16	0.23	0.27	0.10	0.47	0.65	0.24	0.25
1971	0.05	0.30	0.12	0.05	0.36	0.14	0.00	0.00	0.03	0.07	0.14	0.05	0.11
1972	0.00	0.00	0.00	0.01	0.03	0.09	0.08	0.01	0.01	0.00	0.01	0.08	0.03
1973	0.04	0.19	0.04	0.20	0.14	0.16	0.05	0.16	0.05	0.00	0.17	0.12	0.11
1974	0.02	0.10	0.02	0.15	0.22	0.12	0.03	0.00	0.00	0.03	0.04	0.37	0.09
1975	0.12	0.09	0.20	0.05	0.05	0.14	0.02	0.02	0.00	0.14	0.06	0.05	0.08
1976	0.65	0.37	0.08	0.00	0.36	0.37	0.08	0.27	0.11	0.00	0.05	0.10	0.20
1977	0.11	0.18	0.06	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.08	0.04	0.04
1978	0.10	0.12	0.18	0.14	0.03	0.00	0.22	0.12	0.03	0.19	0.50	0.26	0.16
1979	0.05	0.00	0.01	0.04	0.00	0.00	0.01	0.00	0.07	0.01	0.02	0.12	0.03
1980	0.14	0.05	0.13	0.39	0.20	0.71	0.36	0.92	0.39	0.05	0.64	0.27	0.35
1981	0.38	0.18	0.06	0.01	0.02	0.09	0.75	0.23	0.00	0.07	0.02	0.14	0.16
1982	0.10	0.00	0.00	0.00	0.09	0.02	0.00	0.01	0.18	0.50	0.20	0.12	0.10
1983	0.13	0.10	0.08	0.01	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1984	0.00	0.02	0.02	0.12	0.20	0.06	0.11	0.02	0.01	0.05	0.01	0.00	0.05
1985	0.40	0.25	0.11	0.25	0.05	0.00	0.00	0.00	0.00	0.00	0.20	0.11	0.11
1986	0.37	0.15	0.01	0.00	0.09	0.05	0.25	0.07	0.03	0.00	0.05	0.38	0.12
1987	0.13	0.00	0.00	0.00	0.00	0.00	0.19	0.20	0.10	0.03	0.08	0.05	0.06
1988	0.07	0.01	0.02	0.00	0.00	0.00	0.12	0.02	0.00	0.02	0.00	0.00	0.02
1989	0.51	0.68	0.16	0.00	0.27	0.07	0.13	0.09	0.17	0.05	0.03	0.02	0.18
1990	0.13	0.13	0.01	0.02	0.21	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.05
1991	0.22	0.06	0.13	0.04	0.22	0.14	0.03	0.05	0.03	0.11	0.30	0.13	0.12
1992	0.67	0.47	0.07	0.03	0.00	0.00	0.02	0.00	0.07	0.02	0.02	1.00	0.20
1993	0.33	0.10	0.13	0.07	0.07	0.09	0.05	0.04	0.03	0.04	0.08	0.13	0.10

1: Open	>0.1	2: Closed <1 day	0.03-0.1	3: Closed(> week)	< 0.03



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	11.7	25.0	36.7	38.3	26.7	33.3	43.3	55.0	46.7	50.0	35.0	26.7
State 2	30.0	23.3	30.0	26.7	43.3	25.0	21.7	16.7	26.7	26.7	28.3	15.0
State 1	58.3	51.7	33.3	35.0	30.0	41.7	35.0	28.3	26.7	23.3	36.7	58.3

Figure 6. *Occurrence of abiotic states during the Scenario 1*



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	0.0	0.0	6.7	10.0	13.3	13.3	11.7	18.3	20.0	18.3	6.7	0.0
State 2	20.0	33.3	40.0	43.3	26.7	26.7	41.7	40.0	35.0	40.0	38.3	35.0
State 1	80.0	66.7	53.3	46.7	60.0	60.0	46.7	41.7	45.0	41.7	55.0	65.0

Figure 7. *Occurrence of abiotic states during Reference Conditions*

6.2.2 EHI for the Future Scenario 1 - Abiotic Components

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	80	For the Matjies Estuary low flows are defined as flows less than 0.1 m^3/s. As rainfall occurs throughout the year in this region, the hydrology scores were evaluated over the entire 60–year scenario sequence. Months with average flows of less than 0.1 m^3/s occurred under the Reference Conditions for 45% of the time. Under the Scenario 1 low flows occur for 62 % of the time.	L
b. % similarity in mean annual frequency of floods	90	There is a 11% reduction in high flows to the system based on the 95%ile average monthly flows.	L
Hydrology score	**80**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	60	The occurrence of *State 3* increases from 10% under the Reference Conditions to 36% under the Present State. (Following a precautionary approach Mouth Conditions are score conservatively as stated in Table 3.3b of the Estuarine RDM methods (DWAF 2004).)	L
Hydrodynamics and mouth conditions score	**60**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	70	There is a 20% decrease in State 1, leading to increased salinities under open mouth conditions. In addition there is a 26% increase in the occurrence of prolonged mouth closure events (State 3).	L
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	70	A 28% decrease in river flow will decrease the average concentrations of nutrients entering the estuary. Prolonged mouth closure and increased residence times will favour nutrient uptake.	L
2b. Suspended solids (turbidity) in the estuary	70	A 28% decrease in river flow will decrease the average concentrations of suspended solids entering the estuary. Prolonged mouth closure (26% increase) and increased residence times will favour the settling out of suspended solids and water should become slightly clearer.	L
2c. Dissolved oxygen in the estuary	75	A 26% increase in the occurrence of prolonged mouth closure will reduce water exchange, particularly in deeper reaches of the estuary. In addition, there is likely to be an increased rate of accumulation of settled particulate matter. These conditions are likely to favour a slight decrease in average DO.	L
2d. Levels of toxins	-	-	
Water Quality score	**70**		

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	90	Allow 10% change in the intertidal area due to changes in floods and land use.	L
1b	% similarity in sand fraction relative to total sand and mud	90	Allow 10% change in the intertidal area due to changes in floods and land use.	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	Allow 10% change in the intertidal area due to changes in floods and land use.	L
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
	Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
Physical habitat score				

6.2.3 Biotic Components

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

MICROALGAE

There has been a 28% decrease in river flow from the natural MAR, which has resulted in slightly higher water residence times and more frequent mouth closures (state 3 has increased from 10% to 36%). This shift is likely to favour microalgal growth, particularly if the mouth does not close for long periods at a time (<1 week), there is overtopping or if there are still some river inputs of nutrients. There has been no decrease in the magnitude and frequency of floods so it is unlikely that there has been a change in the river inputs of suspended material or nutrients. Results suggest that the open phase (Dec 06) supports a lower average microalgal biomass (phytoplankton chl-a 2.0 µg/l and benthic chl-a 3.8 $\mu g.g^{-1}$) than the closed/intermittent phase (April 07) (phytoplankton chl-a 7.0 $\mu g.l^{-1}$ and benthic chl-a 8.5 $\mu g.g^{-1}$).

Confidence: Low

MACROPHYTES

The increase in low flow, closed mouth conditions and sedimentation due to erosion in the catchment would encourage the growth and expansion of the reeds. This would occur if salinity during the closed mouth state remained less than 20 ppt and water levels were not too high. The percentage occurrence of the closed mouth state appears to be greater in the winter months compared to the spring / summer months. This is not usually the growing season of the plants and therefore the benefits of increased nutrient concentrations and residence time would not necessarily increase the biomass of the plants.

Confidence: Medium

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Frequency of mouth closure has increased residence time of the estuary water, while the reduction in river flow is likely to increase average salinity values. This would favour typical estuarine species, but not freshwater associated species. This scenario assumes that there is still seawater overtopping across the berm. In addition, an increase in algal growth would benefit primary consumers.

Confidence: Medium

FISH

Marine and estuarine fish species favoured by slightly higher salinities and the increased productivity of plants and invertebrates. The greater water surface area and volume during the closed phase would also tend to support a larger fish biomass within the estuary.

Confidence: Medium

BIRDS
The occurrence or time spent by small waders at the estuary is likely to increase because of the increased food supply (small invertebrates). However, these birds are likely to be transient, feeding at other sites in addition to the estuary. The increase in reed abundance would also favour species utilizing such habitats. Confidence: Medium

6.2.4 EHI for the Future Scenario 1 - Biotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	70	A 28% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
2a. Abundance	70	A 28% decrease in MAR will reduce the nutrient load into the estuary. However, residence time will increase, providing a more stable environment leading to an increase in phytoplankton biomass.	L
2b. Community composition	70	A 28% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
Benthic microalgae			
1. Species richness	70	The 26% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to brackish conditions.	L
2a. Abundance	70	There is likely to be an increase in benthic microalgal biomass in response to a 26% increase in the frequency of mouth closure.	L
2b. Community composition	70	The 26% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to brackish conditions.	L
Microalgae score	**70**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	98 (95)	The small increase in nutrients may promote the growth of weedy/ opportunistic species which would displace other slower growing species. The increase in salinity due to an increase in low flow conditions could displace some sensitive brackish species.	L
2a. Abundance	75	The 17% decrease in river flow and increase in the closed mouth state from 10 to 36% would increase reed cover and abundance. The 11% decrease in floods to the estuary and sedimentation due to increased erosion would encourage reed encroachment into the estuary channel. Although nutrient input is reduced because of lower river inflow, nutrients would still enter via floods. Prolonged mouth closure and increased residence times would favour nutrient uptake by the macrophytes which would increase biomass although this would be more beneficial in spring/summer compared to winter when the reeds die-back.	M
2b. Community composition	80	The small increase in nutrients may promote the growth of weedy species resulting in a change in community composition. Reeds may expand into other habitats changing the community composition of the estuary.	L
Macrophytes score	**75**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	80	Because of the increase in salinity (in response to a reduction in MAR), species richness has probably increased slightly	L
2a. Abundance	80	Increased residence time and less frequent flushing (more frequent mouth closure) will lead to abundance levels increasing marginally.	L
2b. Community composition	80	Higher average salinity values has probably lead to an increase in euryhaline species and a reduction in freshwater associated species.	L
Macroinvertebrates			
1. Species richness	80	Because of the increase in salinity (in response to a reduction in MAR), species richness has probably increased slightly.	L
2a. Abundance	80	Higher average salinity values have probably resulted in a marginal increase in abundance. In addition, species that live in association with macrophytes are likely to establish themselves because of the expansion of reed coverage.	L
2b. Community composition	80	Higher average salinity values and greater reed coverage will probably lead to a change in the community. Euryhaline species will also increase, while there will be a reduction in freshwater associated species.	L
Macrocrustacea			
1. Species richness	90	Small change likely in response to increased salinity values and greater coverage of reeds that would favour species utilizing these habitats.	L
2a. Abundance	95	Abundance of some species may have increased slightly because of more stable salinity values and increased red coverage.	L
2b. Community composition	95	Higher average salinity values have probably lead to a slight increase in euryhaline species and a reduction in freshwater associated species.	L
Invertebrates score	**80**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	95 (90)	Possible loss of certain freshwater species from the estuary due to increased salinity.	L
2a. Abundance	95	The abundance of most fish species would increase slightly due to improved feeding and habitat availability.	L
2b. Community composition	95	Very slight changes in community composition due to possible loss of certain freshwater species.	L
Fish score	**90**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	90	Species richness would increase due to a greater reed coverage that supports species associated with these habitats.	L
2a. Abundance	80	Due to an increase in benthic food availability, consumers would spend more time in association with the estuary. Human disturbance in lower reaches, but most of the birds associated with the reeds in the upper reaches.	L
2b. Community composition	80	Because of the change in habitat, community composition would change in favour of those species utilizing reeds. Human disturbance in lower reaches, but most of the birds associated with the reeds in the upper reaches.	L
Bird score	**80**		

6.3 Future Scenario 2: Reference Condition – 0.1 $m^3.s^{-1}$

6.3.1 Abiotic Components

Seasonal variability in river inflow:

Monthly simulated runoff data for the Future Scenario 2 is provided in Table 16. A summary of flow distribution (average monthly flows in $m^3.s^{-1}$) for the Future Scenario 2, derived from the 60-year simulated data set, is provided in Table 15 below:

Table 15. *Summary of flow distributions for Future Scenario 2*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.60	0.51	0.16	0.20	0.31	0.32	0.26	0.51	0.24	0.17	0.59	0.34
90%ile	0.45	0.40	0.15	0.18	0.22	0.25	0.20	0.23	0.12	0.12	0.28	0.28
80%ile	0.28	0.25	0.11	0.10	0.14	0.11	0.12	0.15	0.06	0.06	0.16	0.21
70%ile	0.13	0.14	0.07	0.08	0.06	0.09	0.06	0.05	0.02	0.02	0.08	0.15
60%ile	0.09	0.08	0.02	0.01	0.03	0.06	0.02	0.01	0.00	0.00	0.03	0.09
50%ile	0.06	0.05	0.01	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.07
40%ile	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
30%ile	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Present flood regime

The flood regime is judged to be somewhat reduced from under reference conditions based on the fact that the 95%ile simulated monthly runoff data indicate a 22 % decrease in the floods to the estuary.

Confidence: Medium

Present sediment processes

The hydrological data indicates that the magnitude and occurrence of major floods has been reduced. This also means that the flushing of sediments during such floods has been reduced. It is therefore likely that the sediment dynamics in the estuary is somewhat modified from what it was under the natural conditions. There may be some increased erosion in the catchment.

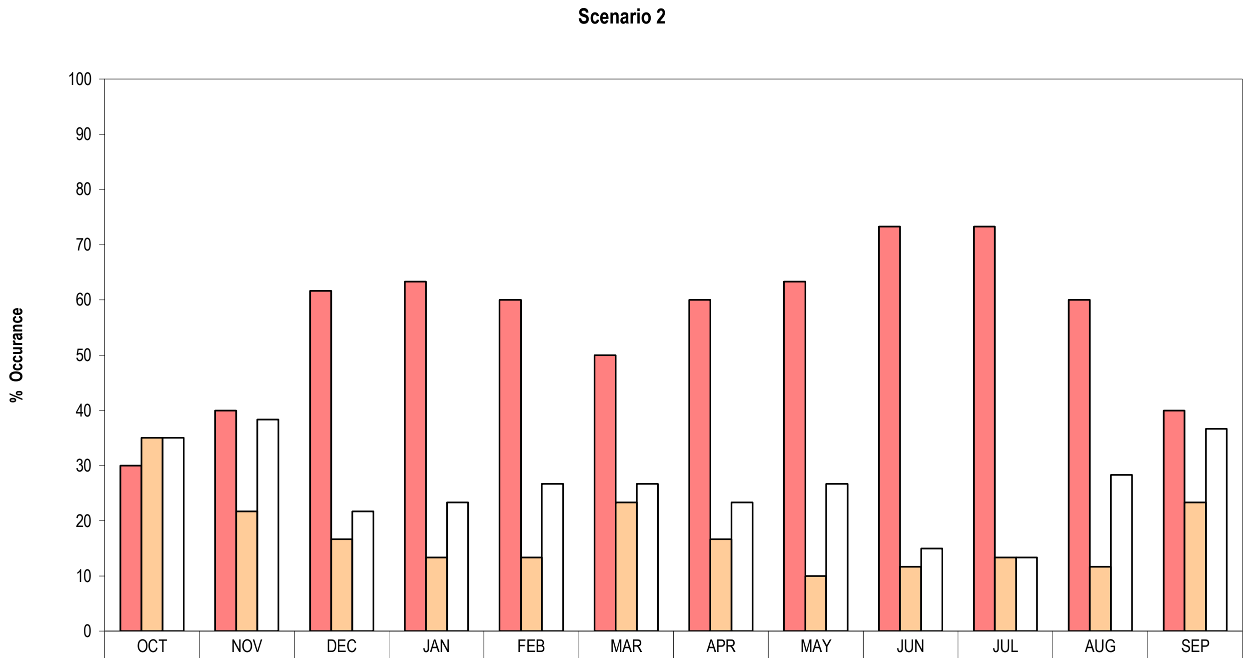
In the case of an in-channel development the impact would be much greater as the estuary is sediment staved from a marine perceptive and mostly fed by sediment for the catchment. An in-channel development (e.g. dam or off-take weir) would cut off this sediment supply and lead to deeping of the subtidal area, loss of intertidal areas, loss of sediment in the cove at the mouth and a different mode of sediment delivery (A Theron, CSIR, pers. com.).

Confidence: Low

Table 16. *Simulated monthly flows ($m^3.s^{-1}$) to the Matjies Estuary for the Future Scenario 2 (Reference Conditions – 0.1 $m^3.s^{-1}$)*

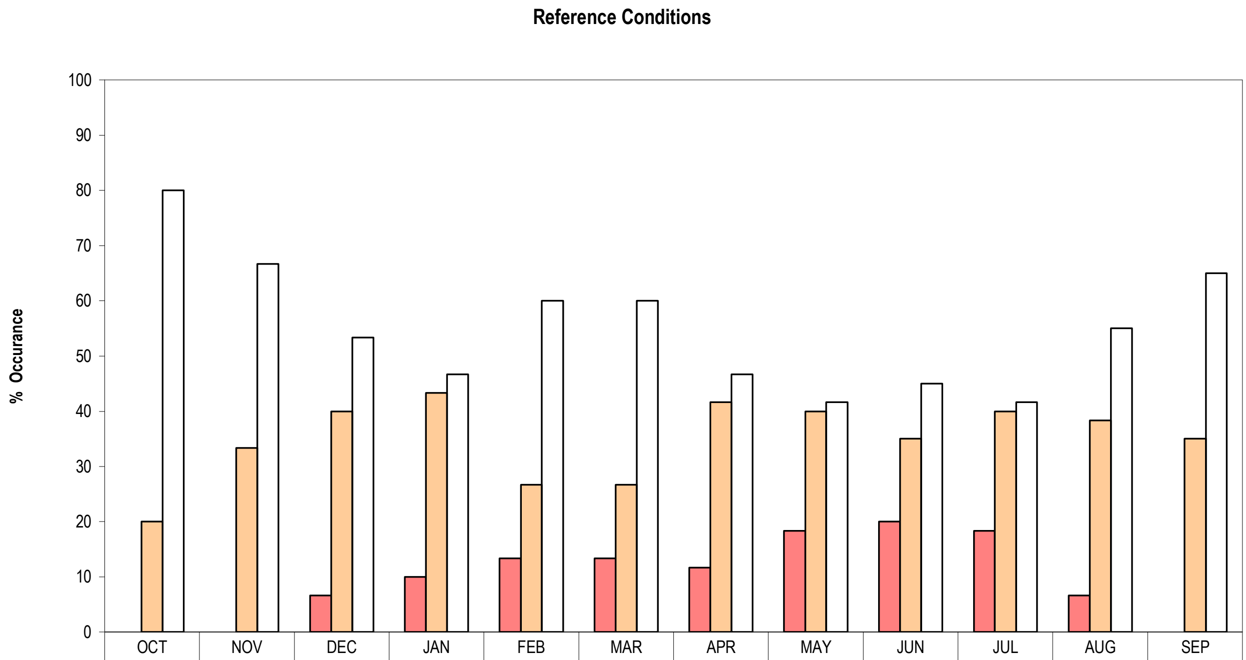
YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.72	0.25	0.00	0.00	0.00	0.00	0.00	1.12	0.47	0.04	0.08	0.20	0.24
1935	0.22	0.19	0.10	0.00	0.00	0.05	0.00	0.11	0.00	0.17	0.03	0.10	0.08
1936	0.14	0.27	0.15	0.00	0.01	0.10	0.00	0.00	0.00	0.01	0.00	0.14	0.07
1937	0.06	0.00	0.12	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1938	0.00	0.16	0.11	0.00	0.56	0.38	0.05	0.00	0.00	0.05	0.26	0.25	0.15
1939	0.07	0.02	0.00	0.09	0.14	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1940	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.03	0.00	0.00	0.00	0.00	0.02
1941	0.27	0.13	0.15	0.19	0.01	0.00	0.00	0.23	0.07	0.00	0.00	0.00	0.09
1942	0.02	0.00	0.00	0.20	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.05
1943	0.12	0.43	0.32	0.00	0.00	0.00	0.00	0.71	0.24	0.07	0.00	0.08	0.16
1944	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.14	0.01	0.00	0.00	0.03
1945	0.00	0.00	0.00	0.01	0.02	0.27	0.05	0.00	0.00	0.00	0.00	0.00	0.03
1946	0.03	0.00	0.00	0.07	0.02	0.15	0.05	0.04	0.01	0.12	0.01	0.06	0.05
1947	0.02	0.07	0.00	0.01	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.02
1948	0.06	0.06	0.00	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
1949	0.00	0.40	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.08	0.06
1950	0.13	0.54	0.26	0.33	0.10	0.00	0.00	0.00	0.00	0.22	0.28	0.27	0.18
1951	0.05	0.00	0.00	0.18	0.13	0.00	0.00	0.00	0.00	0.00	0.15	0.51	0.08
1952	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.07	0.26	0.22	0.07
1953	0.67	0.35	0.05	0.00	0.00	0.00	0.00	0.20	0.08	0.12	0.60	0.26	0.19
1954	0.00	0.09	0.00	0.09	0.67	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.08
1955	0.05	0.58	0.12	0.00	0.02	0.12	0.00	0.25	0.06	0.00	0.00	0.19	0.12
1956	0.45	0.20	0.01	0.00	0.03	0.11	0.00	0.00	0.02	0.00	0.08	0.15	0.09
1957	0.04	0.00	0.00	0.00	0.00	0.16	0.08	0.11	0.02	0.00	0.06	0.01	0.04
1958	0.03	0.00	0.02	0.19	0.03	0.08	0.25	0.15	0.00	0.02	0.18	0.06	0.08
1959	0.10	0.00	0.00	0.11	0.00	0.02	0.15	0.05	0.00	0.08	0.00	0.09	0.05
1960	0.00	0.04	0.15	0.15	0.11	0.25	0.05	0.05	0.00	0.00	0.00	0.00	0.07
1961	0.03	0.00	0.00	0.04	0.00	0.27	0.12	0.00	0.00	0.00	0.70	0.24	0.12
1962	0.58	0.32	0.00	0.01	0.00	0.50	0.20	0.00	0.00	0.10	0.01	0.00	0.14
1963	0.00	0.00	0.05	0.10	0.04	0.01	0.02	0.00	0.09	0.00	0.08	0.44	0.07
1964	0.12	0.08	0.00	0.00	0.00	0.09	0.12	0.04	0.01	0.00	0.00	0.00	0.04
1965	0.31	0.51	0.11	0.17	0.08	0.00	0.00	0.00	0.00	0.00	0.18	0.10	0.12
1966	0.00	0.00	0.00	0.00	0.03	0.19	0.64	0.50	0.12	0.03	0.00	0.15	0.14
1967	0.02	0.04	0.01	0.00	0.00	0.09	0.00	0.00	0.26	0.05	0.00	0.15	0.05
1968	0.12	0.16	0.00	0.00	0.02	0.06	0.00	0.00	0.02	0.00	0.00	0.00	0.03
1969	0.06	0.00	0.00	0.00	0.25	0.03	0.00	0.00	0.00	0.00	0.32	0.10	0.06
1970	0.10	0.00	0.28	0.07	0.23	0.11	0.18	0.22	0.05	0.42	0.60	0.18	0.20
1971	0.00	0.25	0.07	0.00	0.31	0.09	0.00	0.00	0.00	0.02	0.09	0.00	0.07
1972	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.03	0.01
1973	0.00	0.14	0.00	0.15	0.09	0.11	0.00	0.11	0.00	0.00	0.12	0.07	0.07
1974	0.00	0.05	0.00	0.10	0.17	0.07	0.00	0.00	0.00	0.00	0.00	0.32	0.06
1975	0.07	0.04	0.15	0.00	0.00	0.09	0.00	0.00	0.00	0.09	0.01	0.00	0.04
1976	0.60	0.32	0.03	0.00	0.31	0.32	0.03	0.22	0.06	0.00	0.00	0.04	0.16
1977	0.06	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02
1978	0.05	0.07	0.13	0.09	0.00	0.00	0.17	0.07	0.00	0.14	0.45	0.20	0.11
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.06	0.01
1980	0.09	0.00	0.08	0.34	0.15	0.66	0.31	0.87	0.34	0.00	0.59	0.22	0.30
1981	0.33	0.13	0.01	0.00	0.00	0.04	0.70	0.18	0.00	0.02	0.00	0.09	0.13
1982	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.13	0.45	0.15	0.07	0.07
1983	0.08	0.05	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1984	0.00	0.00	0.00	0.07	0.15	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.03
1985	0.35	0.20	0.06	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.06	0.09
1986	0.32	0.10	0.00	0.00	0.04	0.00	0.20	0.02	0.00	0.00	0.00	0.33	0.08
1987	0.08	0.00	0.00	0.00	0.00	0.00	0.14	0.15	0.05	0.00	0.03	0.00	0.04
1988	0.02	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.01
1989	0.46	0.63	0.11	0.00	0.22	0.02	0.08	0.04	0.12	0.00	0.00	0.00	0.14
1990	0.08	0.08	0.00	0.00	0.16	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1991	0.17	0.01	0.08	0.00	0.17	0.09	0.00	0.00	0.00	0.06	0.25	0.08	0.07
1992	0.62	0.42	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.95	0.17
1993	0.28	0.05	0.08	0.02	0.02	0.04	0.00	0.00	0.00	0.00	0.03	0.08	0.05

1: Open	>0.1	2: Closed <1 day	0.03-0.1	3: Closed(> week)	< 0.03



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	30.0	40.0	61.7	63.3	60.0	50.0	60.0	63.3	73.3	73.3	60.0	40.0
State 2	35.0	21.7	16.7	13.3	13.3	23.3	16.7	10.0	11.7	13.3	11.7	23.3
State 1	35.0	38.3	21.7	23.3	26.7	26.7	23.3	26.7	15.0	13.3	28.3	36.7

Figure 8. *Occurrence of abiotic states during Scenario 2*



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	0.0	0.0	6.7	10.0	13.3	13.3	11.7	18.3	20.0	18.3	6.7	0.0
State 2	20.0	33.3	40.0	43.3	26.7	26.7	41.7	40.0	35.0	40.0	38.3	35.0
State 1	80.0	66.7	53.3	46.7	60.0	60.0	46.7	41.7	45.0	41.7	55.0	65.0

Figure 9. *Occurrence of abiotic states during Reference Conditions*

6.3.2 EHI for the Future Scenario 2 - Abiotic Components

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	70	For the Matjies Estuary low flows are defined as flows less than 0.1 $m^3.s^{-1}$. As rainfall occurs throughout the year in this region, the hydrology scores were evaluated over the entire 60–year scenario sequence. Months with average flows of less than 0.1 $m^3.s^{-1}$ occurred under the Reference Conditions for 45% of the time. Under Scenario 2 low flows occur for 74 % of the time.	L
b. % similarity in mean annual frequency of floods	80	The reduction in high flows is deemed to be about 20% as the 95%ile indicates that there is a 22 % decrease in the floods to the estuary from the Reference Conditions.	L
Hydrology score	**70**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	40	The occurrence of *State 3* increases from 10% under the Reference Conditions to 56% under the Present State. (Following a precautionary approach Mouth Conditions are score conservatively as stated in Table 3.3b of the Estuarine RDM methods (DWAF 2004).)	L
Hydrodynamics and mouth conditions score	**40**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	50	There is a 30% decrease in State 1, leading to increased salinities under open mouth conditions. In addition there is a 46% increase in the occurrence of prolonged mouth closure events (State 3).	L
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	50	A 49% decrease in river flow will decrease the average concentrations of nutrients entering the estuary. Prolonged mouth closure (46%) and increased residence times will favour nutrient uptake.	L
2b. Suspended solids (turbidity) in the estuary	50	A 49% decrease in river flow will decrease the average concentrations of suspended solids entering the estuary. Prolonged mouth closure (46% increase) and increased residence times will favour the settling out of suspended solids and water should become slightly clearer.	L
2c. Dissolved oxygen in the estuary	50	A 49% increase in the occurrence of prolonged mouth closure will reduce water exchange, particularly in deeper reaches of the estuary. In addition, there is likely to be an increased rate of accumulation of settled particulate matter. These conditions are likely to favour a slight decrease in average DO.	L
2d. Levels of toxins	-	-	
Water Quality score	**50**		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	80	Allow 20% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 80 would be allocated)	L
1b	% similarity in sand fraction relative to total sand and mud	80	Allow 20% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 80 would be allocated)	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	80	Allow 20% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 80 would be allocated)	L
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
	Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
Physical habitat score		**80**		

6.3.3 Biotic Components

Predicted change in biotic characteristics of the future Scenario 2 compared with the Reference Condition, as well as the causes of these changes:

MICROALGAE

There has been a 49% decrease in river flow from the natural MAR, which has resulted in slightly higher water residence times and more frequent mouth closures (state 3 has increased from 10% to 56%). This shift is likely to favour microalgal growth, particularly if the mouth does not close for long periods at a time (<1 week), there is overtopping or if there are still some river inputs of nutrients. There has been a 22% decrease in floods so it is likely that there has been a change in the river inputs of suspended material or nutrients. Results suggest that the open phase (Dec 06) supports a lower average microalgal biomass (phytoplankton chl-a 2.0 µg/l and benthic chl-a 3.8 $\mu g.g^{-1}$) than the closed/intermittent phase (April 07) (phytoplankton chl-a 7.0 $\mu g.l^{-1}$ and benthic chl-a 8.5 µg/g).

Confidence: Low

MACROPHYTES

Water abstraction is 50% greater than that of Scenario 1 i.e. an abstraction of 0.1 $m^3 s^{-1}$ compared to 0.05 $m^3 s^{-1}$. Floods are reduced by 22%, low flows occur for 74% of the time and the predominant state is the closed mouth condition. This together with sedimentation due to erosion in the catchment would encourage the growth and expansion of the reeds. An increase in reed biomass would occur if salinity during the closed mouth state remained less than 20 ppt and water levels were not too high. Overtopping and the input of saline water during the open mouth phase may prevent the estuary from becoming totally fresh and stagnant.

Confidence: Medium

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Greater frequency of mouth closure will increase residence time of the estuary water, while the reduction in river flow is likely to increase average salinity values. This assumes that there is still overtopping of the berm at the mouth. Conditions would favour typical estuarine species, but not freshwater associated species. In addition, an increase in

benthic algal coverage would benefit primary consumers. Confidence: Medium
FISH
Marine and estuarine fish species favoured by higher salinities and the increased productivity of plants and invertebrates. The greater water surface area and volume during the closed phase would also tend to support a larger fish biomass within the estuary. The 22% reduction in floods would promote more prolonged occupation of the estuary by marine fishes and represents a deviation from the natural (reference) condition. Confidence: Medium
BIRDS
The occurrence or time spent by small waders at the estuary is likely to increase compared to natural because of the increased food supply (small invertebrates). However, these birds are likely to be transient, feeding at other sites in addition to the estuary. The increase in reed abundance would also favour species utilizing such habitats. Confidence: Low

6.3.4 EHI for the Future Scenario 1 - Biotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	50	A 49% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
2a. Abundance	50	A 49% decrease in MAR will reduce the nutrient load into the estuary. However, residence time will increase, providing a more stable environment leading to an increase in phytoplankton biomass.	L
2b. Community composition	50	A 49% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
Benthic microalgae			
1. Species richness	50	The 46% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to more brackish conditions.	L
2a. Abundance	50	There is likely to be an increase in benthic microalgal biomass in response to a 46% increase in the frequency of mouth closure.	L
2b. Community composition	50	The 46% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to brackish conditions.	L
Microalgae score	**50**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	75 (85)	The increase in nutrients may promote the growth of weedy/ opportunistic species which would displace other slower growing species. The increase in salinity due to an increase in low flow conditions could displace some sensitive brackish species.	L

2a. Abundance	55	The 49% decrease in river flow and increase in the closed mouth state from 10 to 56% would increase reed cover and abundance. The 22% decrease in floods to the estuary and sedimentation due to increased erosion would encourage reed encroachment into the estuary channel. Although nutrient input is reduced because of lower river inflow, nutrients would still enter via floods. Prolonged mouth closure and increased residence times would favour nutrient uptake by the macrophytes which would increase biomass although this would be more beneficial in spring/summer compared to winter when the reeds die-back.	M
2b. Community composition	60	The increase in nutrients may promote the growth of weedy species resulting in a change in community composition. Reeds may expand into other habitats changing the community composition of the estuary if the salinity remains brackish (< 20 ppt).	L
Macrophytes score	**55**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	80	Because of the increase in salinity anf phytoplankton biomass (in response to a reduction in MAR and increased mouth closure), species richness has probably increased slightly,	L
2a. Abundance	70	Increased residence time, less frequent flushing (more frequent mouth closure) and increased phytoplankton biomass will lead to abundance levels increasing.	L
2b. Community composition	80	Higher average salinity values has probably lead to an increase in euryhaline species and a reduction in freshwater associated species.	L
Macroinvertebrates			
1. Species richness	60	Because of the increase in salinity (in response to a reduction in MAR) and reed encroachment into the estuary (less frequent flooding), species richness has probably increased slightly.	L
2a. Abundance	60	Higher average salinity values have probably resulted in an increase in abundance. In addition, species that live in association with macrophytes are likely to establish a much greater biomass because of the expansion of reed coverage.	L
2b. Community composition	60	Higher average salinity values and greater reed coverage will probably lead to a change in the community. Euryhaline species will also increase, while there will be a reduction in freshwater associated species.	L
Macrocrustacea			
1. Species richness	70	Shift likely in response to increased salinity values and greater coverage of reeds that would favour species utilizing these habitats.	L
2a. Abundance	70	Abundance of some species may increase because of more stable salinity values and increased reed coverage.	L
2b. Community composition	70	Higher average salinity values have probably lead to a slight increase in euryhaline species and a reduction in freshwater associated species. Composition will also change in response to reed encroachment into the estuary, providing sheltered habitat.	L
Invertebrates score	**60**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	95	Loss of freshwater species from the estuary due to increased salinity.	L
2a. Abundance	60	The abundance of most fish species would increase due to improved feeding and habitat availability. This represents a 40% deviation from natural.	L
2b. Community composition	80	Changes in community composition due to the loss of freshwater species. Greater dominance of the estuary by marine species as a result of the reduced frequency of floods.	L
Fish score	**60**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	60	Species richness would increase due to a greater reed coverage and encroachment into the estuary that supports species associated with these habitats.	L
2a. Abundance	60	Due to an increase in benthic food availability, consumers would spend more time in association with the estuary. Abundance of reed-associated species would also increase despite human disturbance in the lower reaches.	L
2b. Community composition	60	Because of the change in habitat, community composition would change fairly significantly in favour of those species utilizing reeds.	L
Bird score	**60**		

6.4 Future Scenario 3: Reference Condition – 0.2 $m^3.s^{-1}$

6.4.1 Abiotic Components

Seasonal variability in river inflow:

Monthly simulated runoff data for the Future Scenario 3 is provided in Table 18. A summary of flow distribution (average monthly flows in $m^3.s^{-1}$) for the Future Scenario 3, derived from the 60-year simulated data set, is provided in Table 17 below:

Table 17. *Summary of flow distributions for Future Scenario 3*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.49	0.41	0.06	0.10	0.21	0.22	0.16	0.41	0.14	0.07	0.49	0.23
90%ile	0.34	0.30	0.05	0.08	0.12	0.15	0.10	0.13	0.02	0.02	0.18	0.17
80%ile	0.17	0.15	0.01	0.00	0.04	0.01	0.02	0.05	0.00	0.00	0.06	0.10
70%ile	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
60%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Present flood regime

The flood regime is judged to be significantly modified from that of the reference conditions as the 95%ile indicates that there is a 45 % decrease in the floods to the estuary.

Confidence: Low

Present sediment processes

The hydrological data indicates that the magnitude and occurrence of major floods have been reduced by 45%. This means that the sediment delivery to the estuary is becoming sporadic and some changes in habitat can be expected, e.g. deepening of the subtidal area and loss of intertidal areas in the upper reaches, while the lower estuary would fill in with marine sand resulting in loss of subtidal and intertidal areas.

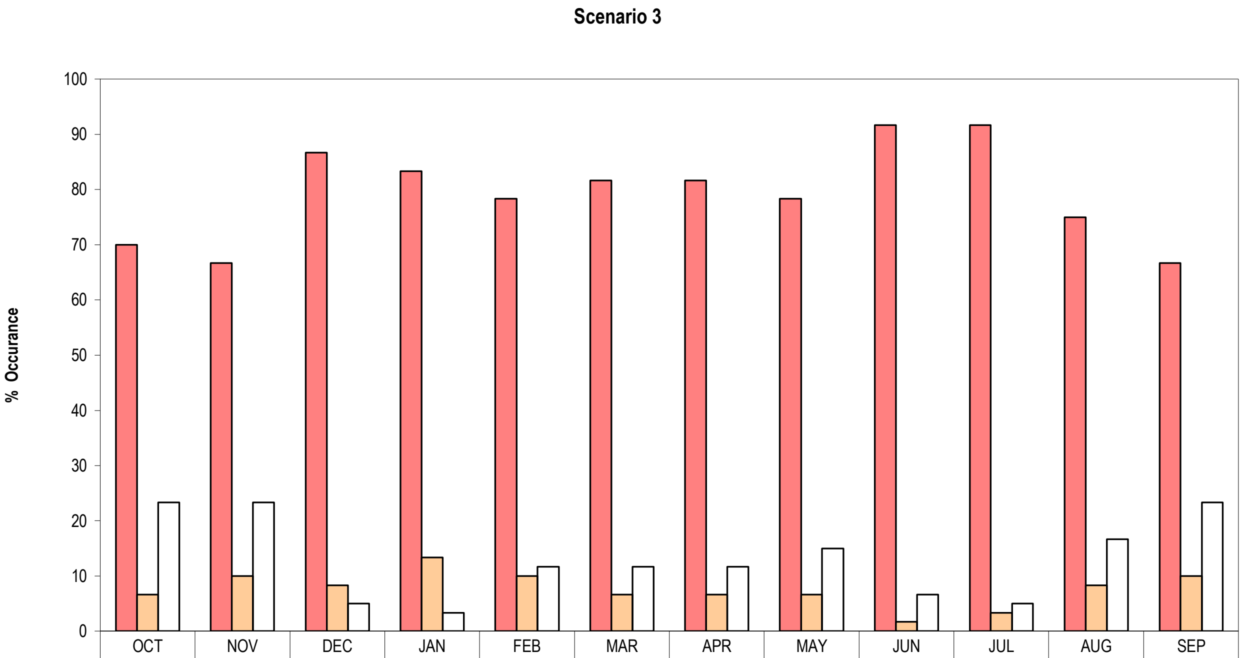
In the case of an in-channel development the impact would be even more serious as the estuary relies on the cathment for a significant part of its sediment budget. An in-channel development (e.g. dam or off-take weir) would reduce the sediment supply and in the long term could lead to the scouring of the system to bed rock in some areas.

Confidence: Low

Table 18. *Simulated monthly flows ($m^3.s^{-1}$) to the Matjies Estuary for the Future Scenario 3 (Reference Conditions – 0.2 $m^3.s^{-1}$)*

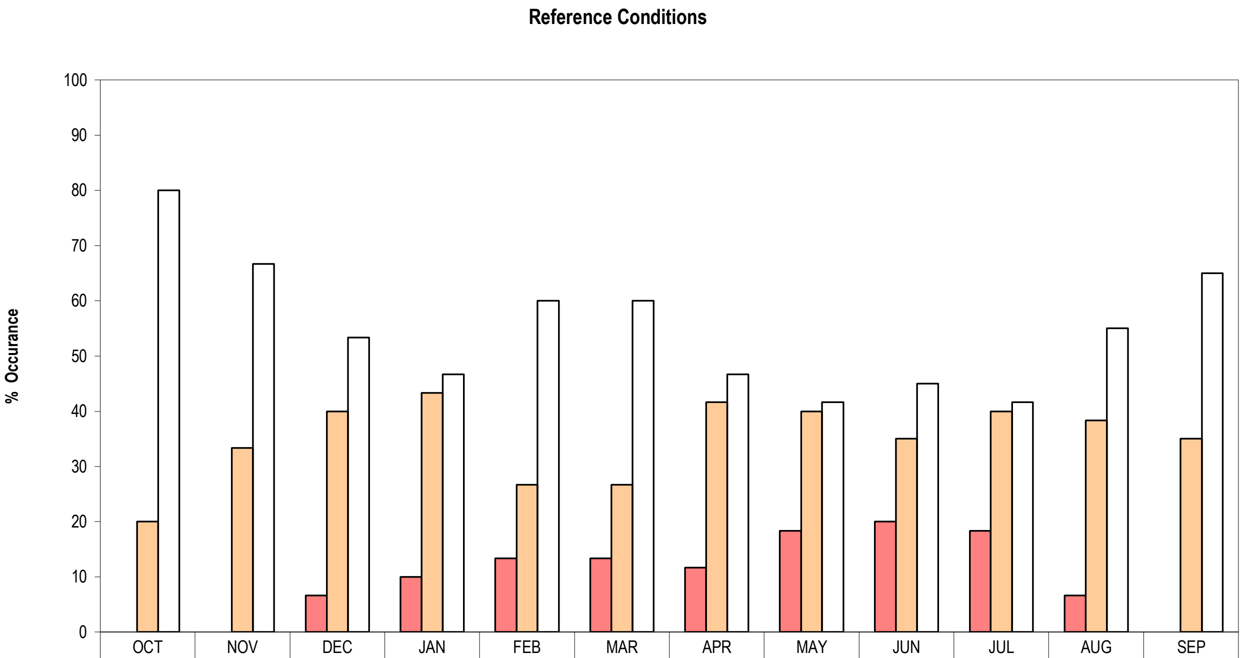
YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.62	0.15	0.00	0.00	0.00	0.00	0.00	1.02	0.37	0.00	0.00	0.10	0.19
1935	0.12	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.00	0.02
1936	0.04	0.17	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02
1937	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1938	0.00	0.06	0.01	0.00	0.46	0.28	0.00	0.00	0.00	0.00	0.16	0.15	0.09
1939	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1940	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.01
1941	0.17	0.03	0.05	0.09	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.04
1942	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.03
1943	0.02	0.33	0.22	0.00	0.00	0.00	0.00	0.61	0.14	0.00	0.00	0.00	0.11
1944	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.00	0.00	0.00	0.01
1945	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1946	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.01
1947	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1949	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
1950	0.03	0.44	0.16	0.23	0.00	0.00	0.00	0.00	0.00	0.12	0.18	0.17	0.11
1951	0.00	0.00	0.00	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.05	0.41	0.05
1952	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.11	0.03
1953	0.55	0.25	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.02	0.50	0.16	0.13
1954	0.00	0.00	0.00	0.00	0.57	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.05
1955	0.00	0.48	0.02	0.00	0.00	0.02	0.00	0.15	0.00	0.00	0.00	0.09	0.06
1956	0.34	0.10	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.04
1957	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.01
1958	0.00	0.00	0.00	0.09	0.00	0.00	0.15	0.05	0.00	0.00	0.08	0.00	0.03
1959	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.05	0.05	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.02
1961	0.00	0.00	0.00	0.00	0.00	0.17	0.02	0.00	0.00	0.00	0.60	0.14	0.08
1962	0.47	0.22	0.00	0.00	0.00	0.40	0.10	0.00	0.00	0.00	0.00	0.00	0.10
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.03
1964	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.20	0.41	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.06
1966	0.00	0.00	0.00	0.00	0.00	0.09	0.54	0.40	0.02	0.00	0.00	0.05	0.09
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.04	0.02
1968	0.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1969	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.03
1970	0.00	0.00	0.18	0.00	0.13	0.01	0.08	0.12	0.00	0.32	0.50	0.08	0.12
1971	0.00	0.15	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.04	0.00	0.05	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.01
1974	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.02
1975	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.49	0.22	0.00	0.00	0.21	0.22	0.00	0.12	0.00	0.00	0.00	0.00	0.10
1977	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.03	0.00	0.00	0.00	0.07	0.00	0.00	0.04	0.35	0.10	0.05
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.24	0.05	0.56	0.21	0.77	0.24	0.00	0.49	0.11	0.22
1981	0.23	0.03	0.00	0.00	0.00	0.00	0.60	0.08	0.00	0.00	0.00	0.00	0.08
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.35	0.05	0.00	0.04
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.24	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.04
1986	0.21	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.23	0.05
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.01
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.35	0.53	0.01	0.00	0.12	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.09
1990	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.06	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.02
1992	0.50	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.14
1993	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

1: Open	>0.1	2: Closed <1 day	0.03-0.1	3: Closed(> week)	< 0.03



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	70.0	66.7	86.7	83.3	78.3	81.7	81.7	78.3	91.7	91.7	75.0	66.7
State 2	6.7	10.0	8.3	13.3	10.0	6.7	6.7	6.7	1.7	3.3	8.3	10.0
State 1	23.3	23.3	5.0	3.3	11.7	11.7	11.7	15.0	6.7	5.0	16.7	23.3

Figure 10. *Occurrence of abiotic states during Scenario 3*



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	0.0	0.0	6.7	10.0	13.3	13.3	11.7	18.3	20.0	18.3	6.7	0.0
State 2	20.0	33.3	40.0	43.3	26.7	26.7	41.7	40.0	35.0	40.0	38.3	35.0
State 1	80.0	66.7	53.3	46.7	60.0	60.0	46.7	41.7	45.0	41.7	55.0	65.0

Figure 11. *Occurrence of abiotic states during Reference Conditions*

6.4.2 EHI for the Future Scenario 3 - Abiotic Components

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	60	For the Matjies Estuary low flows are defined as flows less than 0.1 m^3/s. As rainfall occurs throughout the year in this region, the hydrology scores were evaluated over the entire 60–year scenario sequence. Months with average flows of less than $0.1 m^3/s$ occurred under the Reference Conditions for 45% of the time. Under the Scenario 3 low flows occur for 87 % of the time.	L
b. % similarity in mean annual frequency of floods	55	Based 95%ile there is a 45 % decrease in the floods to the estuary.	L
Hydrology score	**55**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	25	The occurrence of *State 3* increases from 10% under the Reference Conditions to 79% under the Present State. (Following a precautionary approach Mouth Conditions are score conservatively as stated in Table 3.3b of the Estuarine RDM methods (DWAF 2004).)	L
Hydrodynamics and mouth conditions score	**25**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	20	There is a 40% decrease in State 1, leading to increased salinities under open mouth conditions. In addition there is a 70% increase in the occurrence of prolonged mouth closure events (State 3).	L
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	25	A 73% decrease in river flow will decrease the average concentrations of nutrients entering the estuary. Prolonged mouth closure (69%) and increased residence times will favour nutrient uptake.	L
2b. Suspended solids (turbidity) in the estuary	25	A 49% decrease in river flow will decrease the average concentrations of suspended solids entering the estuary. Prolonged mouth closure (46% increase) and increased residence times will favour the settling out of suspended solids and water should become slightly clearer.	L
2c. Dissolved oxygen in the estuary	25	A 49% increase in the occurrence of prolonged mouth closure will reduce water exchange, particularly in deeper reaches of the estuary. In addition, there is likely to be an increased rate of accumulation of settled particulate matter. These conditions are likely to favour a slight decrease in average DO.	L
2d. Levels of toxins	-	-	
Water Quality score	**20**		

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	55	Allow 45% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 20 would be allocated)	L
1b	% similarity in sand fraction relative to total sand and mud	55	Allow 45% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 20 would be allocated)	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	55	Allow 45% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 20 would be allocated)	L
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
	Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
Physical habitat score		**95**		

6.4.3 Biotic Components

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

MICROALGAE

There has been a 73% decrease in river flow from the natural MAR, which has resulted in slightly higher water residence times and more frequent mouth closures (state 3 has increased from 10% to 79%). This shift is likely to favour microalgal growth, particularly if the mouth does not close for long periods at a time (<1 week), there is overtopping or if there are still some river inputs of nutrients. There has been a ~45% decrease in floods so it is likely that there has been a change in the river inputs of suspended material or nutrients. Results suggest that the open phase (Dec 06) supports a lower average microalgal biomass (phytoplankton chl-a 2.0 $\mu g.l^{-1}$ and benthic chl-a 3.8 $\mu g.g^{-1}$) than the closed/intermittent phase (April 07) (phytoplankton chl-a 7.0 $\mu g.l^{-1}$ and benthic chl-a 8.5 $\mu g.g^{-1}$).

Confidence: Low

MACROPHYTES

Water abstraction is now 0.2 $m^3 s^{-1}$. Floods are reduced by 45%, low flows occur for 87% of the time and the mouth is mostly closed (79% of the time). The subtidal area would deepen and there would be a loss of intertidal habitat in the upper reaches due to reduced sediment input. The lack of floods and low velocity closed mouth conditions would encourage the growth and expansion of the reeds. There would be an increase in reed biomass if salinity during the closed mouth state remained less than 20 ppt and water levels were not too high. Overtopping and the input of saline water during the open mouth phase may prevent the estuary from becoming totally fresh and stagnant.

Confidence: Low

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Greater frequency of mouth closure will increase residence time of the estuary water, but because of less frequent overtopping (mouth remains closed for 79% of the time), salinity values are likely to move towards the freshwater end of the salinity range. Overtopping of the berm now occurs occasionally. Reed coverage is more expansive (less frequent flooding) and this would favour species associated with a reed habitat and a reduction of biomass of those

species that utilize open habitats. Confidence: Low
FISH
Estuarine fish species would be favoured by the prolonged closed phase, moderate salinities and the increased productivity of plants and invertebrates. The greater water surface area and volume during the closed phase would also tend to support a larger fish biomass within the estuary. The lack of floods would promote breeding by estuarine species which would become more dominant within the overall fish community. The juvenile recruitment of some marine fish species may be adversely affected by the prolonged closed mouth phase. Confidence: Low
BIRDS
The occurrence or time spent by small waders at the estuary is likely to decrease compared to natural because of less open habitat in which to forage. In addition, species associated with a reed habitat would increase. Confidence: Low

6.4.4 EHI for the Future Scenario 3 - Abiotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	50	A 73% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
2a. Abundance	25	A 73% decrease in MAR will reduce the nutrient load into the estuary. However, residence time will increase, providing a more stable environment leading to an increase in phytoplankton biomass.	L
2b. Community composition	25	A 73% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
Benthic microalgae			
1. Species richness	25	The 69% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to more brackish conditions. Some deepening of the channel and loss of intertidal areas will affect the benthic microalgae directly.	L
2a. Abundance	25	There is likely to be an increase in benthic microalgal biomass in response to a 46% increase in the frequency of mouth closure.	L
2b. Community composition	25	The 46% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to brackish conditions.	L
Microalgae score	**25**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	50 (70)	The increase in nutrients may promote the growth of weedy/ opportunistic species which would displace other slower growing species. The increase in salinity due to an increase in low flow conditions could displace some sensitive brackish species. The loss of intertidal habitat in the upper reaches due to lack of floods and reduced sediment input could also result in species loss. Opportunistic species would be lost as floods would no longer reset the estuary.	L

2a. Abundance	30	Floods are reduced by 45%, low flows occur for 87% of the time and the mouth is mostly closed (79% of the time). The less dynamic environment would encourage the growth of and expansion of reeds into the estuary channel. There would be an increase in reed biomass if salinity during the closed mouth state remained less than 20 ppt and water levels were not too high.	L
2b. Community composition	35	Reeds may expand into other habitats changing the community composition of the estuary if the salinity remains brackish (< 20 ppt). There will be a loss of open water habitat.	L
Macrophytes score	**30**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	60	Because of the increase in reed coverage and possible decrease in salinity, conditions would favour a more freshwater type community with higher species richness compared to typical estuarine species.	L
2a. Abundance	60	Increased residence time, less frequent flushing (more frequent mouth closure) and reduced salinity values will favour an increase in abundance of freshwater associated species.	L
2b. Community composition	50	Reduced salinity values and the expanding reed coverage will favour freshwater associated species and those species that utilize protection and habitat offered by reeds.	L
Macroinvertebrates (Zoobenthos)			
1. Species richness	40	Because of the decrease in salinity (in response to less frequent overtopping at the mouth) and reed encroachment into the estuary (less frequent flooding), species richness has probably increased.	L
2a. Abundance	40	Lower average salinity values have probably resulted in an increase in abundance. In addition, species that live in association with macrophytes are likely to establish a much greater biomass because of the expansion of reed coverage.	L
2b. Community composition	40	Lower average salinity values and greater reed coverage will probably lead to a change in the community. Euryhaline species will also decrease, while there will be an increase in freshwater associated species.	L
Macrocrustacea (Hyperbenthos)			
1. Species richness	50	Shift likely in response to decreased salinity values and greater coverage of reeds that would favour species utilizing these habitats.	L
2a. Abundance	50	Abundance of some species may increase because of increased reed coverage.	L
2b. Community composition	50	Lower average salinity values will probably lead to a slight decrease in euryhaline species and an increase in freshwater associated species. Composition will also change in response to reed encroachment into the estuary, providing sheltered habitat.	L
Invertebrates score	**40**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	60	Loss of freshwater and some marine species from the estuary due to changes in salinity and extended closed mouth phase.	L
2a. Abundance	40	The abundance of most fish species, especially estuarine taxa, would increase markedly due to improved feeding and habitat availability.	L
2b. Community composition	50	Changes in community composition due to the loss of freshwater and selected marine species, as well as the increase in the abundance of estuarine breeding taxa.	L
Fish score	**40**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	30	Species richness would increase due to a greater reed coverage and encroachment into the estuary that supports species associated with these habitats.	L
2a. Abundance	30	Abundance of reed-associated species would also increase despite human disturbance in the lower reaches.	L
2b. Community composition	30	Because of the change in habitat, community composition would change fairly significantly in favour of those species utilizing reeds. Species that favour open habitats may now only visit the estuary occasionally and will be subjected to human disturbance in the lower reaches.	L
Bird score	**30**		

6.5 Future Scenario 4: River Scenario C/D

6.5.1 Abiotic Components

Seasonal variability in river inflow:

Monthly simulated runoff data for the Future Scenario 4 is provided in Table 20. A summary of flow distribution (average monthly flows in $m^3.s^{-1}$) for the Future Scenario 4, derived from the 60-year simulated data set, is provided in Table 19 below:

Table 19. *Summary of flow distributions for Future Scenario 4*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.16	0.07	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.04	0.08	0.06
90%ile	0.16	0.07	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.04	0.08	0.06
80%ile	0.14	0.06	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.04	0.07	0.06
70%ile	0.12	0.06	0.03	0.03	0.03	0.05	0.04	0.05	0.04	0.04	0.06	0.05
60%ile	0.10	0.05	0.03	0.03	0.03	0.05	0.04	0.04	0.04	0.03	0.06	0.05
50%ile	0.08	0.05	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.05	0.04
40%ile	0.07	0.04	0.03	0.02	0.02	0.04	0.03	0.03	0.03	0.03	0.04	0.04
30%ile	0.05	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.03
20%ile	0.04	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02
10%ile	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.02
1%ile	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Present flood regime

The flood regime is judged to be highly modified from that of the reference conditions as the 95%ile indicates that there is an 87 % decrease in the floods to the estuary.

Confidence: Low

Present sediment processes

The hydrological data indicates that the magnitude and occurrence of major floods have been reduced by 87%. This means that the sediment delivery to the estuary is becoming sporadic and some changes in habitat can be expected, e.g. deepening of the subtidal area and loss of intertidal areas in the upper reaches, while the whole estuary would fill in with marine sand resulting in loss of subtidal and intertidal areas.

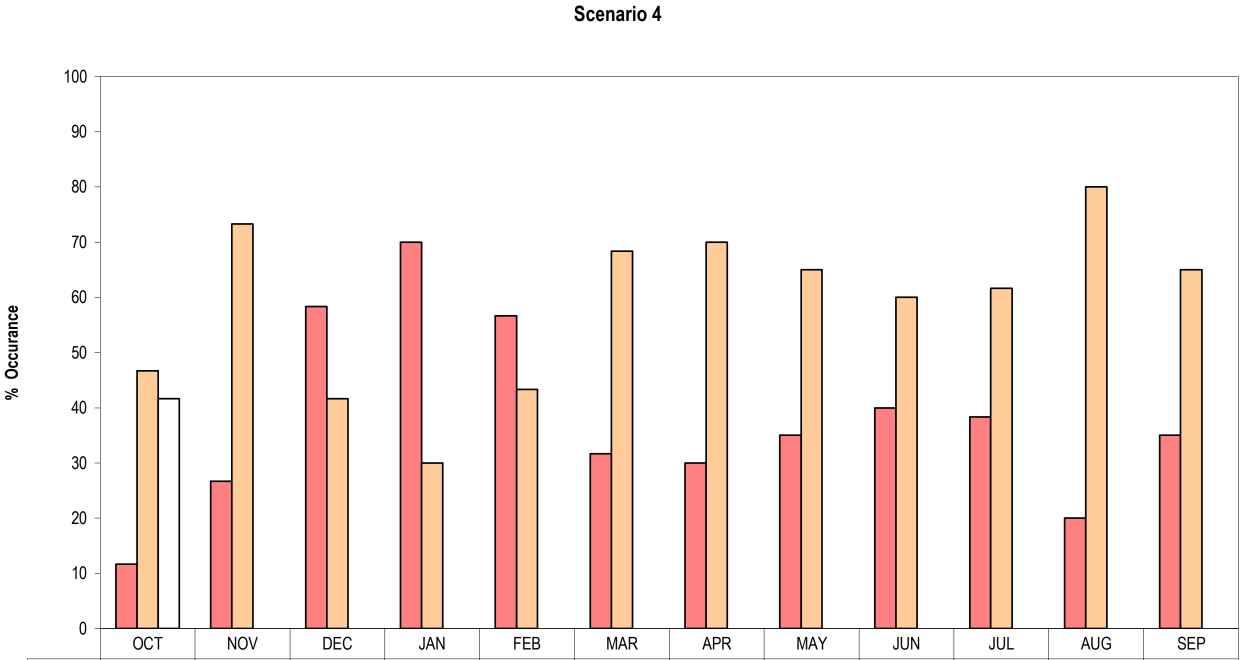
Confidence: Low

***Table 20.** Simulated monthly flows ($m^3.s^{-1}$) to the Matjies Estuary for the Future Scenario 4 (River Class C/D)*

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.16	0.06	0.02	0.01	0.01	0.03	0.04	0.05	0.04	0.04	0.06	0.06	0.05
1935	0.14	0.06	0.03	0.03	0.02	0.05	0.03	0.05	0.04	0.04	0.06	0.05	0.05
1936	0.13	0.07	0.03	0.02	0.02	0.05	0.03	0.01	0.01	0.04	0.03	0.05	0.04
1937	0.08	0.03	0.03	0.03	0.01	0.04	0.04	0.02	0.02	0.01	0.02	0.02	0.03
1938	0.04	0.06	0.03	0.02	0.04	0.05	0.04	0.01	0.01	0.04	0.08	0.06	0.04
1939	0.09	0.04	0.03	0.03	0.04	0.04	0.03	0.01	0.02	0.03	0.02	0.03	0.03
1940	0.02	0.02	0.01	0.03	0.01	0.02	0.05	0.05	0.03	0.03	0.02	0.03	0.03
1941	0.14	0.06	0.03	0.03	0.03	0.03	0.02	0.05	0.04	0.03	0.03	0.02	0.04
1942	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.02	0.02	0.05	0.06	0.03
1943	0.12	0.07	0.03	0.03	0.02	0.03	0.02	0.05	0.04	0.04	0.05	0.04	0.04
1944	0.08	0.03	0.01	0.01	0.01	0.01	0.01	0.05	0.04	0.04	0.03	0.02	0.03
1945	0.02	0.02	0.02	0.03	0.03	0.05	0.04	0.01	0.01	0.02	0.04	0.02	0.03
1946	0.06	0.03	0.01	0.03	0.03	0.05	0.04	0.05	0.04	0.04	0.05	0.04	0.04
1947	0.05	0.05	0.02	0.03	0.02	0.03	0.05	0.04	0.01	0.01	0.01	0.03	0.03
1948	0.08	0.05	0.03	0.03	0.03	0.02	0.02	0.04	0.02	0.01	0.01	0.02	0.03
1949	0.02	0.07	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.07	0.05	0.03
1950	0.12	0.07	0.03	0.03	0.03	0.02	0.01	0.04	0.04	0.04	0.08	0.06	0.05
1951	0.07	0.02	0.01	0.03	0.04	0.02	0.04	0.03	0.03	0.03	0.07	0.06	0.04
1952	0.13	0.04	0.02	0.02	0.02	0.02	0.02	0.01	0.04	0.04	0.08	0.06	0.04
1953	0.16	0.07	0.03	0.01	0.01	0.03	0.03	0.05	0.04	0.04	0.08	0.06	0.05
1954	0.03	0.06	0.02	0.03	0.04	0.05	0.03	0.02	0.02	0.02	0.02	0.01	0.03
1955	0.08	0.07	0.03	0.01	0.03	0.05	0.04	0.05	0.04	0.02	0.02	0.05	0.04
1956	0.16	0.06	0.03	0.02	0.03	0.05	0.04	0.02	0.04	0.03	0.06	0.05	0.05
1957	0.06	0.02	0.02	0.02	0.01	0.05	0.05	0.05	0.04	0.02	0.06	0.03	0.04
1958	0.06	0.02	0.03	0.03	0.03	0.05	0.05	0.05	0.03	0.04	0.07	0.04	0.04
1959	0.11	0.04	0.01	0.03	0.02	0.04	0.05	0.05	0.03	0.04	0.05	0.05	0.04
1960	0.03	0.04	0.03	0.03	0.04	0.05	0.04	0.05	0.03	0.03	0.04	0.02	0.04
1961	0.06	0.03	0.02	0.03	0.02	0.05	0.05	0.03	0.02	0.01	0.08	0.06	0.04
1962	0.16	0.07	0.03	0.03	0.02	0.05	0.05	0.04	0.03	0.04	0.05	0.02	0.05
1963	0.04	0.02	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.06	0.06	0.04
1964	0.12	0.05	0.02	0.01	0.01	0.05	0.05	0.05	0.04	0.03	0.03	0.01	0.04
1965	0.15	0.07	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.01	0.07	0.05	0.04
1966	0.02	0.02	0.03	0.03	0.03	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.04
1967	0.05	0.04	0.03	0.01	0.02	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.04
1968	0.12	0.06	0.03	0.02	0.03	0.05	0.04	0.01	0.04	0.03	0.03	0.02	0.04
1969	0.08	0.03	0.01	0.02	0.04	0.04	0.01	0.01	0.01	0.01	0.08	0.05	0.03
1970	0.11	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.04	0.08	0.05	0.05
1971	0.04	0.06	0.03	0.03	0.04	0.05	0.02	0.02	0.03	0.04	0.07	0.03	0.04
1972	0.02	0.02	0.01	0.02	0.02	0.04	0.04	0.04	0.03	0.02	0.03	0.04	0.03
1973	0.03	0.06	0.03	0.03	0.03	0.05	0.04	0.05	0.04	0.02	0.07	0.04	0.04
1974	0.03	0.05	0.02	0.03	0.04	0.05	0.03	0.01	0.03	0.03	0.05	0.06	0.03
1975	0.09	0.04	0.03	0.03	0.02	0.05	0.03	0.04	0.03	0.04	0.05	0.03	0.04
1976	0.16	0.07	0.03	0.01	0.04	0.05	0.04	0.05	0.04	0.02	0.05	0.04	0.05
1977	0.08	0.06	0.03	0.01	0.01	0.01	0.02	0.03	0.04	0.03	0.06	0.03	0.03
1978	0.07	0.05	0.03	0.03	0.02	0.02	0.05	0.05	0.03	0.04	0.08	0.06	0.04
1979	0.04	0.02	0.01	0.03	0.01	0.01	0.03	0.02	0.04	0.03	0.04	0.04	0.03
1980	0.11	0.04	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.03	0.08	0.06	0.05
1981	0.15	0.06	0.03	0.02	0.01	0.04	0.05	0.05	0.03	0.04	0.04	0.05	0.05
1982	0.07	0.02	0.01	0.01	0.03	0.03	0.02	0.04	0.04	0.04	0.07	0.04	0.03
1983	0.10	0.05	0.03	0.02	0.02	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.03
1984	0.02	0.03	0.02	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.01	0.03
1985	0.15	0.06	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.07	0.04	0.04
1986	0.15	0.06	0.01	0.01	0.03	0.04	0.05	0.04	0.03	0.02	0.05	0.06	0.05
1987	0.10	0.02	0.01	0.01	0.01	0.02	0.05	0.05	0.04	0.03	0.06	0.03	0.04
1988	0.05	0.02	0.02	0.01	0.01	0.02	0.05	0.04	0.02	0.03	0.02	0.01	0.02
1989	0.16	0.07	0.03	0.01	0.04	0.04	0.05	0.05	0.04	0.03	0.04	0.02	0.05
1990	0.09	0.05	0.02	0.02	0.04	0.04	0.02	0.03	0.02	0.02	0.02	0.01	0.03
1991	0.13	0.04	0.03	0.02	0.04	0.05	0.03	0.04	0.03	0.04	0.07	0.04	0.05
1992	0.16	0.07	0.03	0.02	0.01	0.02	0.03	0.03	0.04	0.03	0.03	0.06	0.04
1993	0.14	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.06	0.04	0.05

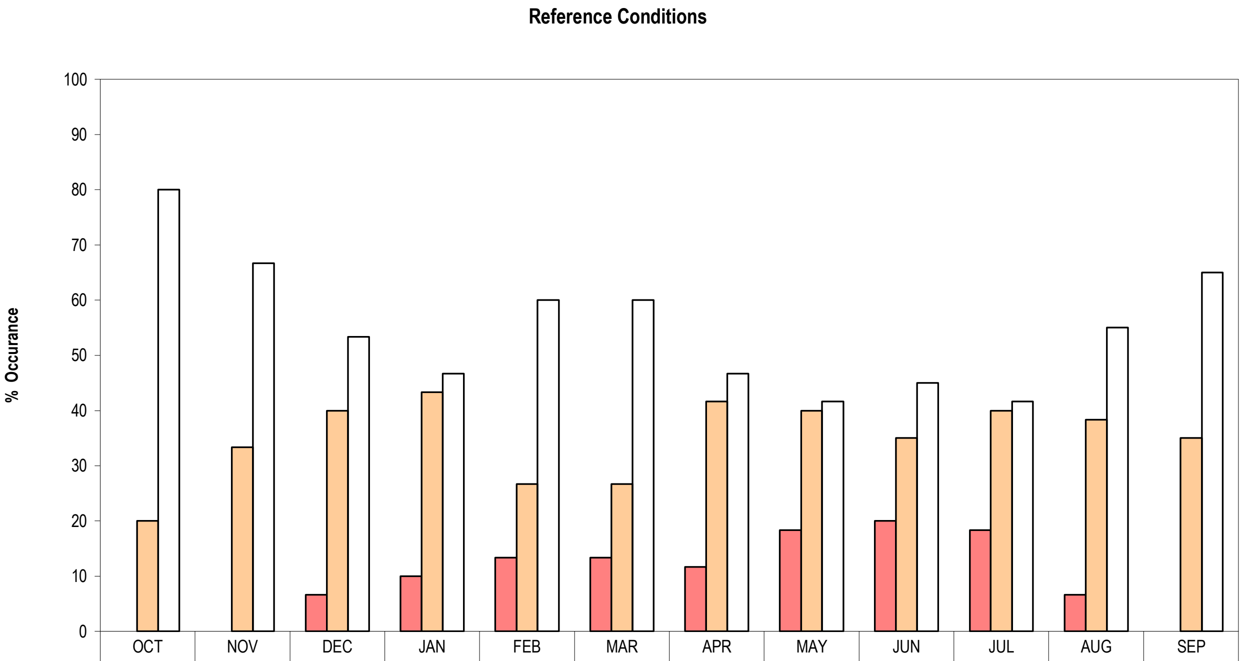
1: Open	>0.1	2: Closed <1 day	0.03-0.1	3: Closed(> week)	< 0.03

Occurrence of Abiotic states during the Scenario 4 and Reference Condition



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	11.7	26.7	58.3	70.0	56.7	31.7	30.0	35.0	40.0	38.3	20.0	35.0
State 2	46.7	73.3	41.7	30.0	43.3	68.3	70.0	65.0	60.0	61.7	80.0	65.0
State 1	41.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 12. *Occurrence of abiotic states during Scenario 4*



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	0.0	0.0	6.7	10.0	13.3	13.3	11.7	18.3	20.0	18.3	6.7	0.0
State 2	20.0	33.3	40.0	43.3	26.7	26.7	41.7	40.0	35.0	40.0	38.3	35.0
State 1	80.0	66.7	53.3	46.7	60.0	60.0	46.7	41.7	45.0	41.7	55.0	65.0

Figure 13. *Occurrence of abiotic states during Reference Conditions*

6.5.2 EHI for the Future Scenario 4 – Abiotic components

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition	50	For the Matjies Estuary low flows are defined as flows less than 0.1 m^3/s. As rainfall occurs throughout the year in this region, the hydrology scores were evaluated over the entire 60–year scenario sequence. Months with average flows of less than 0.1 m^3/s occurred under the Reference Conditions for 45% of the time. Under the Scenario 4 low flows occur for 97 % of the time.	L
b. % similarity in mean annual frequency of floods	13	The 95%ile indicates that there is a 87 % decrease in the floods to the estuary	M
Hydrology score	**13**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	60	The occurrence of *State 3* increases from 10% under the Reference Conditions to 38% under the Present State. (Following a precautionary approach Mouth Conditions are score conservatively as stated in Table 3.3b of the Estuarine RDM methods (DWAF 2004).)	L
Hydrodynamics and mouth conditions score	**60**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	30	There is a 50% decrease in State 1, leading to increased salinities under open mouth conditions. In addition there is a 28% increase in the occurrence of prolonged mouth closure events (State 3).	L
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	25	A 76% decrease in river flow will decrease the average concentrations of nutrients entering the estuary. Prolonged mouth closure (38%) and increased residence times will favour nutrient uptake. An in-channel dam would reduce nutrient input from the catchment.	L
2b. Suspended solids (turbidity) in the estuary	25	A 76% decrease in river flow will decrease the average concentrations of suspended solids entering the estuary. Prolonged mouth closure (38% increase) and increased residence times will favour the settling out of suspended solids and water should become slightly clearer.	L
2c. Dissolved oxygen in the estuary	60	A 38% increase in the occurrence of prolonged mouth closure will reduce water exchange, particularly in deeper reaches of the estuary. In addition, there is likely to be an increased rate of accumulation of settled particulate matter. These conditions are likely to favour a slight decrease in average DO.	L
2d. Levels of toxins	-	-	
Water Quality score	**25**		

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	10	Allow 90% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 0 would be allocated)	L
1b	% similarity in sand fraction relative to total sand and mud	10	Allow 90% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 0 would be allocated)	L
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	10	Allow 90% change in the intertidal area due to changes in floods and land use. (In the case of an in-channel development the impact would be much greater and a score of 0 would be allocated)	L
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
	Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	95	Sedimentation may have occurred due to change in land-use in the catchment.	L
Physical habitat score		**10**		

6.5.3 Biotic Components

Predicted change in biotic characteristics of the future Scenario 4 compared with the Reference Condition, as well as the causes of these changes:

MICROALGAE

There has been a 76% decrease in river flow from the natural MAR, which has resulted in slightly higher water residence times and more frequent mouth closures (state 3 has increased from 10% to 38%). This shift is likely to favour microalgal growth, particularly if the mouth does not close for long periods at a time (<1 week), there is overtopping or if there are still some river inputs of nutrients. There has been a ~50% decrease in floods so it is likely that there has been a change in the river inputs of suspended material or nutrients. Results suggest that the open phase (Dec 06) supports a lower average microalgal biomass (phytoplankton chl-a 2.0 $\mu g.l^{-1}$ and benthic chl-a 3.8 $\mu g.g^{-1}$) than the closed/intermittent phase (April 07) (phytoplankton chl-a 7.0 µg/l and benthic chl-a 8.5 $\mu g.g^{-1}$).

Confidence: Low

MACROPHYTES

Scenario 4 represents a scenario for a Class B/C river. The biggest difference in this Scenario compared to the other scenarios is the reduction in floods (87%) and the subsequent change (90%) in the intertidal and subtidal habitat due to sporadic sediment delivery. The estuary would fill in with marine sand. If this sand remained stable it could potentially be colonized by reeds or grasses such as brakgras, *Sporobolus virginicus*. Despite the increase in low flow conditions which now occur for 97% of the time the estuary will only remain closed for 38% of the time. The estuary would be more saline than that of Scenario 3 and reed expansion will not be as great because at high tide saline water will dominate. The estuary would be more stable due to the lack of resetting by floods. This would reduce the number of opportunistic species.

Confidence: Low

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

The invertebrate community is likely to change significantly compared to natural because of mouth closure that has increased to nearly 40% of the time (closed for longer than 1 week). Floods are significantly reduced and the estuary would become shallower due to marine sediment input. More saline conditions would favour typical estuarine species, but would result in a reduction of a freshwater associated community. This is in contrast to scenario 3 where freshwater associated species will increase and typical estuarine species will decline Confidence: Low
FISH
The fish community and marine species in particular, are likely to be adversely affected by the shallowing of the estuary. Widely fluctuating salinities caused by the alternate marine and freshwater conditions will prevent certain fish species from occupying the system. The limited habitat diversity and vulnerability to bird predation in shallow water will result in a major decline in fish abundance when compared to the reference condition. Confidence: Low
BIRDS
The occurrence or time spent by small waders at the estuary is likely to decrease compared to natural because of a reduction in intertidal area. In addition, species associated with a reed habitat would increase. Human disturbance remain a problem in the lower reaches. Confidence: Low

6.5.4 EHI for the Future Scenario 3 - Abiotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	25	A 76% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
2a. Abundance	25	A 76% decrease in MAR will reduce the nutrient load into the estuary. However, residence time will increase, providing a more stable environment leading to an increase in phytoplankton biomass.	L
2b. Community composition	25	A 76% decrease in MAR will reduce the amount of freshwater, and associated phytoplankton, flowing into the estuary.	L
Benthic microalgae			
1. Species richness	70	The 28% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to more brackish conditions. Some deepening of the channel and loss of intertidal areas will affect the benthic microalgae directly.	L
2a. Abundance	70	There is likely to be an increase in benthic microalgal biomass in response to a 28% increase in the frequency of mouth closure.	L
2b. Community composition	70	The 28% increase in the frequency of mouth closure is likely to create more stable conditions within the estuary, favouring the settling out of suspended material. As a result, the relative abundance of cyanobacteria is likely to increase as well as species adapted to brackish conditions.	L
Microalgae score	**25**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	40 (65)	The increase in salinity due to an increase in low flow conditions could displace some sensitive brackish species. The loss of intertidal habitat in the upper reaches due to lack of floods and reduced sediment input could also result in species loss. Floods are severely reduced and opportunistic species colonizing the estuary after floods would be lost.	L

2a. Abundance	40	Floods are reduced by 87%, low flows occur for 97% of the time and the mouth remains closed for 38% of the time. The less dynamic environment would encourage the growth of and expansion of reeds into the estuary channel that would fill in with marine sand.	L
2b. Community composition	45	Reeds may expand into other habitats changing the community composition of the estuary if the salinity remains brackish (< 20 ppt). Reed expansion would be less than that for Scenario 3 as the mouth remains open for longer and the estuary is potentially more saline.	L
Macrophytes score	**40**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	30	Because of the increase in reed coverage and increase in salinity, conditions would favour a more estuarine type community. A freshwater associated community would decline, resulting in a loss of species richness. Sedimentation will reduce available habitat.	L
2a. Abundance	20	Increased residence time, less frequent flushing (more frequent mouth closure) and increased salinity values will favour an increase in abundance of typical estuarine species. Sedimentation will reduce available habitat.	L
2b. Community composition	20	Increased salinity values and the expanding reed coverage will favour typical estuarine species and those species that utilize protection and habitat offered by reeds. A freshwater associated community would decline. Sedimentation will reduce available habitat.	L
Macroinvertebrates			
1. Species richness	30	Because of the increase in salinity (in response to low flows and prolonged mouth closure) and reed encroachment into the estuary (less frequent flooding), species richness has probably increased. Sedimentation and frequent marine input will create a shallow fluctuating habitat.	L
2a. Abundance	30	Higher average salinity values have probably resulted in an increase in abundance. In addition, species that live in association with macrophytes are likely to establish a much greater biomass because of the expansion of reed coverage.	L
2b. Community composition	30	Higher average salinity values and greater reed coverage will probably lead to a change in the community. Euryhaline species will also increase, while there will be an decrease in freshwater associated species.	L
Macrocrustacea			
1. Species richness	30	Shift likely in response to increased salinity values and greater coverage of reeds that would favour species utilizing these habitats. Sedimentation and frequent marine input will create a shallow fluctuating habitat.	L
2a. Abundance	30	Abundance of some species may increase because of increased reed coverage. Sedimentation and frequent marine input will create a shallow fluctuating habitat.	L
2b. Community composition	30	Higher average salinity values will probably lead to a slight increase in euryhaline species and an decrease in freshwater associated species. Composition will also change in response to reed encroachment into the estuary, providing sheltered habitat.	L
Invertebrates score	**20**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	40	Loss of most marine species and all freshwater species from the estuary due to reduced habitat (sediment infilling) when the mouth opens.	L
2a. Abundance	20	The abundance of most fish species, especially marine taxa, would decline markedly due to reduced habitat availability.	L
2b. Community composition	30	Changes in community composition due to the loss of marine species.	L
Fish score	**20**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	30	Species richness would increase due to a greater reed coverage and encroachment into the estuary that supports species associated with these habitats. Because of a decline in intertidal area, wading birds will spend less time at the estuary.	L
2a. Abundance	30	Abundance of reed-associated species would also increase and wading birds will decrease.	L
2b. Community composition	30	Because of the change in habitat, community composition would change fairly significantly in favour of those species utilizing reeds. Species that favour open habitats may now only visit the estuary occasionally. Human disturbance remain unchanged in the lower reaches.	L
Bird score	**30**		

7 Recommended Ecological Flow Requirement for the Matjies Estuary

The individual Estuarine Health Index scores, as well as the corresponding Ecological Reserve Categories for the scenarios are listed in Table 21:

Table 21. *Summary of individual Estuarine Health Index scores and Ecological Reserve Category for the Future Development Scenarios 1 to 4*

Variable	Weight	Present	Runoff scenario			
			1	2	3	4
Hydrology	25	92	84	74	58	35
Hydrodynamics/mouth condition	25	75	60	40	25	60
Water quality	25	83	70	50	23	27
Physical habitat alteration	25	95	90	80	55	10
Habitat Health Score (weighted)		**86**	**76**	**61**	**32**	**18**
Microalgae	20	85	70	50	25	25
Macrophytes	20	90	75	55	30	40
Invertebrates	20	90	65	35	17	10
Fish	20	95	90	60	35	17
Birds	20	90	80	35	10	10
Biotic Health Score (weighted)		**90**	**76**	**47**	**18**	**10**
Estuarine Health Index Score		**89**	**76**	**54**	**25**	**14**
Ecological Reserve Category (ERC)		**B**	**B**	**D**	**E**	**F**

The evaluation of the simulated runoff scenarios was used to derive the recommended Ecological Flow Requirement. The recommended Ecological Flow Requirement is defined as the runoff 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 ERC.

In evaluating Future Scenarios 1 to 4 it was assumed that only river inflow from the Matjies catchment will be reduced and that all other related anthropogenic activities (e.g. human disturbance) will remain at present levels.

Scenario 1 will maintain the Matjies Estuary in the recommended ERC as it differs very little in reduction of runoff (no change in flood frequency or volume) from the Present State. **Scenario 1 was selected as the Recommended Ecological Flow Requirement.**

Table 22. *Summary of flow distributions under Future Scenario 1*

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95%ile	0.65	0.56	0.21	0.25	0.36	0.37	0.31	0.56	0.29	0.22	0.64	0.39
90%ile	0.50	0.45	0.20	0.23	0.27	0.30	0.25	0.28	0.17	0.17	0.33	0.33
80%ile	0.33	0.30	0.16	0.15	0.19	0.16	0.17	0.20	0.11	0.11	0.21	0.26
70%ile	0.18	0.19	0.12	0.13	0.11	0.14	0.11	0.10	0.07	0.07	0.13	0.20
60%ile	0.14	0.13	0.07	0.06	0.08	0.11	0.07	0.06	0.05	0.05	0.08	0.14
50%ile	0.11	0.10	0.06	0.05	0.07	0.08	0.04	0.02	0.03	0.03	0.05	0.12
40%ile	0.10	0.08	0.04	0.03	0.05	0.05	0.03	0.01	0.02	0.02	0.04	0.09
30%ile	0.08	0.04	0.02	0.01	0.03	0.02	0.02	0.00	0.00	0.00	0.02	0.05
20%ile	0.05	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
10%ile	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

It might be possible to push Scenario 3 from an ERC E to a D and Scenario 2 from an ERC D to a C if flow can be maintained (capping flow) in a range of at least 0.03 to 0.05 $m^3.s^{-1}$. It is however very difficult to accurately measure flow as low as 0.03 $m^3.s^{-1}$.

It is expected that River Class B/C (not investigated as part of this study) will keep the Matjies Estuary in a higher ERC B than the Scenario 1 investigated in this study, as long as all baseflows and floods are allowed through.

The following recommendations are made before abstraction may be considered:

- Improved flow data is required
- The exact amount of water that will be abstracted must be quantified
- Capping flows need to be investigated
- No effluent may be pumped back into the river

8 References

Department of Water Affairs and Forestry (DWAF) 2004a. Water resource protection and assessment policy implementation process. Resource directed measures for protection of water resource: Methodology for the determination of the ecological water requirements for estuaries. Version 2. Pretoria: Department of Water Affairs and Forestry.

Theron, A. 2007. Personell communication. CSIR, Stellenbosch.

Turpie JK 2004b. Improving the biodiversity importance rating of estuaries. Water Research Commission Report No. 1247/1/04. Pp 109-120. Pretoria: Water Research Commission

Appendix A

AVAILABLE INFORMATION AND DATA

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	Estelle van Niekerk BKS Consulting Engineers	Provided for 1934 – 1993. Medium to low confidence as no runoff data is available
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)	1936,1960,1971,1974 1977, 1979, 1980, 1980	Collected for DEAT
Continuous water level recordings near mouth of the estuary	Measured for 20/3/2007	
Mouth observations	N/A	
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)	May 2007; April 2007; December 2006; June 1994 (T Harrison, unpublished data); September 1989 (NRIO, unpublished data)	
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	December 2006 and April 2007 (this study). June 1994 (Harrison, unpublished data).	
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	None	
Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary	April 2007 (this study), December 2006 (this study)	Collected 800 m from estuary mouth.
Water quality (e.g. system variables, nutrients and toxic substances)measurements on near-shore seawater	April 2007 (this study), December 2006 (this study)	Nutrients measured just outside mouth area.

Data availability on microalgae

DATA REQUIRED	AVAILABILITY	COMMENT
Chlorophyll-a measurements taken at 5 stations at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements must be taken coinciding with typically high and low flow conditions.	December 2006 and April 2007 (this study)	
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations (at least). Epipelic diatoms need to be collected for identification. These measurements must to be taken coinciding with a typical high and low flow condition (in temporarily closed estuaries measurements must include open as well as closed mouth conditions).	December 2006 and April 2007 (this study).	Sediment dominated by sand: episammic diatoms likely to dominate in this estuary.
Simultaneous measurements of flow, light, salinity, temperature, nutrients and substrate type (for benthic microalgae) need to be taken at the sampling stations during both the phytoplankton and benthic microalgal surveys.	December 2006 and April 2007 (this study).	

Data availability on macrophytes

DATA REQUIRED	AVAILABILITY	COMMENT
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (if available) Available orthophoto maps	1936,1960,1971,1974 1977, 1979, 1980, 1980	Collected for DEAT
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	Identified during a field survey in December 2006 and April 2007.	
Permanent transects: - Measurements of percentage plant cover along an elevation gradient - Measurements of salinity, water level, sediment moisture content and turbidity	Unavailable	Measurements along permanent transects are unnecessary for this small estuary as there are no extensive salt marsh areas.

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	No data	
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.	December 2006 and April 2007 (this study).	Sediment dominated by sand, highly dynamic
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.	No data	System small and shallow. Access limited and not possible to operate a boat.
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 data	System small and shallow. Access limited and not possible to operate a boat.

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.	CSIR survey in September 1994, and the SAIAB survey in April 2007.	Very limited access to the deeper upper reaches and not possible to operate a boat in the shallow lower and middle reaches.

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).	No data	

Appendix B

SOUT AND MATJIES RIVERS

ECOLOGICAL RESERVE DETERMINATION STUDIES FOR THE WATER RESOURCES OF THE K70A QUATERNARY CATCHMENT

Estelle Van Niekerk

BKS Consulting Egineers

ECOLOGICAL RESERVE DETERMINATION STUDIES FOR THE WATER RESOURCES OF THE K70A QUATERNARY CATCHMENT

OVERVIEW OF CATCHMENT

The Matjies River is a small coastal river that drains into the sea at Keurboomstrand. The Matjies River enters the sea just west of Natures Valley, and the Groot River flows into the sea slightly further east at Natures Valley. All these rivers, together with a few smaller coastal rivers are in the K70A catchment area.

The total catchment area of K70A is 170 km^2. The Mean Annual Precipitation (MAP) for the K70A catchment is 920 mm and the Mean Annual Evaporation (MAE) is 1400 mm (WR90). The Natural Mean Annual Runoff (MAR) of K70A according to the Ninham Shand report (2003) is approximately 60 million m^3.

This region exhibits neither a summer nor a winter rainfall characteristic. Rain is experienced throughout the year with the highest precipitation during spring (September to November) and again during late summer (February and March). Rainfall higher than 1000 mm can be expected in the mountain areas. The MAP decreases from east to west. The Bloukrans and the Groot River catchments have MAP's in excess of 1020 mm, whereas the drier Upper Keurbooms catchment has a MAP of only 660 mm.

AVAILABLE DATA

There are no flow gauging stations in the Matjies and Matjies Rivers. The best available flow data are simulated monthly data by Ninham Shand with the Pitman model for the period 1934 to 1993. There is a big difference in the MARs calculated by WR90 and Ninham Shand. The WR90 study used a station (K6H002 on the Keurbooms River) in their calibration to transfer parameters to the K70A catchment. K6H002 was later closed because most of the water by-passed the weir which resulted in very poor observed data at this gauging station. A new flow gauge was built at the confluence of the Keurbooms and Palmiet Rivers in October 1997 to replace K6H002. Ninham Shand used the calibration parameters of a gauging station (K7H001) on the Bloukrans River to simulate stream flow records for the rivers in quaternary K70A.

Table 1. *Details of the rivers in K70A*

River (NinhamShand Catchment number)	Ninham Shand (1934 – 1993)			MAP mm	MAE mm
	Natural MAR million m^3 (mm)	Present MAR million m^3	Catch. Area km^2		
Matjies (710)	5 (212)	4	24	810	1 285
Sout (720)	11 (309)	11	35.5	886	1 280
Groot (730)	36 (433)	36	83	1 023	1 260
Other small rivers	Not available	Not available	27.5	n/a	n/a
TOTAL for Sout & Matjies & Groot Rivers	**52.2**	**51.3**	**170**	**n/a**	**n/a**

LAND USE

Nature Valley abstracts water for domestic use from the Groot River in K70A. Water is also abstracted for irrigation in the Groot River. All abstractions are downstream of the gauging station K7H001. There is an interbasin transfer from the Matjies to the Buffels / Matjies Rivers at Kurland Estate. Small amounts of treated effluent are also discharged into the Matjies River. The land use developments are based on 1993 information and are summarized in Table 2. Keurboomstrand used to get water from the Matjies River abstracted close to the estuary, but this scheme has been abandoned and Keurboomstrand receives their water from the central water purification works of the Bitou municipality since 2002. Water abstracted from the Matjies River is negligible.

Table 2. *Catchment developments in quaternary K70A*

Location	Catchment area (km^2)	Irrigation (km^2)	Farm Dams and Abstractions	Forest area (km^2)
K7H001	55	None	None	4.2
Buffels EWR site 1 (Matjies River)	6.3	1.38	Transfer of water from the Matjies to the Buffels/Matjies River	14.2
Wit River IFR site 1 (Sout River)	11.4	None	None	12.5
Groot River	83	None	None	23.2

NATURAL FLOW RECORDS FOR THE MATJIES AND MATJIE RIVERS

The simulated flow and land use records from the Bitou Municipality Augmentation Study were obtained from Ninham Shand. The above study used the Bloukrans (Catchment 740) calibration parameters to derive simulated monthly flow records for the Matjies and Matjies Rivers for the period 1934 to 1993. The parameters used in the simulation are given in Table 3.

Table 3. *Parameters used in simulation of natural flow records for the rivers in K70A.*

Param	POW	SL	ST	FT	GW	ZMIN	ZMAX	PI	TL	GL	R
K7H001	2	0	100	40	0	0	160	1.5	0.25	0	0

The statistics of the flow data and land use data are given in Table 4.

Table 4. *Statistics of flow and land use records*

River	Catchment Area km^2	Natural flow Million m^3	Afforestation Million m^3	Irrigation Million m^3	Other Million m^3
Matjies	24	5.0	0.060	0.083	0.000
Sout	35.5	11.215	0.000	0.000	0.000
Groot	83	35.802	0.000	0.000	0.000

PRESENT DAY FLOW RECORDS FOR THE MATJIES AND MATJIE RIVERS

The natural flow record for the Matjies River was accepted as the present day flow record. The present day flow record for the Matjies River was derived by using the WRYM model to simulate the impact of a dam of 0.25 million m^3 with a surface area of 0.06 km^2 just upstream of the EWR site. No abstractions were made from this dam. The impact of this dam is extremely small since evaporation and rainfall on the dam are very similar.

EWR SITES IN THE SOUT AND MATJIEs RIVERS

On the 29th and 30th November 2006 a field visit to collect data to this study area was organized. The EWR sites chosen to do the Reserves are given in **Table 5**. The flow measured at the EWR sites are given in **Table 5**.

***Table 5**. Details and flow measured at the EWR sites*

EWR site	EWR name	Coordinates	Level of Reserve	Catchment Area (km^2)	Flow m^3/s
K7H001	N/A	N/A	Data measured by DWAF	55	0.52
Buffels River (Matjies)	Buffels EWR1	33.57.960S, 23.28.681E	Rapid III	6.3	0.007
Sout River	Matjies EWR1	33.55.681S, 23.29.362E	Intermediate	11.4	0.12

SUMMARY OF DATA

Sout River

- No measured data are available. The only data available are 60 years (1934 – 1993) of simulated monthly data based on calibration parameters from the Bloukrans River.
- The land use in the catchment is small and considered negligible with regards to water quantity. Land development in the catchment is restricted to a water transfer to the Matjies River via a small canal and some 13 km2 of indigenous forests.
- The natural MAR and present day MAR is estimated to be 11.22 million m3.

Matjies River

- There are no measured data available. The only data available are 60 years of simulated monthly data based on calibration parameters from the Bloukrans River.
- There are approximately 14km2 of indigenous forest, 0.3 km2 of afforestation (cultivated) and 1.4km2 of irrigation in the catchment
- The Matjies River receives a small amount of water from the Matjies River and some treated effluent is returned to this river. The amounts are negligible.
- There is a dam of 0.25 million m3 just upstream of the EWR site. The dam was modelled with no abstractions from it. It was assumed that abstractions from this dam are negligible.
- In the past water was abstracted just before the estuary for Keurboomsstrand. Since 2002, Keurboomstrand receives their domestic water from other sources.
- The natural MAR has decreased from a natural MAR of 5.10 million m3 to 4.27 million m3 in its present state.

CONCLUSIONS ON RELIABILITY AND CONFIDENCE IN DATA

- The Sout River is in a natural state with regards to water quantity and the natural MAR and present day MAR is estimated to be the same at 11.22 million m3.
- The MAR of the Matjies River has been decreased to 84% of natural MAR from 5.10 in the natural state to 4.27 million m3 in the present state.
- There are no measured flow data available for the Matjies and Matjies Rivers. All flow data was simulated with the WRSM2000 model. The simulation parameters were transferred from the Bloukrans River. Very little rainfall data exist in the mountains. The confidence in the flow data is medium but low for low flows.
- There is a flow gauge in the Sout / Wit River but no flow data because there is no rating curve. This is a possible source of data for future use. This data are collected by DWAF: Regional office (George).

Appendix C

SUMMARY OF ADDITIONAL INFORMATION AND DATA COLLECTED

Hydrodynamics

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1. Study site

Figure 1. *Aerial photo (2004) of the Matjies Estuary*

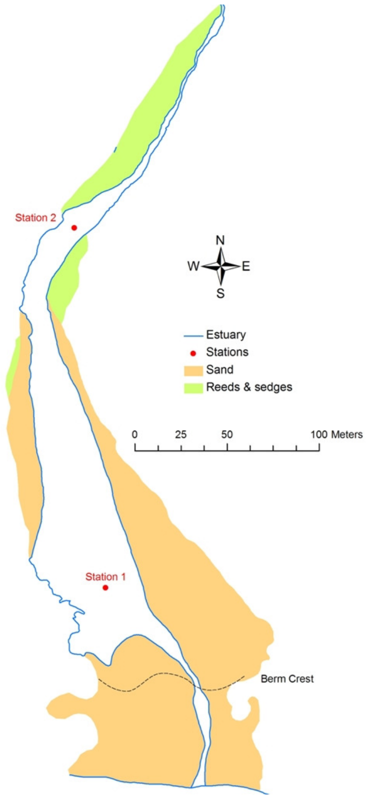


Figure 2. *Study site map showing the variability of the lower reaches of the Matjies Estuary*

2. Physico-chemical data

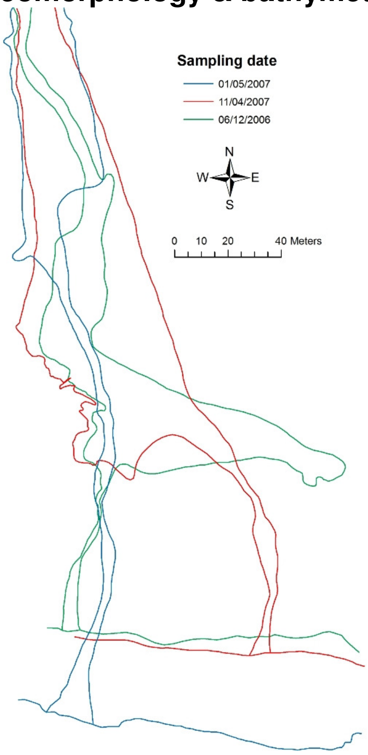
2.1. Low flow (December 2006)

Station	Depth (m)	Salinity (ppt)	Conductivity (mS or uS)	Temp (^{o}C)	Secchi (cm)
1	0	3	3147	27.5	35
1	0.2	16.3	27.41	22.9	
1	0.5	20.9	33.51	21	
2	0	0.6	1135	22.8	35
2	0.5	15.2	22.77	21.3	
2	1	20.5	32.38	20.1	

2.2. High flow (April 2007)

Station	Depth (m)	Salinity (ppt)	O2 %	Temp (^{o}C)	Secchi (cm)
1	0	4.2	90.3	17.6	50
1	0.5	4.1	91.3	17.6	
2	0	3.2	101.1	18.3	50
2	0.5	10.9	71.9	22.5	

3. Beach berm geomorphology & bathymetry



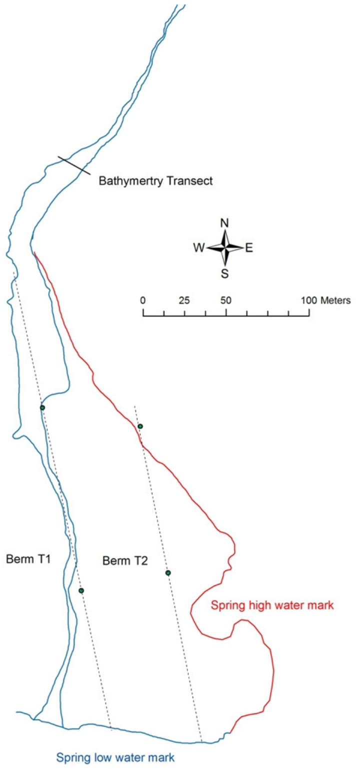


Figure 3. *Map showing variability in the position of the lower reaches of the Matjies Estuary*

Figure 4. *Study site map showing the location of the berm and bathymetry transects on 01/05/07*

Surface water area of the Matjies Estuary during three sampling periods

Date	Surface area (m^2)
6 December 2006	4565.81
11 April 2007	6936.13
1 May 2007	3919.01
Mean	5140.31

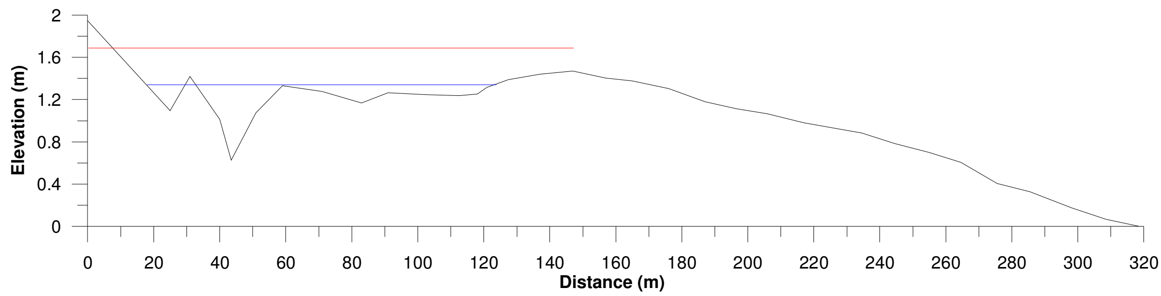


Figure 5. *Profile of Matjies beach berm Transect 1*

Blue line denotes the water level in the estuary as it was on 01/05/07. The red line indicates the highest water level reached for prolonged periods (closed mouth conditions) in the estuary (determined from water marks against the rocks at Station 2).

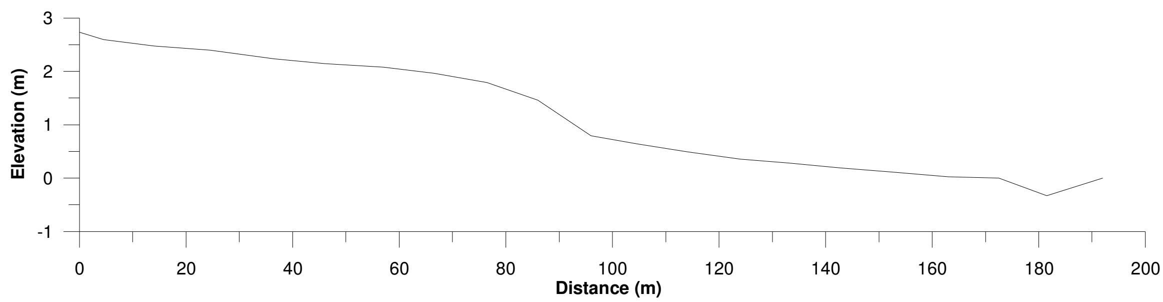


Figure 6. *Profile of Matjies beach berm Transect 2*

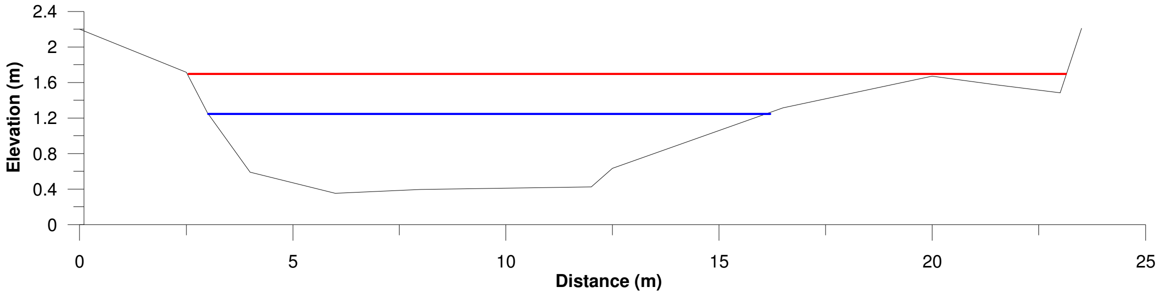


Figure 7. *Profile of Matjies Estuary Transect 1*

4. Salinity run

Distance from station to the sea (see adjacent Figure)	
Station	**Distance (m)**
1	8
2	85
3	160
4	205
5	235
6	270
7	305
8	350
9	385
10	420
11	455
12	480

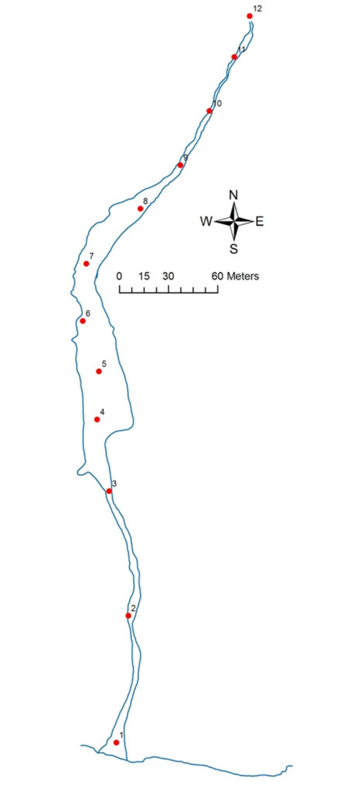


Figure 8. *Position of the salinity and temperature run stations*

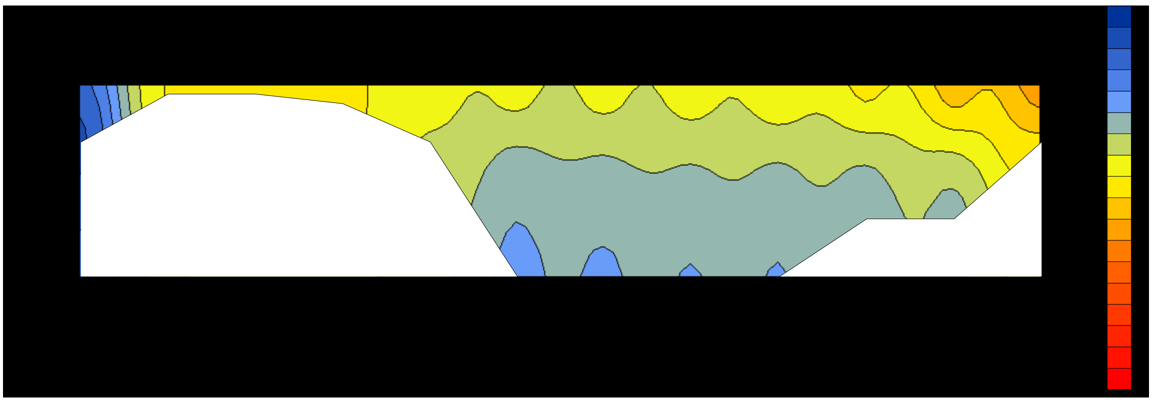


Figure 9. *Salinity profile of the Matjies Estuary on 01/05/07 following marine ingress*

Water Quality & Microalgae

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Raw Data

Table 5 Nutrient (µM) and phytoplankton chlorophyll *a* ($\mu g.l^{-1}$) concentrations in the Majies estuary.						
December 2006						
	Distance	**NH4+**	**SRP**	**TOxN**	**Silicate**	**Chl *a***
Sea	0	1.89	0.46	8.44	6.64	0.24
1S	0.2	1.37	1.02	42.69	84.37	0.36
1B	0.2	2.93	0.90	32.20	43.55	4.77
2S	0.35	1.86	0.94	41.13	87.99	0.27
2B	0.35	1.19	0.48	21.31	46.17	2.52
River	0.5	0.58	0.92	32.34	79.35	1.42
April 2007						
	Distance	**NH4+**	**SRP**	**TOxN**	**Silicate**	**Chl *a***
Sea	0	3.52	0.14	0.17	13.21	6.48
1S	0.2	7.38	0.06	0.63	165.35	2.69
1B	0.2	0.88	0.10	1.84	181.74	2.60
2S	0.35	4.94	0.11	8.11	167.96	9.80
2B	0.35	7.90	0.27	1.71	83.54	13.08
River	0.5	6.52	0.61	11.77	202.61	0.21

Table 6 Intertidal (I) and subtidal (S) benthic chlorophyll *a* in the Majies estuary ($\mu g.l^{-1}$).				
December 2006				
Distance	**I Chl**	**SEM**	**Sub Chl**	**SEM**
0.2	1.09	0.10	0.43	0.08
0.35	3.63	0.70	9.98	0.80
April 2007				
Distance	**I Chl**	**SEM**	**Sub Chl**	**SEM**
0.2	4.55	0.07	5.27	0.63
0.35	15.38	1.78	8.64	0.87

Macrophytes

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The estuary is short (0.6 km) and characterised by steep slopes. There is limited intertidal area and the available habitat for macrophytes is thus small. Total area covered by macrophytes is 1868.4 m^2 (Figure 1). Sediment movement and channel migration in the lower and mouth reaches of the estuary prevent the establishment of permanent macrophyte areas. Brakgras, *Sporobolus virginicus* occurs here as well as the sedge *Ficinia nodosa.* Brakgras is common along the margins of salt marshes or in dune slacks.

The dominant macrophyte in the Matjies Estuary is common reed, *Phragmites australis*. This is a cosmopolitan plant capable of growing quickly in favourable environments and producing large clumps of thick rhizomes. It has periods of die-back in winter or when under stress. Other plants present include sharp rush, *Juncus kraussii*, buffalo grass, *Stenotaphrum secundatum* and brassbuttons, *Cotula coronopifolia*. Most aerial photographs and observations shows that the mouth of the Matjies Estuary is predominantly open which indicates that the estuary is perched as the vegetation reflects a brackish (< 20 ppt) system.

Sediment movement and channel migration in the lower and mouth reaches of the estuary prevent the establishment of permanent submerged macrophyte beds. Filamentous macroalgae may be present during intermittently closed and closed phases.

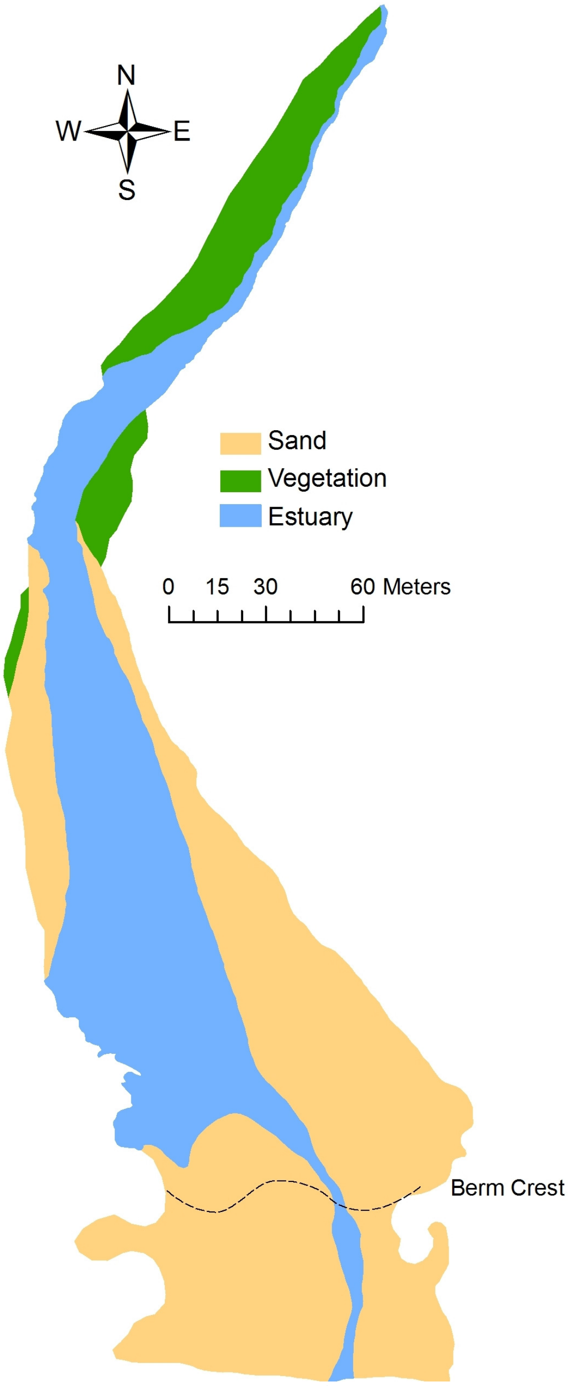

Figure 1. *Vegetation map of the Matjies Estuary*

Invertebrates

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Zooplankton
There are no available data on the zooplankton and it was not possible to deploy zooplankton nets. However, because of the shallow nature of the system and frequent shift in salinity (because of the relatively small volume of water in the estuary and inflow patterns of fresh and saltwater), zooplankton biomass is likely to be low. The uppermost reaches are also likely to be colonized by freshwater associated species, different to those near the mouth.

Benthic invertebrates
The sandy substrata characterizing the Matjies Estuary is relatively mobile and observations suggest that the lower channel is constantly changing in shape and position. This is reflected in the benthic community which is composed of relatively few species (mostly amphipods) that are large and mobile (See Table 1 below). Chironomid larvae were also present, mostly in the upper reaches. Two species of *Grandidierella* commonly found in other South African estuaries were the most important species, but maximum densities were relatively low (Table 1). Abundance levels between the two visits also differed significantly.

Larger invertebrates
No larger invertebrates were observed during the two sampling trips.

Table 1. *Subtidal benthic invertebrates (mean abundance per m^2) (calculated from the mean of three replicates collected during each trip).*

	Site	
	1	**2**
Polychaeta		
Ologochaete sp.	0	52
Isopoda		
Anthurid sp.	0	50
Pontogeloides latipes	9	34
Amphipoda		
Corophium triaenonyx	0	1025
Grandidierella lignorum	0	1142
Grandidierella lutosa	0	2250
Insectivora		
Chironomid larvae	25	7267

Fish

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Executive Summary

A total of nine fish species from five families have been recorded from the Matjies Estuary. Two of these species are dependent on estuaries for breeding purposes, and include resident taxa such as the Knysna sandgoby *Psammogobius knysnaensis* and prison goby *Caffrogobius gilchristi*. A total of three marine species, including the Cape stumpnose *Rhabdosargus holubi* and Cape moony *Monodactylus falciformis*, are dependent on estuaries as nursery areas. A further two marine species (striped mullet *Liza tricuspidens* and southern mullet *Liza richardsonii*) are at least partially dependent on estuaries as nursery areas. One catadromous species, the freshwater mullet *Myxus capensis* was recorded throughout the estuary. The freshwater Eastern Cape redfin *Pseudobarbus afer* was found in the middle reaches of the system where salinities were <5 psu. No stenohaline marine species were recorded in the estuary due to the low salinities and lack of a permanent connection to the sea.

This study has shown that:

(1) The Matjies Estuary supports an ichthyofauna dominated by 0+ juvenile mugilids (mullet) that utilize the system as a nursery area.
(2) Most of the fish species found in the estuary are associated with the benthos, either the microphytobenthos in the case of detritivorous mugilids or the zoobenthos in the case of carnivorous sparids and gobies.
(3) Poor planktonic food resources as a result of clear, nutrient poor river inflow have contributed to the apparent absence of planktivorous fish species within this estuary.
(4) Reduced river flow is likely to result in a less frequent estuarine/marine linkage and therefore a reduced marine migrant fish component within the system.

1. INTRODUCTION

The state of knowledge of the Matjies Estuary fish fauna is very limited. Two brief surveys have been conducted, one by Harrison in September 1994 and one by Whitfield in April 2007. Both surveys have shown that the estuary is dominated by marine migrant fish species that utilise the system primarily as a nursery area.

1.1 Study area

The Matjies Estuary is a small system located in a "laterally confined valley" (Harrison et al. 1995). The estuary is separated from the sea by a wide sandy barrier, across which a sinuous, shallow outflow channel is sometimes located. At high tide, seawater can enter the estuary across the beach which then results in elevated salinities prevailing in the lower reaches. Freshwater inflow tends to keep salinities in the upper and middle reaches of the estuary low, although salinity stratification can occur in these regions (Harrison et al. 1995). The river water has a low pH and characteristic clear dark brown colour due to dissolved humic substances leached from the catchment forests and fynbos. Rainfall in the region occurs throughout the year and the river has slightly higher flows in autumn and spring due to elevated rainfall during these months.

1.2 Background information and aims

The 'health' of the system, when analysed using the fish community as an indicator (Harrison et al. 2000), was poor when compared to similar estuaries within the warm-temperate region. In contrast the water quality and aesthetics of the estuary were classified as good (Harrison et al. 2000).

This report synthesizes information on the fish component of the Matjies Estuary Rapid Reserve Study, including:

- Species composition and estuarine dependence categories for those species found in the estuary;
- A preliminary assessment of the relative importance of the estuary to different species or groups of species;
- A preliminary assessment of the likely effects of altered river inflows on the ichthyofauna;
- Providing recommendations for further work in order to enhance the reliability of predictions of fish responses to changes in Matjies River flow.

2. Fish community

2.1 The Matjies Estuary ichthyofauna

A total of nine fish species from five families, analysed using the categories outlined in Table 2.1, have been recorded from the Matjies Estuary (Table 2.2). Two of these species are dependent on estuaries for breeding purposes, and include resident taxa such as the Knysna sandgoby *Psammogobius knysnaensis* and prison goby *Caffrogobius gilchristi*. A total of three marine species, including the Cape stumpnose *Rhabdosargus holubi* and Cape moony *Monodactylus falciformis*, are dependent on estuaries as nursery areas. A further two marine species (striped mullet *Liza tricuspidens* and southern mullet *Liza richardsonii*) are at least partially dependent on estuaries as nursery areas. One catadromous species, the freshwater mullet *Myxus capensis* was recorded throughout the estuary. The freshwater Eastern Cape redfin *Pseudobarbus afer* was found in the middle reaches of the system where salinities were <5 psu. No stenohaline marine species were recorded in the estuary due to the low salinities and lack of a permanent connection to the sea.

An analysis of the fish species groupings in the Matjies Estuary according to life history traits of the various taxa is shown in Figure 2.1. This figure indicates that marine migrant species are dominant, followed by estuarine residents and then catadromous and freshwater taxa. Catadromous taxa are represented by the freshwater mullet which is able to survive in the estuary if the river is unavailable for colonisation. Given the predominantly closed phase of the estuary mouth and the small size of the Matjies catchment, it is unlikely that catadromous anguillid eels enter the Matjies Estuary in any significant numbers.

Fish species groupings in the Matjies Estuary analysed according to relative abundance indicated that once again marine immigrant species are dominant followed by estuarine residents (Harrison & Whitfield data unpublished). When these fish species groupings are analysed according to relative biomass of the various taxa, marine immigrants are shown to be overwhelmingly dominant (Harrison unpublished data). This dominance is because all the estuarine residents are small species and therefore contribute considerably less to the overall catch when analysed on a biomass basis.

Based on their distributional ranges, six (67%) of the fish species recorded in the Matjies Estuary are southern African endemics. The high degree of endemism can be attributed to the locality of the Matjies Estuary within the warm temperate biogeographic region. According to the fish sampling that has been conducted in the estuary there are no rare or endangered fish species within the system.

The food web structure of the Matjies Estuary fish community appears to be dominated by mugilids feeding on microphytobenthos and macrophytic detritus generated from catchment and riparian vegetation. The clear waters do not appear to be able to support populations of zooplanktivorous fish species such the estuarine roundherring *Gilchristella aestuaria* or Cape silverside *Atherina breviceps*. The absence of submerged macrophytes and limited areas of emergent plant species within the estuary resulted in relatively small populations of macrophyte associated fish species such as *Rhabdosargus holubi* and *Monodactylus falciformis*. Overall the estuary had a food web structure dominated by fish species (mugilids) feeding predominantly on microphytobenthos and the remainder of the species dependent on zoobenthos associated with the benthic detritus food web.

Table 2.1 *The five major categories of fishes that utilize South African estuaries*

I	Estuarine species that breed in South African estuaries. Further subdivided into:	
	Ia	Resident species which have not been recorded spawning in the marine or freshwater environment
	Ib	Resident species which also have marine or freshwater breeding populations
II	Euryhaline marine species (marine migrants) which usually breed at sea with the juveniles showing varying degrees of dependence on South African estuaries. Further subdivided into:	
	IIa	Juveniles dependent on estuaries as nursery areas
	IIb	Juveniles occur mainly in estuaries, but are also found at sea
	IIc	Juveniles occur in estuaries, but are usually more abundant at sea
III	Marine species which occur in estuaries in small numbers but are not dependent on these systems. These species are known as marine stragglers.	
IV	Freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. Includes some species which may breed in both freshwater and estuarine systems.	
V	Catadromous species which use estuaries as transit routes between the marine and freshwater environments and may also occupy estuaries in certain regions. Further subdivided into:	
	Va	Obligate catadromous species which require a freshwater phase in their development.
	Vb	Facultative catadromous species which do not require a freshwater phase in their development.

Table 2.2 *A list of indigenous fish species recorded in the Matjies Estuary. The species are classified into five major categories of estuarine-dependence as outlined in Table 2.1 and southern African endemic taxa are indicated with an asterisk (*)*

Family	**Scientific name**	**Common name**	**Category**
Cyprinidae	*Pseudobarbus afer*	Eastern Cape redfin	IV
Gobiidae	*Caffrogobius gilchristi**	Prison goby	……….Ib
Gobiidae	*Psammogobius knysnaensis**	Speckled sandgoby	Ib
Monodactylidae	*Monodactylus falciformis*	Oval moony	IIa
Mugilidae	*Liza richardsonii**	Southern mullet	IIc
Mugilidae	*Liza tricuspidens**	Striped mullet	IIb
Mugilidae	*Mugil cephalus*	Flathead mullet	IIa
Mugilidae	*Myxus capensis**	Freshwater mullet	Vb
Sparidae	*Rhabdosargus holubi**	Cape stumpnose	IIa

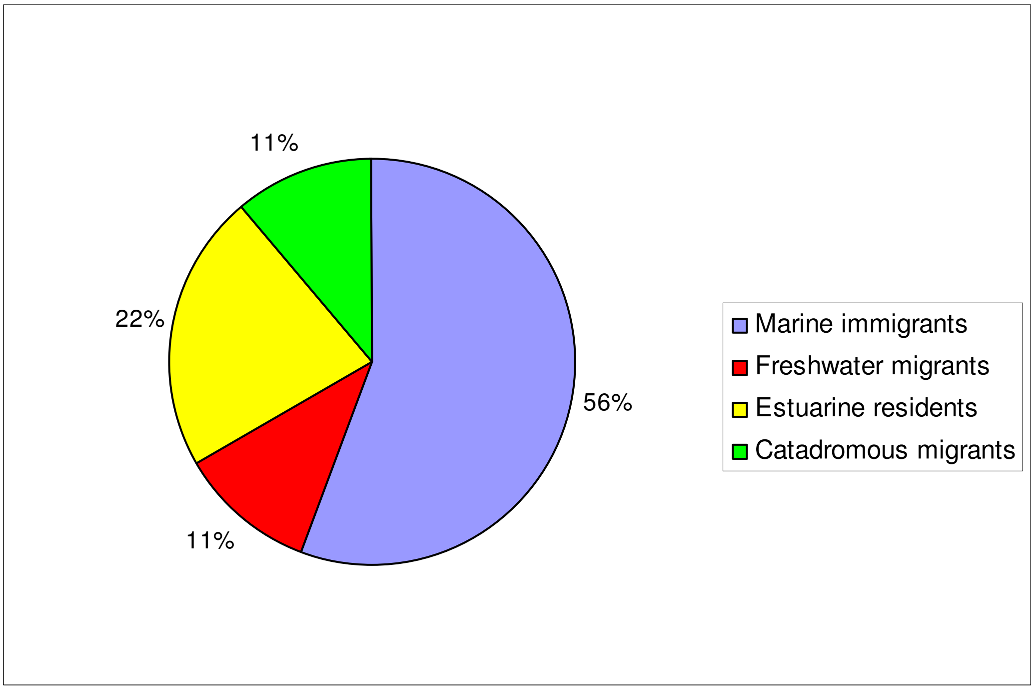

Figure 2.1 *Fish species groupings in the Matjies Estuary analysed according to life history traits of the various taxa (data from Harrison unpublished).*

2.2 Conclusions

Based on this review, the following conclusions can be reached:
(1) The Matjies Estuary supports an ichthyofauna dominated by 0+ juvenile mugilids (mullet) that utilize the system as a nursery area.
(2) Most of the fish species found in the estuary are associated with the benthos, either the microphytobenthos in the case of detritivorous mugilids or the zoobenthos in the case of carnivorous sparids and gobies.
(3) Poor planktonic food resources as a result of clear, nutrient poor river inflow have contributed to the apparent absence of planktivorous fish species within this estuary.
(4) Reduced river flow is likely to result in a less frequent estuarine/marine linkage and therefore a reduced marine migrant fish component within the system.

2.3 Further studies

Our current understanding of the ichthyofauna of the Matjies Estuary is limited to two brief fish surveys. More detailed studies would provide additional information on the structure and functioning of fish assemblages within this estuarine system and their responses to altered river flow regimes.

2.4 Acknowledgements

The use of unpublished fish information supplied by Dr Trevor Harrison is gratefully acknowledged.

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Birds

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Kelp gulls and Black Oystercatchers were the only species observed during the two field visits to the estuary (up to 24 Kelp Gulls at any one time). Observations suggest that they use the estuary as a roosting and bathing area. No waders were observed (although species such as White-fronted Sandplover are likely to spend time near the mouth). Upstream of the beach and in the gorge, other birds associated with the estuary are also likely to occur (e.g. Cape Wagtail, Pied and Giant Kingfishers).

Appendix D

Proposed changes to RDM methodology for estuaries

Proposed changes to RDM methodology for estuaries

The following changes were proposed during the Matjies Estuary Rapid Reserve Determination Study:

- The Estuarine RDM Methods need to consider **Dissolve Organic Matter** in the scoring of the Water Quality.
- The Estuarine RDM Methods need to standardise on the manner in which **estuarine invertebrates** are sample, analyse and reported. It is recommended that an estuarine invertebrate workshop be convened to deal with this issue between biogeographically regions.
- The **definition for Species Richness** needs to be refined to reflect a temporal component. For example, in systems that fluctuate seasonally a loss of a species for longer than a year from the system would require an adjustment of the Species Richness score.
- The **EHI scoring spreadsheet also needs to be modified,** so that the **Species Richness percentage** is calculated to the desired score automatically. The current scoring guideline does not fit a curve and needs to be recalculated.
- The **definition of Community Composition** needs to be refined to reflect the concept of a mix in populations clearly, for example, a change in the dominance of a group species.
- A detailed **bathymetric survey** should be a data requirement in RDM studies conducted on all small estuaries (TOCE's). The bathymetric map will provide important volume and area figures that will assist in quantifying the biological response to changes in the hydrodynamics.
- Additional guidelines are required to determine the **Recommended Ecological Reserve Category**.

Appendix E

Data requirements for Future RDM Studies on Matjies Estuary

Data requirements for Future RDM Studies on Matjies Estuary

Data requirements to improve the confidence of the preliminary determination of the Ecological Water Requirements for the Matjies Estuary are set out in the method for Estuaries. It is recommended that the following monitoring be conducted to improve the confidence (largely based on the recommended data requirements for a Comprehensive level determination).

NOTE:

It is strongly recommended that surveys to collect the additional data requirements on the different abiotic and biotic components in the Matjies Estuary be coordinated (i.e. undertaken simultaneously) to prevent duplication and to enable scientists to quantify linkage between different abiotic and biotic processes, a key requirements in predicting the effects of the modification in river inflow.

Abiotic components (hydrodynamics)

- *Continuous river flow gauging at the head of the estuary*
- *Additional continuous water level recordings near the mouth of the estuary.*
- *Aerial photographs of estuary every 5 years – preferably colour, geo-referenced rectified aerial photographs at 1: 5 000 scale covering the entire estuary (based on the geographical boundary), and taken at low tide in summer. These photographs must include the breaker zone near the mouth.*
- *Bathymetric survey during a spring and neap tide for both high and low tide. Bathymetry transects should include the berm and be spaced at least 50 m apart along the length of the estuary.*

Abiotic components (sediment dynamics)

- *Series of cross-section profiles along the beach, bar, mouth and (at ~ 25 m intervals) as well as upstream along the entire estuary (at ~50 m intervals from the +5 m MSL contour on the left bank, trough the estuary to the +5 m MSL contour on the right bank), using D-GPS and echo-sounding). This should be done every 3- 5 years (and immediately after a flood) to quantify the sediment deposition rate in the estuary.*
- *Series of sediment <u>grab</u> samples for the analysis of particle size distribution (PSD), cohesive nature and organic content, taken every 3 years (and immediately after a flood) along the length of the estuary (at ~ 50 m intervals across the estuary including the inter- and supratidal areas). Representative samples should also be collected from the adjacent beach and sand bar.*
- *A series of sediment <u>core</u> samples for historical sediment characterisation taken once-off, but ideally just after a medium to large flood as well as a year (or two) later along the same grid as the grab samples (see above).*

Abiotic components (water quality)

- *Quarterly water quality measurements on system variables [conductivity, temperature, pH, dissolved oxygen, turbidity, suspended solids], inorganic nutrients [e.g. nitrate, ammonium and reactive phosphate] and, if possible, toxic substances in river water entering the estuary. Ideally, particulate organic carbon input should also be recorded.*
- *Quarterly longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide.*
- *Quarterly water quality measurements on system variables [pH, dissolved oxygen, turbidity, suspended solids], inorganic nutrients [e.g. nitrate, ammonium and reactive phosphate] taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide (at least 4 stations including the sea)*
- *Ideally organic nutrients (i.e. dissolved and particulate organic carbon) should also be recorded*

Microalgae

- *Chlorophyll-a measurements taken at 4 stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements should be taken coinciding with the different Abiotic States.*
- *Intertidal and subtidal benthic chlorophyll-a measurements taken at 4 stations. Epipelic diatoms need to be collected for identification.Measurements should be taken coinciding with the different Abiotic States.*
  The microalgal survey must be done at the same time as the water quality survey.

Macrophytes

- *Analyses of the aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (earliest year available). A GIS map of the estuary must be produced indicating the present and reference condition distribution of the different plant community types.*
- *Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit. The extent of anthropogenic impacts (e.g. trampling, mining) must be noted.*

  Permanent transects (fixed monitoring stations that can be used to measure change in vegetation in response to changes in salinity and inundation patterns) must be set up along an elevation gradient: Measurements of percentage plant cover of each plant species in duplicate quadrats (1 m^2).Measurements of sediment salinity, water content, depth to water table and water table salinity.

Invertebrates

- *Compile a detailed sediment distribution map of the estuary. Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates.*
- *The Matjies Estuary needs to be sampled quarterly over at least one year to account for the seasons followed by another year covering summer and winter. During each survey, collect sediment samples for analysis of grain size[1] and organic content at the 2 benthic sites.*
- *During each survey determine the longitudinal distribution of salinity, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity)[3] at each of the 2 benthic sampling sites*
- *Collect a set of benthic samples from 2 sites, each site consisting of six replicate grabs stored separately. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (i.e. quarterly) data sets for at least one year are required.*
- *Collect replicated hyperbenthic samples at the same benthic sites identified above. 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 (i.e. quarterly) data sets for at least one year are required.*
- *Collect replicated zooplankton samples at each of the 2 benthic sites at night. Seasonal (i.e. quarterly) data sets for at least one year are required.*
- *Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key that require a connection to the marine environment at specific times of the year.*

Fish

- *The Matjies Estuary needs to be sampled quarterly over at least one year to account for the seasons.*
- *Seine-nets to sample small and juvenile fish. All species in the catch should be identified, counted and measured (total length). The estuary is too small to make use of gill-nets.*

Birds

- *Undertake full bird counts of all water-associated birds quarterly for one year, the area covered must include the entire estuary and its floodplain, incorporating all habitats used by water-associated birds for feeding, breeding or roosting.*