DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES

SOUT ESTUARY

INTERMEDIATE RESERVE DETERMINATION STUDY

TECHNICAL COMPONENT

October 2007

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Approved for the Directorate: Resource Directed Measures, DWAF by:

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Executive summary

Introduction

The findings of the preliminary Ecological Water Requirement study on the Sout Estuary (Intermediate 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 Sout catchment.

The Sout Estuary is a small permanently open estuary situated approximately 2 km west of Nature's Valley in the Western Cape. The estuary is flanked by two Temporarily Open/Closed estuaries, i.e. the Matjies Estuary to the west and the Groot Estuary to the East. The Sout Estuary is a small black water system of about 1.1 km long. The Sout Estuary is situated within the De Vasselot Section of the Tsitsikamma National Park and protected in its entirety.

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

- Appendix A Specialist report: Hydrology
- Appendix B Specialist report: Hydrodynamics
- Appendix C Specialist report: Water Quality and Microalgae
- Appendix D Specialist report: Macrophytes
- Appendix E Specialist report: Invertebrates
- Appendix F Specialist report: Ichthyofauna
- Appendix G Specialist report: Birds
- Appendix H Proposed changes to RDM methodology for estuaries

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
Water quality and microalgae	**Mr Gavin Snow**	Nelson Mandela Metropolitan University, gavin.snow@nmmu.ac.za
Macrophytes	**Prof Janine Adams**	Nelson Mandela Metropolitan University, janine.adams@nmmu.ac.za
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 the 30th and 31st of August 2007 were:

Person	Affiliation/role	Contact details
Ms Retha Stassen	Overall Project Leader	rethas@lantic.net
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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 Sout 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 Sout Estuary, the geographical boundaries are defined as follows (Google Earth, WGS 1984):

- **Downstream boundary:** Estuary mouth (33°59'19.67"S; 23°32'8.73"E) (indicated by the number 1 in Plate 2)

- **Upstream boundary:** Approximately 0.6 km upstream of the mouth (33°59'2.08"S; 23°32'6.60"E) (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*

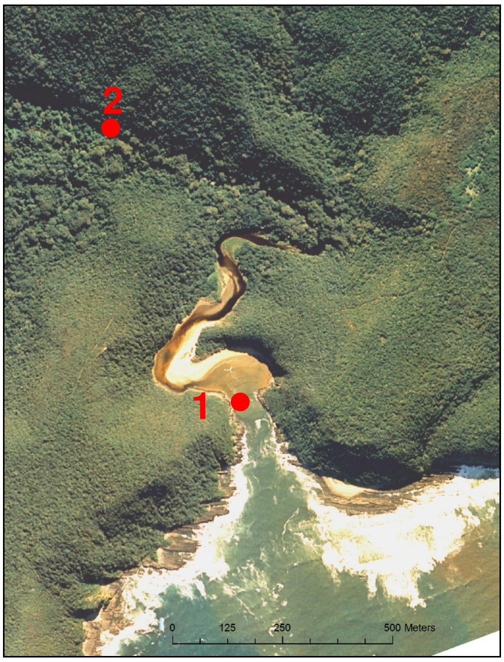

Plate 2. *Geographical boundaries*

Present Ecological Status (PES)

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

Variable	Weight	Score	Weighted score
Hydrology	25	97	24
Hydrodynamics and mouth condition	25	100	25
Water quality	25	90	23
Physical habitat alteration	25	95	24
Habitat health score			**95**
Microalgae	20	90	18
Macrophytes	20	100	20
Invertebrates	20	100	20
Fish	20	90	18
Birds	20	95	19
Biotic Health Score			**95**
Estuarine Health Score			**95**

The Estuarine Health Index score for the Sout Estuary, based on its Present State, is **95**, translating into a **Present Ecological Status** of a **A,** 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 Sout Estuary were as follows:

Criterion	Weight	Score	Weighted score
Estuary Size	15	30	5
Zonal Rarity Type	10	50	5
Habitat Diversity	25	20	5
Biodiversity Importance	25	61.5	15
Functional Importance	25	40	10
Estuarine Importance Score			**40**

The overall **Estuarine Importance Score** for the Sout Estuary, based on its Present State, is **40**, 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 Sout 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 Sout Estuary fall within a protected area (De Vasselot Section of the Tsitsikamma National Park) and according to the guidelines for assigning a recommended Ecological Reserve Category, the Sout Estuary should therefore be classified as a Category A or Best Attainable State.

Current/desired protection status and estuary importance	Recommended Ecological Reserve Category	Policy basis
Protected area **Desired Protected Area**	**A or BAS***	**Protected and desired protected areas should be restored to and maintained in the best possible state of health**
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 (million m^3/annum)	% remaining
Reference	Reference Condition	11.22	100
Present	Present State	10.10	90.00
Future Scenario 1	Reference Conditions – 0.05 m^3/s abstraction	9.69	86.40
Future Scenario 2	Reference Conditions – 0.10 m^3/s abstraction	8.27	73.68
Future Scenario 3	Reference Conditions – 0.20 m^3/s abstraction	5.92	52.74
Future Scenario 4	River Class A/B	4.85	43.21

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

- There are no measured flow data available for the Sout River. 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 is a flow gauge in the Sout / Wit River but no flow data because there is no rating curve for the station. This is a possible source of data for future use. This data are collected by DWAF: Regional office (George).
- The current land use in the catchment is 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 km^2 of indigenous forests.
- The natural MAR and present day MAR is estimated to be 11.22 million m^3.
- 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 would have a significant impact on the sediment balance of the system as it is sediment staved (very little marine sediment enters the system).

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	97	92	84	67	62
Hydrodynamics/mouth condition	25	100	100	100	100	20
Water quality	25	90	85	70	45	45
Physical habitat alteration	25	95	95	90	85	20
Habitat Health Score (weighted)		**95**	**93**	**86**	**70**	**30**
Microalgae	20	90	85	70	45	35
Macrophytes	20	100	95	90	70	25
Invertebrates	20	100	95	80	60	40
Fish	20	90	85	80	70	40
Birds	20	95	90	80	80	25
Biotic Health Score (weighted)		**95**	**90**	**80**	**59**	**26**
Estuarine Health Index Score		**95**	**92**	**83**	**64**	**28**
Ecological Reserve Category (ERC)		**A**	**A**	**B**	**C**	**E**

Recommended ecological flow requirement for the Sout 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 Sout 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 Sout 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.**

***Sout Estuary: Summary of flow distributions* under Future Scenario 1**

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	1.49	1.37	0.80	0.89	1.39	1.29	1.49	1.99	0.88	1.05	1.42	1.53
90%ile	0.94	1.00	0.52	0.60	0.68	0.73	0.59	0.64	0.43	0.44	0.77	0.75
80%ile	0.69	0.66	0.39	0.43	0.51	0.44	0.43	0.49	0.29	0.31	0.52	0.60
70%ile	0.44	0.51	0.32	0.37	0.33	0.40	0.30	0.28	0.24	0.22	0.37	0.50
60%ile	0.36	0.38	0.24	0.23	0.28	0.33	0.23	0.20	0.20	0.17	0.24	0.37
50%ile	0.31	0.31	0.22	0.19	0.25	0.25	0.17	0.11	0.15	0.14	0.18	0.32
40%ile	0.28	0.26	0.16	0.16	0.21	0.21	0.13	0.09	0.11	0.11	0.15	0.27
30%ile	0.24	0.16	0.13	0.11	0.16	0.14	0.12	0.06	0.05	0.07	0.11	0.16
20%ile	0.18	0.11	0.09	0.06	0.12	0.07	0.07	0.03	0.02	0.02	0.08	0.11
10%ile	0.11	0.07	0.07	0.03	0.03	0.03	0.02	0.00	0.00	0.01	0.04	0.06
1%ile	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02

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 (0.02 $m^3.s^{-1}$)
- No effluent may be pumped back into the river
- No in-stream dam developments should be considered

Ecological specifications

Ecological Specifications are clear and measurable specifications of ecological attributes (in the case of estuaries - hydrodynamics, sediment dynamics, water quality and different biotic components) that define a specific ecological reserve category, in the case of the Sout Estuary for a **Category A.** Thresholds of potential concern (TPC) are defined as measurable end points related to specific abiotic or biotic indicators that if reached (or when modelling predicts that such points will be reached) prompts management action. The ecological specifications and associated TPCs for the Sout Estuary are listed below:

COMPONENT	ECOLOGICAL SPECIFICATION/RESOURCE QUALITY OBJECTIVE	THRESHOLD OF POTENTIAL CONCERN	POTENTIAL CAUSES
Birds	The birds are a poor indicator of ecosystem change in the Sout Estuary, due to very low numbers, species richness and ongoing human disturbance. The estuary is very small with relatively low biomass of food resources that result in birds on the estuary being mostly transient.	1.1 TPCs will be reached for other components before the birds will be affected (e.g. invertebrates)	1.1 Human disturbance
Fish	Retain present fish assemblage	2.1 Decrease in abundance of marine fish migrants to <80% of the overall ichthyofauna. 2.2 Increase in abundance of estuarine resident fish species >20% of the overall ichthyofauna. 2.3 Loss of all marine stragglers from the estuary or increase in abundance of marine stragglers to >10% of the overall ichthyofauna.	2.1 Reduced marine fish recruitment due lack of riverine cues to marine inshore environment. 2.2 Marine exchange is reduced, mouth becomes more restricted and estuarine environment becomes more stable. 2.3 Change in marine influence on the estuary caused by mouth constriction (loss of marine stragglers) or by river flow reduction (increase in marine stragglers) .
Invertebrates	Maintain current levels of zoobenthic abundance (including seasonal variation)	3.1 Decrease in abundance of >50% in terms of numbers per m-2 over entire estuarine area (4 sample sites plus cove)	Changes to sediment grain size distribution and organic content
	The zoobenthic invertebrates must be characterised by predominantly estuarine taxa	3.2 <50% of benthic invertebrates (by abundance) are typically estuarine taxa compared to freshwater associated taxa (e.g. becomes dominated by insect larvae)	State of the mouth excludes marine influence (salinity gradient weakens)
	The mudprawn *Upogebia africana* must maintain presence in the estuary	3.3 <50% of average abundance of the population remaining	Extended mouth closure, or weak water exchange between estuary and the sea
	Retain current species assemblage of two basic communities; A sand associated community in the lower estuary (Sites 1 and 2) and a mud-associated community in the middle and upper estuary (Sites 3 and 4)	3.4 Similarity indices (Bray-Curtis) between sandy sites (Sites 1 and 2) and muddy sites (Sites 3 and 4) should not exceed 25% similarity (under natural conditions, similarity <10%).	Changes in the sediment characteristics
	Benthic invertebrates should maintain current mix of species, dominated by amphipods	3.5 Other taxa such as polychaetes begin to dominate	Input of organic material derived from the catchment declines. Organic input, particularly at times of high flow provide an important source of nutrients that fuel the foodweb.
Macrophytes	Maintain the present distribution (2007) and abundance of the different plant community types (e.g. 0.3 ha intertidal salt marsh, 0.3 ha supratidal salt marsh, 2.3 ha total water surface area).	4.1 Greater than 20% change in the area covered by different plant community types	Semi-closed mouth condition, increase in water level and change in salinity
	Prevent the establishment of reeds in the estuary and replacement of saline habitats (salt marsh) with brackish habitats (reeds)	4.2 Reeds are present and cover an area of 0.1 ha	Salinity remains lower than 20 ppt for longer than 6 months of the year
	Prevent the growth of filamentous green algae associated with low flow, closed mouth conditions.	4.3 Filamentous green algae are present and cover 0.1 ha	Increase in nutrients, semi-closed mouth state and low flow conditions (<0.1 m3/s)
Microalgae	Maintain phytoplankton biomass as under baseline conditions	5.1 Phytoplankton biomass should not exceed 10 µg/L.	Increase in nutrient concentration (particularly DIN and DIP), reduction in flow or semi-closed mouth condition.
	Maintain phytoplankton group diversity (diatoms, dinoflagellates, flagellates, greens etc.).	5.2 Dominance (> 10% relative abundance) of one bloom-forming group of algae (i.e. blue-greens & dinoflagellates).	Increased loads of nutrients (particularly DIN and DIP) and organic matter, decrease in dissolved oxygen (<3 mg/L).
	Maintain intertidal and subtidal biomass of benthic microalgae in sheltered shallow waters	5.3 Average benthic microalgal biomass should remain between 5 and 20 µg/g, both intertidally and subtidally.	Disturbance of sediments could cause decrease in biomass (<5 ug/g). Prolonged elevated turbidity and nutrients could increase biomass > 20 ug/g.
	Maintain benthic microalgal species diversity (i.e. Blue-greens, greens, diatoms & euglenoids).	5.4 Dominance (>10% RA) by nuisance forms (e.g. cyanophytes, etc.)	Disturbance of sediments; Water quality (turbidity, nutrients); Flow
Water quality	Water quality of river inflow not to cause exceedence of TPCs set for water quality in the estuary (see below).	6.1 DIN-N, SRP-P and silicate-Si should not exceed 250 ug/L, 75ug/L and 3500 ug/L in the upper reaches (900 m from mouth) respectively.	Quality of river inflow
	Salinity intrusion should not to cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae	6.2 Salinity in the upper reaches of the estuary, during low flows, should not be >30 ppt for any length of time.	Quality of river inflow

COMPONENT	ECOLOGICAL SPECIFICATION/RESOURCE QUALITY OBJECTIVE	THRESHOLD OF POTENTIAL CONCERN	POTENTIAL CAUSES
	System variables (pH, turbidity, dissolved oxygen) should not to cause exceedence of TPCs for invertebrates, macrophytes and microalgae	6.3 pH greater than 8.5 or less than 6.5. 6.4 Secchi depth less than bottom or 1 m (except during floods) 6.5 Dissolved oxygen concentrations fall below 3 mg/L.	Quality of river inflow
Hydro-dynamics	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality	7.1 'Reserve for Water Quantity' as represented by flow distribution of Scenario 1	Illegal abstraction and future dam developments
	Maintain open mouth status to allow for habitat requirements of birds, fish, macrophytes, microalgae and water quality.	7.2 Permanently open mouth through out the year	Flow reduction
	Maintain channel dimensions and a low berm height at the mouth to allow for significant tidal variation (i.e. tidal flushing) to maintain habitat requirements for birds, fish, macrophytes, microalgae and water quality.	7.3 Spring tidal amplitude < 1.4 m on a spring high tide	Build up of marine sediment in the mouth area as a result of flood reductions
Sediment dynamics	Changes in water depth in estuary not to cause exceedance of TPCs in vegetation, invertebrates and fish (see above).	8.1 Greater than 10 cm change in sediment deposition/erosion in the estuary.	Reduction in floods to the estuary and changes in land use
	Decrease in channel depth (and/or channel dimension) and an increase in the sand berm height in the mouth area restricting tidal variation and tidal flushing	8.2 Greater than 20 cm average increase in berm height from present and shallowing of the channel	Reduction in floods to the estuary and changes in land use
	Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates.	8.3 The median bed sediment diameter should not deviate more than factor 3 as recorded in the baseline survey.	Reduced flow causing increased marine sediment influx with a larger particle size.
	Changes in organic content in sediments not to cause exceedence of TPCs set for benthic invertebrates.	8.4 The median sediment organic load should not deviate more than factor 3 as recorded in the baseline survey.	Reduced flow causing increased marine sediment influx with a lower organic content.

The Sout Estuary, being a complex system, does require (consecutive) seasonal surveys to improve the confidence of the Reserve, as well as to set a suitable and reliable baseline (high confidence) for the different abiotic and biotic components in a long-term monitoring programme. Additional baseline data requirements were recommended based on the generic data requirements stipulated for an Intermediate Ecological Reserve Determination (DWAF, 2004a) as well as subsequent updates as proposed by Taljaard *et al.* (2003).

Additional baseline data requirements are listed in the Table below and have been prioritised, using the following criteria:

	High Priority, important for a suitable and reliable baseline (high confidence)
	Medium Priority, will improve the confidence of baseline, and should be added if funding is available
	Low priority, will further improve confidence of baseline, but not considered to be a critical factor in the case of the Sout Estuary

For baseline surveys the quantification of linkages between different abiotic and biotic components are very important, and exclusion of certain components is likely to result in only incremental gain in confidence which may not warrant the effort.

The purpose of long-term monitoring programmes, in this context, is to assess (or audit) whether the Ecological Specifications (defined as part of the Ecological Reserve determination process) are being complied with after implementation of the Reserve. In addition, these programmes can also be used to improve and refine the Ecological Reserve measures (including the Resource Quality Objectives), in the longer-term through an iterative process (Taljaard *et al*. 2003).

A proposed long-term resource monitoring programme for the Sout Estuary is also provided below. Should the components within the programme need to be prioritised prior to the completion of the baseline studies (when higher confidence will allow for a sensible prioritisation), it was concluded that the emphasis should be placed on monitoring of the abiotic 'driver' components.

Additional baselines studies to improve confidence of Reserve and to set baseline for long-term monitoring in the Sout Estuary are as follows:

(orange)	**High priority**
(yellow)	**Medium Priority**
(green)	**Low priority**

ECOLOGICAL COMPONENT	MONITORING ACTION	RELATED TPC	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (No. Stations)
BIRDS	No additional baseline data required	-	-	-
FISH	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1 & 2.3	Once during November (Spring) using seine net	4 stations x 4 replicates
	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1, 2.2 & 2.3	Once during March (Autumn) using seine net	4 stations x 4 replicates
	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1, 2.2 & 2.3	At least one severe flood (>5 m3/s) and one severe drought (<0.1 m3/s for 6 months) monitored	4 stations x 4 replicates
INVERTEBRATES	Gather data on benthic community composition (grab samples) and determine density of Upogebia africana (hole counts)	3.1 to 3.5	Once during June/July and Nov-March	5 sites
	If the mouth becomes very constricted (tidal variation < 30 cm) conduct field trip to determine status of the benthic community listed above. Abiotic data must include sediment samples for particle size analysis.	3.1 to 3.5	Once, and then every quarter during the constricted mouth phase	5 sites
MACROPHYTES	No additional baseline are data required.	-	-	-
MICROALGAE	Measure phytoplankton biomass and group composition during high and low flow.	5.1 & 5.2	Twice (high flow & low flow)	6 (sea, river and 4 in the estuary)
	Measure benthic microalgal biomass and species composition during high and low flow.	5.3 & 5.4	Twice (high flow & low flow)	6 (sea, river and 4 in the estuary
WATER QUALITY	Water quality in estuary: 1) Salinity & temperature profiles, 2) system variables (pH, DO, turbidity, TSS), 3) inorganic nutrients (DIN, SRP-P and silicate-Si). Salinity and temperature must be collected at 0.5 m intervals, while other water quality parameters are collected in surface and bottom waters.	6.1 to 6.5	Twice (high flow and low flow); sampling must coincide with microalgal & invertebrate surveys.	20 sites (Salinity & temp.), 5 for other parameters.
HYDRO-DYNAMICS	Water level recordings (leveled to mean sea level)	7.1 to 7.3	Continuous	Near mouth
	River flow gauging	7.1 to 7.3	Continuous	Above head of tidal influnce
SEDIMENT DYNAMICS	Bathymetric survey: Detailed cross-section profiles of the estuary and sand berm and cove at the mouth (leveled to mean sea level)	8.1 & 8.2	Once and if possible survey after a flood (> 15 m3/s)	Collected at fixed 50 m, but more detailed in the mouth
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and organic content.	8.3 & 8.4	Once and if possible survey after a flood (> 15 m3/s)	Collected at cross-section profiles (see above)

Proposed long-term resource monitoring programme for the Sout Estuary are as follows:

	High priority
	Medium Priority
	Low priority

ECOLOGICAL COMPONENT	MONITORING ACTION	RELATED TPC	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (No. Stations)
BIRDS	No additional baseline data required	-	-	-
FISH	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1, 2.2 & 2.3	March baseline surveys repeated once every 3 years	4 stations x 4 replicates
INVERTEBRATES	Gather data on benthic community composition (grab samples) and determine density of Upogebia africana (hole counts)	3.1 to 3.5	Once every summer	5 sites
	If the mouth becomes constricted (tidal variation < 30 cm) conduct field trip to determine status of the benthic community listed above.	3.1 to 3.5	Every quarter during the closed mouth phase	5 sites
MACROPHYTES	Area covered by different plant community types to be assessed from aerial photographs and measured during a summer ground survey to: 1) verify areas covered by different plant community types, 2) check for the presence of reeds, 3) check for the presence of macroalgae. Produce a GIS map for comparison with baseline.	4.1 to 4.3	Every 3 years	Entire estuary
MICROALGAE	Measure phytoplankton biomass and group composition during low flow.	5.1 & 5.2	2yr following implementation and 3yr thereafter during Nov - March (low flow)	6 (sea, river and 4 stations in the estuary)
	Measure benthic microalgal biomass and species composition during low flow.	5.3 & 5.4	2yr following implementation and 3yr thereafter during Nov - March (low flow)	6 (sea, river and 4 stations in the estuary)
	When there is an algal bloom collect samples as required	5.1 & 5.2	Immediately and at 2 week intervals for 6 weeks	6 (sea, river and 4 stations in the estuary)
WATER QUALITY	Water quality in estuary: 1) Salinity & temperature profiles, 2) system variables (pH, DO, turbidity, TSS), 3) inorganic nutrients (DIN, SRP-P and silicate-Si). Salinity and temperature must be collected at 0.5 m intervals, while other water quality parameters are collected in surface and bottom waters.	6.1 to 6.5	Samples to be collected coinciding with related biological sampling surveys.	20 sites (Salinity & temp.), 5 for other parameters.
HYDRO-DYNAMICS	Water level recordings.	7.1 to 7.3	Continuous	Near mouth
	Flow gauging.	7.1 to 7.3	Continuous	Above head of tidal influence
	Aerial photographs of estuary (earliest available year as well as most recent)	7.1 to 7.3 4.1 to 4.3	Every 3 years	Entire estuary
SEDIMENT DYNAMICS	Bathymetric survey: Detailed cross-section profiles of the estuary and sand berm and cove at the mouth (leveled to mean sea level)	8.1 & 8.2	If possible survey after a flood (> 15 m3/s) and once every 3 years	Collected at fixed 50 m, but more detailed in the mouth
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and organic content.	8.3 & 8.4	If possible survey after a flood (> 15 m3/s) and once every three years	Collected at cross-section profiles (see above)

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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
TPC	Threshold of Potential Concern

1 Introduction

1.1 Background

The findings of the preliminary Ecological Water Requirement study on the Sout Estuary (intermediate 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 Sout catchment.

1.2 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
Water quality and microalgae	**Mr Gavin Snow**	Nelson Mandela Metropolitan University, gavin.snow@nmmu.ac.za
Macrophytes	**Prof Janine Adams**	Nelson Mandela Metropolitan University, janine.adams@nmmu.ac.za
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 the 30th and 31st of August 2007 were:

Person	Affiliation/role	Contact details
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

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:

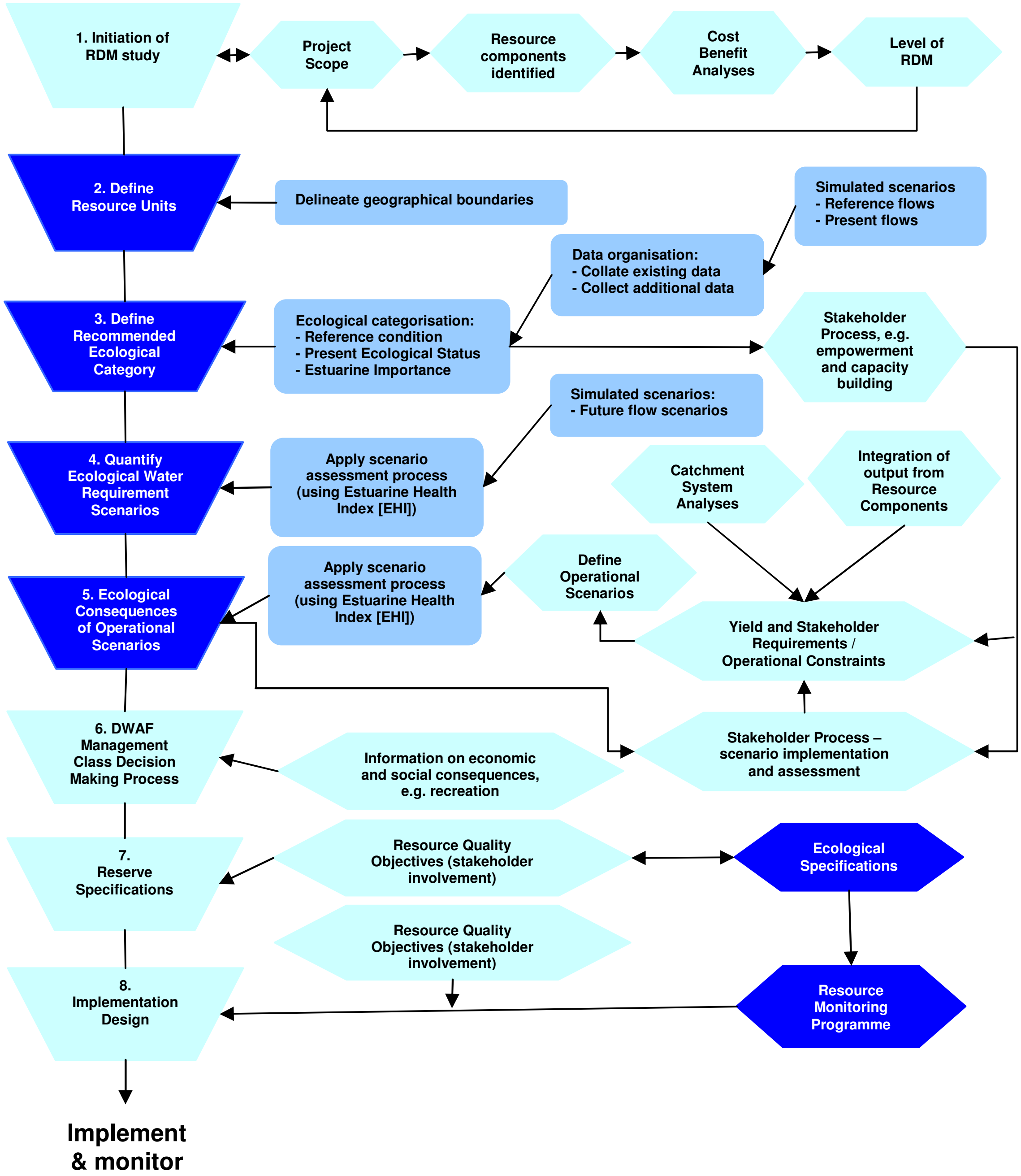


Figure 1. *Procedures for an Intermediate Ecological Reserve Determination on estuaries, in context of the broader RDM process) (modified from DWAF, 2004)*

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

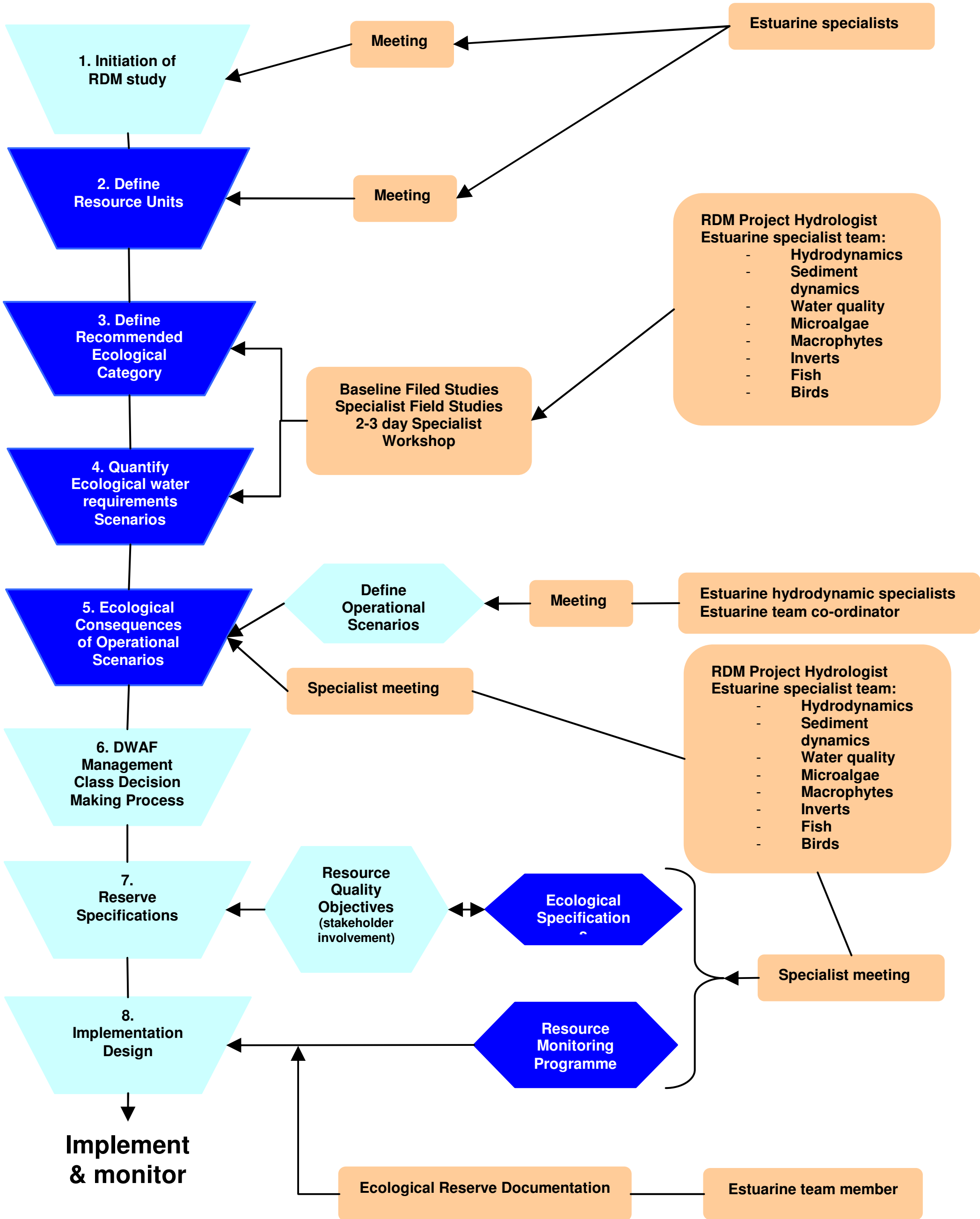


Figure 2. *Indication of human resource requirements for an Intermediate Ecological Reserve determination on estuaries (modified after DWAF, 2004).*

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 Sout 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 Sout is a small estuary with a catchment area of 35.5 km^2 (Van Niekerk 2007; Appendix B). The total river length is 15 km (CSIR 1983). The Mean Annual Precipitation is estimated at 886 mm.

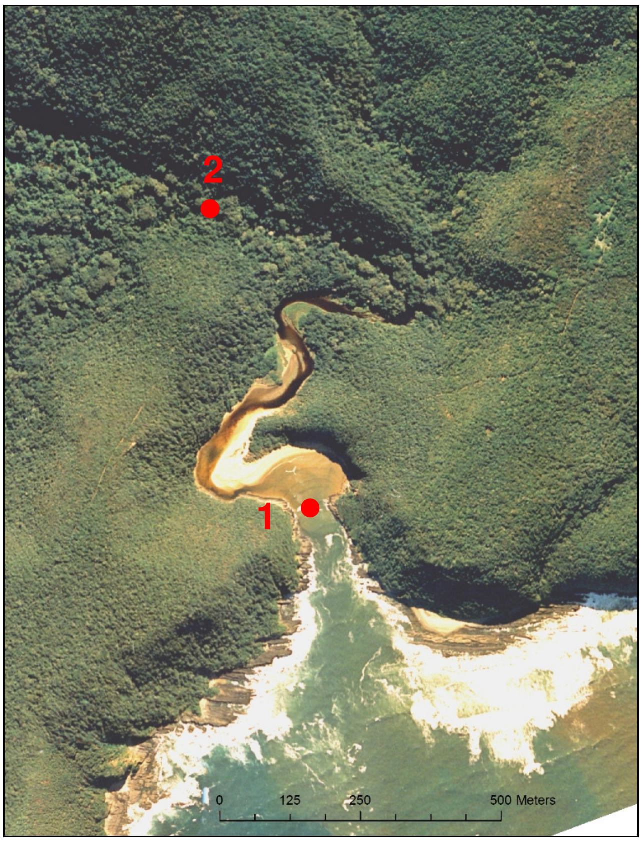
This region exhibits neither summer nor winter rainfall characteristics. Rain is experienced throughout the year with the highest precipitation during spring (September to November) and again during late summer (February and March). The river flows throughout the year with the rate of flow fluctuating with rainfall. Rainfall higher than 1000 mm can be expected in the mountain areas. The mean annual precipitation decreases from east to west.

The Sout River is in a near natural state with regards to water quantity, with the natural MAR estimated to be 11.22 million m^3 and 90 % of the natural flow record accepted as the present day flows.

2.2 Geographical Boundaries

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

- **Downstream boundary:** Estuary mouth (33°59'19.67"S; 23°32'8.73"E) (indicated by the number 1 in Plate 3).
- **Upstream boundary:** Approximately 1.1 km upstream of the mouth (33°59'2.08"S; 23°32'6.60"E) (indicated by the number 2 in Plate 3).
- **Lateral boundaries:** 5 m contour above MSL along the banks, a delineation that could be readily referenced from an ortho-photograph of the area.



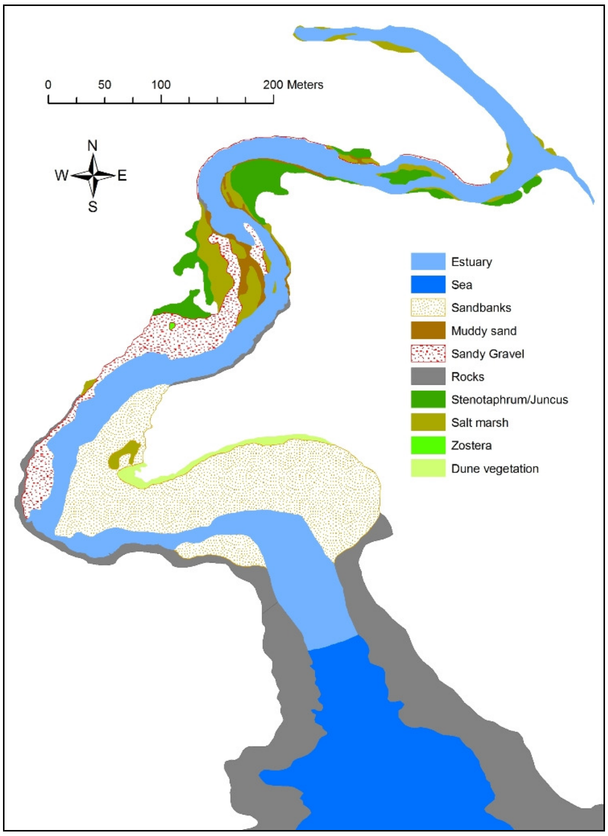


Plate 3. *Geographical boundaries and vegetation map of the Sout Estuary*

3 Ecological Reserve Categorisation

3.1 Typical Abiotic States

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

State	Flows (m^3/s)
State 1: Predominantly fresh	> 1.0
State 2: Gradient	1.0 - 0.05
State 3: Marine Dominated	< 0.05

As very little reliable data was available on the river inflow into the estuary a conceptual model was developed for the abiotic states based on the bathymetry data collected during this study.

Assumptions and limitation of the Sout Estuary's conceptual model:

- The simulated average monthly flows are of low confidence as there was no inflow data available to calibrate the data set for this system.

- Bathymetry data collected during this study indicated that:

Tide	Area (m^2)	Volume (m^3)
Spring high	47 520	59 053
Spring low	18 496	5 539
Average	29 025	53 513

- Based on the volumetric study the Sout Estuary requires a flow between 2.7 $m^3.s^{-1}$ (high tide) and 0.3 $m^3.s^{-1}$ (low tide) to flush the estuary over a six hour period.

- An average monthly flow > 1.0 $m^3.s^{-1}$ represents a month in which the river inflow were high enough (>2.7 $m^3.s^{-1}$) for the Sout Estuary to be freshwater dominated for days to a week at a time.

- The Sout Estuary is very shallow on the low tide and easily reset to a marine state during the high tide. It is estimated that at flow less than 0.05 $m^3.s^{-1}$ the system would tend to remain in a predominantly marine state with little chance of a salinity gradient forming. This assumption is conservative as no flow data were available to confirm the estimate.

- 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 would have a significant impact on the sediment balance of the system as it is sediment starved (very little marine sediment enters the system).

Abiotic State 1: Predominantly fresh

Typical flow patterns: Average monthly flows greater than 1.0 m^3/s.

Confidence: High

State of the mouth: The mouth is wide open.

Confidence: High

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

Confidence: High

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

Tidal variation in the mouth area varies between 1.7 m (during a spring tide) to 0.5 m (during a neap tide). In the middle reaches tidal variation is expected to be approximately 1.0 to 0.3 m for a spring and neap tide respectively.

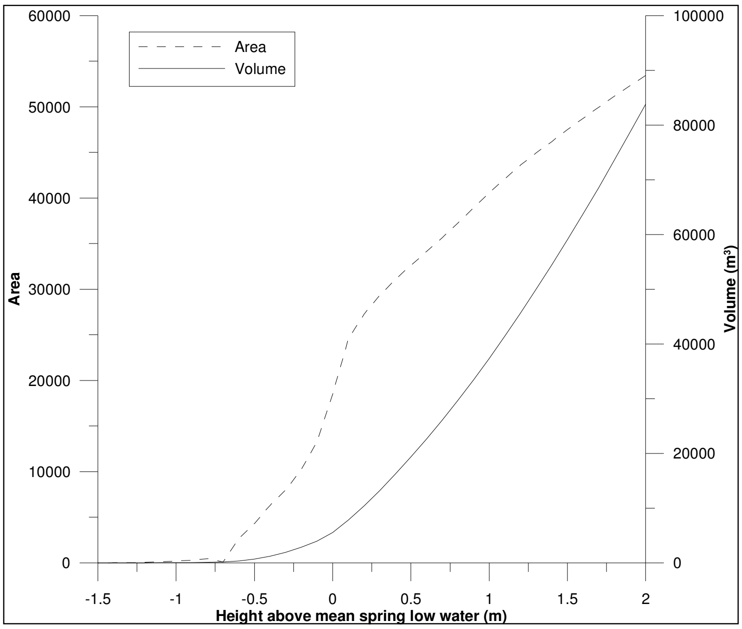
Tidal damping will occur during peak flood events.

Confidence: Low

Retention times of water masses: Retention time is very short (less than one day).

Confidence: Medium

Total volume: Between 5 500 m^3 (at spring low tide) and 60 000 m^3 (at spring high tide)



Confidence: Medium

Salinity distributions in the estuary: Because this state is driven by high flow events the system will be freshwater dominated for the duration of the event, lasting between a few days to a week. After the high flow event, saline water will penetrate the system on the high tide but be easily eroded on the low tide resulting in a predominantly fresh estuary.

During this state there will also be significant input of freshwater into the little cove at the mouth resulting in an extension of the estuarine area by about 150 - 200 m.

Confidence: Medium

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

Temperature: Temperatures in the Sout 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 Sout 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 Sout 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 Sout 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. DIN is likely to be <250 $\mu g.l^{-1}$ (18 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 <50 $\mu g.l^{-1}$ (4 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 <350 $\mu g.l^{-1}$ (13 µM) throughout the estuary.

Confidence: Medium

State 2: Salinity Gradient

Typical flow patterns: Average monthly flows between 0.05 and 1.0 m^3/s.

Confidence: Low

State of the mouth: The mouth is open.

Confidence: High

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

Confidence: Medium

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

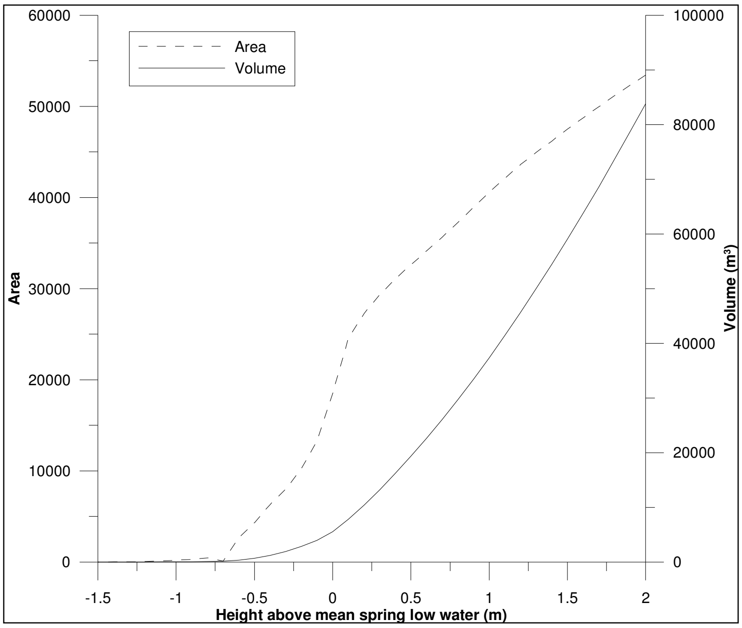
Tidal variation in the mouth area varies between 1.7 m (during a spring tide) to 0.5 m (during a neap tide). In the middle reaches tidal variation is expected to be approximately 1.0 to 0.3 m for a spring and neap tide respectively.

Confidence: Medium

Retention times of water masses: Retention time is very short (a few days), with some deeper areas taking up to a week to flush.

Confidence: Medium

Total volume: Between 5 500 m^3 (at spring low tide) and 60 000 m^3 (at spring high tide)



Confidence: Medium

Salinity distributions in the estuary:

During this state the Sout Estuary fluctuates between a very saline system on high tides and a brackish system on the low tides.

During the high tide the system becomes marine dominated (> 30 ppt) with only a small gradient forming in the upper reaches of the system. The extent to which saline water will penetrate is determined by the height of the tide, for example, marine water penetrated the Sout Estuary up to 0.8 km from the mouth on a spring high tide with a salinity gradient only forming in the remaining 300 m.

During the low tide the estuary will revert to a more brackish stratified system with a longitudinal and vertical gradient forming along the system. The system will be freshwater dominated in the upper reaches (< 10 ppt), with pockets of saline water (> 20 ppt) in the deeper areas (>1.0 m) of the estuary at ~0.5 km from the mouth.

During this state there will some input of freshwater into the little cove at the mouth resulting in an extension of the estuarine area by about 50 - 100 m.

Confidence: Medium

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

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

pH: pH in the Sout 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.

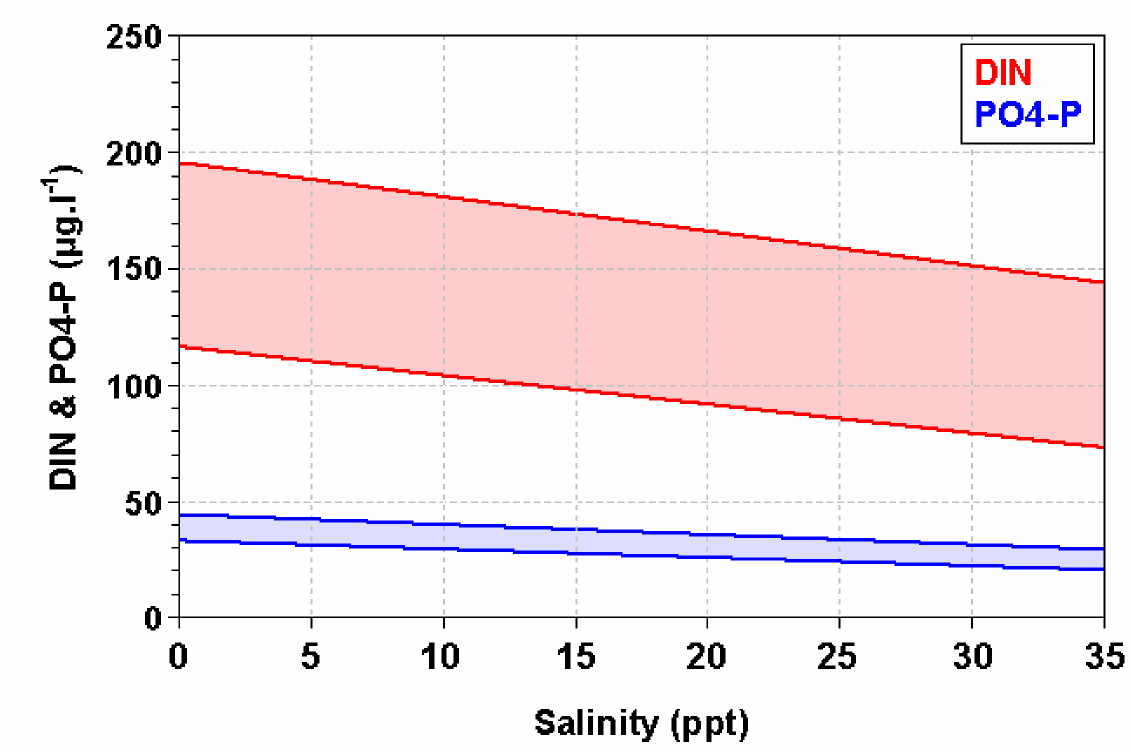
Dissolved oxygen: The Sout Estuary should generally be well-oxygenated (>7 mg.l^{-1}) because the estuary is shallow and does not appear to carry a heavy load of organic matter. Well-oxygenated marine water is likely to replenish water in deeper pools (~2 m deep) due to tidal exchange.

Turbidity: Turbidity in the Sout 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}).

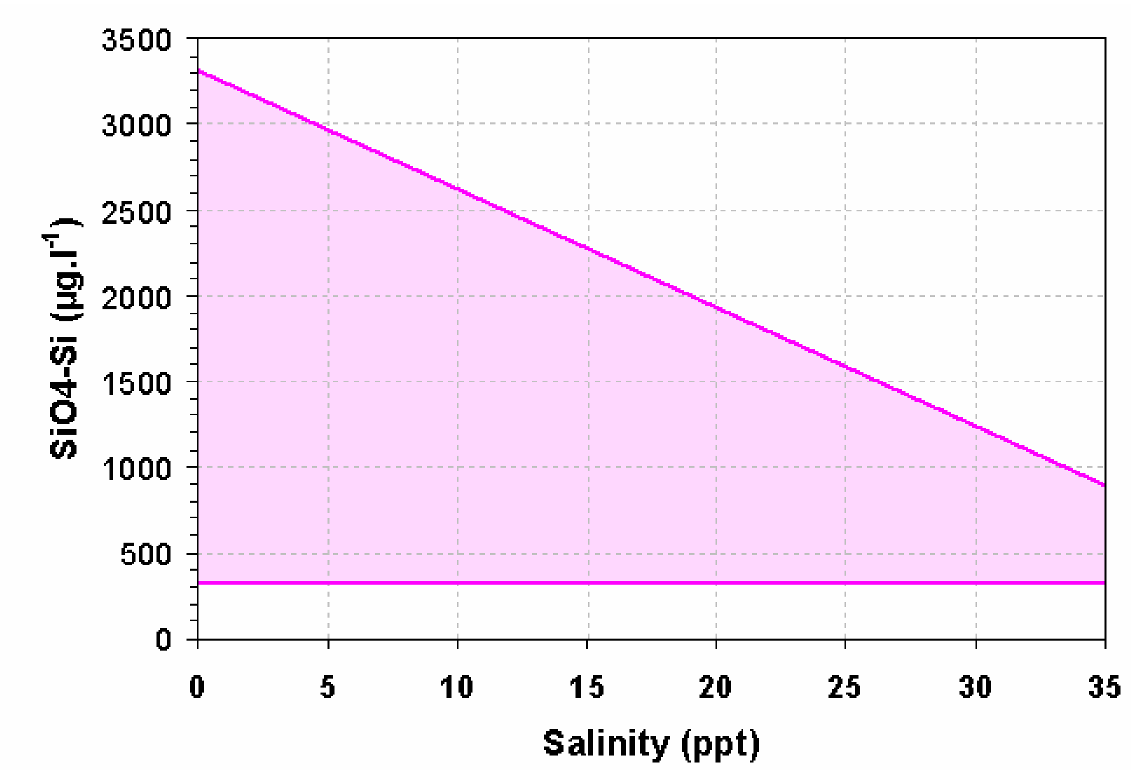
Confidence: Medium

Nutrients

The relationship between inorganic nutrient concentrations versus salinity is estimated to be as follows during State 2: Salinity gradient (based on December 2006 and April 2007 measurements);



The upper DIN and PO4-P limits were based on December 2006 data (surface salinity ranged from 0.1 to 5.0 ppt) and the lower limits on April 2007 data (surface salinity ranged from 4.2 to 28.3 ppt). To orientate oneself in terms of the spatial distribution of nutrient concentrations along the estuary during periods of river inflow, the nutrient versus salinity plots should be compared with corresponding longitudinal salinity profiles.



The upper SiO4-Si limit was based on December 2006 data (surface salinity ranged from 0.1 to 5.0 ppt) and the lower limit on April 2007 data (surface salinity ranged from 4.2 to 28.3 ppt).

Confidence: Medium

Abiotic State 3: Marine Dominated

Typical flow patterns: Average monthly flows less than 0.05 m^3/s.

Confidence: Low

State of the mouth: The mouth is open.

Confidence: High

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

Confidence: High

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

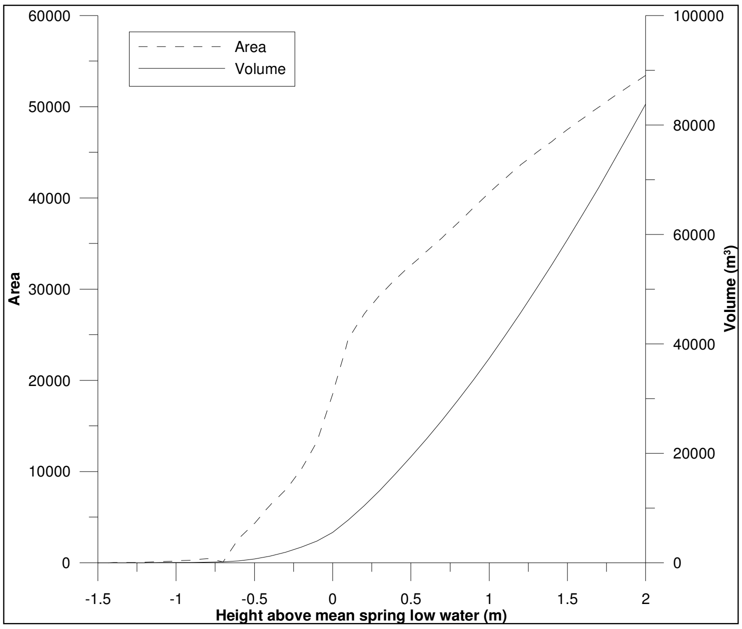
Tidal variation in the mouth area varies between 1.7 m (during a spring tide) to 0.5 m (during a neap tide). In the middle reaches tidal variation is excepted to be approximately a 1.0 to 0.3 m for a spring and neap tide respectively.

Confidence: Medium

Retention times of water masses: Retention time is lles than 2 weeks as tidal flushing still occurs on a significant scale.

Confidence: Medium

Total volume: Between 5 500 m^3 (at spring low tide) and 60 000 m^3 (at spring high tide)



Confidence: Medium

Salinity distributions in the estuary:

During this state the Sout Estuary is marine dominated (> 30 ppt) on both the high and the low tide. A small salinity gradient may form on the low tide in the upper reaches depending on the river inflow. For example at an inflow of 0.05 $m^3.s^{-1}$ less than 20 % of the system will have gradient over the low tide (6 hr).

There will be no significant freshwater input into the little cove at the mouth.

Confidence: Medium

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

Temperature: Temperatures in the Sout 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 Sout 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 Sout 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 Sout Estuary is expected to be low throughout; secchi depth > water column depth.

Confidence: Medium

Nutrients:

Dissolved Inorganic Nitrogen-N (DIN): The estuary will be dominated by seawater. DIN is likely to be <70 $\mu g.l^{-1}$ (<5 µM) throughout the estuary.

Dissolved reactive phosphorus-P: The estuary will be dominated by seawater. Dissolved reactive phosphorus is likely to be <20 $\mu g.l^{-1}$ (<0.7 µM) throughout the estuary.

Dissolved reactive silicate-Si: The estuary will be dominated by seawater. Dissolved reactive silicate is likely to be <800 $\mu g.l^{-1}$ (29 µM) throughout the estuary.

Confidence: Medium

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 Sout 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
99%ile	1.39	1.28	0.76	0.85	1.30	1.21	1.39	1.83	0.83	0.99	1.32	1.38
90%ile	0.89	0.95	0.51	0.58	0.66	0.70	0.58	0.62	0.43	0.44	0.74	0.69
80%ile	0.67	0.64	0.40	0.43	0.51	0.44	0.43	0.48	0.30	0.32	0.52	0.57
70%ile	0.44	0.50	0.34	0.38	0.34	0.40	0.32	0.30	0.26	0.25	0.37	0.48
60%ile	0.37	0.38	0.26	0.25	0.30	0.34	0.26	0.23	0.23	0.20	0.26	0.37
50%ile	0.33	0.32	0.24	0.22	0.27	0.27	0.20	0.15	0.18	0.17	0.21	0.32
40%ile	0.30	0.28	0.19	0.19	0.23	0.23	0.17	0.13	0.14	0.14	0.18	0.28
30%ile	0.26	0.19	0.16	0.15	0.19	0.17	0.15	0.10	0.09	0.11	0.14	0.19
20%ile	0.20	0.15	0.13	0.10	0.15	0.11	0.11	0.08	0.06	0.07	0.12	0.14
10%ile	0.14	0.11	0.10	0.07	0.07	0.07	0.07	0.04	0.05	0.05	0.08	0.10
1%ile	0.09	0.06	0.04	0.05	0.03	0.04	0.02	0.01	0.02	0.03	0.05	0.07

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. The 99%ile indicates that there is a 10 % decrease in the floods to the estuary, but this is a remnant of the process followed to generate the hydrology and not seen as a real increase.

Confidence: Medium

Present sediment processes

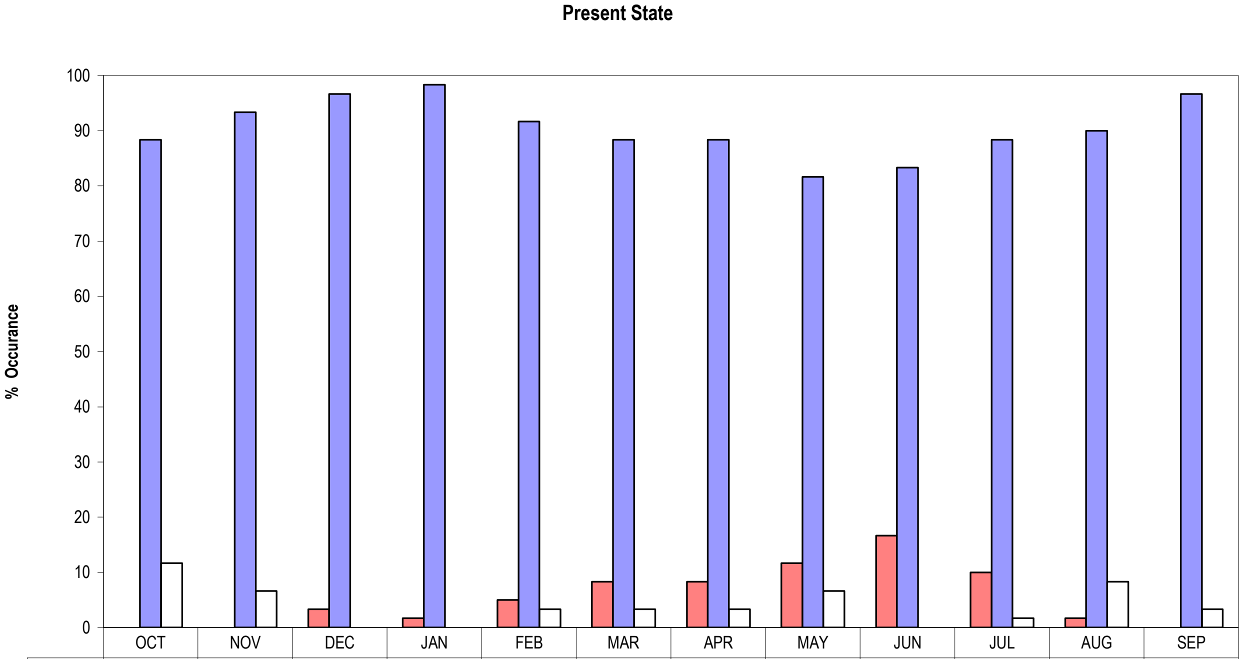
The hydrological data indicates that the magnitude and occurrence of major floods has hardly been reduced. This also means that the flushing of sediments during such floods has hardly been reduced. It is therefore likely that the sedimentation in the estuary is not much different from what it was under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

Confidence: Medium

Table 2. *Simulated monthly volumes in the Sout 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	1.44	0.63	0.12	0.05	0.15	0.19	0.21	2.06	1.00	0.24	0.34	0.57	0.58
1935	0.61	0.57	0.41	0.22	0.23	0.33	0.16	0.42	0.19	0.52	0.23	0.38	0.36
1936	0.48	0.71	0.52	0.19	0.25	0.43	0.15	0.02	0.05	0.25	0.13	0.48	0.30
1937	0.33	0.17	0.45	0.47	0.14	0.22	0.21	0.07	0.04	0.03	0.08	0.16	0.20
1938	0.23	0.53	0.44	0.11	1.21	0.91	0.27	0.05	0.02	0.31	0.71	0.66	0.46
1939	0.31	0.25	0.20	0.40	0.51	0.31	0.14	0.07	0.05	0.17	0.10	0.19	0.22
1940	0.14	0.11	0.07	0.21	0.10	0.12	0.66	0.25	0.18	0.15	0.08	0.16	0.19
1941	0.73	0.45	0.51	0.60	0.25	0.15	0.07	0.65	0.33	0.14	0.12	0.11	0.34
1942	0.28	0.19	0.24	0.61	0.27	0.20	0.13	0.04	0.08	0.08	0.22	0.79	0.26
1943	0.43	0.99	0.81	0.19	0.21	0.18	0.08	1.42	0.59	0.33	0.18	0.34	0.48
1944	0.32	0.16	0.07	0.05	0.06	0.04	0.02	0.51	0.48	0.20	0.12	0.09	0.18
1945	0.14	0.08	0.17	0.26	0.28	0.72	0.28	0.04	0.03	0.10	0.16	0.13	0.20
1946	0.28	0.15	0.10	0.37	0.28	0.51	0.31	0.29	0.23	0.44	0.19	0.31	0.29
1947	0.25	0.35	0.16	0.25	0.23	0.14	0.43	0.15	0.03	0.05	0.05	0.22	0.19
1948	0.34	0.34	0.21	0.40	0.32	0.07	0.13	0.14	0.06	0.03	0.04	0.16	0.19
1949	0.10	0.94	0.34	0.05	0.07	0.04	0.03	0.09	0.05	0.27	0.43	0.36	0.23
1950	0.46	1.18	0.69	0.84	0.41	0.09	0.03	0.14	0.23	0.63	0.72	0.67	0.51
1951	0.25	0.05	0.03	0.58	0.47	0.11	0.19	0.11	0.10	0.12	0.51	1.11	0.30
1952	0.46	0.30	0.18	0.14	0.21	0.08	0.07	0.04	0.42	0.34	0.69	0.59	0.29
1953	1.35	0.82	0.29	0.07	0.02	0.18	0.17	0.61	0.34	0.44	1.27	0.60	0.51
1954	0.14	0.39	0.16	0.40	1.41	0.47	0.16	0.09	0.07	0.07	0.06	0.06	0.29
1955	0.32	1.24	0.41	0.11	0.29	0.46	0.19	0.67	0.29	0.06	0.07	0.57	0.39
1956	1.03	0.56	0.24	0.19	0.30	0.44	0.19	0.08	0.27	0.14	0.36	0.49	0.36
1957	0.28	0.08	0.18	0.17	0.07	0.53	0.37	0.43	0.23	0.07	0.34	0.23	0.25
1958	0.26	0.12	0.26	0.60	0.28	0.38	0.70	0.49	0.16	0.24	0.55	0.29	0.36
1959	0.39	0.20	0.10	0.43	0.17	0.27	0.52	0.30	0.18	0.37	0.19	0.36	0.29
1960	0.17	0.30	0.52	0.52	0.44	0.69	0.30	0.30	0.14	0.11	0.18	0.13	0.32
1961	0.28	0.16	0.15	0.31	0.24	0.73	0.43	0.11	0.05	0.03	1.41	0.58	0.37
1962	1.22	0.78	0.17	0.25	0.19	1.10	0.57	0.17	0.09	0.41	0.21	0.10	0.44
1963	0.21	0.11	0.32	0.43	0.31	0.25	0.27	0.10	0.40	0.19	0.37	0.99	0.33
1964	0.39	0.36	0.16	0.08	0.07	0.40	0.45	0.29	0.24	0.18	0.10	0.09	0.23
1965	0.79	1.14	0.40	0.54	0.37	0.08	0.10	0.11	0.06	0.04	0.57	0.40	0.38
1966	0.12	0.14	0.24	0.22	0.31	0.60	1.36	1.09	0.36	0.23	0.15	0.48	0.44
1967	0.23	0.30	0.26	0.08	0.19	0.41	0.22	0.15	0.71	0.28	0.18	0.48	0.29
1968	0.43	0.52	0.19	0.20	0.29	0.36	0.18	0.05	0.28	0.18	0.12	0.10	0.24
1969	0.33	0.19	0.05	0.16	0.70	0.25	0.03	0.01	0.02	0.05	0.80	0.37	0.25
1970	0.40	0.17	0.73	0.34	0.68	0.43	0.57	0.62	0.26	0.96	1.25	0.46	0.57
1971	0.18	0.68	0.34	0.22	0.82	0.39	0.11	0.09	0.18	0.26	0.39	0.18	0.32
1972	0.09	0.09	0.10	0.15	0.19	0.31	0.28	0.13	0.13	0.09	0.12	0.28	0.16
1973	0.17	0.49	0.20	0.51	0.40	0.44	0.21	0.43	0.20	0.05	0.45	0.33	0.32
1974	0.14	0.33	0.14	0.43	0.56	0.37	0.16	0.05	0.10	0.18	0.20	0.78	0.29
1975	0.32	0.30	0.51	0.23	0.23	0.42	0.15	0.15	0.11	0.40	0.21	0.20	0.27
1976	1.26	0.77	0.27	0.06	0.80	0.82	0.25	0.63	0.30	0.07	0.21	0.29	0.48
1977	0.34	0.47	0.25	0.10	0.04	0.05	0.12	0.11	0.23	0.11	0.27	0.17	0.19
1978	0.30	0.37	0.49	0.40	0.18	0.06	0.54	0.34	0.16	0.48	1.02	0.53	0.41
1979	0.16	0.08	0.13	0.22	0.11	0.04	0.15	0.08	0.26	0.13	0.16	0.33	0.16
1980	0.39	0.23	0.37	0.86	0.52	1.36	0.75	1.67	0.72	0.15	1.23	0.52	0.73
1981	0.80	0.43	0.24	0.12	0.16	0.30	1.44	0.48	0.09	0.25	0.14	0.38	0.40
1982	0.30	0.11	0.13	0.07	0.32	0.15	0.06	0.14	0.47	1.04	0.44	0.32	0.29
1983	0.36	0.32	0.29	0.14	0.18	0.26	0.10	0.03	0.05	0.06	0.05	0.11	0.16
1984	0.09	0.15	0.15	0.37	0.53	0.24	0.34	0.14	0.14	0.23	0.12	0.07	0.21
1985	0.85	0.59	0.34	0.60	0.21	0.03	0.02	0.01	0.05	0.05	0.51	0.31	0.30
1986	0.81	0.39	0.13	0.09	0.32	0.23	0.61	0.23	0.16	0.09	0.20	0.82	0.34
1987	0.32	0.06	0.11	0.08	0.03	0.11	0.49	0.51	0.30	0.14	0.26	0.19	0.22
1988	0.25	0.14	0.16	0.09	0.06	0.07	0.37	0.15	0.05	0.15	0.09	0.10	0.14
1989	1.04	1.34	0.38	0.06	0.65	0.24	0.38	0.29	0.45	0.19	0.16	0.14	0.44
1990	0.36	0.38	0.13	0.16	0.54	0.28	0.07	0.10	0.09	0.06	0.12	0.10	0.20
1991	0.54	0.22	0.37	0.18	0.55	0.40	0.16	0.23	0.17	0.32	0.69	0.30	0.35
1992	1.27	0.96	0.23	0.17	0.11	0.08	0.17	0.12	0.26	0.15	0.13	1.76	0.45
1993	0.65	0.30	0.38	0.29	0.28	0.30	0.23	0.19	0.16	0.17	0.28	0.35	0.30

1: Freshwater	>1.0	2: Gradient	0.05 -1.0	3: Marine	< 0.05



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Series1	0.0	0.0	3.3	1.7	5.0	8.3	8.3	11.7	16.7	10.0	1.7	0.0
Series2	88.3	93.3	96.7	98.3	91.7	88.3	88.3	81.7	83.3	88.3	90.0	96.7
Series3	11.7	6.7	0.0	0.0	3.3	3.3	3.3	6.7	0.0	1.7	8.3	3.3

Figure 3. *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*:**

None at present, saw mill used to discharge wood chips and sawdust into the river

Confidence: Medium

Human exploitation (consumptive or non-consumptive):

The Sout Estuary is situated within a National Park and although angling is allowed, it is restricted to the rocky shore at the mouth. The Sout Estuary is a popular area to hike to and the disturbance factor for the birds is high.

Confidence: High

Artificial mouth breachings:

None

Confidence: High

3.2.2 Biotic Components

MICROALGAE

Phytoplankton Average phytoplankton chlorophyll *a* was low in Dec. '06 (0.55 ± 0.12 $\mu g.l^{-1}$) and April '07 (0.47 ± 0.10 $\mu g.l^{-1}$). Tidal flows effectively flush the estuary not providing sufficient residence time for a higher phytoplankton biomass to develop. In addition, nutrient concentrations in the river water were relatively low and DIN:DIP was ~4 suggesting that phytoplankton growth is N-limited. Flagellates and diatoms dominated the phytoplankton (54% and 43% respectively) and low densities of cyanobacteria and dinoflagellates were present in the middle/upper reaches. However, total cell density was low (<1000 $cells.ml^{-1}$). Microalgal community structure and biomass is likely to be similar to the reference condition.

Benthic microalgae Average benthic chlorophyll *a* was 16.6 ± 1.9 $\mu g.g^{-1}$ and 8.4 ± 1.4 $\mu g.g^{-1}$ in April 2007 and December 2006 respectively. These contents are regarded as close to average for permanently open estuaries in the area (13.9 ± 0.9 $\mu g.g^{-1}$). The highest contents were measured in the middle reaches of the estuary (0.5 km from the mouth). Microalgal community structure and biomass is likely to be similar to the reference condition.

Confidence: High

MACROPHYTES

Steep banks and lack of substantial intertidal areas results in limited macrophyte extent. The Sout is in a near natural state with regards to water quantity as it receives close to 90% of natural MAR. One can therefore assume that the macrophytes have changed little over time. The small size of the estuary, maximum length 1.1 km, also results in small macrophyte areas. The dominant species are the estuarine rush *Juncus kraussii*, *Cotula coronopifolia* and buffalo grass *Stenotaphrum secundatum*. These species are usually indicative of brackish conditions. There is also a small area of salt marsh where *Chenolea diffusa, Sarcocornia perennis* and *Sporobolus virginicus* are dominant. The submerged macrophyte, *Zostera capensis*, is also present in very small quantities in the middle reaches of the estuary.

Confidence: High

INVERTEBRATES

Zooplankton

There are no data on the Zooplankton of the estuary, but biomass and species composition is likely to be very low. This is mainly because of the shallow nature of the estuary and water exchange is very high between high and low water. Only deeper pockets will have water resident for more than a few days. During high flow events (>1 m^3 per second), the estuary is river dominated and salinity values remain low. High variation in salinity over short time periods therefore, will preclude the establishment of a significant zooplankton community.

Benthic invertebrates (zoobenthos)

There are small areas where intertidal species such as *Upogebia africana, Callianassa kraussi* and the saltmarsh crab *Sesarman catenata* become established. Biomass and density is not considered high. Species richness of the subtidal zoobenthic community (15 – 17 species) is also low and only hardy species that are able to tolerate the fluctuating salinity become established. Compared to other estuaries, the Sout has a very low level of different zoobenthic species.

Larger invertebrates

As for zooplankton and the zoobenthos. Larger invertebrates will only be able to survive in deeper holes where fixed structures such as rocks and driftwood provide protection from predators. Available areas for species to survive are also few and very small in area.

Confidence: Medium

FISH
Nineteen fish species from 10 families have been recorded in the Sout Estuary. Some species (e.g. *Psammogobius knysnaensis* and *Caffrogobius gilchristi*) will breed in the estuary, with most of the species (e.g. *Liza dumerili* and *Rhabdosargus holubi*) breeding at sea and using the estuarine environment as a nursery area. The ichthyofauna is dominated by 0+ juvenile marine fishes that utilize the almost pristine system as a nursery area. The input of macrodetritus from both the river catchment and adjacent coastal zone appear to be important drivers of the food web within this estuary, especially the zoobenthos. Most of the fish species found within the estuary are associated with the benthos, feeding either on the microphytobenthos and detritus in the case of mugilids or the zoobenthos in the case of carnivorous sparids. Poor planktonic food resources as a result of clear, nutrient poor river inflow have contributed to low abundance, biomass and diversity of planktivorous fish species within this system. Reduced river flow is likely to result in marine conditions penetrating further upstream, resulting in expanded marine migrant and marine straggler fish components within the system. Based on their distributional ranges, 14 (74%) of the fish species recorded in the Sout Estuary are southern African endemics. The high degree of endemism can be attributed to the locality of the Sout Estuary within the warm temperate biogeographic region. Confidence: Medium
BIRDS
Bird counts reflect only few species and low numbers of birds associated with the estuary. Most of these species will also utilize areas outside the Sout Estuary (adjacent shoreline and Groot Estuary). 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>:** The permanently open mouth maintains a well-flushed estuary, providing little nutrient and residence time for phytoplankton growth and development. The mouth is unlikely to close. No impact. *Confidence: High*
	<u>Macrophytes</u>: The mouth of the estuary remains open introducing seawater and maintaining brackish conditions suitable for the dominant plant species. Confidence: High
	<u>Invertebrates</u>: The open mouth ensures a significant tidal exchange and this leads to a significant shift in salinity values between high and low tide. Under conditions of mouth closure, there may be a decrease in invertebrate biomass and species richness. This is because the larger species such as saltmarsh crabs and the mudprawn require a marine phase of development. Confidence: Medium.
	<u>Fish</u>: The fish fauna of the Sout Estuary is dominated by estuarine-associated marine species that benefit from the permanently open mouth. If the mouth was to close there would be a proportional increase in the abundance of estuarine species and the migrations of marine species into and out of the estuary would be affected. Confidence: Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Birds: The larger invertebrates such as *Upogebia africana* are an important source of food for some bird species. If these invertebrates disappear, predatory birds that feed on them will move away from the estuary. Smaller waders may increase slightly in number, since a larger volume of water trapped in the estuary under conditions of mouth closure may provide a greater abundance of food (small crustaceans). Confidence: Low
Exposure of inter-tidal areas during low tide	**Microalgae:** The average chlorophyll *a* content of the intertidal sediment (13.0 ± 2.7 $\mu g.g^{-1}$) was slightly higher than that measured in the subtidal sediment (11.6 ± 4.3 $\mu g.g^{-1}$). No impact. *Confidence: High*
	Macrophytes: Large intertidal salt marsh areas are absent due to limited space. However the strong tidal flows have created elevated islands colonized by brackish species. Confidence: High
	Invertebrates: Only small patches of intertidal habitat are available for invertebrates to colonize. Because of the steep-sided nature of the shoreline, no significant change is likely to occur as available habitat. Confidence: Medium
	Fish: Exposure of intertidal areas during low tide is a natural phenomenon and one which fish species are well adapted to. No impact. Confidence: High
	Birds: No significant change in available habitat is likely to occur and bird numbers are unlikely to change. Confidence:
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: Medium*
	Macrophytes: Growth of submerged macrophytes is restricted because of the strong tidal flows and a lack of a suitable substrate (silt). Three small patches of *Zostera capensis* was found in the middle reaches. The beach sand in the cove area are colonised by typical beach / dune plants. The salt marsh vegetation is restricted to elevated islands of silty sediment because of the strong tidal currents. Confidence: High
	Invertebrates: No change in current sediment distribution is likely to occur, thus not influencing invertebrate communities. Confidence:
	Fish: Since sediment characteristics and processes are similar to the reference state, little or no change is likely to have occurred within the fish community. Confidence: Medium
	Birds: As for invertebrates (no change in food resources). Confidence: Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
Retention times of water masses	**Microalgae:** Microalgal biomass is tightly associated with flow velocity and retention time. Retention time between the three states varies from <1 day (state 1) to ~2 weeks. Microalgal biomass is likely to be lowest during state 1 and highest when a salinity gradient is present (state 2). However, an optimal retention time of ~6 weeks (based on Gamtoos and Sundays estuary research) does not occur in this estuary so average phytoplankton chlorophyll *a* is unlikely to exceed 1.0 $\mu g.l^{-1}$. Retention times are similar to the reference state so there is no impact. *Confidence: Medium*
	Macrophytes: There is strong tidal exchange and retention time is low. Algal mats typical of closed estuaries are absent. Confidence: High
	Invertebrates: Invertebrate biomass and species richness is kept low because of the significant tidal exchange and rapid shift in salinity. Confidence:
	Fish: Reduced planktonic productivity associated with the low retention time of water masses has resulted in a limited zooplanktonic fish component within the estuary. This is a natural state for this system. Confidence: High
	Birds: Food resources are low and consequently, avian predators remain relatively low. Confidence: Low
Flow velocities	**Microalgae:** Microalgal biomass is tightly associated with 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 1.0 $m^3.s^{-1}$ were to occur, then there would be no salinity gradient and residence time would be <1 day resulting in low phytoplankton biomass (chlorophyll a <0.5 $\mu g.l^{-1}$). Flow is similar to the reference state so there is no impact. *Confidence: Medium*
	Macrophytes: Strong tidal flows probably prevent the permanent establishment of submerged macrophyte areas. Confidence: High
	Invertebrates: Strong tidal flows and high water exchange negatively influence the non-burrowing invertebrate community. Confidence: Medium.
	Fish: The different flow velocities recorded within this system will not have a negative impact on the behaviour of the resident or migratory fish species. Confidence: High
	Birds: Because of low food resources affected by flow velocities, avian predators remain low in number. Confidence: Low
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*

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Macrophytes: The volume of the estuary changes greatly between high and low tide thus limiting the establishment of submerged plants and restricting the saltmarsh vegetation to elevated hummocks/islands. Confidence: High
	Invertebrates: Strong flushing brought about by tidal exchange precludes the establishment of dense populations of invertebrates. Confidence: Medium
	Fish: The shallow nature of the estuary favours small fish species and the juveniles of larger species. Large predatory fishes are only likely to enter the system at high tide when the estuary volume is at a maximum. Confidence: Medium
	Birds: Because of large exchanges in water volume between high and low tide, invertebrate food resources are limited and this affects the birds relient on them as food resources. The shallow nature of the estuary and its small size also precludes the establishment of a large fish biomass and this will lead to a relatively low number of piscivorous birds. Confidence: Medium.
Salinities	**Microalgae:** Phytoplankton chlorophyll *a* responds significantly to nutrients in freshwater (particularly PO_4^{3+}, NO_3^{2-} and NH_4^+). A full salinity range from fresh at the head of the estuary becoming marine at the mouth with a strong vertical gradient is ideal for maximum microalgal biomass and diversity. However, strong tidal flushing and low residence time in the Sout estuary limits microalgal growth to <1.0 µg.l^{-1}. *Confidence: High*
	Macrophytes: Salinity varies greatly even over a tidal cycle. Only hardy plants adapted to a wide salinity tolerance range would occur here. Interestingly most of the species present are adapted to brackish conditions. Their survival is therefore dependent on freshwater inflow from the river but probably also lateral flow from the steep banks. Confidence: Medium
	Invertebrates: The significant shift in salinity distribution between high and low tide only allows a few hardy species to colonize the estuary. These same species also need to cope with freshwater conditions during times of high river flow. The estuary is also very small are salinity changes will be very rapid, even under moderate changes in river flow. Confidence: Medium
	Fish: Fishes are tolerant of a wide range of salinities but marine fishes will temporarily leave the estuary when freshwater conditions prevail. Once salinities increase, these species will return to the system. Stenohaline marine fishes will only occur in the estuary when seawater salinities prevail. Confidence: Medium
	Birds: See invertebrates and fish – low food availability Confidence: Medium
Other water quality variables	**Microalgae:** Elevated nutrients, fine sediment and organic matter imported in riverwater generally support a higher microalgal biomass. Currently, levels of these variables appear to be low and similar to the reference condition so there is no impact. *Confidence: High.*

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Macrophytes: The water quality is largely pristine and therefore no increase in macrophyte growth has occurred in response to high nutrient input. Confidence: High
	Invertebrates: No change Confidence: High
	Fish: The very clear water in this estuary results in a low representation of turbid water fish species. No change. Confidence: High
	Birds: No change Confidence: High

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)	**Microalgae:** N/A Confidence:
	Macrophytes: N/A Confidence:
	Invertebrates: N/A Confidence:
	Fish: N/A Confidence:
	Birds: N/A Confidence:
Human exploitation (consumptive and non-consumptive)	**Microalgae:** Human exploitation is minimal, similar to reference condition. Confidence: High
	Macrophytes: N/A Confidence:
	Invertebrates: Very low Confidence: High
	Fish: Recreational fishing does occur in this estuary but is not intensive due the inaccessibility of the estuary to most anglers. Confidence: Medium
	Birds: Human disturbance Confidence: High

3.3 Reference Conditions

3.3.1 Abiotic Components

Seasonal variability in river inflow:

Monthly simulated runoff data for the Sout Estuary Reference (or natural) Condition is provided in Table 4. 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
99%ile	1.54	1.42	0.85	0.94	1.44	1.34	1.54	2.04	0.93	1.10	1.47	1.53
90%ile	0.99	1.05	0.57	0.65	0.73	0.78	0.64	0.69	0.48	0.49	0.82	0.77
80%ile	0.74	0.71	0.44	0.48	0.56	0.49	0.48	0.54	0.34	0.36	0.57	0.63
70%ile	0.49	0.56	0.37	0.42	0.38	0.45	0.35	0.33	0.29	0.27	0.42	0.53
60%ile	0.41	0.43	0.29	0.28	0.33	0.38	0.28	0.25	0.25	0.22	0.29	0.41
50%ile	0.36	0.36	0.27	0.24	0.30	0.30	0.22	0.16	0.20	0.19	0.23	0.36
40%ile	0.33	0.31	0.21	0.21	0.26	0.26	0.18	0.14	0.16	0.16	0.20	0.32
30%ile	0.29	0.21	0.18	0.16	0.21	0.19	0.17	0.11	0.10	0.12	0.16	0.21
20%ile	0.23	0.16	0.14	0.11	0.17	0.12	0.12	0.08	0.07	0.07	0.13	0.16
10%ile	0.16	0.12	0.12	0.08	0.08	0.08	0.07	0.04	0.05	0.06	0.09	0.11
1%ile	0.10	0.06	0.04	0.05	0.03	0.04	0.03	0.01	0.02	0.03	0.05	0.07

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.

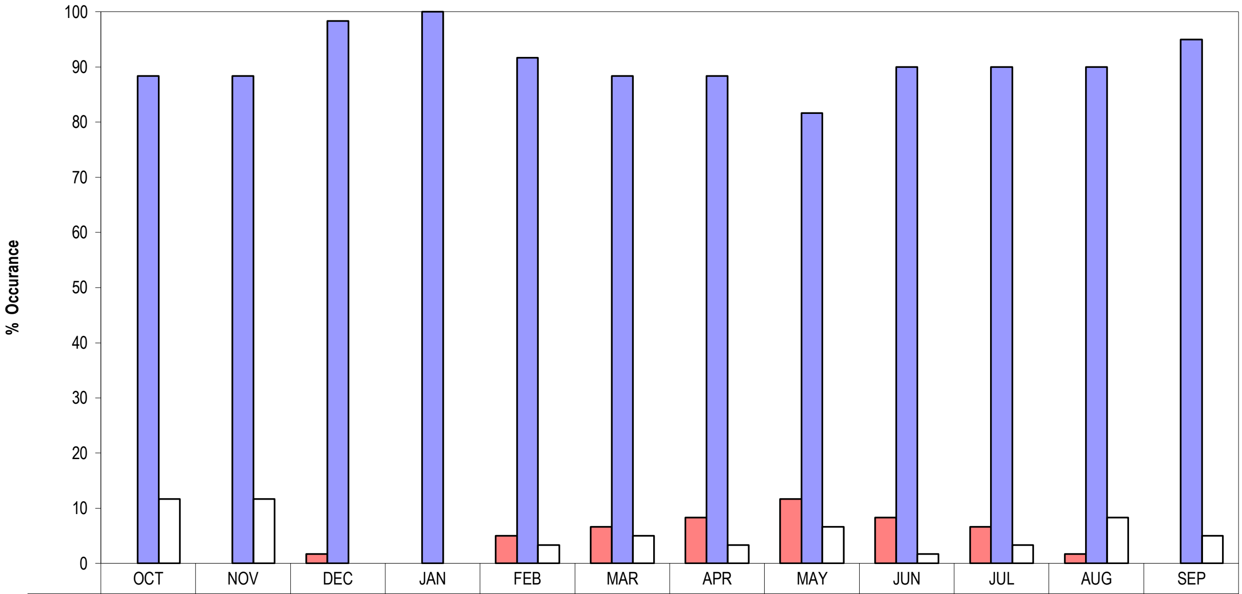
Confidence: Low

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

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	1.61	0.69	0.13	0.06	0.17	0.21	0.23	2.29	1.11	0.26	0.38	0.63	0.65
1935	0.68	0.63	0.46	0.24	0.26	0.37	0.18	0.46	0.22	0.58	0.26	0.42	0.40
1936	0.54	0.79	0.57	0.22	0.27	0.47	0.17	0.02	0.06	0.27	0.15	0.53	0.34
1937	0.37	0.19	0.50	0.53	0.15	0.24	0.24	0.07	0.05	0.04	0.09	0.17	0.22
1938	0.25	0.59	0.49	0.13	1.35	1.02	0.30	0.06	0.02	0.34	0.78	0.73	0.51
1939	0.34	0.27	0.22	0.44	0.56	0.34	0.15	0.07	0.05	0.19	0.11	0.22	0.25
1940	0.16	0.13	0.08	0.24	0.11	0.13	0.74	0.28	0.20	0.17	0.09	0.18	0.21
1941	0.81	0.50	0.56	0.67	0.27	0.17	0.08	0.72	0.37	0.15	0.14	0.12	0.38
1942	0.31	0.22	0.27	0.68	0.30	0.22	0.14	0.04	0.09	0.09	0.24	0.88	0.29
1943	0.48	1.10	0.90	0.21	0.23	0.20	0.09	1.58	0.65	0.37	0.20	0.38	0.53
1944	0.35	0.18	0.08	0.05	0.06	0.05	0.03	0.57	0.53	0.23	0.13	0.10	0.20
1945	0.16	0.09	0.19	0.29	0.31	0.80	0.32	0.04	0.03	0.12	0.18	0.14	0.22
1946	0.31	0.17	0.11	0.41	0.31	0.56	0.34	0.32	0.25	0.49	0.22	0.34	0.32
1947	0.28	0.39	0.18	0.27	0.26	0.16	0.47	0.17	0.04	0.05	0.06	0.25	0.21
1948	0.38	0.38	0.24	0.44	0.36	0.08	0.14	0.16	0.07	0.03	0.05	0.17	0.21
1949	0.11	1.05	0.37	0.06	0.08	0.04	0.03	0.10	0.05	0.30	0.48	0.41	0.26
1950	0.51	1.32	0.77	0.93	0.45	0.10	0.03	0.16	0.26	0.70	0.80	0.75	0.56
1951	0.27	0.06	0.03	0.64	0.52	0.13	0.21	0.13	0.11	0.13	0.56	1.23	0.34
1952	0.51	0.33	0.20	0.15	0.23	0.09	0.07	0.04	0.47	0.38	0.77	0.65	0.32
1953	1.50	0.91	0.32	0.08	0.02	0.20	0.19	0.68	0.38	0.49	1.41	0.67	0.57
1954	0.15	0.43	0.18	0.44	1.57	0.52	0.18	0.10	0.08	0.07	0.07	0.07	0.32
1955	0.36	1.38	0.45	0.13	0.32	0.52	0.22	0.75	0.32	0.07	0.07	0.63	0.43
1956	1.15	0.63	0.27	0.21	0.33	0.49	0.21	0.09	0.30	0.15	0.40	0.54	0.40
1957	0.31	0.09	0.21	0.19	0.08	0.59	0.41	0.48	0.25	0.08	0.37	0.25	0.28
1958	0.29	0.13	0.29	0.67	0.31	0.42	0.78	0.54	0.18	0.27	0.62	0.32	0.40
1959	0.43	0.22	0.12	0.48	0.19	0.29	0.58	0.33	0.20	0.41	0.21	0.41	0.32
1960	0.19	0.33	0.58	0.57	0.49	0.77	0.33	0.33	0.16	0.12	0.20	0.15	0.35
1961	0.31	0.18	0.17	0.35	0.27	0.81	0.47	0.12	0.05	0.03	1.56	0.64	0.41
1962	1.35	0.87	0.19	0.28	0.21	1.22	0.63	0.19	0.10	0.45	0.24	0.11	0.49
1963	0.23	0.13	0.35	0.48	0.34	0.28	0.30	0.11	0.44	0.21	0.41	1.10	0.37
1964	0.43	0.40	0.18	0.09	0.08	0.44	0.51	0.32	0.26	0.21	0.11	0.10	0.26
1965	0.87	1.26	0.44	0.60	0.41	0.09	0.11	0.12	0.07	0.05	0.64	0.45	0.43
1966	0.14	0.16	0.27	0.25	0.34	0.67	1.51	1.21	0.41	0.26	0.17	0.54	0.49
1967	0.25	0.33	0.29	0.09	0.21	0.45	0.25	0.17	0.79	0.31	0.21	0.54	0.32
1968	0.48	0.58	0.21	0.22	0.33	0.40	0.20	0.06	0.31	0.20	0.13	0.11	0.27
1969	0.37	0.21	0.05	0.18	0.78	0.28	0.04	0.01	0.02	0.06	0.89	0.41	0.28
1970	0.44	0.19	0.81	0.38	0.76	0.48	0.63	0.69	0.29	1.06	1.39	0.51	0.64
1971	0.21	0.76	0.38	0.25	0.91	0.43	0.12	0.10	0.20	0.29	0.43	0.20	0.36
1972	0.10	0.10	0.11	0.16	0.21	0.34	0.32	0.15	0.14	0.10	0.13	0.31	0.18
1973	0.19	0.55	0.22	0.56	0.45	0.49	0.23	0.48	0.22	0.05	0.50	0.36	0.36
1974	0.15	0.36	0.15	0.47	0.62	0.41	0.17	0.06	0.12	0.20	0.22	0.86	0.32
1975	0.35	0.34	0.57	0.25	0.26	0.46	0.17	0.16	0.12	0.44	0.24	0.22	0.30
1976	1.40	0.86	0.29	0.07	0.89	0.91	0.27	0.69	0.33	0.07	0.24	0.32	0.53
1977	0.38	0.52	0.27	0.11	0.04	0.05	0.14	0.12	0.26	0.12	0.30	0.19	0.21
1978	0.33	0.41	0.54	0.45	0.20	0.06	0.60	0.38	0.17	0.53	1.14	0.59	0.45
1979	0.18	0.08	0.14	0.25	0.12	0.04	0.17	0.09	0.29	0.14	0.18	0.37	0.17
1980	0.43	0.25	0.41	0.96	0.57	1.52	0.83	1.86	0.80	0.17	1.36	0.58	0.81
1981	0.88	0.48	0.27	0.13	0.18	0.33	1.60	0.54	0.10	0.28	0.16	0.42	0.45
1982	0.33	0.12	0.14	0.08	0.35	0.16	0.07	0.15	0.52	1.15	0.49	0.35	0.33
1983	0.40	0.36	0.32	0.16	0.20	0.29	0.11	0.03	0.06	0.07	0.06	0.12	0.18
1984	0.10	0.17	0.17	0.41	0.59	0.27	0.38	0.16	0.15	0.26	0.13	0.08	0.24
1985	0.95	0.66	0.37	0.67	0.23	0.03	0.03	0.01	0.05	0.06	0.56	0.35	0.33
1986	0.90	0.43	0.14	0.10	0.36	0.25	0.68	0.25	0.18	0.10	0.23	0.91	0.38
1987	0.36	0.07	0.12	0.09	0.04	0.13	0.54	0.57	0.33	0.16	0.28	0.21	0.24
1988	0.28	0.15	0.18	0.10	0.07	0.08	0.41	0.16	0.05	0.17	0.10	0.11	0.16
1989	1.15	1.49	0.42	0.07	0.72	0.26	0.42	0.32	0.51	0.21	0.18	0.16	0.49
1990	0.40	0.42	0.15	0.18	0.60	0.31	0.07	0.11	0.10	0.07	0.13	0.11	0.22
1991	0.60	0.25	0.41	0.20	0.61	0.44	0.18	0.26	0.19	0.36	0.76	0.34	0.38
1992	1.42	1.07	0.25	0.19	0.12	0.09	0.19	0.13	0.29	0.17	0.15	1.96	0.50
1993	0.72	0.34	0.42	0.32	0.31	0.33	0.26	0.21	0.18	0.19	0.31	0.39	0.33

1: Freshwater	>1.0	2: Gradient	0.05 -1.0	3: Marine	< 0.05

Reference Conditions



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
State 3	0.0	0.0	1.7	0.0	5.0	6.7	8.3	11.7	8.3	6.7	1.7	0.0
State 2	88.3	88.3	98.3	100.0	91.7	88.3	88.3	81.7	90.0	90.0	90.0	95.0
State 1	11.7	11.7	0.0	0.0	3.3	5.0	3.3	6.7	1.7	3.3	8.3	5.0

Figure 4. *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

Phytoplankton Average phytoplankton chlorophyll *a* was low in Dec. '06 (0.55 ± 0.12 µg.l^{-1}) and April '07 (0.47 ± 0.10 µg.l^{-1}). Phytoplankton chlorophyll *a* of >1.0 µg.l-1 was measured in the bottom water (>0.5 m) in the middle reaches of the estuary. Tidal flows effectively flush the estuary not providing sufficient residence time for a higher phytoplankton biomass to develop. In addition, nutrient concentrations in the river water were relatively low and DIN:DIP was ~4 suggesting that phytoplankton growth is N-limited. Flagellates and diatoms dominated the phytoplankton (54% and 43% respectively) and low densities of cyanobacteria and dinoflagellates were present in the middle/upper reaches. However, total cell density was low (<1000 cells.ml^{-1}). Microalgal community structure and biomass is likely to be similar to the reference condition.

Benthic microalgae Average benthic chlorophyll *a* was 16.6 ± 1.9 µg.g^{-1} and 8.4 ± 1.4 µg.g^{-1} in April 2007 and December 2006 respectively. These contents are regarded as close to average for permanently open estuaries in the area (13.9 ± 0.9 µg.g^{-1}). The highest contents were measured in the middle reaches of the estuary (0.5 km from the mouth). Microalgal community structure and biomass is likely to be similar to the reference condition.

Confidence: High

MACROPHYTES

The estuary is largely pristine and therefore the present distribution, biomass and species composition of macrophytes is expected to be largely natural. A slight increase in low flow from 4.2% to 5.6% would have had little effect on the macrophytes. The change in salinity in response to this is probably smaller than the variation in salinity over a tidal cycle.

Confidence: High

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

Because of the minimal shift in abiotic conditions between present state compared to natural, the invertebrate community is considered to be the same between the two states. Any shift in community structure is likely to be well within natural fluctuations over time.

Confidence: High

FISH

The similarity in abiotic conditions between the natural (reference) and present state suggests that little change in the fish community is likely to have occurred within this estuary. Some deviation in community composition may have occurred due to over-exploitation of selected fish species (e.g. white steenbras *Lithognathus lithognathus*) in other parts of South Africa. Slight reduction in benthic microalgae will result in lower mugilid fish stocks.

Confidence: High

BIRDS

Because of the minimal shift in the biotic community between present state compared to natural, the bird community is considered to be similar between the two states. Any shift in community structure is likely to be well within natural fluctuations over time.

Confidence: Medium

3.4 Present Ecological Status of the Sout 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	98	For the Sout Estuary low flows are defined as flows less than 0.05 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 0.05 m^3/s occurred under the Reference Conditions for 4.2 % of the time. Under the Present State low flows occur for 5.6 % of the time.	Medium
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 99%ile indicates that there is only a 10 % decrease in the floods to the estuary, but this is an artefact of the way the hydrology was generated)	Medium
Hydrology score	**95**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	100	N/A	Medium
Hydrodynamics and mouth conditions score	**100**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	90	As the river inflow to the Sout Estuary is very similar to the Reference Conditions, it is assumed that the salinity concentrations will also be very similar.	Low
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	90	The Sout estuary receives inorganic nutrients primarily through river inflow. However, the nutrient-salinity gradient is low indicating low nutrient concentrations in the riverwater. DIN, PO_4-P and SiO_4-Si concentrations seldom exceed 200 $\mu g.l^{-1}$, 50 $\mu g.l^{-1}$ and 3000 $\mu g.l^{-1}$ in the riverwater and are assumed to be similar to the reference state with only a slight change in response to the change in salinity.	Low
2b. Suspended solids (turbidity) in the estuary	90	Turbidity in the Sout estuary is generally low and light penetrates to the sediment throughout the estuary. However, secchi depths of <50 cm are likely to be measured in the estuary during high flow events (state 1). The level of suspended solids is likely to be similar to the reference state.	Low
2c. Dissolved oxygen in the estuary	95	The Sout estuary is well oxygenated primarily through tidal flushing. Oxygen levels will seldom drop below 7 mg/l. Allow slight decrease in DO due to reduction in floods.	Medium
2d. Levels of toxins	-	-	
Water Quality score	**90**		

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.	Low
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.	Low
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.	Low
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
	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	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
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 (95%)	Slight reduction in flow has led to a decrease in freshwater species entering the estuary.	Medium
2a. Abundance	100	Microalgal biomass in the estuary is generally low due to tidal flushing, so no significant change expected.	Medium / Low
2b. Community composition	95	Slight reduction in flow has led to a decrease in freshwater species entering the estuary.	Medium
Benthic microalgae			
1. Species richness	90 (95%)	Slight change as a result of change in intertidal area and sedimentation.	Low
2a. Abundance	95	Slight change as a result of change in intertidal area and sedimentation.	Low
2b. Community composition	95	Slight change as a result of change in intertidal area and sedimentation.	Low
Microalgae score	**95**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	The small change in flow, floods and salinity would have little effect on the macrophytes.	Medium
2a. Abundance/Biomass	100	The flow regime is largely natural and therefore abundance and biomass is also close to natural.	Medium
2b. Community composition	100	There has been little change in the driving physical factors that would have caused a change in macrophyte community composition.	Medium
Macrophytes score	**100**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	100	No change is expected because of the similarity in the abiotic conditions between natural and present day conditions.	Medium
2a. Abundance	100	As above	Medium
2b. Community composition	100	As above	Medium
Macroinvertebrates (Benthos)			
1. Species richness	100	As above	Medium
2a. Abundance	100	As above	Medium
2b. Community composition	100	As above	Medium
Macrocrustacea			
1. Species richness	100	As above	Medium
2a. Abundance	100	As above	Medium
2b. Community composition	100	As above	Medium
Invertebrates score	**100**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	All species found in the Sout Estuary reference condition are likely to be recorded in its present state.	High
2a. Abundance	90	Some angling fish species may occur in reduced numbers within the Sout Estuary due to over-exploitation in other parts of South Africa. Slight reduction in benthic microalgae will result in lower mugilid fish stocks.	Medium
2b. Community composition	90	Because of exploitation of certain fish species by anglers, the community composition is expected to deviate slightly from the natural condition. Slight reduction in mugilid fish stocks will alter fish composition.	Medium
Fish score	**90**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	No change is expected because of the similarity in the abiotic conditions between natural and present day conditions	Medium
2a. Abundance	95	Human disturbance and a slight reduction in food resources for larger birds (herons, cormorants, etc.)	Medium
2b. Community composition	95	Human disturbance and a slight reduction in food resources for larger birds (herons, cormorants, etc.)	Medium
Bird score	**95**		

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:

COMPONENT	% CHANGE CAUSED BY NON-FLOW RELATED ACTIVITIES	MOTIVATION	CONFIDENCE
Microalgae	50%	Slight change in benthic microalgae as a result of sedimentation.	Low
Macrophytes	No change		
Invertebrates	No change		
Fish	100%	Activities of anglers in the Sout Estuary but particularly over-exploitation in other parts of the targeted species' range.	Medium
Birds	100%	Human disturbance and a slight reduction in food resources for larger birds (herons, cormorants, etc.) as a result of over-exploitation.	Medium

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	97	24
Hydrodynamics and mouth condition	25	100	25
Water quality	25	90	23
Physical habitat alteration	25	95	24
Habitat health score			**95**
Microalgae	20	90	18
Macrophytes	20	100	20
Invertebrates	20	100	20
Fish	20	90	18
Birds	20	95	19
Biotic Health Score			**95**
Estuarine Health Score			**95**

The Estuarine Health Index score for the Sout Estuary, based on its Present State, is **95**, translating into a **Present Ecological Status** of a **A,** 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 Sout Estuary

The **Functional importance** of the Sout Estuary on a regional scale is estimated to be **40,** 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)	40
Movement corridor for river invertebrates and fish breeding in sea	40
Roosting area for marine or coastal birds	20
Catchment detritus, nutrients and sediments to sea	40
Functional importance score (Maximum score)	**40**

The **Estuarine Importance scores** allocated to the Sout 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	30	5
Zonal Rarity Type	10	50	5
Habitat Diversity	25	20	5
Biodiversity Importance	25	61.5	15
Functional Importance	25	40	10
Estuarine Importance Score			**40**

The overall **Estuarine Importance Score** for the Sout Estuary, based on its Present State, is **40**, 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 Sout Estuary fall within a protected area (De Vasselot Section of the Tsitsikamma National Park) and according to the guidelines for assigning a recommended Ecological Reserve Category, the Sout Estuary should therefore be classified as a Category A or Best Attainable State 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 A), BKS Consulting Engineers. A summary of the mean annual runoffs (MAR) of the various Simulated Monthly Runoff Scenarios used for this Intermediate 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	11.22	100
Present	Present State	10.10	90.00
Future Scenario 1	Reference Conditions – 0.05 m^3/s abstraction	9.69	86.40
Future Scenario 2	Reference Conditions – 0.10 m^3/s abstraction	8.27	73.68
Future Scenario 3	Reference Conditions – 0.20 m^3/s abstraction	5.92	52.74
Future Scenario 4	River Class A/B	4.85	43.21

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

- There are no measured flow data available for the Sout 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 is a flow gauge in the Sout / Wit River but no flow data because there is no rating curve for the station. This is a possible source of data for future use. This data are collected by DWAF: Regional office (George).
- The current land use in the catchment is 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 km^2 of indigenous forests.
- The natural MAR and present day MAR is estimated to be 11.22 million m^3.
- 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 would have a significant impact on the sediment balance of the system as it is sediment staved (very little marine sediment enters the system).

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
99%ile	1.49	1.37	0.80	0.89	1.39	1.29	1.49	1.99	0.88	1.05	1.42	1.53
90%ile	0.94	1.00	0.52	0.60	0.68	0.73	0.59	0.64	0.43	0.44	0.77	0.75
80%ile	0.69	0.66	0.39	0.43	0.51	0.44	0.43	0.49	0.29	0.31	0.52	0.60
70%ile	0.44	0.51	0.32	0.37	0.33	0.40	0.30	0.28	0.24	0.22	0.37	0.50
60%ile	0.36	0.38	0.24	0.23	0.28	0.33	0.23	0.20	0.20	0.17	0.24	0.37
50%ile	0.31	0.31	0.22	0.19	0.25	0.25	0.17	0.11	0.15	0.14	0.18	0.32
40%ile	0.28	0.26	0.16	0.16	0.21	0.21	0.13	0.09	0.11	0.11	0.15	0.27
30%ile	0.24	0.16	0.13	0.11	0.16	0.14	0.12	0.06	0.05	0.07	0.11	0.16
20%ile	0.18	0.11	0.09	0.06	0.12	0.07	0.07	0.03	0.02	0.02	0.08	0.11
10%ile	0.11	0.07	0.07	0.03	0.03	0.03	0.02	0.00	0.00	0.01	0.04	0.06
1%ile	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02

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 99%ile indicates that there is only a 3.1 % decrease in the floods to the estuary.

Confidence: Medium

Present sediment processes

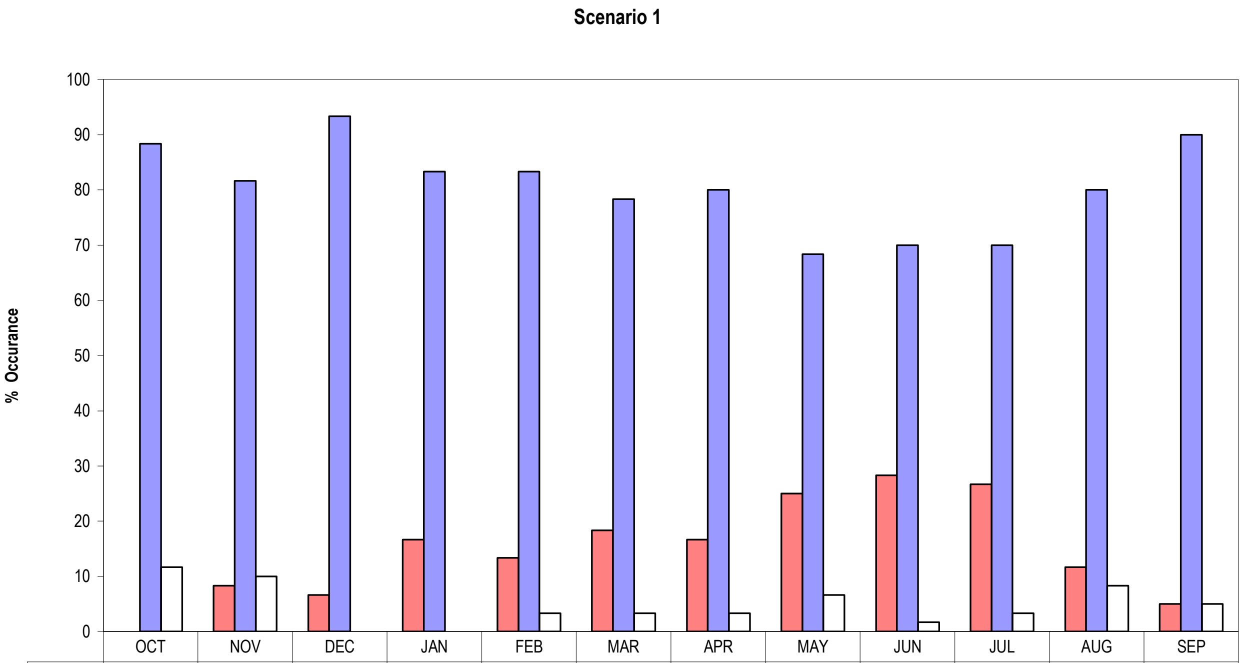
The hydrological data indicates that the magnitude and occurrence of major floods has hardly been reduced. This also means that the flushing of sediments during floods has hardly been reduced. It is therefore assumed that the sedimentation in the estuary is not much different from what it was under natural conditions. There may be some increased erosion in the catchment.

Confidence: Low

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

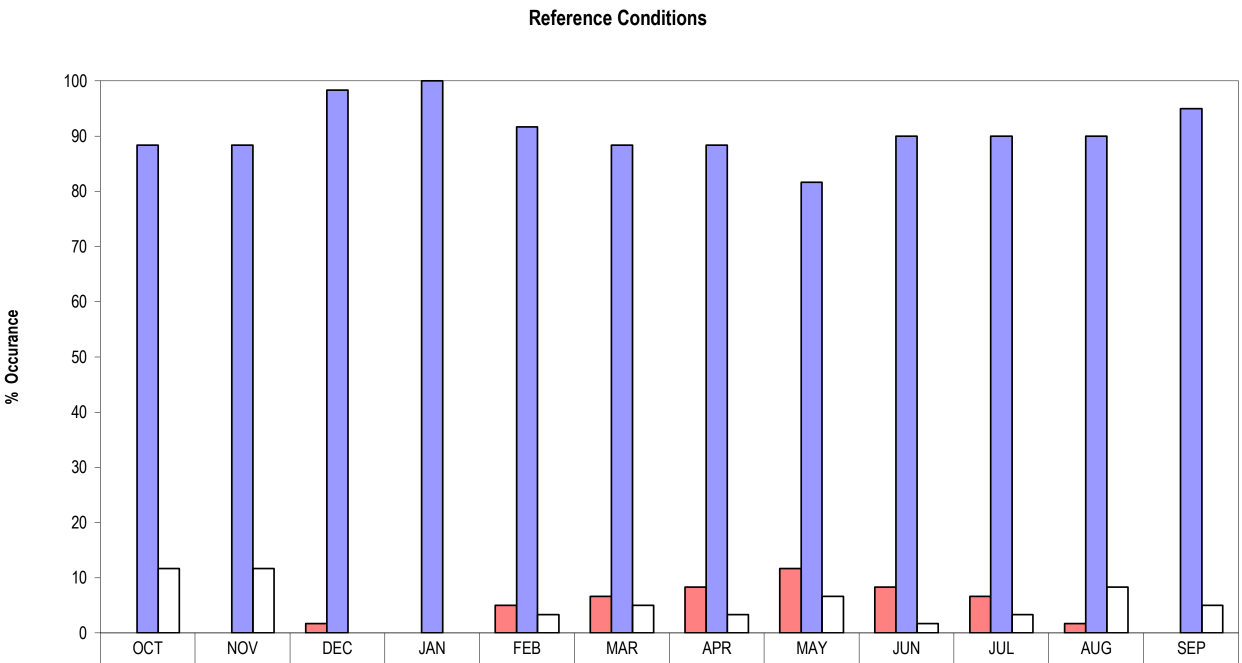
YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	1.56	0.64	0.08	0.01	0.12	0.16	0.18	2.24	1.06	0.21	0.33	0.60	0.60
1935	0.63	0.58	0.41	0.19	0.21	0.32	0.13	0.41	0.17	0.53	0.21	0.39	0.35
1936	0.49	0.74	0.52	0.17	0.22	0.42	0.12	0.00	0.01	0.22	0.10	0.49	0.29
1937	0.32	0.14	0.45	0.48	0.10	0.19	0.19	0.02	0.00	0.00	0.04	0.13	0.17
1938	0.20	0.54	0.44	0.08	1.30	0.97	0.25	0.01	0.00	0.29	0.73	0.70	0.46
1939	0.29	0.22	0.17	0.39	0.51	0.29	0.10	0.02	0.00	0.14	0.06	0.17	0.20
1940	0.11	0.08	0.03	0.19	0.06	0.08	0.69	0.23	0.15	0.12	0.04	0.13	0.16
1941	0.76	0.45	0.51	0.62	0.22	0.12	0.03	0.67	0.32	0.10	0.09	0.08	0.33
1942	0.26	0.17	0.22	0.63	0.25	0.17	0.09	0.00	0.04	0.04	0.19	0.85	0.24
1943	0.43	1.05	0.85	0.16	0.18	0.15	0.04	1.53	0.60	0.32	0.15	0.34	0.48
1944	0.30	0.13	0.03	0.00	0.01	0.00	0.00	0.52	0.48	0.18	0.08	0.06	0.15
1945	0.11	0.04	0.14	0.24	0.26	0.75	0.27	0.00	0.00	0.07	0.13	0.09	0.17
1946	0.26	0.12	0.06	0.36	0.26	0.51	0.29	0.27	0.20	0.44	0.17	0.30	0.27
1947	0.23	0.34	0.13	0.22	0.21	0.11	0.42	0.12	0.00	0.00	0.01	0.20	0.17
1948	0.33	0.33	0.19	0.39	0.31	0.03	0.09	0.11	0.02	0.00	0.00	0.13	0.16
1949	0.06	1.00	0.32	0.01	0.03	0.00	0.00	0.05	0.00	0.25	0.43	0.37	0.21
1950	0.46	1.27	0.72	0.88	0.40	0.05	0.00	0.11	0.21	0.65	0.75	0.72	0.52
1951	0.22	0.01	0.00	0.59	0.47	0.08	0.16	0.08	0.06	0.08	0.51	1.22	0.29
1952	0.46	0.28	0.15	0.10	0.18	0.04	0.02	0.00	0.42	0.33	0.72	0.62	0.28
1953	1.45	0.86	0.27	0.03	0.00	0.15	0.14	0.63	0.33	0.44	1.36	0.64	0.52
1954	0.10	0.38	0.13	0.39	1.52	0.47	0.13	0.05	0.03	0.02	0.02	0.02	0.27
1955	0.31	1.33	0.40	0.08	0.27	0.47	0.17	0.70	0.27	0.02	0.02	0.60	0.39
1956	1.10	0.58	0.22	0.16	0.28	0.44	0.16	0.04	0.25	0.10	0.35	0.51	0.35
1957	0.26	0.04	0.16	0.14	0.03	0.54	0.36	0.43	0.20	0.03	0.32	0.21	0.23
1958	0.24	0.08	0.24	0.62	0.26	0.37	0.73	0.49	0.13	0.22	0.57	0.28	0.35
1959	0.38	0.17	0.07	0.43	0.14	0.24	0.53	0.28	0.15	0.36	0.16	0.37	0.27
1960	0.14	0.28	0.53	0.52	0.44	0.72	0.28	0.28	0.11	0.07	0.15	0.10	0.30
1961	0.26	0.13	0.12	0.30	0.22	0.76	0.42	0.07	0.00	0.00	1.51	0.61	0.37
1962	1.30	0.82	0.14	0.23	0.16	1.17	0.58	0.14	0.05	0.40	0.19	0.06	0.44
1963	0.18	0.08	0.30	0.43	0.29	0.23	0.25	0.06	0.39	0.16	0.36	1.09	0.32
1964	0.38	0.35	0.13	0.04	0.03	0.39	0.46	0.27	0.21	0.16	0.06	0.05	0.21
1965	0.82	1.21	0.39	0.55	0.36	0.04	0.06	0.07	0.02	0.00	0.59	0.41	0.38
1966	0.09	0.11	0.22	0.20	0.29	0.62	1.46	1.16	0.36	0.21	0.12	0.50	0.44
1967	0.20	0.28	0.24	0.04	0.16	0.40	0.20	0.12	0.74	0.26	0.16	0.50	0.27
1968	0.43	0.53	0.16	0.17	0.28	0.35	0.15	0.01	0.26	0.15	0.08	0.06	0.22
1969	0.32	0.16	0.00	0.13	0.73	0.23	0.00	0.00	0.00	0.01	0.84	0.37	0.23
1970	0.39	0.14	0.76	0.33	0.71	0.43	0.58	0.64	0.24	1.01	1.34	0.47	0.59
1971	0.16	0.71	0.33	0.20	0.86	0.38	0.07	0.05	0.15	0.24	0.38	0.15	0.31
1972	0.05	0.05	0.06	0.11	0.16	0.29	0.27	0.10	0.09	0.05	0.08	0.27	0.13
1973	0.14	0.50	0.17	0.51	0.40	0.44	0.18	0.43	0.17	0.00	0.45	0.32	0.31
1974	0.10	0.31	0.10	0.42	0.57	0.36	0.12	0.01	0.07	0.15	0.17	0.84	0.27
1975	0.30	0.29	0.52	0.20	0.21	0.41	0.12	0.11	0.07	0.39	0.19	0.18	0.25
1976	1.35	0.81	0.24	0.02	0.84	0.86	0.22	0.64	0.28	0.02	0.19	0.28	0.48
1977	0.33	0.47	0.22	0.06	0.00	0.00	0.09	0.07	0.21	0.07	0.25	0.15	0.16
1978	0.28	0.36	0.49	0.40	0.15	0.01	0.55	0.33	0.12	0.48	1.09	0.56	0.40
1979	0.13	0.03	0.09	0.20	0.07	0.00	0.12	0.04	0.24	0.09	0.13	0.33	0.12
1980	0.38	0.20	0.36	0.91	0.52	1.47	0.78	1.81	0.75	0.12	1.31	0.55	0.76
1981	0.83	0.43	0.22	0.08	0.13	0.28	1.55	0.49	0.05	0.23	0.11	0.38	0.40
1982	0.28	0.07	0.09	0.03	0.30	0.11	0.02	0.10	0.47	1.10	0.44	0.32	0.28
1983	0.35	0.31	0.27	0.11	0.15	0.24	0.06	0.00	0.01	0.02	0.01	0.07	0.13
1984	0.05	0.12	0.12	0.36	0.54	0.22	0.33	0.11	0.10	0.21	0.08	0.03	0.19
1985	0.90	0.61	0.32	0.62	0.18	0.00	0.00	0.00	0.00	0.01	0.51	0.31	0.29
1986	0.85	0.38	0.09	0.05	0.31	0.20	0.63	0.20	0.13	0.05	0.18	0.89	0.33
1987	0.31	0.02	0.07	0.04	0.00	0.08	0.49	0.52	0.28	0.11	0.23	0.17	0.19
1988	0.23	0.10	0.13	0.05	0.02	0.03	0.36	0.11	0.00	0.12	0.05	0.06	0.11
1989	1.10	1.44	0.37	0.02	0.67	0.21	0.37	0.27	0.46	0.16	0.13	0.11	0.44
1990	0.35	0.37	0.10	0.13	0.55	0.26	0.02	0.06	0.05	0.02	0.08	0.06	0.17
1991	0.55	0.20	0.36	0.15	0.56	0.39	0.13	0.21	0.14	0.31	0.71	0.30	0.33
1992	1.37	1.02	0.20	0.14	0.07	0.04	0.14	0.08	0.24	0.12	0.10	1.97	0.46
1993	0.67	0.29	0.37	0.27	0.26	0.28	0.21	0.16	0.13	0.14	0.26	0.35	0.28

1: Freshwater	>1.0	2: Gradient	0.05 -1.0	3: Marine	< 0.05



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Series1	0.0	8.3	6.7	16.7	13.3	18.3	16.7	25.0	28.3	26.7	11.7	5.0
Series2	88.3	81.7	93.3	83.3	83.3	78.3	80.0	68.3	70.0	70.0	80.0	90.0
Series3	11.7	10.0	0.0	0.0	3.3	3.3	3.3	6.7	1.7	3.3	8.3	5.0

Figure 5. *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	1.7	0.0	5.0	6.7	8.3	11.7	8.3	6.7	1.7	0.0
State 2	88.3	88.3	98.3	100.0	91.7	88.3	88.3	81.7	90.0	90.0	90.0	95.0
State 1	11.7	11.7	0.0	0.0	3.3	5.0	3.3	6.7	1.7	3.3	8.3	5.0

Figure 6. *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	90	For the Sout Estuary low flows are defined as flows less than 0.05 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 0.05 m^3/s occurred under the Reference Conditions for 4.2% of the time. Under the Present State low flows occur for 14.7 % of the time.	Medium
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 99%ile indicates that there is only a 3.1 % decrease in the floods to the estuary.	Medium
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	100	N/A	Medium
Hydrodynamics and mouth conditions score	**100**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	85	There is a 10% increase in State 3: Marine dominated and a 3.1 % reduction in State 1: Predominately fresh.	Medium
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	85	The 3.6% reduction in MAR will cause a slight shift to a more marine dominated state (10% increase in state 3), resulting in a slight decrease in the average concentration of nutrients in the estuary.	Medium
2b. Suspended solids (turbidity) in the estuary	85	The 3.6% reduction in MAR will cause a slight shift to a more marine dominated state (10% increase in state 3), resulting in a slight decrease in the average concentration of suspended solids in the estuary.	Medium
2c. Dissolved oxygen in the estuary	95	The mouth is permanently open and there is strong tidal flushing. Allow slight change in average DO due to reduction in floods.	Medium
2d. Levels of toxins	-	-	
Water Quality score	**85**		

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of <u>intertidal sediment</u> 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.	Low
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.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or	95	Allow 5% change in the intertidal area due to changes in floods and land use.	Low

	channel morphology			
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
	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	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
Physical habitat score		**95**		

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

Average phytoplankton biomass in the Sout estuary is low (~0.5 $\mu g.l^{-1}$). A decrease in river flow will reduce the concentrations of nutrients and suspended solids entering the estuary, which could result in a decrease in microalgal biomass. However, lower river flows and the reduced frequency of flood events will provide a more stable environment for microalgae, particularly in the middle reaches during periods of a longitudinal salinity gradient (state 2). An increase in state 2 will increase species biomass, richness and abundance (more cyanobacteria, dinoflagellates and chlorophytes) but longer periods of low/no flow (state 3) will result in the estuary becoming marine dominated with a low microalgal biomass, richness and abundance (diatoms and flagellates will dominate). Benthic microalgae are not as dependent on the water column chemistry as the phytoplankton.

Confidence: Medium

MACROPHYTES

Low flows now occur for 14.7% of the time compared to 4.2%. This results in a 10% increase in the marine dominated phase and an increase in salinity which may result in the loss of area of species and a slight reduction in biomass of the predominantly brackish macrophytes. These small changes would not change species richness and community composition.

Confidence: Medium

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

The increasing incidence of the marine dominated phase (14.7% as opposed to 4.2% of the time) will lead to a small increase in species richness, but not biomass. Zooplankton biomass will remain low since the exchange of tidal volume will change very little compared to natural. Although there is a marginal decrease in flood events, invertebrates are not likely to change because of this. Main impact is through a change in salinity distribution at times of low flow.

Confidence: Medium

FISH

The slight increase in the incidence of a marine dominated phase within the Sout Estuary will result in marine species occupying more of the estuary and for longer periods of time. This may translate into a small increase in biomass since most of the potential fish species colonising the estuary are derived from the marine environment. The marginal decrease in flood events will not have a significant impact on fish stocks which could increase slightly because river flooding tends to result in many species having to leave the estuary during such an event.

Confidence: Medium

BIRDS

The bird community will change marginally as a result of anthropogenic disturbance and exploitation of fish stocks.

Confidence: Medium

6.2.4 EHI for the Future Scenario 1 - Biotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	90 (95%)	Slight reduction in flow has led to a decrease in freshwater species entering the estuary.	Medium
2a. Abundance	95	Microalgal biomass in the estuary is generally low due to tidal flushing. However, a decrease in flow could decrease the nutrient load slightly.	Medium / Low
2b. Community composition	85	Slight reduction in flow has led to a decrease in freshwater species entering the estuary. Slight increase in state 3 favours the dominance by flagellates and diatoms.	Medium
Benthic microalgae			
1. Species richness	90 (95%)	Slight change as a result of change in intertidal area and sedimentation.	Low
2a. Abundance	90	Slight change as a result of change in intertidal area and sedimentation.	Low
2b. Community composition	90	Slight change as a result of change in intertidal area and sedimentation.	Low
Microalgae score	**85**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100 (100%)	No change in species richness	Medium
2a. Abundance	95	The increase in salinity would reduce the biomass and cover of the dominant macrophytes. Potential increase in the area covered by *Zostera capensis* as a result of increased salinity and more stable sediment conditions due to a 3.1% reduction in floods.	Medium
2b. Community composition	100	No change in community composition is expected.	Medium
Macrophytes score	**95**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	95 (90%)	A small increase in species richness is likely because of the 10% increase in marine dominance.	Low
2a. Abundance	95	Abundance is likely to increase marginally since euryhaline salinity values will persist more often in the upper reaches.	Low
2b. Community composition	95	The mix of species will change slightly because of a slight increase in average salinity values.	Low
Macroinvertebrates (zoobenthos)			
1. Species richness	95	A small increase in species richness is likely because of the 10% increase in marine dominance, particularly in the lower reaches.	Low
2a. Abundance	95	Abundance is likely to increase marginally since euryhaline salinity values will persist more often in the upper reaches.	Low
2b. Community composition	95	The mix of species will change slightly because of a slight increase in average salinity values.	Low
Macrocrustacea			
1. Species richness	95	A small increase in species richness is likely because of the 10% increase in marine dominance, particularly in the lower reaches.	Low
2a. Abundance	95	Abundance is likely to increase marginally since euryhaline salinity values will persist more often in the upper reaches (euryhaline species).	Low
2b. Community composition	95	The mix of species will change slightly because of a slight increase in average salinity values.	Low
Invertebrates score	**95**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	Species richness is unlikely to change under this scenario.	Medium
2a. Abundance	85	The increase in marine conditions is likely to result in a slight increase in average marine fish abundance. Exploitation impacts are included in this assessment.	Low
2b. Community composition	85	Any increase in marine fish abundance is also likely to result in a slight change in fish community composition. Exploitation impacts are included in this assessment.	Medium
Fish score	**85**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	No change in species richness is likely.	
2a. Abundance	90	Abundance is likely to increase marginally since invertebrate food resources (euryhaline species) will increase slightly. Anthropogenic disturbance and exploitation of fish resources.	Medium
2b. Community composition	90	The mix of species will change slightly because of a slight increase in average salinity values. Anthropogenic disturbance and exploitation of fish resources.	Medium
Bird score	**90**		

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
99%ile	1.44	1.32	0.75	0.84	1.34	1.24	1.44	1.94	0.83	1.00	1.37	1.48
90%ile	0.89	0.95	0.47	0.55	0.63	0.68	0.54	0.59	0.38	0.39	0.72	0.69
80%ile	0.64	0.61	0.34	0.38	0.46	0.39	0.38	0.44	0.24	0.26	0.47	0.55
70%ile	0.39	0.46	0.27	0.32	0.27	0.35	0.25	0.23	0.19	0.17	0.32	0.45
60%ile	0.31	0.33	0.19	0.18	0.23	0.28	0.18	0.15	0.15	0.12	0.19	0.32
50%ile	0.26	0.26	0.17	0.14	0.20	0.20	0.12	0.06	0.10	0.09	0.13	0.27
40%ile	0.23	0.21	0.11	0.11	0.16	0.16	0.08	0.04	0.06	0.06	0.10	0.22
30%ile	0.19	0.11	0.08	0.06	0.11	0.09	0.07	0.01	0.00	0.02	0.06	0.11
20%ile	0.13	0.06	0.04	0.01	0.07	0.02	0.02	0.00	0.00	0.00	0.03	0.06
10%ile	0.06	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
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 very little change for months of flow higher than 0.1 $m^3.s^{-1}$. The 99%ile indicates that there is a 6.8 % 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 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. There may be some increased erosion in the catchment.

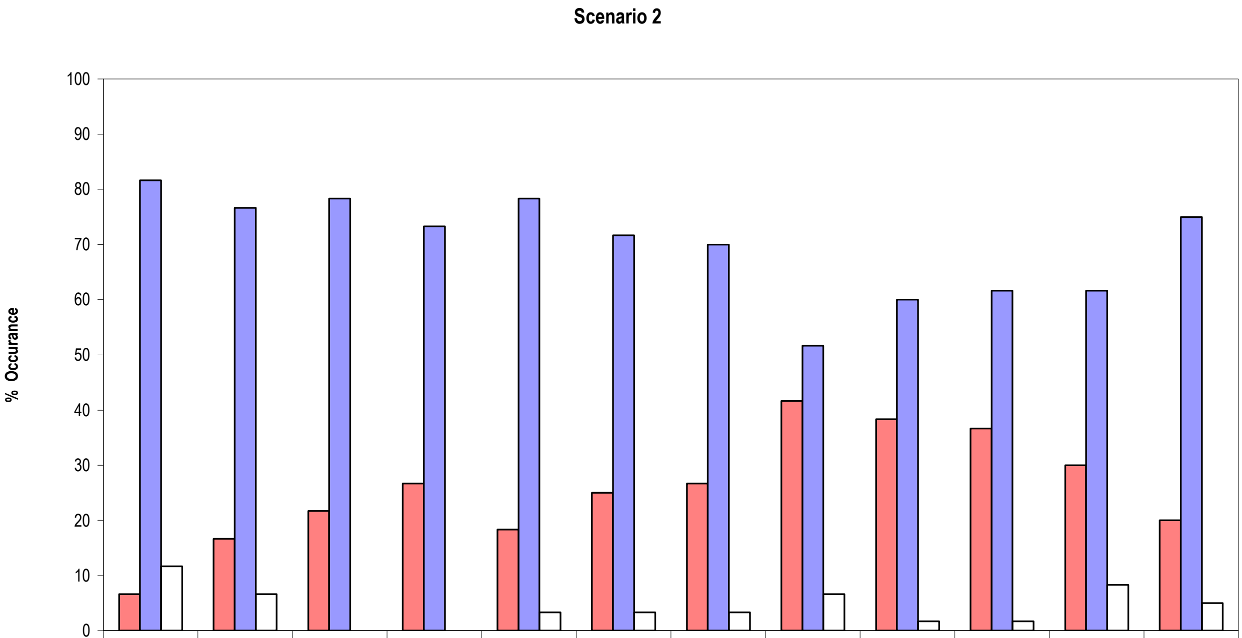
In the case of an in-channel development the impact would be much greater as the estuary is sediment staved from a marine perceptive and mostly fed by sediment for the catchment. An in-channel development (e.g. dam or off-take weir) would cut off this sediment supply and lead to deeping of the subtidal 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 Sout Estuary for the Future Scenario 2 (Reference Conditions – 0.1 $m^3.s^{-1}$)*

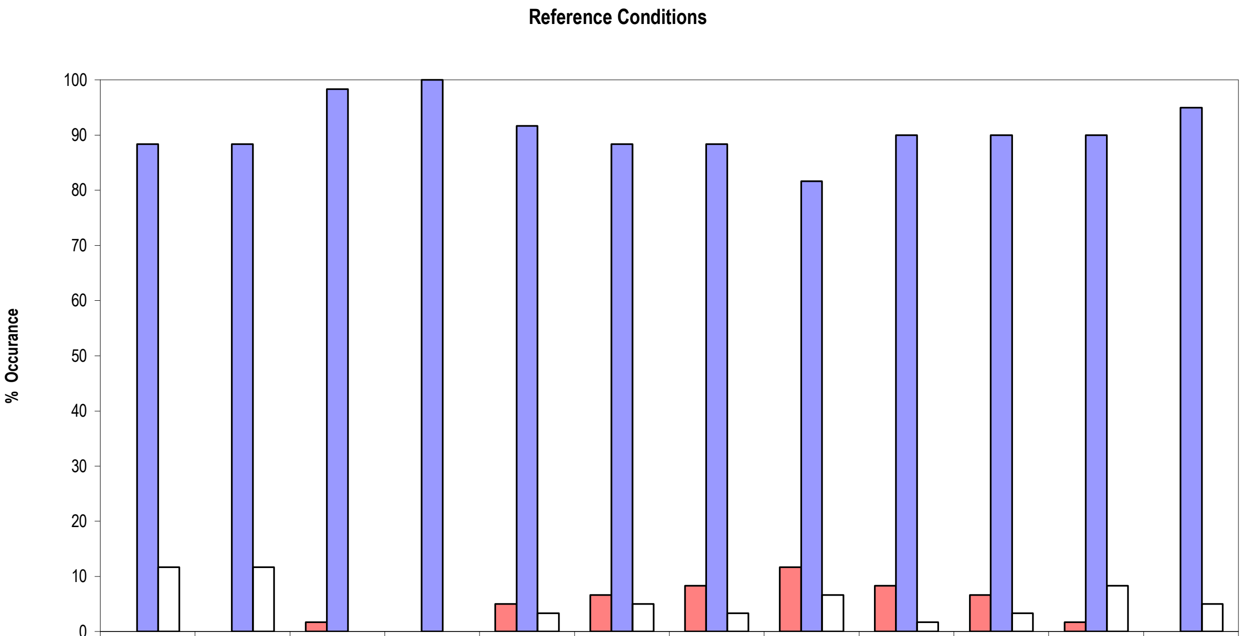
YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	1.51	0.59	0.03	0.00	0.07	0.11	0.13	2.19	1.01	0.16	0.28	0.55	0.55
1935	0.58	0.53	0.36	0.14	0.16	0.27	0.08	0.36	0.12	0.48	0.16	0.34	0.30
1936	0.44	0.69	0.47	0.12	0.17	0.37	0.07	0.00	0.00	0.17	0.05	0.44	0.25
1937	0.27	0.09	0.40	0.43	0.05	0.14	0.14	0.00	0.00	0.00	0.00	0.08	0.13
1938	0.15	0.49	0.39	0.03	1.25	0.92	0.20	0.00	0.00	0.24	0.68	0.65	0.42
1939	0.24	0.17	0.12	0.34	0.46	0.24	0.05	0.00	0.00	0.09	0.01	0.12	0.15
1940	0.06	0.03	0.00	0.14	0.01	0.03	0.64	0.18	0.10	0.07	0.00	0.08	0.11
1941	0.71	0.40	0.46	0.57	0.17	0.07	0.00	0.62	0.27	0.05	0.04	0.02	0.28
1942	0.21	0.12	0.17	0.58	0.20	0.12	0.04	0.00	0.00	0.00	0.14	0.80	0.20
1943	0.38	1.00	0.80	0.11	0.13	0.10	0.00	1.48	0.55	0.27	0.10	0.29	0.43
1944	0.25	0.08	0.00	0.00	0.00	0.00	0.00	0.47	0.43	0.13	0.03	0.00	0.12
1945	0.06	0.00	0.09	0.19	0.20	0.70	0.22	0.00	0.00	0.02	0.08	0.04	0.13
1946	0.21	0.07	0.01	0.31	0.21	0.46	0.24	0.22	0.15	0.39	0.12	0.25	0.22
1947	0.18	0.29	0.08	0.17	0.16	0.06	0.37	0.07	0.00	0.00	0.00	0.15	0.13
1948	0.28	0.28	0.14	0.34	0.25	0.00	0.04	0.06	0.00	0.00	0.00	0.08	0.12
1949	0.01	0.95	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.38	0.32	0.18
1950	0.41	1.22	0.67	0.83	0.35	0.00	0.00	0.06	0.16	0.60	0.70	0.67	0.47
1951	0.17	0.00	0.00	0.54	0.42	0.03	0.11	0.03	0.01	0.03	0.46	1.17	0.25
1952	0.41	0.23	0.10	0.05	0.13	0.00	0.00	0.00	0.37	0.28	0.67	0.57	0.23
1953	1.40	0.81	0.22	0.00	0.00	0.10	0.09	0.58	0.28	0.39	1.31	0.59	0.48
1954	0.05	0.33	0.08	0.34	1.47	0.42	0.08	0.00	0.00	0.00	0.00	0.00	0.23
1955	0.26	1.28	0.35	0.03	0.22	0.42	0.12	0.65	0.22	0.00	0.00	0.55	0.34
1956	1.05	0.53	0.17	0.11	0.23	0.39	0.11	0.00	0.20	0.05	0.30	0.45	0.30
1957	0.21	0.00	0.11	0.09	0.00	0.49	0.31	0.38	0.15	0.00	0.27	0.16	0.18
1958	0.19	0.03	0.19	0.57	0.20	0.32	0.68	0.44	0.08	0.17	0.52	0.23	0.30
1959	0.33	0.12	0.02	0.38	0.09	0.19	0.48	0.23	0.10	0.31	0.11	0.32	0.22
1960	0.09	0.23	0.48	0.47	0.39	0.67	0.23	0.23	0.06	0.02	0.10	0.05	0.25
1961	0.21	0.08	0.07	0.25	0.17	0.71	0.37	0.02	0.00	0.00	1.46	0.56	0.33
1962	1.25	0.77	0.09	0.18	0.11	1.12	0.53	0.09	0.00	0.35	0.14	0.01	0.39
1963	0.13	0.03	0.25	0.38	0.24	0.18	0.20	0.01	0.34	0.11	0.31	1.04	0.27
1964	0.33	0.30	0.08	0.00	0.00	0.34	0.41	0.22	0.16	0.11	0.01	0.00	0.16
1965	0.77	1.16	0.34	0.50	0.31	0.00	0.01	0.02	0.00	0.00	0.54	0.36	0.33
1966	0.04	0.06	0.17	0.15	0.24	0.57	1.41	1.11	0.31	0.16	0.07	0.45	0.39
1967	0.15	0.23	0.19	0.00	0.11	0.35	0.15	0.07	0.69	0.21	0.11	0.45	0.22
1968	0.38	0.48	0.11	0.12	0.23	0.30	0.10	0.00	0.21	0.10	0.03	0.01	0.17
1969	0.27	0.11	0.00	0.08	0.68	0.18	0.00	0.00	0.00	0.00	0.79	0.32	0.20
1970	0.34	0.09	0.71	0.28	0.66	0.38	0.53	0.59	0.19	0.96	1.29	0.42	0.54
1971	0.11	0.66	0.28	0.15	0.81	0.33	0.02	0.00	0.10	0.19	0.33	0.10	0.26
1972	0.00	0.00	0.01	0.06	0.11	0.24	0.22	0.05	0.04	0.00	0.03	0.22	0.08
1973	0.09	0.45	0.12	0.46	0.35	0.39	0.13	0.38	0.12	0.00	0.40	0.27	0.26
1974	0.05	0.26	0.05	0.37	0.52	0.31	0.07	0.00	0.02	0.10	0.12	0.79	0.22
1975	0.25	0.24	0.47	0.15	0.16	0.36	0.07	0.06	0.02	0.34	0.14	0.13	0.20
1976	1.30	0.76	0.19	0.00	0.79	0.81	0.17	0.59	0.23	0.00	0.14	0.23	0.43
1977	0.28	0.42	0.17	0.01	0.00	0.00	0.04	0.02	0.16	0.02	0.20	0.10	0.12
1978	0.23	0.31	0.44	0.35	0.10	0.00	0.50	0.28	0.07	0.43	1.04	0.51	0.36
1979	0.08	0.00	0.04	0.15	0.02	0.00	0.07	0.00	0.19	0.04	0.08	0.28	0.08
1980	0.33	0.15	0.31	0.86	0.47	1.42	0.73	1.76	0.70	0.07	1.26	0.49	0.71
1981	0.78	0.38	0.17	0.03	0.08	0.23	1.50	0.44	0.00	0.18	0.06	0.33	0.35
1982	0.23	0.02	0.04	0.00	0.25	0.06	0.00	0.05	0.42	1.05	0.39	0.26	0.23
1983	0.30	0.26	0.22	0.06	0.10	0.19	0.01	0.00	0.00	0.00	0.00	0.02	0.10
1984	0.00	0.07	0.07	0.31	0.49	0.17	0.28	0.06	0.05	0.16	0.03	0.00	0.14
1985	0.85	0.56	0.27	0.57	0.13	0.00	0.00	0.00	0.00	0.00	0.46	0.26	0.26
1986	0.80	0.33	0.04	0.00	0.26	0.15	0.58	0.15	0.08	0.00	0.13	0.83	0.28
1987	0.26	0.00	0.02	0.00	0.00	0.03	0.44	0.47	0.23	0.06	0.18	0.12	0.15
1988	0.18	0.05	0.08	0.00	0.00	0.00	0.31	0.06	0.00	0.07	0.00	0.01	0.06
1989	1.05	1.39	0.32	0.00	0.62	0.16	0.32	0.22	0.41	0.11	0.08	0.06	0.39
1990	0.30	0.32	0.05	0.08	0.50	0.21	0.00	0.01	0.00	0.00	0.03	0.01	0.13
1991	0.50	0.15	0.31	0.10	0.51	0.34	0.08	0.16	0.09	0.26	0.66	0.24	0.28
1992	1.32	0.97	0.15	0.09	0.02	0.00	0.09	0.03	0.19	0.07	0.05	1.92	0.41
1993	0.62	0.24	0.32	0.22	0.21	0.23	0.16	0.11	0.08	0.09	0.21	0.30	0.23

1: Freshwater	>1.0	2: Gradient	0.05 -1.0	3: Marine	< 0.05



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Series1	6.7	16.7	21.7	26.7	18.3	25.0	26.7	41.7	38.3	36.7	30.0	20.0
Series2	81.7	76.7	78.3	73.3	78.3	71.7	70.0	51.7	60.0	61.7	61.7	75.0
Series3	11.7	6.7	0.0	0.0	3.3	3.3	3.3	6.7	1.7	1.7	8.3	5.0

Figure 7. *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	1.7	0.0	5.0	6.7	8.3	11.7	8.3	6.7	1.7	0.0
State 2	88.3	88.3	98.3	100.0	91.7	88.3	88.3	81.7	90.0	90.0	90.0	95.0
State 1	11.7	11.7	0.0	0.0	3.3	5.0	3.3	6.7	1.7	3.3	8.3	5.0

Figure 8. *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	80	For the Sout Estuary low flows are defined as flows less than 0.05 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 0.05 $m^3.s^{-1}$ occurred under the Reference Conditions for 4.2% of the time. Under the Present State low flows occur for 25.7 % of the time.	Low
b. % similarity in mean annual frequency of floods	90	The reduction in high flows is deemed to be very little based on the reduction in monthly flows. The 99%ile indicates that there is a 6.8% decrease in the floods to the estuary.	Medium
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	100	N/A	Medium
Hydrodynamics and mouth conditions score	**100**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	70	There is a 20% increase in State 3: Marine dominated and a 6.8% reduction in State 1: Predominately fresh.	Medium
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	70	The 16.3% reduction in MAR will cause a shift to a more marine dominated state (20% increase in state 3), resulting in a decrease in the average concentration of nutrients in the estuary.	Medium
2b. Suspended solids (turbidity) in the estuary	70	The 16.3% reduction in MAR will cause a shift to a more marine dominated state (20% increase in state 3), resulting in a decrease in the average concentration of suspended solids in the estuary.	Medium
2c. Dissolved oxygen in the estuary	95	The mouth is permanently open and there is strong tidal flushing. Allow slight change in average DO due to reduction in floods.	Medium
2d. Levels of toxins			
Water Quality score	**70**		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of <u>intertidal sediment</u> 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. (In the case of an in-channel development the impact would be much greater and a score of 80 would be allocated)	Low
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. (In the case of an in-channel development the impact would be much greater and a score of 80 would be allocated)	Low
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. (In the case of an in-channel development the impact would be much greater and a score of 80 would be allocated)	Low

Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
	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	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
Physical habitat score		**90**		

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
Average phytoplankton biomass in the Sout estuary is low (~0.5 µg.l^{-1}). A decrease in river flow will reduce the concentrations of nutrients and suspended solids entering the estuary, which could result in a decrease in microalgal biomass. However, lower river flows and the reduced frequency of flood events will provide a more stable environment for microalgae, particularly in the middle reaches during periods of a longitudinal salinity gradient (state 2). An increase in state 2 will increase species biomass, richness and abundance (more cyanobacteria, dinoflagellates and chlorophytes) but longer periods of low/no flow (state 3) will result in the estuary becoming marine dominated with a low microalgal biomass, richness and abundance (diatoms and flagellates will dominate). Benthic microalgae are not as dependent on the water column chemistry as the phytoplankton. *Confidence: Medium*
MACROPHYTES
Low flows now occur for 25.7% of the time compared to 4.2%. This results in a 20% increase in the marine dominated phase and an increase in salinity which may result in the loss of some species and a reduction in biomass of the predominantly brackish macrophytes. These changes may result in a small loss of brackish communities at the expense of more saline communities. The 10% change in the intertidal area due to changes in floods and land use are not expected to influence the macrophytes, although increased sediment stability due to a lack of floods could increase the area covered by *Zostera capensis.* Confidence: Medium
INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)
The increase in marine dominance (25.7% of the time compared to 4.2% of the time) will lead to a moderate change in the invertebrate community. Biomass will also decrease slightly, mainly due to a decrease in the euryhaline copepods (e.g. *Pseudodiaptomus hessei* that favours relatively low salinity water). The 10% reduction in intertidal area will also lead to a loss on benthic invertebrates such as the mudprawn *Upogebia africana*. The extension of marine dominance upstream will also result in a moderate loss in biomass of those species that favour relatively low salinity water (e.g. *Grandidierella lignorum*). Confidence: Medium
FISH
The increased marine conditions will be favourable for many of the estuary-associated marine species. This will translate into an increase in biomass since most of the potential fish species colonising the estuary are derived from the marine environment. The decrease in flood events will probably cause an overall increase in fish stocks because river flooding tends to result in many species having to leave the estuary during a flood event. Over-exploitation of selected angling species has been included in this assessment. Confidence: Medium
BIRDS
The reduction in intertidal area will lead to a lower biomass of species such as the mudprawn *Upogebia africana,* hence leading to a decrease in biomass of food resources for birds feeding in the intertidal. Overall, time spent on the estuary will be less as birds will move to other feeding areas. Human disturbance will influence bird presence on the estuary, particularly larger species. Piscivirous birds will spend less time at the estuary because of a reduction in fish stocks. Confidence: Medium

6.3.4 EHI for the Future Scenario 1 - Biotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	80 (90%)	Reduction in flow has led to a decrease in freshwater species entering the estuary.	Low
2a. Abundance	90	Microalgal biomass in the estuary is generally low due to tidal flushing. However, a slight decrease in flow could decrease the amount of nutrients entering the estuary.	Medium
2b. Community composition	70	Slight reduction in flow has led to a decrease in freshwater species entering the estuary. Slight increase in state 3 favours the dominance by flagellates and diatoms.	Medium
Benthic microalgae			
1. Species richness	80 (90%)	Slight change as a result of change in intertidal area and sedimentation. Longer periods of low/no flow (state 3) supports more marine species, which is usually lower in species richness.	Low
2a. Abundance	75	Slight change as a result of change in intertidal area and sedimentation. Longer periods of state 3: water-column is more marine dominated with lower nutrient concentrations and lower deposition of flocculated material.	Low
2b. Community composition	75	Slight change as a result of change in intertidal area and sedimentation. Longer periods of low/no flow (state 3) supports more marine species.	Low
Microalgae score	**70**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	95 (97.5%)	The 20% increase in the marine dominated phase and resultant increase in salinity may result in the loss of some brackish species.	Low
2a. Abundance	90	The increase in salinity would reduce the biomass and cover of the dominant macrophytes.	Medium
2b. Community composition	95	The increase in salinity may result in a small loss of brackish communities at the expense of more saline communities.	Medium
Macrophytes score	**90**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	80 (90%)	Species that favour low salinity conditions are likely to be lost from the estuary.	Medium
2a. Abundance	80	Higher salinity values will lead to a change in biomass of common euryhaline copepods such as *Pseudodiaptomus hessei*.	Medium
2b. Community composition	85	The mix of species will change because of changes in salinity distribution along the estuary.	Medium
Macroinvertebrates			
1. Species richness	80 (90%)	Species that favour low salinity conditions are likely to be lost from the estuary.	Medium
2a. Abundance	80	Higher salinity values will lead to a change in biomass of species that favour low salinity conditions (*Grandidierella lignorum*). Because of the loss in intertidal area (habitat loss), abundance of species such as *Upogebia africana* will decrease.	Medium
2b. Community composition	85	The mix of species will change because of changes in salinity distribution along the estuary.	Medium
Macrocrustacea			
1. Species richness	80	As above	Medium
2a. Abundance	80	As above	Medium
2b. Community composition	85	As above	Medium
Invertebrates score	**80**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	Species richness is unlikely to change under this scenario.	Medium
2a. Abundance	80	The increase in marine conditions is likely to result in an increase in average marine fish abundance.	Low
2b. Community composition	80	An increase in marine fish abundance is also likely to result in a change in fish community composition.	Medium
Fish score	**80**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	95 (97.5%)	Species richness might decrease slightly because of the change in benthic community composition and biomass.	Medium
2a. Abundance	80	Abundance levels will also decrease slightly because of a loss in food biomass. Human disturbance would also lead to a reduction in abundance levels, especially larger birds.	Medium
2b. Community composition	80	Community composition will change slightly, but because bird abundance levels are not high generally, the overall impact is not too severe. Some species will spend more time at other feeding sites away from the estuary.	Medium
Bird score	**80**		

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
99%ile	1.32	1.22	0.65	0.74	1.24	1.14	1.34	1.84	0.73	0.90	1.27	1.37
90%ile	0.76	0.85	0.37	0.45	0.53	0.58	0.44	0.49	0.28	0.29	0.62	0.59
80%ile	0.52	0.51	0.24	0.28	0.36	0.29	0.28	0.34	0.14	0.16	0.37	0.45
70%ile	0.28	0.36	0.17	0.22	0.17	0.25	0.15	0.13	0.09	0.07	0.22	0.34
60%ile	0.21	0.23	0.09	0.08	0.13	0.18	0.08	0.05	0.05	0.02	0.09	0.22
50%ile	0.16	0.16	0.07	0.04	0.10	0.10	0.02	0.00	0.00	0.00	0.03	0.16
40%ile	0.13	0.11	0.01	0.01	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.12
30%ile	0.09	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
20%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
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 comparable to the reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than 0.1 $m^3.s^{-1}$. The 99%ile indicates that there is a 14.5 % decrease in the floods to the estuary.

Confidence: Medium

Present sediment processes

The hydrological data indicates that the magnitude and occurrence of major floods have been reduced by 14.5%. This means that the flushing of sediments during such floods has only been reduced in a small manner. It is therefore likely that the sedimentation in the estuary is not much different from what it was under natural conditions. There may be some increased erosion in the catchment.

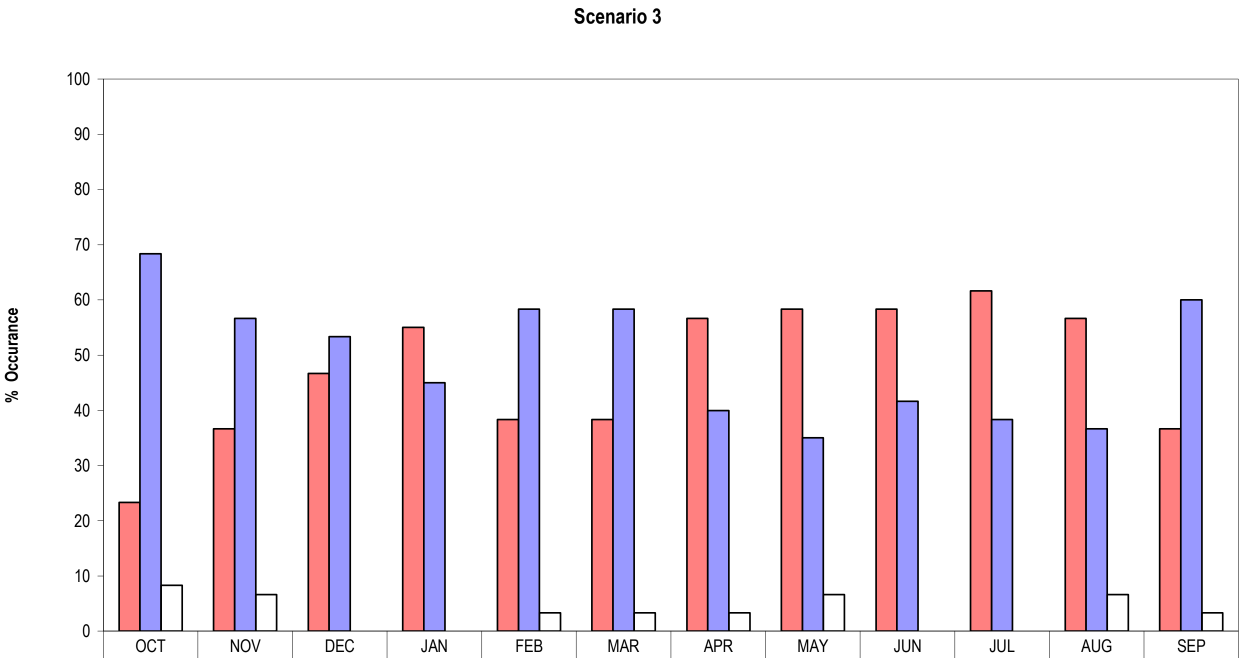
In the case of an in-channel development the impact would be much greater as the estuary is sediment staved from a marine perceptive and mostly fed by sediment for the catchment. An in-channel development (e.g. dam or off-take weir) would cut off this sediment supply and lead to deeping of the subtidal 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 18.** Simulated monthly flows ($m^3.s^{-1}$) to the Sout Estuary for the Future Scenario 3 (Reference Conditions – 0.2 $m^3.s^{-1}$)*

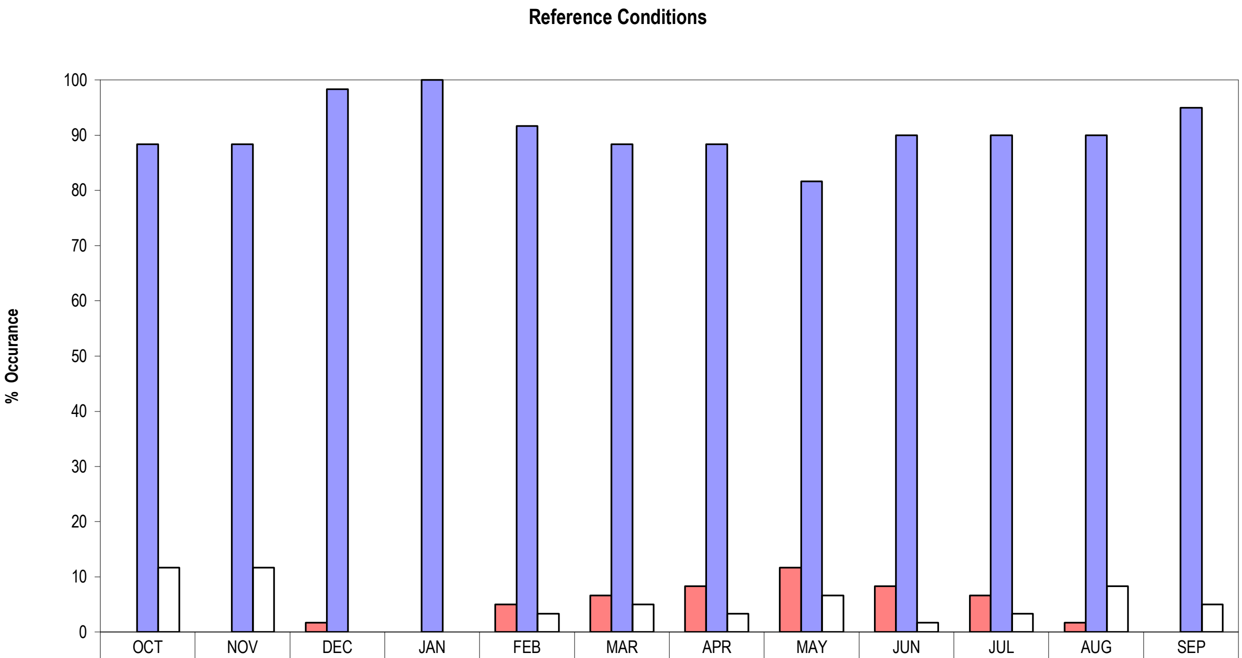
YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	1.41	0.49	0.00	0.00	0.00	0.01	0.03	2.09	0.91	0.06	0.18	0.45	0.47
1935	0.47	0.43	0.26	0.04	0.05	0.17	0.00	0.26	0.02	0.38	0.06	0.23	0.20
1936	0.33	0.59	0.37	0.02	0.07	0.27	0.00	0.00	0.00	0.07	0.00	0.34	0.17
1937	0.16	0.00	0.30	0.33	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.07
1938	0.05	0.39	0.29	0.00	1.15	0.82	0.10	0.00	0.00	0.14	0.58	0.55	0.34
1939	0.14	0.07	0.02	0.24	0.36	0.14	0.00	0.00	0.00	0.00	0.00	0.02	0.08
1940	0.00	0.00	0.00	0.04	0.00	0.00	0.54	0.08	0.00	0.00	0.00	0.00	0.05
1941	0.59	0.30	0.36	0.47	0.07	0.00	0.00	0.52	0.17	0.00	0.00	0.00	0.21
1942	0.10	0.02	0.07	0.48	0.10	0.02	0.00	0.00	0.00	0.00	0.04	0.70	0.13
1943	0.27	0.90	0.70	0.01	0.03	0.00	0.00	1.38	0.45	0.17	0.00	0.19	0.34
1944	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.33	0.03	0.00	0.00	0.07
1945	0.00	0.00	0.00	0.09	0.10	0.60	0.12	0.00	0.00	0.00	0.00	0.00	0.08
1946	0.11	0.00	0.00	0.21	0.11	0.36	0.14	0.12	0.05	0.29	0.02	0.14	0.13
1947	0.08	0.19	0.00	0.07	0.06	0.00	0.27	0.00	0.00	0.00	0.00	0.05	0.06
1948	0.17	0.18	0.04	0.24	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
1949	0.00	0.85	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.28	0.21	0.13
1950	0.30	1.12	0.57	0.73	0.25	0.00	0.00	0.00	0.06	0.50	0.60	0.57	0.39
1951	0.07	0.00	0.00	0.44	0.32	0.00	0.01	0.00	0.00	0.00	0.36	1.07	0.19
1952	0.30	0.13	0.00	0.00	0.03	0.00	0.00	0.00	0.27	0.18	0.57	0.47	0.16
1953	1.26	0.71	0.12	0.00	0.00	0.00	0.00	0.48	0.18	0.29	1.21	0.48	0.39
1954	0.00	0.23	0.00	0.24	1.37	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.18
1955	0.15	1.18	0.25	0.00	0.12	0.32	0.02	0.55	0.12	0.00	0.00	0.45	0.26
1956	0.92	0.43	0.07	0.01	0.13	0.29	0.01	0.00	0.10	0.00	0.20	0.35	0.21
1957	0.10	0.00	0.01	0.00	0.00	0.39	0.21	0.28	0.05	0.00	0.17	0.06	0.11
1958	0.09	0.00	0.09	0.47	0.10	0.22	0.58	0.34	0.00	0.07	0.42	0.13	0.21
1959	0.23	0.02	0.00	0.28	0.00	0.09	0.38	0.13	0.00	0.21	0.01	0.21	0.13
1960	0.00	0.13	0.38	0.37	0.29	0.57	0.13	0.13	0.00	0.00	0.00	0.00	0.17
1961	0.11	0.00	0.00	0.15	0.07	0.61	0.27	0.00	0.00	0.00	1.36	0.46	0.25
1962	1.11	0.67	0.00	0.08	0.01	1.02	0.43	0.00	0.00	0.25	0.04	0.00	0.30
1963	0.03	0.00	0.15	0.28	0.14	0.08	0.10	0.00	0.24	0.01	0.21	0.93	0.18
1964	0.22	0.20	0.00	0.00	0.00	0.24	0.31	0.12	0.06	0.01	0.00	0.00	0.10
1965	0.65	1.06	0.24	0.40	0.21	0.00	0.00	0.00	0.00	0.00	0.44	0.26	0.27
1966	0.00	0.00	0.07	0.05	0.14	0.47	1.31	1.01	0.21	0.06	0.00	0.35	0.30
1967	0.05	0.13	0.09	0.00	0.01	0.25	0.05	0.00	0.59	0.11	0.01	0.35	0.14
1968	0.27	0.38	0.01	0.02	0.12	0.20	0.00	0.00	0.11	0.00	0.00	0.00	0.09
1969	0.16	0.01	0.00	0.00	0.58	0.08	0.00	0.00	0.00	0.00	0.69	0.22	0.15
1970	0.24	0.00	0.61	0.18	0.55	0.28	0.43	0.49	0.09	0.86	1.19	0.32	0.44
1971	0.01	0.56	0.18	0.05	0.71	0.23	0.00	0.00	0.00	0.09	0.23	0.00	0.17
1972	0.00	0.00	0.00	0.00	0.01	0.14	0.12	0.00	0.00	0.00	0.00	0.11	0.03
1973	0.00	0.35	0.02	0.36	0.24	0.29	0.03	0.28	0.02	0.00	0.30	0.17	0.17
1974	0.00	0.16	0.00	0.27	0.42	0.21	0.00	0.00	0.00	0.00	0.02	0.69	0.15
1975	0.15	0.14	0.37	0.05	0.05	0.26	0.00	0.00	0.00	0.24	0.04	0.02	0.11
1976	1.16	0.66	0.09	0.00	0.69	0.71	0.07	0.49	0.13	0.00	0.04	0.12	0.35
1977	0.17	0.32	0.07	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.10	0.00	0.06
1978	0.13	0.21	0.34	0.25	0.00	0.00	0.40	0.18	0.00	0.33	0.94	0.41	0.27
1979	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.18	0.03
1980	0.23	0.05	0.21	0.76	0.37	1.32	0.63	1.66	0.60	0.00	1.16	0.39	0.61
1981	0.66	0.28	0.07	0.00	0.00	0.13	1.40	0.34	0.00	0.08	0.00	0.22	0.26
1982	0.12	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.32	0.95	0.29	0.16	0.17
1983	0.20	0.16	0.12	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.05
1984	0.00	0.00	0.00	0.21	0.39	0.07	0.18	0.00	0.00	0.06	0.00	0.00	0.08
1985	0.72	0.46	0.17	0.47	0.03	0.00	0.00	0.00	0.00	0.00	0.36	0.15	0.20
1986	0.67	0.23	0.00	0.00	0.16	0.05	0.48	0.05	0.00	0.00	0.03	0.73	0.20
1987	0.15	0.00	0.00	0.00	0.00	0.00	0.34	0.37	0.13	0.00	0.08	0.01	0.09
1988	0.08	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.02
1989	0.92	1.29	0.22	0.00	0.52	0.06	0.22	0.12	0.31	0.01	0.00	0.00	0.31
1990	0.19	0.22	0.00	0.00	0.40	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.08
1991	0.39	0.05	0.21	0.00	0.41	0.24	0.00	0.06	0.00	0.16	0.56	0.14	0.18
1992	1.18	0.87	0.05	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	1.81	0.33
1993	0.51	0.14	0.22	0.12	0.11	0.13	0.06	0.01	0.00	0.00	0.11	0.19	0.13

1: Freshwater	>1.0	2: Gradient	0.05 -1.0	3: Marine	< 0.05



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Series1	23.3	36.7	46.7	55.0	38.3	38.3	56.7	58.3	58.3	61.7	56.7	36.7
Series2	68.3	56.7	53.3	45.0	58.3	58.3	40.0	35.0	41.7	38.3	36.7	60.0
Series3	8.3	6.7	0.0	0.0	3.3	3.3	3.3	6.7	0.0	0.0	6.7	3.3

Figure 9. *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	1.7	0.0	5.0	6.7	8.3	11.7	8.3	6.7	1.7	0.0
State 2	88.3	88.3	98.3	100.0	91.7	88.3	88.3	81.7	90.0	90.0	90.0	95.0
State 1	11.7	11.7	0.0	0.0	3.3	5.0	3.3	6.7	1.7	3.3	8.3	5.0

Figure 10. *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	55	For the Sout Estuary low flows are defined as flows less than 0.05 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 0.05 m^3/s occurred under the Reference Conditions for 4.2% of the time. Under the Present State low flows occur for 47.2 % of the time.	Low
b. % similarity in mean annual frequency of floods	85	Based 99%ile there is a 14.5 % decrease in the floods to the estuary.	Medium
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	100	N/A	Medium
Hydrodynamics and mouth conditions score	**100**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	45	There is a 43% increase in State 3: Marine dominated and a 14.5 % reduction in State 1: Predominately fresh.	Medium
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	45	The 47.3% reduction in MAR will cause a shift to a more marine dominated state (43% increase in state 3), resulting in a decrease in the average concentration of nutrients in the estuary.	Medium
2b. Suspended solids (turbidity) in the estuary	45	The 47.3% reduction in MAR will cause a shift to a more marine dominated state (43% increase in state 3), resulting in a decrease in the average concentration of suspended solids in the estuary.	Medium
2c. Dissolved oxygen in the estuary	90	The mouth is permanently open and there is strong tidal flushing. Allow slight change in average DO due to reduction in floods.	Medium
2d. Levels of toxins			
Water Quality score	**45**		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	85	Allow 15% 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 50 would be allocated)	Low
1b	% similarity in sand fraction relative to total sand and mud	85	Allow 15% 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 50 would be allocated)	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	85	Allow 15% 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 50 would be allocated)	Low

Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
	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	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
Physical habitat score		**85**		

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

Average phytoplankton biomass in the Sout estuary is low (~0.5 µg.l^{-1}). A decrease in river flow will reduce the concentrations of nutrients and suspended solids entering the estuary, which could result in a decrease in microalgal biomass. However, lower river flows and the reduced frequency of flood events will provide a more stable environment for microalgae, particularly in the middle reaches during periods of a longitudinal salinity gradient (state 2). An increase in state 2 will increase species biomass, richness and abundance (more cyanobacteria, dinoflagellates and chlorophytes) but longer periods of low/no flow (state 3) will result in the estuary becoming marine dominated with a low microalgal biomass, richness and abundance (diatoms and flagellates will dominate). Benthic microalgae are not as dependent on the water column chemistry as the phytoplankton.

Confidence: Medium

MACROPHYTES

Low flows now occur for 47.2% of the time compared to 4.2%. This results in a 43% increase in the marine dominated phase and an increase in salinity which may result in the loss of some species and a reduction in biomass of the predominantly brackish macrophytes. The higher salinity may result in a reduction of brackish communities at the expense of more saline communities. The 15% change in the intertidal area due to changes in floods and land use will reduce the area covered by intertidal macrophytes e.g. *Cotula coronopifolia*. Lateral flow and rainfall will become more important in lowering the salinity of the soil and water column.

Confidence: Medium

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

The increase in marine dominance (47.2% of the time compared to 4.2% of the time under natural conditions) will lead to a marked change in the invertebrate community. Variability over time (response to shifts in abiotic states) will decrease, remaining mostly in response to marine dominance. Biomass will also decrease, mainly due to a decrease in the euryhaline copepods (e.g. *Pseudodiaptomus hessei* that favours relatively low salinity water). The 15% reduction in intertidal area will also lead to a reduction in benthic invertebrates such as the mudprawn *Upogebia africana*. The extension of marine dominance upstream will also result in a reduction in both species and biomass of those species that favour relatively low salinity water.

Confidence: Medium

FISH

The increased marine conditions will be favourable for many of the estuary-associated marine species. This will translate into an increase in biomass since most of the potential fish species colonising the estuary are derived from the sea. The decrease in flood events will cause an overall increase in fish stocks because river flooding tends to result in many species having to leave the estuary during such an event. Over-exploitation of selected marine fish species is included in this analysis.

Confidence: Medium

BIRDS

The reduction in intertidal area will lead to a lower biomass of species such as the mudprawn *Upogebia africana,* hence leading to a decrease in biomass of food resources for birds feeding in the intertidal. Overall, time spent on the estuary will be less as birds will move to other feeding areas. Human disturbance will impact on time spent by larger bird species on the estuary (heron's, egrets, etc.).

Confidence: Medium

6.4.4 EHI for the Future Scenario 3 - Abiotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	70 (85%)	Reduction in flow has led to a decrease in freshwater species entering the estuary.	Low
2a. Abundance	85	Microalgal biomass in the estuary is generally low due to tidal flushing. However, a decrease in flow will reduce the nutrient load into the estuary.	Low
2b. Community composition	45	Reduction in flow has led to a decrease in freshwater species entering the estuary. Increase in state 3 favours the dominance by flagellates and diatoms.	Medium
Benthic microalgae			
1. Species richness	70 (85%)	Slight change as a result of change in intertidal area and sedimentation. Longer periods of low/no flow (state 3) supports more marine species, which is usually lower in species richness.	Low
2a. Abundance	50	Slight change as a result of change in intertidal area and sedimentation. Longer periods of state 3: water-column is more marine-dominated with lower nutrient concentrations and lower deposition of flocculated material.	Low
2b. Community composition	50	Slight change as a result of change in intertidal area and sedimentation. Longer periods of low/no flow (state 3) support more marine species.	Low
Microalgae score	**45**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	90 (95%)	The 43% increase in the marine dominated phase and resultant increase in salinity may result in the loss of brackish species.	Medium
2a. Abundance	70	The increase in salinity would reduce the biomass and cover of the dominant macrophytes. The 15% change in the intertidal area due to changes in floods and land use will reduce the area covered by intertidal macrophytes e.g. *Cotula coronopifolia*.	Medium
2b. Community composition	80	The increase in salinity may result in a loss of brackish communities at the expense of more saline communities.	Medium
Macrophytes score	**70**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	70 (85%)	Species that favour low salinity conditions are likely to be lost from the estuary and in some case may not recover.	Medium
2a. Abundance	70	Higher salinity values will lead to a change in biomass of common euryhaline copepods such as *Pseudodiaptomus hessei*.	Medium
2b. Community composition	65	The mix of species will change because of changes in salinity distribution along the estuary.	Medium
Macroinvertebrates			
1. Species richness	70 (85%)	Species that favour low salinity conditions are likely to be lost from the estuary.	Medium
2a. Abundance	60	Higher salinity values will lead to a change in biomass of species that favour low salinity conditions (*Grandidierella lignorum*). Because of the loss in intertidal area (habitat loss), abundance of species such as *Upogebia africana* will also decrease.	Medium
2b. Community composition	65	The mix of species will change because of changes in salinity distribution along the estuary.	Medium

Macrocrustacea			
1. Species richness	70 (85%)	As above	Medium
2a. Abundance	60	As above	Medium
2b. Community composition	65	As above	Medium
Invertebrates score	**60**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	100	Species richness is unlikely to change under this scenario.	Medium
2a. Abundance	70	The increase in marine conditions is likely to result in an increase in average marine fish abundance.	Low
2b. Community composition	70	Any increase in marine fish abundance is also likely to result in a change in fish community composition.	Medium
Fish score	**70**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	95 (97.5%)	Species richness might decrease slightly because of the change in benthic community composition and biomass. Some species may leave the estuary because of human disturbance.	Low
2a. Abundance	80	Abundance levels will also decrease slightly because of a loss in food biomass.	Medium
2b. Community composition	80	Community composition will change, but because bird abundance levels are not high generally, the overall impact is not too severe. Some species will spend most time at other feeding sites away from the estuary.	Medium
Bird score	**80**		

6.5 Future Scenario 4: River Scenario A/B

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
99%ile	0.80	0.18	0.15	0.14	0.16	0.40	0.14	0.13	0.11	0.10	0.13	0.70
90%ile	0.74	0.18	0.15	0.14	0.16	0.40	0.14	0.13	0.11	0.10	0.13	0.67
80%ile	0.62	0.18	0.15	0.14	0.16	0.40	0.14	0.13	0.11	0.10	0.13	0.59
70%ile	0.49	0.18	0.15	0.14	0.16	0.39	0.14	0.12	0.11	0.10	0.12	0.50
60%ile	0.36	0.17	0.14	0.13	0.15	0.36	0.13	0.12	0.11	0.09	0.12	0.41
50%ile	0.24	0.15	0.12	0.11	0.13	0.30	0.12	0.11	0.10	0.09	0.11	0.29
40%ile	0.19	0.13	0.10	0.09	0.10	0.25	0.10	0.09	0.09	0.08	0.10	0.24
30%ile	0.13	0.10	0.07	0.07	0.07	0.17	0.08	0.07	0.07	0.07	0.08	0.18
20%ile	0.09	0.07	0.05	0.04	0.05	0.11	0.05	0.04	0.05	0.05	0.06	0.12
10%ile	0.07	0.04	0.03	0.03	0.03	0.07	0.04	0.02	0.03	0.03	0.04	0.08
1%ile	0.06	0.03	0.03	0.03	0.03	0.04	0.03	0.01	0.02	0.02	0.03	0.06

Present flood regime

The flood regime is judged to be highly modified from that of the reference conditions as the 99%ile indicates that there is an 80.5 % decrease in the floods to the estuary.

Confidence: Medium

Present sediment processes

The hydrological data indicates that the magnitude and occurrence of major floods have been reduced by 80.5%. 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, loss of intertidal areas and loss of sediment in the cove at the mouth) (A Theron, CSIR, pers. com.).

In the case of an in-channel development the impact would be very serious as the estuary is sediment starved from a marine perspective and mostly fed by sediment for the catchment. An in-channel development (e.g. dam or off-take weir) would cut off all the sediment supply and in the long term could lead to the scouring of the system to bed rock in some areas.

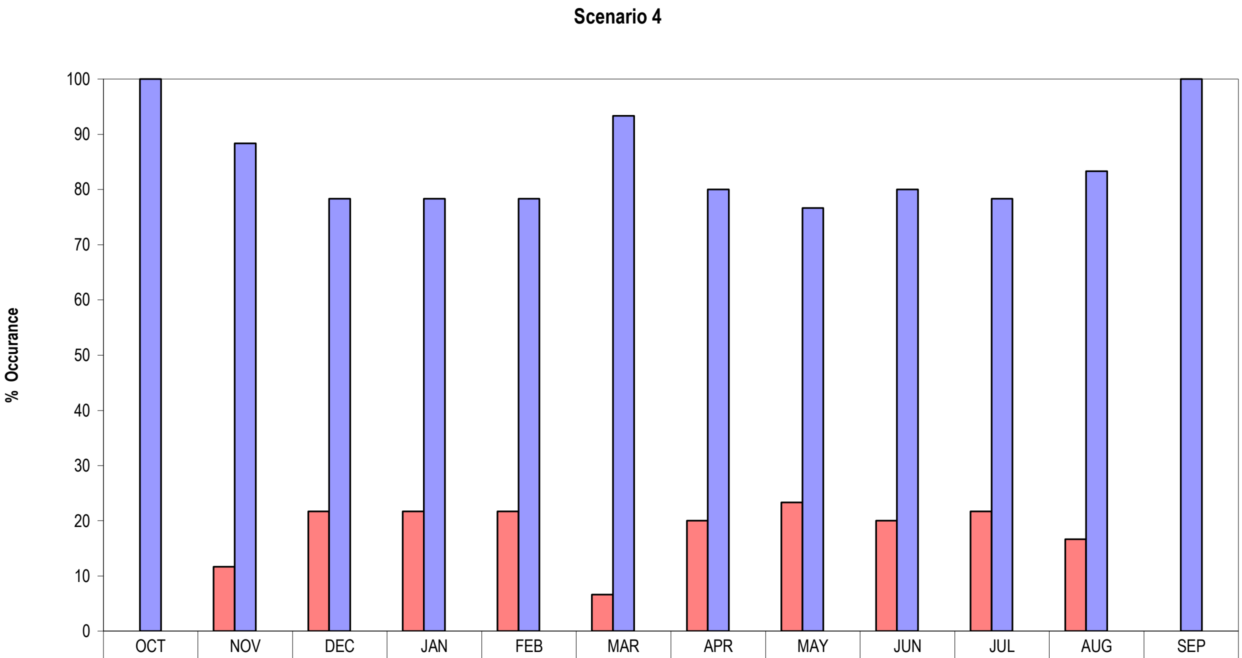
Confidence: Low

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

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ave
1934	0.80	0.18	0.04	0.03	0.05	0.20	0.12	0.13	0.11	0.10	0.12	0.59	0.21
1935	0.60	0.18	0.15	0.11	0.10	0.35	0.10	0.12	0.10	0.10	0.12	0.42	0.21
1936	0.53	0.18	0.15	0.10	0.11	0.40	0.08	0.02	0.04	0.10	0.08	0.50	0.19
1937	0.25	0.09	0.15	0.14	0.05	0.23	0.12	0.04	0.03	0.02	0.04	0.14	0.11
1938	0.10	0.18	0.15	0.05	0.16	0.40	0.13	0.03	0.02	0.10	0.13	0.66	0.18
1939	0.21	0.12	0.10	0.14	0.16	0.34	0.07	0.04	0.04	0.09	0.05	0.18	0.13
1940	0.07	0.05	0.03	0.11	0.04	0.12	0.14	0.12	0.10	0.08	0.04	0.15	0.09
1941	0.64	0.17	0.15	0.14	0.11	0.16	0.04	0.13	0.11	0.08	0.07	0.10	0.16
1942	0.15	0.10	0.12	0.14	0.13	0.22	0.07	0.02	0.06	0.06	0.12	0.70	0.16
1943	0.48	0.18	0.15	0.09	0.09	0.18	0.04	0.13	0.11	0.10	0.10	0.35	0.17
1944	0.23	0.08	0.03	0.03	0.03	0.05	0.03	0.13	0.11	0.10	0.06	0.06	0.08
1945	0.07	0.04	0.09	0.13	0.13	0.40	0.13	0.02	0.02	0.07	0.10	0.11	0.11
1946	0.16	0.07	0.03	0.14	0.13	0.40	0.14	0.12	0.10	0.10	0.11	0.27	0.15
1947	0.12	0.16	0.07	0.12	0.11	0.14	0.14	0.11	0.02	0.03	0.03	0.21	0.10
1948	0.27	0.16	0.11	0.14	0.15	0.07	0.07	0.10	0.05	0.02	0.03	0.14	0.11
1949	0.06	0.18	0.15	0.03	0.03	0.04	0.03	0.06	0.04	0.10	0.13	0.40	0.10
1950	0.51	0.18	0.15	0.14	0.16	0.10	0.03	0.10	0.11	0.10	0.13	0.67	0.20
1951	0.11	0.03	0.03	0.14	0.16	0.11	0.11	0.08	0.08	0.07	0.13	0.70	0.15
1952	0.51	0.13	0.09	0.06	0.09	0.08	0.04	0.02	0.11	0.10	0.13	0.62	0.16
1953	0.80	0.18	0.14	0.03	0.02	0.19	0.10	0.13	0.11	0.10	0.13	0.64	0.21
1954	0.07	0.17	0.07	0.14	0.16	0.40	0.09	0.05	0.06	0.05	0.03	0.06	0.11
1955	0.23	0.18	0.15	0.05	0.14	0.40	0.11	0.13	0.11	0.04	0.03	0.59	0.18
1956	0.79	0.18	0.12	0.09	0.15	0.40	0.11	0.04	0.11	0.08	0.12	0.51	0.23
1957	0.15	0.04	0.09	0.08	0.03	0.40	0.14	0.13	0.11	0.05	0.12	0.22	0.13
1958	0.13	0.06	0.13	0.14	0.13	0.38	0.14	0.13	0.09	0.10	0.13	0.25	0.15
1959	0.42	0.10	0.03	0.14	0.06	0.29	0.14	0.12	0.10	0.10	0.11	0.40	0.17
1960	0.08	0.13	0.15	0.14	0.16	0.40	0.13	0.12	0.09	0.07	0.10	0.11	0.14
1961	0.16	0.08	0.06	0.13	0.11	0.40	0.14	0.08	0.03	0.02	0.13	0.61	0.16
1962	0.80	0.18	0.09	0.12	0.07	0.40	0.14	0.11	0.07	0.10	0.12	0.08	0.19
1963	0.09	0.05	0.14	0.14	0.15	0.28	0.13	0.07	0.11	0.09	0.12	0.70	0.17
1964	0.40	0.16	0.07	0.04	0.03	0.39	0.14	0.12	0.11	0.09	0.05	0.06	0.14
1965	0.69	0.18	0.15	0.14	0.16	0.09	0.05	0.08	0.05	0.02	0.13	0.45	0.18
1966	0.06	0.07	0.12	0.11	0.15	0.40	0.14	0.13	0.11	0.10	0.09	0.50	0.17
1967	0.10	0.13	0.13	0.04	0.07	0.39	0.12	0.11	0.11	0.10	0.10	0.50	0.16
1968	0.48	0.18	0.10	0.10	0.14	0.37	0.11	0.03	0.11	0.09	0.07	0.08	0.15
1969	0.25	0.10	0.03	0.08	0.16	0.28	0.03	0.01	0.02	0.03	0.13	0.41	0.13
1970	0.44	0.09	0.15	0.14	0.16	0.40	0.14	0.13	0.11	0.10	0.13	0.49	0.21
1971	0.08	0.18	0.15	0.11	0.16	0.38	0.05	0.06	0.10	0.10	0.12	0.17	0.14
1972	0.06	0.04	0.03	0.07	0.08	0.34	0.13	0.09	0.09	0.06	0.07	0.24	0.11
1973	0.08	0.18	0.10	0.14	0.16	0.40	0.12	0.13	0.10	0.03	0.13	0.30	0.15
1974	0.07	0.16	0.05	0.14	0.16	0.37	0.09	0.03	0.08	0.09	0.11	0.70	0.17
1975	0.22	0.14	0.15	0.12	0.10	0.39	0.08	0.11	0.08	0.10	0.12	0.19	0.15
1976	0.80	0.18	0.14	0.03	0.16	0.40	0.13	0.13	0.11	0.05	0.12	0.24	0.21
1977	0.27	0.18	0.13	0.05	0.03	0.05	0.06	0.08	0.11	0.07	0.12	0.16	0.11
1978	0.19	0.17	0.15	0.14	0.06	0.06	0.14	0.12	0.09	0.10	0.13	0.56	0.16
1979	0.08	0.04	0.04	0.11	0.04	0.04	0.08	0.05	0.11	0.08	0.10	0.32	0.09
1980	0.42	0.12	0.15	0.14	0.16	0.40	0.14	0.13	0.11	0.09	0.13	0.55	0.21
1981	0.70	0.17	0.12	0.05	0.05	0.33	0.14	0.13	0.07	0.10	0.09	0.42	0.20
1982	0.18	0.05	0.04	0.03	0.15	0.15	0.04	0.10	0.11	0.10	0.13	0.29	0.11
1983	0.34	0.15	0.14	0.06	0.06	0.29	0.05	0.02	0.04	0.04	0.03	0.09	0.11
1984	0.06	0.07	0.06	0.14	0.16	0.27	0.14	0.10	0.09	0.10	0.06	0.06	0.11
1985	0.73	0.18	0.15	0.14	0.09	0.03	0.03	0.01	0.03	0.03	0.13	0.28	0.15
1986	0.71	0.17	0.04	0.04	0.16	0.24	0.14	0.12	0.09	0.06	0.11	0.70	0.22
1987	0.23	0.03	0.04	0.03	0.03	0.11	0.14	0.13	0.11	0.08	0.12	0.18	0.10
1988	0.12	0.06	0.07	0.04	0.03	0.08	0.14	0.11	0.04	0.08	0.04	0.07	0.07
1989	0.79	0.18	0.15	0.03	0.16	0.26	0.14	0.12	0.11	0.09	0.09	0.12	0.19
1990	0.33	0.17	0.05	0.07	0.16	0.31	0.04	0.06	0.07	0.04	0.06	0.07	0.12
1991	0.57	0.12	0.15	0.09	0.16	0.39	0.10	0.12	0.10	0.10	0.13	0.26	0.19
1992	0.80	0.18	0.12	0.08	0.04	0.09	0.10	0.09	0.11	0.08	0.08	0.70	0.21
1993	0.61	0.14	0.15	0.13	0.14	0.33	0.12	0.11	0.09	0.09	0.12	0.36	0.20

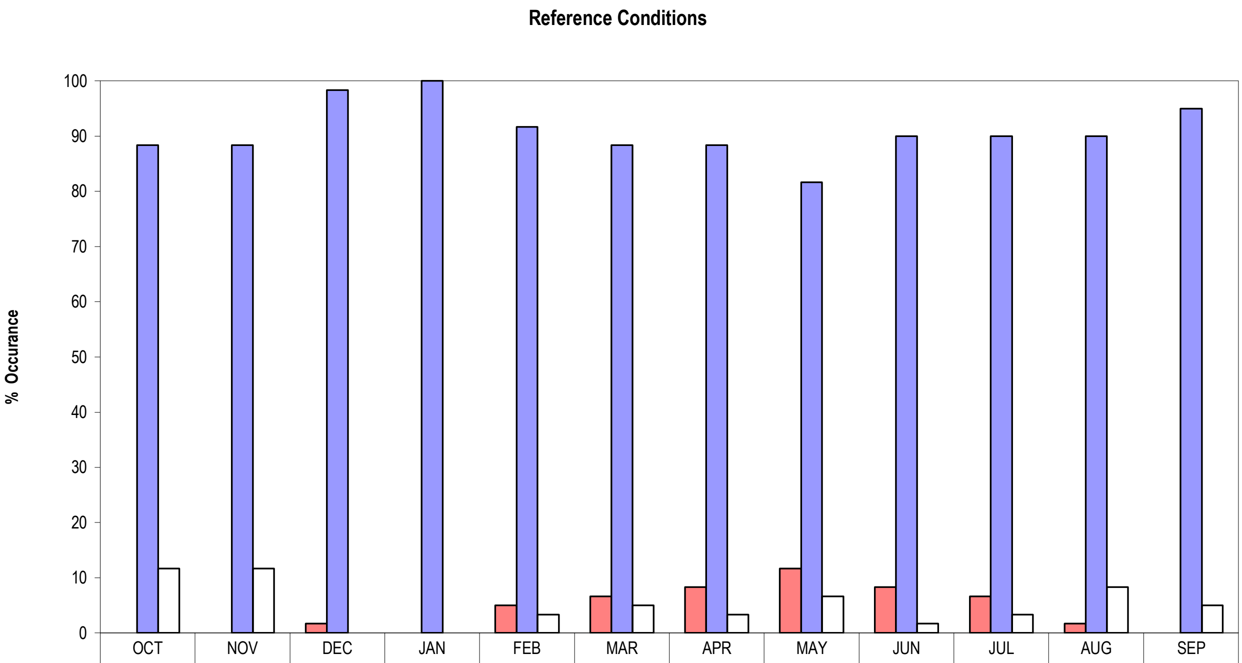
1: Freshwater	>1.0	2: Gradient	0.05 -1.0	3: Marine	< 0.05

Occurrence of Abiotic states during the Scenario 4 and Reference Condition



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Series1	0.0	11.7	21.7	21.7	21.7	6.7	20.0	23.3	20.0	21.7	16.7	0.0
Series2	100.0	88.3	78.3	78.3	78.3	93.3	80.0	76.7	80.0	78.3	83.3	100.0
Series3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 11. *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	1.7	0.0	5.0	6.7	8.3	11.7	8.3	6.7	1.7	0.0
State 2	88.3	88.3	98.3	100.0	91.7	88.3	88.3	81.7	90.0	90.0	90.0	95.0
State 1	11.7	11.7	0.0	0.0	3.3	5.0	3.3	6.7	1.7	3.3	8.3	5.0

Figure 12. *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	90	For the Sout Estuary low flows are defined as flows less than 0.05 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 0.05 m^3/s occurred under the Reference Conditions for 4.2% of the time. Under the Present State low flows occur for 15.4 % of the time.	Low
b. % similarity in mean annual frequency of floods	20	The reduction in high flows is deemed to be very little based on the very limited reduction in monthly flows. (The 99%ile indicates that there is only a 80.5 % decrease in the floods to the estuary)	Medium
Hydrology score	**20**		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure, e.g. over a 5 or 10 year period	20	Semi-closed state a probability if floods are reduced. Tidal range and amplitude reduced	Low
Hydrodynamics and mouth conditions score	**20**		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	60	There is a 10% increase in State 3: Marine dominated and an 80.5% reduction in State 1: Predominately fresh. However, the increase in berm height in the semi-closed state will result in a reduction in marine input under state 2 into the system and development of stratified fresher conditions, especially in the middle and upper reaches.	Low
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	35	Average inorganic nutrient concentration will decrease as a result of the lower volumes of riverwater entering the estuary (43.2% of MAR) and because of the 10% increase in state 3. Most nutrients are likely to be taken up within the instream development (assuming the development is a dam/weir).	Low
2b. Suspended solids (turbidity) in the estuary	35	Average suspended solid concentration will decrease as a result of the lower volumes of riverwater entering the estuary (43.2% of MAR) and because of the 10% increase in state 3. Most suspended solids are likely to settle out of suspension within the instream development (assuming the development is a dam/weir).	Low
2c. Dissolved oxygen in the estuary	70	The mouth is semi-closed and there is no strong tidal flushing. Allow change in average DO due to reduction in floods, countered by the possible deepening of the estuary.	Low
2d. Levels of toxins	-	-	
Water Quality score	**35**		

Physical habitat alteration

VARIABLE		SCORE	MOTIVATION	CONFIDENCE
1. Resemblance of intertidal sediment structure and distribution to reference condition				
1a	% similarity in intertidal area exposed	20	Allow 80% change in the intertidal area due to changes in floods and land use. For example: a significant increase in berm height and infilling of the lower reaches of the estuary with marine sediment.	Low
1b	% similarity in sand fraction relative to total sand and mud	20	Allow 80% change in the intertidal area due to changes in floods and land use.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	20	Allow 80% change in the subtidal area due to changes in floods and land use. For example: a significant increase in berm height and infilling of the lower reaches of the estuary with marine sediment.	Low
Anthropogenic influence:				
	Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
	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	50	Sedimentation may have occurred due to change in land-use in the catchment.	Low
Physical habitat score		**20**		

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

Average phytoplankton biomass in the Sout estuary is low (~0.5 $\mu g.l^{-1}$). A decrease in river flow will reduce the concentrations of nutrients and suspended solids entering the estuary, which could result in a decrease in microalgal biomass. In addition, assuming the instream development is a dam, nutrients could be taken up within the impoundment and suspended solids could settle out of the water column. However, lower river flows and the reduced frequency of flood events will provide a more stable environment for microalgae, particularly in the middle reaches during periods of a longitudinal salinity gradient (state 2). An increase in state 2 will increase species biomass, richness and abundance (more cyanobacteria, dinoflagellates and chlorophytes) but during periods of low/no flow (10% increase in state 3) will result in the estuary becoming marine dominated with a low microalgal biomass, richness and abundance (diatoms and flagellates will dominate). Benthic microalgae are not as dependent on the water column chemistry as the phytoplankton.

Confidence: Medium

MACROPHYTES

Low flows are similar to that of Scenario 1 and occur for 15.4 % of the time. Therefore in terms of low flow this scenario is better than Scenarios 2 and 3. However the big change is the reduction of floods. For Scenario 4 the magnitude and occurrence of major floods have been reduced by 80.5%. The semi-closed mouth state and increase in berm height will cut the estuary off from the marine environment. Brackish and lack of flushing by floods will increase the area covered by the macrophytes.

Confidence: Low

INVERTEBRATES (including Zooplankton, Benthic invertebrates and Macro crustaceans)

The presence of a salinity gradient for a greater proportion of the time will result in a loss of species (particularly marine associated species), but a probable increase in zooplankton biomass. This is due to greater residence time of the estuarine water. However, the increase in biomass will be countered by low phytoplankton availability. The severe loss in flood events will result in most of the intertidal area not being available for colonisation and leading to a loss int eh benthic intertidal community. The subtidal benthic community will respond positively to the microalgal increase and

the detritus input from the potential development of *Phragmites* reedbeds. Confidence: Low
FISH
The semi-closed state of the estuary mouth will still permit recruitment of marine migrant species into the estuary and the larger water surface area and volume will enable the system to support higher numbers and biomass of fishes. The estuarine resident species will also benefit from the more stable estuarine conditions and their numbers will increase considerably. Conversely marine stragglers will disappear from the estuary as they are dependant on marine conditions in order to survive. Confidence: Low
BIRDS
Most species of birds that forage in the intertidal will probably no longer remain on the estuary. In addition the increase in *Phragmites* will attract those species that require dense foliage and this will increase species abundance. The increase in depth of the estuary will promote fish abundance and hence piscivorous bird numbers. Human disturbance will still influence wading birds but probably not piscivorous birds. Confidence: Low

6.5.4 EHI for the Future Scenario 3 - Abiotic Components

Microalgae

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Phytoplankton			
1. Species richness	80 (90%)	A 47.3% decrease in river flow, the absence of flood events and a 10% increase in the marine dominated phase (state 3) reduce the nutrient loads entering the estuary and limits low salinity water to the extreme upper reaches of the estuary. The mouth is likely to be in the semi-closed state so there is likely to be an increase in cyanophytes and dinoflagellates in response to the more stable environment.	Low
2a. Abundance	80	Phytoplankton abundance is low in the estuary during the present state so there is unlikely to be a further decrease in biomass due to reduced flow. However, pulses have been severely reduced so periods of elevated nutrients following pulses have been nearly lost. Allow for a slight decrease in average biomass.	Low
2b. Community composition	35	Diatoms and flagellates were dominant in the present state. The semi-closed mouth will favour the presence of more dinoflagellates, chlorophytes and cyanophytes.	Low
Benthic microalgae			
1. Species richness	80 (90%)	All habitats will still be available during this scenario. Allow for a slight (10%) change due to an increase in the amount of sand and decrease in intertidal area.	Low
2a. Abundance	35	The estuary will become semi-closed, there will be a decrease in intertidal area and residence time will increase. This will favour the flocculation of fine particulate material, which favours an increase in benthic microalgal biomass: i.e. more favourable substrate and increased mineralisation of nutrients.	Low
2b. Community composition	35	There will be an increased accumulation of sand in the lower reaches, favouring an increase in the episammic microalgal component. The settling out and accumulation of fine particulate material from the water column is likely to increase the relative abundance of cyanobacteria and chlorophytes (euglenoids in particular) in the middle and upper reaches of the estuary.	Low
Microalgae score	**35**		

Macrophytes

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	25 (50%)	Because of the reduction in floods opportunistic species will be lost. The loss of intertidal area will result in a loss of *Cotula*, *Zostera*, *Sarcocornia perennis* (and maybe Chenolea) and a possible *Phragmites australis* colonisation.	Low
2a. Abundance	50	A loss of intertidal brackish habit and replacement by *Phragmites australis.*	Low
2b. Community composition	50	There will be a loss of intertidal habitat which will change the community composition. Brackish macrophytes (reeds and grasses) will expand into the saline habitats.	Low
Macrophytes score	**25**		

Invertebrates

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Zooplankton			
1. Species richness	80 (90%)	A small decrease in species richness expected because of a loss of marine dominance and an increase in euryhaline conditions	Low
2a. Abundance	80	Because of the high reduction in floods, the euryhaline community that responds to floods (i.e. *Pseudodiaptomus hessei*) will be relatively infrequent. Overall, there will be a decrease in biomass because of a lack of pulsing. This will also be countered by the input of detritus from the macrophyte community.	Low
2b. Community composition	40	The mix of species will change because of the loss of floods and the dominance of euryhaline conditions.	Low
Zoobenthos			
1. Species richness	80 (90%)	The significant decrease in the marine influence will lead to a loss of species that occur near the mouth. Small pocket remnants of hardy marine associated species will remain in the deeper pockets.	Low
2a. Abundance	50	Because of the loss in intertidal area, biomass of those species present (*Upogebia africana*) will decrease significantly. Species such as *Upogebia africana* and saltmarsh crabs are relatively large and usually contribute much to invertebrate biomass. This will be countered by an increase in the abundance of smaller subtidal species because of an increase in microphytobenthos and detritus from macrophyte community.	Low
2b. Community composition	40	Community mix will change significantly because of the loss in intertidal area and the persistence of euryhaline conditions.	Low
Hyperbenthos			
1. Species richness	80	The significant decrease in the marine influence will lead to a loss of species that occur near the mouth. Small pocket remnants of hardy marine associated species will remain in the deeper pockets.	Low
2a. Abundance	50	Because of the loss in intertidal area, biomass of those species present (*Upogebia africana*) will decrease significantly. Species such as *Upogebia africana* and saltmarsh crabs are relatively large and usually contribute much to invertebrate biomass. This will be countered by an increase in the abundance of smaller subtidal species because of an increase in microphytobenthos and detritus from macrophyte community.	Low
2b. Community composition	40	Community mix will change significantly because of the loss in intertidal area and the persistence of euryhaline conditions.	Low
Invertebrates score	**40**		

Fish

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	80 (90%)	A slight change in species richness is likely in this scenario due to a loss of marine stragglers.	Low
2a. Abundance	50	There will be a considerable increase in the abundance of estuarine species due to the more stable estuarine conditions. There will also be an increase in the abundance and size composition of marine migrant species under this scenario.	Low
2b. Community composition	40	Changes in marine fish abundance, particularly the balance between marine migrants and estuarine species is likely to result in a significant change in fish community composition.	Low
Fish score	**40**		

Birds

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Species richness	25 (50%)	Species that forage in the intertidal area will only occasionally frequent the estuary because of the loss of food resources. Because of the deepening of the estuary, piscivorous birds will increase compared to the natural shallow state. There will also be an increase of those species associated with reed coverage.	Low
2a. Abundance	80	There will be a significant decrease in biomass of intertidal foraging because of a reduction in intertidal habitat. Abundance of piscivorous birds and those associated with reeds will increase.	Low
2b. Community composition	25	The loss of intertidal and deepening of the estuary will probably result in a change in community composition compared to the natural state. Human disturbance will become more localised and negatively influence those species associated with remaining intertidal areas.	Low
Bird score	**25**		

7 Recommended Ecological Flow Requirement for the Sout 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	97	92	84	67	62
Hydrodynamics/mouth condition	25	100	100	100	100	20
Water quality	25	90	85	70	45	45
Physical habitat alteration	25	95	95	90	85	20
Habitat Health Score (weighted)		**95**	**93**	**86**	**70**	**30**
Microalgae	20	90	85	70	45	35
Macrophytes	20	100	95	90	70	25
Invertebrates	20	100	95	80	60	40
Fish	20	90	85	80	70	40
Birds	20	95	90	80	80	25
Biotic Health Score (weighted)		**95**	**90**	**80**	**59**	**26**
Estuarine Health Index Score		**95**	**92**	**83**	**64**	**28**
Ecological Reserve Category (ERC)		**A**	**A**	**B**	**C**	**E**

Recommended ecological flow requirement for the Sout 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 Sout 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 Sout Estuary in the recommended ERC as it differs very little in reduction of runoff from the Present State (3.6% reduction in MAR). **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
99%ile	1.49	1.37	0.80	0.89	1.39	1.29	1.49	1.99	0.88	1.05	1.42	1.53
90%ile	0.94	1.00	0.52	0.60	0.68	0.73	0.59	0.64	0.43	0.44	0.77	0.75
80%ile	0.69	0.66	0.39	0.43	0.51	0.44	0.43	0.49	0.29	0.31	0.52	0.60
70%ile	0.44	0.51	0.32	0.37	0.33	0.40	0.30	0.28	0.24	0.22	0.37	0.50
60%ile	0.36	0.38	0.24	0.23	0.28	0.33	0.23	0.20	0.20	0.17	0.24	0.37
50%ile	0.31	0.31	0.22	0.19	0.25	0.25	0.17	0.11	0.15	0.14	0.18	0.32
40%ile	0.28	0.26	0.16	0.16	0.21	0.21	0.13	0.09	0.11	0.11	0.15	0.27
30%ile	0.24	0.16	0.13	0.11	0.16	0.14	0.12	0.06	0.05	0.07	0.11	0.16
20%ile	0.18	0.11	0.09	0.06	0.12	0.07	0.07	0.03	0.02	0.02	0.08	0.11
10%ile	0.11	0.07	0.07	0.03	0.03	0.03	0.02	0.00	0.00	0.01	0.04	0.06
1%ile	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02

River Scenario A/B includes an in-stream dam development that will reduce the magnitude and occurrence of major floods by 80.5%. Although baseflow will still be maintained, the reduction in floods will severely affect the estuary, especially as the potential is high that the estuary may change from a permanently open to a temporarily open/closed estuary.

It is recommended that River Scenario B as an off-stream development be investigated. This scenario without the in-stream dam development will allow the majority of the floods to reach the estuary and may provide another alternative similar to Run-off Scenario 1.

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 (0.02 $m^3.s^{-1}$)
- No effluent may be pumped back into the river
- No in-stream dam developments should be considered

8 Ecological Specification

Currently the *Resource directed measures for protection of water resource: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004a) does not provide any guidance on the determination of ecological specifications for estuaries. Therefore, the approach that was applied and approved by DWAF as part of the Thukela study was followed (DWAF, 2004b).

Ecological Specifications are clear and measurable specifications of ecological attributes (in the case of estuaries - hydrodynamics, sediment dynamics, water quality and different biotic components) that define a specific ecological reserve category, in this case a **Category A.** The ecological specifications for the Sout Estuary are listed in Table 23.

Thresholds of potential concern (TPC) are defined as measurable end points related to specific abiotic or biotic indicators that if reached (or when modelling predicts that such points will be reached) prompts management action. In essence, thresholds of potential concern endpoints should be defined such that they provide early warning signals of potential non-compliance to ecological specification (i.e. not the point of 'no return'). In essence, this concept implies that the indicators (or monitoring activities) selected as part of long-term monitoring programme need to include biotic and abiotic components that are particularly sensitive to ecological changes associated with changes in river inflow. The TPCs, associated with each of the ecological specifications are also provided in Table 23.

Table 23: *Ecological Specifications and TPC associated with an Ecological Category A in the Sout Estuary*

COMPONENT	ECOLOGICAL SPECIFICATION/RESOURCE QUALITY OBJECTIVE	THRESHOLD OF POTENTIAL CONCERN	POTENTIAL CAUSES
Birds	The birds are a poor indicator of ecosystem change in the Sout Estuary, due to very low numbers, species richness and ongoing human disturbance. The estuary is very small with relatively low biomass of food resources that result in birds on the estuary being mostly transient.	1.2 TPCs will be reached for other components before the birds will be affected (e.g. invertebrates)	1.2 Human disturbance
Fish	Retain present fish assemblage	2.4 Decrease in abundance of marine fish migrants to <80% of the overall ichthyofauna. 2.5 Increase in abundance of estuarine resident fish species >20% of the overall ichthyofauna. 2.6 Loss of all marine stragglers from the estuary or increase in abundance of marine stragglers to >10% of the overall ichthyofauna.	2.4 Reduced marine fish recruitment due lack of riverine cues to marine inshore environment. 2.5 Marine exchange is reduced, mouth becomes more restricted and estuarine environment becomes more stable. 2.6 Change in marine influence on the estuary caused by mouth constriction (loss of marine stragglers) or by river flow reduction (increase in marine stragglers) .
Invertebrates	Maintain current levels of zoobenthic abundance (including seasonal variation)	3.1 Decrease in abundance of >50% in terms of numbers per m-2 over entire estuarine area (4 sample sites plus cove)	Changes to sediment grain size distribution and organic content
	The zoobenthic invertebrates must be characterised by predominantly estuarine taxa	3.2 <50% of benthic invertebrates (by abundance) are typically estuarine taxa compared to freshwater associated taxa (e.g. becomes dominated by insect larvae)	State of the mouth excludes marine influence (salinity gradient weakens)
	The mudprawn *Upogebia africana* must maintain presence in the estuary	3.3 <50% of average abundance of the population remaining	Extended mouth closure, or weak water exchange between estuary and the sea
	Retain current species assemblage of two basic communities; A sand associated community in the lower estuary (Sites 1 and 2) and a mud-associated community in the middle and upper estuary (Sites 3 and 4)	3.4 Similarity indices (Bray-Curtis) between sandy sites (Sites 1 and 2) and muddy sites (Sites 3 and 4) should not exceed 25% similarity (under natural conditions, similarity <10%).	Changes in the sediment characteristics
	Benthic invertebrates should maintain current mix of species, dominated by amphipods	3.5 Other taxa such as polychaetes begin to dominate	Input of organic material derived from the catchment declines. Organic input, particularly at times of high flow provide an important source of nutrients that fuel the foodweb.

COMPONENT	ECOLOGICAL SPECIFICATION/RESOURCE QUALITY OBJECTIVE	THRESHOLD OF POTENTIAL CONCERN	POTENTIAL CAUSES
Macrophytes	Maintain the present distribution (2007) and abundance of the different plant community types (e.g. 0.3 ha intertidal salt marsh, 0.3 ha supratidal salt marsh, 2.3 ha total water surface area).	4.1 Greater than 20% change in the area covered by different plant community types	Semi-closed mouth condition, increase in water level and change in salinity
	Prevent the establishment of reeds in the estuary and replacement of saline habitats (salt marsh) with brackish habitats (reeds)	4.2 Reeds are present and cover an area of 0.1 ha	Salinity remains lower than 20 ppt for longer than 6 months of the year
	Prevent the growth of filamentous green algae associated with low flow, closed mouth conditions.	4.3 Filamentous green algae are present and cover 0.1 ha	Increase in nutrients, semi-closed mouth state and low flow conditions (<0.1 m3/s)
Microalgae	Maintain phytoplankton biomass as under baseline conditions	5.2 Phytoplankton biomass should not exceed 10 µg/L.	Increase in nutrient concentration (particularly DIN and DIP), reduction in flow or semi-closed mouth condition.
	Maintain phytoplankton group diversity (diatoms, dinoflagellates, flagellates, greens etc.).	5.2 Dominance (> 10% relative abundance) of one bloom-forming group of algae (i.e. blue-greens & dinoflagellates).	Increased loads of nutrients (particularly DIN and DIP) and organic matter, decrease in dissolved oxygen (<3 mg/L).
	Maintain intertidal and subtidal biomass of benthic microalgae in sheltered shallow waters	5.3 Average benthic microalgal biomass should remain between 5 and 20 µg/g, both intertidally and subtidally.	Disturbance of sediments could cause decrease in biomass (<5 ug/g). Prolonged elevated turbidity and nutrients could increase biomass > 20 ug/g.
	Maintain benthic microalgal species diversity (i.e. Blue-greens, greens, diatoms & euglenoids).	5.4 Dominance (>10% RA) by nuisance forms (e.g. cyanophytes, etc.)	Disturbance of sediments; Water quality (turbidity, nutrients); Flow
Water quality	Water quality of river inflow not to cause exceedence of TPCs set for water quality in the estuary (see below).	6.6 DIN-N, SRP-P and silicate-Si should not exceed 250 ug/L, 75ug/L and 3500 ug/L in the upper reaches (900 m from mouth) respectively.	Quality of river inflow
	Salinity intrusion should not to cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae	6.7 Salinity in the upper reaches of the estuary, during low flows, should not be >30 ppt for any length of time.	Quality of river inflow
	System variables (pH, turbidity, dissolved oxygen) should not to cause exceedence of TPCs for invertebrates, macrophytes and microalgae	6.8 pH greater than 8.5 or less than 6.5. 6.9 Secchi depth less than bottom or 1 m (except during floods) 6.10 Dissolved oxygen concentrations fall below 3 mg/L.	Quality of river inflow

COMPONENT	ECOLOGICAL SPECIFICATION/RESOURCE QUALITY OBJECTIVE	THRESHOLD OF POTENTIAL CONCERN	POTENTIAL CAUSES
Hydro-dynamics	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality	7.4 'Reserve for Water Quantity' as represented by flow distribution of Scenario 1	Illegal abstraction and future dam developments
	Maintain open mouth status to allow for habitat requirements of birds, fish, macrophytes, microalgae and water quality.	7.5 Permanently open mouth through out the year	Flow reduction
	Maintain channel dimensions and a low berm height at the mouth to allow for significant tidal variation (i.e. tidal flushing) to maintain habitat requirements for birds, fish, macrophytes, microalgae and water quality.	7.6 Spring tidal amplitude < 1.4 m on a spring high tide	Build up of marine sediment in the mouth area as a result of flood reductions
Sediment dynamics	Changes in water depth in estuary not to cause exceedance of TPCs in vegetation, invertebrates and fish (see above).	8.5 Greater than 10 cm change in sediment deposition/erosion in the estuary.	Reduction in floods to the estuary and changes in land use
	Decrease in channel depth (and/or channel dimension) and an increase in the sand berm height in the mouth area restricting tidal variation and tidal flushing	8.6 Greater than 20 cm average increase in berm height from present and shallowing of the channel	Reduction in floods to the estuary and changes in land use
	Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates.	8.7 The median bed sediment diameter should not deviate more than factor 3 as recorded in the baseline survey.	Reduced flow causing increased marine sediment influx with a larger particle size.
	Changes in organic content in sediments not to cause exceedence of TPCs set for benthic invertebrates.	8.8 The median sediment organic load should not deviate more than factor 3 as recorded in the baseline survey.	Reduced flow causing increased marine sediment influx with a lower organic content.

9 Resource Monitoring Programme

9.1 Baseline Data Requirements

The status of baseline data currently available for different abiotic and biotic components in the Sout Estuary, after completion of the current ecological reserve determination study, is summarised in the following section.

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, 1971, 1974, 1960, 4-12-1972, 05-1974, 5-04-1976, 8-04-1977, 21-04-1979	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)	April 2007 (this study), December 2006 (this study); June 1994 (T Harisson, unpublished data); April 1981 (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 900 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 changes from sand near the mouth to gravel in the upper reaches: episammic and epilithic diatoms 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, 1971, 1974, 1960, 4-12-1972, 05-1974, 5-04-1976, 8-04-1977, 21-04-1979, Google Earth	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.	This study Field survey in 2006	
Permanent transects: - Measurements of percentage plant cover along an elevation gradient - Measurements of salinity, water level, sediment moisture content and turbidity	No data	There are no large salt marsh areas and therefore these data are unnecessary for this estuary.

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.	This study.	
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	ECRU survey April 1981. This study.	
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.	Six species recorded during the ECRU survey in 1981. This study.	Intertidal samples collected

DATA REQUIRED	AVAILABILITY	COMMENT
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. 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.	No data available	No vehicle access
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 available	No vehicle access

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.	Three fish surveys of the Sout Estuary have been undertaken, namely the ECRU survey in April 1981, CSIR survey in September 1994, and the SAIAB survey in April 2007.	The absence of vehicle and boat access to the estuary meant that the range of gear types used was limited primarily to seine and cast netting.

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).	Western Cape Wader Study Group – Summer 1978 -79. This study	

9.2 Additional Baseline Data Requirements

The status of baseline studies currently available for the Sout Estuary are summarised above. The Sout Estuary, being a complex system, does require (consecutive) seasonal surveys to improve the confidence of the Reserve, as well as to set a suitable and reliable baseline (high confidence) for the different abiotic and biotic components in a long-term monitoring programme. Additional baseline data requirements were recommended based on the generic data requirements stipulated for an Intermediate Ecological Reserve Determination (DWAF, 2004a) as well as subsequent updates as proposed by Taljaard *et al.* (2003).

Additional baseline data requirements are listed in Table 24 and have been prioritised, using the following criteria:

	High Priority, important for a suitable and reliable baseline (high confidence)
	Medium Priority, will improve the confidence of baseline, and should be added if funding is available
	Low priority, will further improve confidence of baseline, but not considered to be a critical factor in the case of the Sout Estuary

For baseline surveys the quantification of linkages between different abiotic and biotic components are very important, and exclusion of certain components is likely to result in only incremental gain in confidence which may not warrant the effort.

Table 24: *Additional baseline data required to increase confidence of Reserve and to set baseline for long-term monitoring in the Sout Estuary*

ECOLOGICAL COMPONENT	MONITORING ACTION	RELATED TPC (see Table 23)	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (No. Stations)
BIRDS	No additional baseline data required	-	-	-
FISH	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1 & 2.3	Once during November (Spring) using seine net	4 stations x 4 replicates
	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1, 2.2 & 2.3	Once during March (Autumn) using seine net	4 stations x 4 replicates
	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1, 2.2 & 2.3	At least one severe flood (>5 m3/s) and one severe drought (<0.1 m3/s for 6 months) monitored	4 stations x 4 replicates
INVERTEBRATES	Gather data on benthic community composition (grab samples) and determine density of Upogebia africana (hole counts)	3.1 to 3.5	Once during June/July and Nov-March	5 sites
	If the mouth becomes very constricted (tidal variation < 30 cm) conduct field trip to determine status of the benthic community listed above. Abiotic data must include sediment samples for particle size analysis.	3.1 to 3.5	Once, and then every quarter during the constricted mouth phase	5 sites
MACROPHYTES	No additional baseline are data required.	-	-	-
MICROALGAE	Measure phytoplankton biomass and group composition during high and low flow.	5.1 & 5.2	Twice (high flow & low flow)	6 (sea, river and 4 in the estuary)
	Measure benthic microalgal biomass and species composition during high and low flow.	5.3 & 5.4	Twice (high flow & low flow)	6 (sea, river and 4 in the estuary
WATER QUALITY	Water quality in estuary: 1) Salinity & temperature profiles, 2) system variables (pH, DO, turbidity, TSS), 3) inorganic nutrients (DIN, SRP-P and silicate-Si). Salinity and temperature must be collected at 0.5 m intervals, while other water quality parameters are collected in surface and bottom waters.	6.1 to 6.5	Twice (high flow and low flow); sampling must coincide with microalgal & invertebrate surveys.	20 sites (Salinity & temp.), 5 for other parameters.
HYDRODYNAMIC	Water level recordings (leveled to mean sea level)	7.1 to 7.3	Continuous	Near mouth
	River flow gauging	7.1 to 7.3	Continuous	Above head of tidal influnce
SEDIMENT DYNAMICS	Bathymetric survey: Detailed cross-section profiles of the estuary and sand berm and cove at the mouth (leveled to mean sea level)	8.1 & 8.2	Once and if possible survey after a flood (> 15 m3/s)	Collected at fixed 50 m, but more detailed in the mouth
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and organic content.	8.3 & 8.4	Once and if possible survey after a flood (> 15 m3/s)	Collected at cross-section profiles (see above)

9.3 Long-Term Resource Monitoring Programme

The purpose of long-term monitoring programmes, in this context, is to assess (or audit) whether the Ecological Specifications (defined as part of the Ecological Reserve determination process) are being complied with after implementation of the Reserve. In addition, these programmes can also be used to improve and refine the Ecological Reserve measures (including the Resource Quality Objectives), in the longer-term through an iterative process (Taljaard *et al*., 2003).

Although baseline studies and long-term monitoring programmes have different purposes, it is extremely important that long-term monitoring programmes follow on from similarly structured baseline studies. In essence, the monitoring activities selected for the long-term monitoring programme should be derived from the monitoring activities conducted as part of the baseline studies, but implemented on less intensive spatial and/or temporal scales (Taljaard *et al*., 2003).

Abiotic and biotic indicators considered relevant for a long-term monitoring programme on the Sout Estuary is listed in Table 25. Should the components within the programme need to be prioritised prior to the completion of the baseline studies (when higher confidence will allow for a sensible prioritisation), it was concluded that the emphasis should be placed on monitoring of the abiotic 'driver' components.

Table 25: *Long-term resource monitoring programme proposed for the Sout Estuary after implementation of the Reserve*

ECOLOGICAL COMPONENT	MONITORING ACTION	RELATED TPC (see Table 23)	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (No. Stations)
BIRDS	No additional baseline data required	-	-	-
FISH	Four sets of samples from the cove, lower, middle and upper reaches of the estuary using seine nets. Confirmation of seine net catches from the cove to be conducted using underwater visual census.	2.1, 2.2 & 2.3	March baseline surveys repeated once every 3 years	4 stations x 4 replicates
INVERTEBRATES	Gather data on benthic community composition (grab samples) and determine density of Upogebia africana (hole counts)	3.1 to 3.5	Once every summer	5 sites
	If the mouth becomes constricted (tidal variation < 30 cm) conduct field trip to determine status of the benthic community listed above.	3.1 to 3.5	Every quarter during the closed mouth phase	5 sites
MACROPHYTES	Area covered by different plant community types to be assessed from aerial photographs and measured during a summer ground survey to: 1) verify areas covered by different plant community types, 2) check for the presence of reeds, 3) check for the presence of macroalgae. Produce a GIS map for comparison with baseline.	4.1 to 4.3	Every 3 years	Entire estuary
MICROALGAE	Measure phytoplankton biomass and group composition during low flow.	5.1 & 5.2	2yr following implementation and 3yr thereafter during Nov - March (low flow)	6 (sea, river and 4 stations in the estuary)
	Measure benthic microalgal biomass and species composition during low flow.	5.3 & 5.4	2yr following implementation and 3yr thereafter during Nov - March (low flow)	6 (sea, river and 4 stations in the estuary)
	When there is an algal bloom collect samples as required	5.1 & 5.2	Immediately and at 2 week intervals for 6 weeks	6 (sea, river and 4 stations in the estuary)
WATER QUALITY	Water quality in estuary: 1) Salinity & temperature profiles, 2) system variables (pH, DO, turbidity, TSS), 3) inorganic nutrients (DIN, SRP-P and silicate-Si). Salinity and temperature must be collected at 0.5 m intervals, while other water quality parameters are collected in surface and bottom waters.	6.1 to 6.5	Samples to be collected coinciding with related biological sampling surveys.	20 sites (Salinity & temp.), 5 for other parameters.
HYDRODYNAMICS	Water level recordings.	7.1 to 7.3	Continuous	Near mouth
	Flow gauging.	7.1 to 7.3	Continuous	Above head of tidal influence
	Aerial photographs of estuary (earliest available year as well as most recent)	7.1 to 7.3 4.1 to 4.3	Every 3 years	Entire estuary
SEDIMENT DYNAMICS	Bathymetric survey: Detailed cross-section profiles of the estuary and sand berm and cove at the mouth (leveled to mean sea level)	8.1 & 8.2	If possible survey after a flood (> 15 m3/s) and once every 3 years	Collected at fixed 50 m, but more detailed in the mouth
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and organic content.	8.3 & 8.4	If possible survey after a flood (> 15 m3/s) and once every three years	Collected at cross-section profiles (see above)

A proposed Monitoring Decision Support System (MDSS) to be applied in the long-term resource monitoring of estuaries, as part of the RDM process, is illustrated in Figure 13 (modified after DWAF, 2004b).

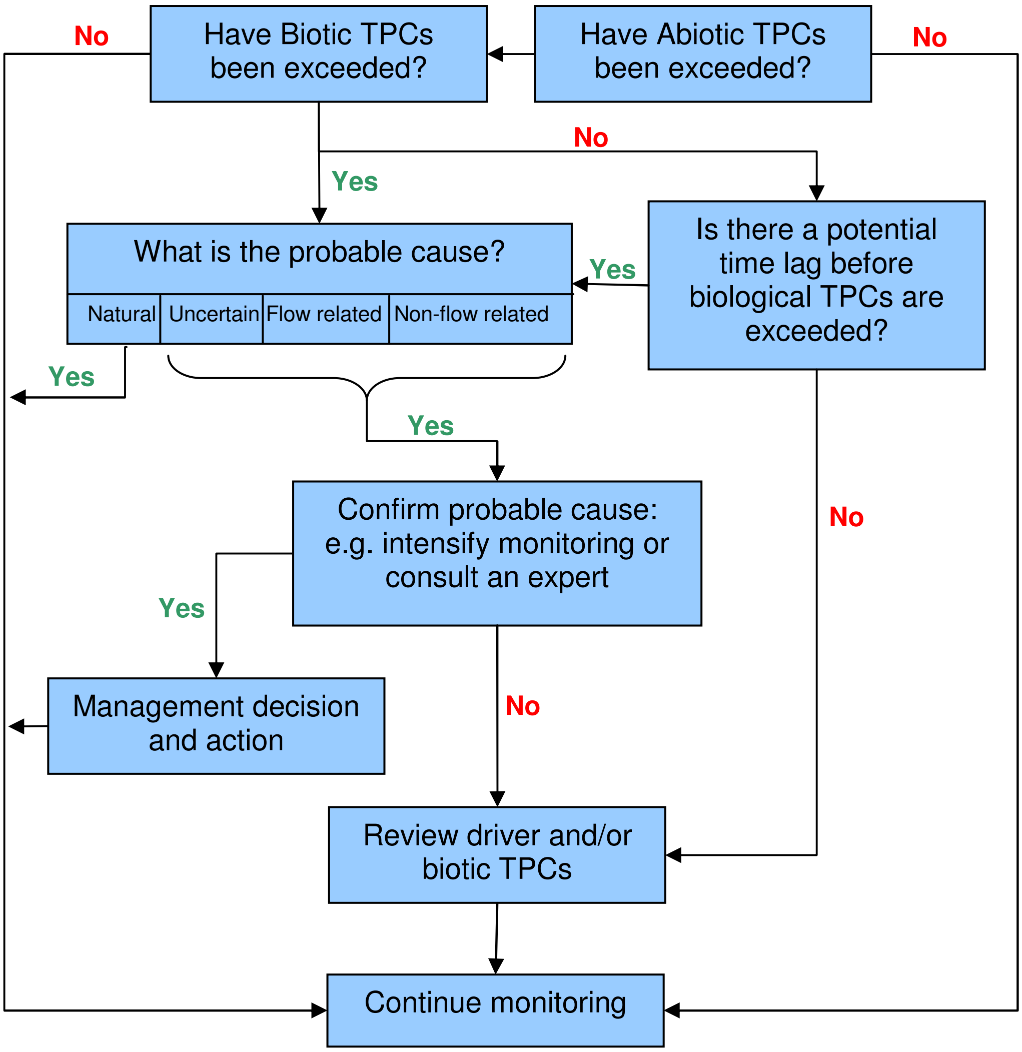


Figure 13: *Proposed Monitoring Decision Support System (MDSS) to be applied in the long-term resource monitoring of estuaries*

10 References

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Appendix A

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 Sout 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 Matjies & 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 SOUT AND MATJIES 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 Sout 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 SOUT AND MATJIES 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	Sout 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 Sout 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 Sout 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 B

Specialist Report: Hydrodynamics

by

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Content

Figures

Tables

1 Access

The Sout Estuary lies 17 km northeast of Plettenberg Bay with access from the old N2 freeway at the bottom of the Groot River Pass through the resort of Nature's Valley, with the last 1.7 km along the coast on foot.

Figure 3. Upper reaches of the Sout Estuary

2 Catchment

The Sout is a small permanently open estuary with a catchment area of 35.5k m^2 (Van Niekerk 2007; Appendix A). The total river length is 15 km (CSIR 1983). The Mean Annual Precipitation is estimated at 886 mm.

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). The river flow throughout the year with the rate of flow fluctuating with rainfall. Rainfall higher than 1000 mm can be expected in the mountain areas. The Mean Annual Precipitation decreases from east to west.

The Sout River is in a near natural state with regards to water quantity, with the natural MAR estimated to be 11.22 million m^3 and the 90 % of the natural flow record accepted as the present day flows.

No measured data were available for this study. The only data available are 60 years (1934 – 1993) of simulated monthly data based on calibration parameters from the Bloukrans River. There is a flow gauge in the Sout / Wit River but the data is not useable because there is no rating curve. This is a possible source of data for future use. The data are collected by DWAF: Regional Office

(George). All flow data was simulated (from the Bloukrans River) with the WRSM2000 model. The confidence in the flow data is medium and low for low flows.

3 Land Use

The land use in the catchment is small and considered negligible with regards to water quantity. About 12.5 km^2 of the catchment consist of indigenous forest. Land development in the catchment is restricted to a water interbasin transfer from the Sout River to the Buffels / Matjies River via a small canal at Kurland Estate. The land use figures used in this study are based on 1993 information.

4 Estuary dimensions

The Sout Estuary is a small black water system of about 1.1 km long with a maximum width of 0.08 km (Figure 4). The estuary is gorge-like with steep slopes dropping from the coastal plateau to the shores of the estuary. The river valley opens up about 700 m from the sea before entering a cove bounded by rocky headlands.

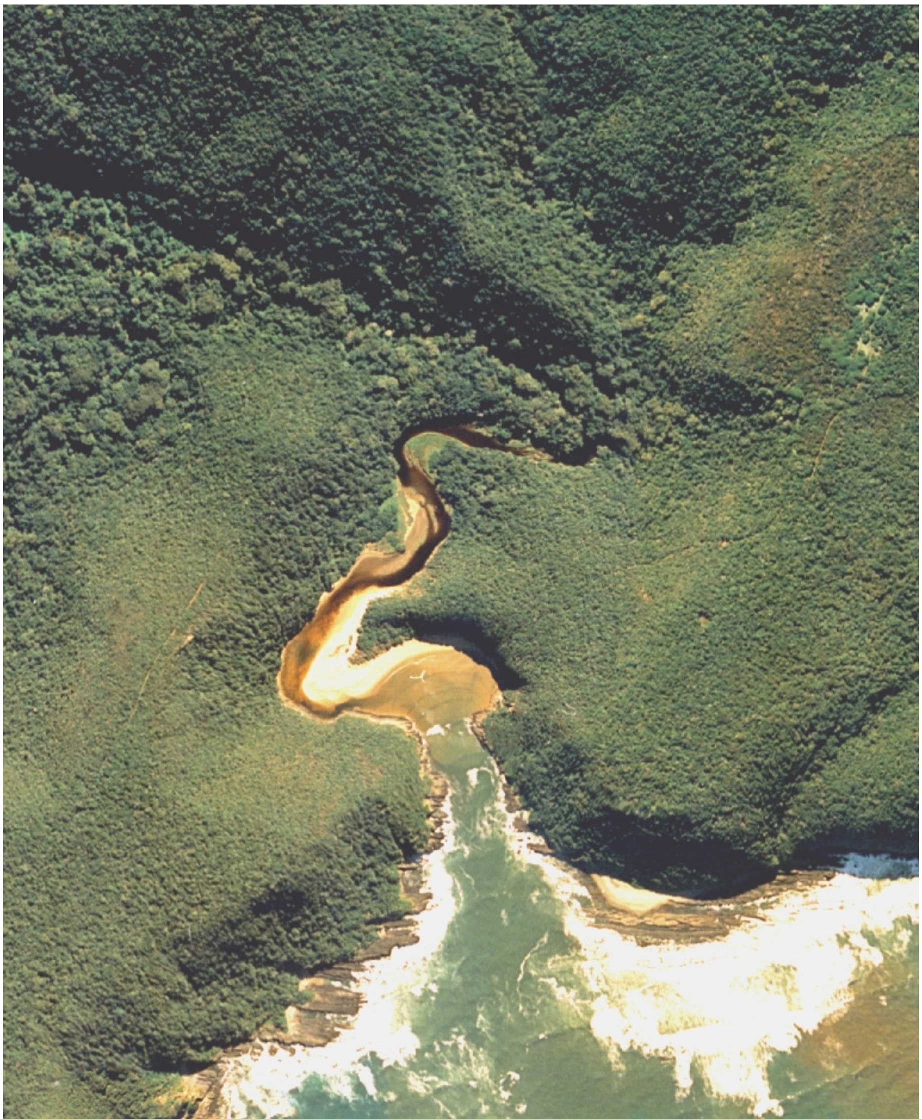

Figure 4. Aerial photo (2004) of the Sout Estuary

To assist with volume estimates for the Sout Estuary a bathymetric survey was undertaken on 21 March 2007 during spring low tide (see Figure 5). Figure 6 to **Figure 9** graphically illustrates the results of the bathymetrical survey. The blue line on the graphs denotes the spring low tide water level and the red line the previous spring high tide water level. What is evident from these measurements is that very little water remains in the system during a low tide.

The Sout Estuary is generally very shallow, < 1.0 m, with occasional pools up to 2 m deep (see Transect 5, 8 and 11) scattered along the tidal reach. The pools contain fine sand and organic material from decaying matter.

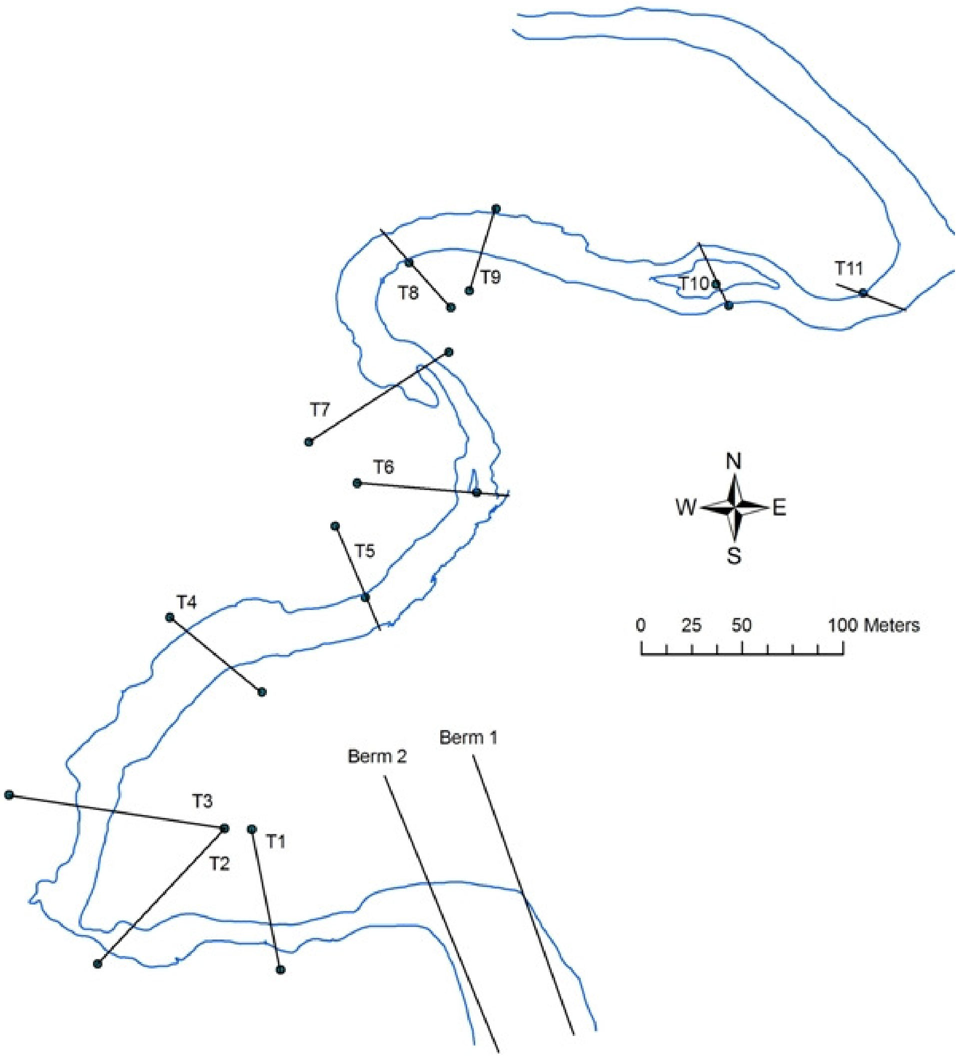

Figure 5. Locality map of the bathymetric survey transects (21/03/07)

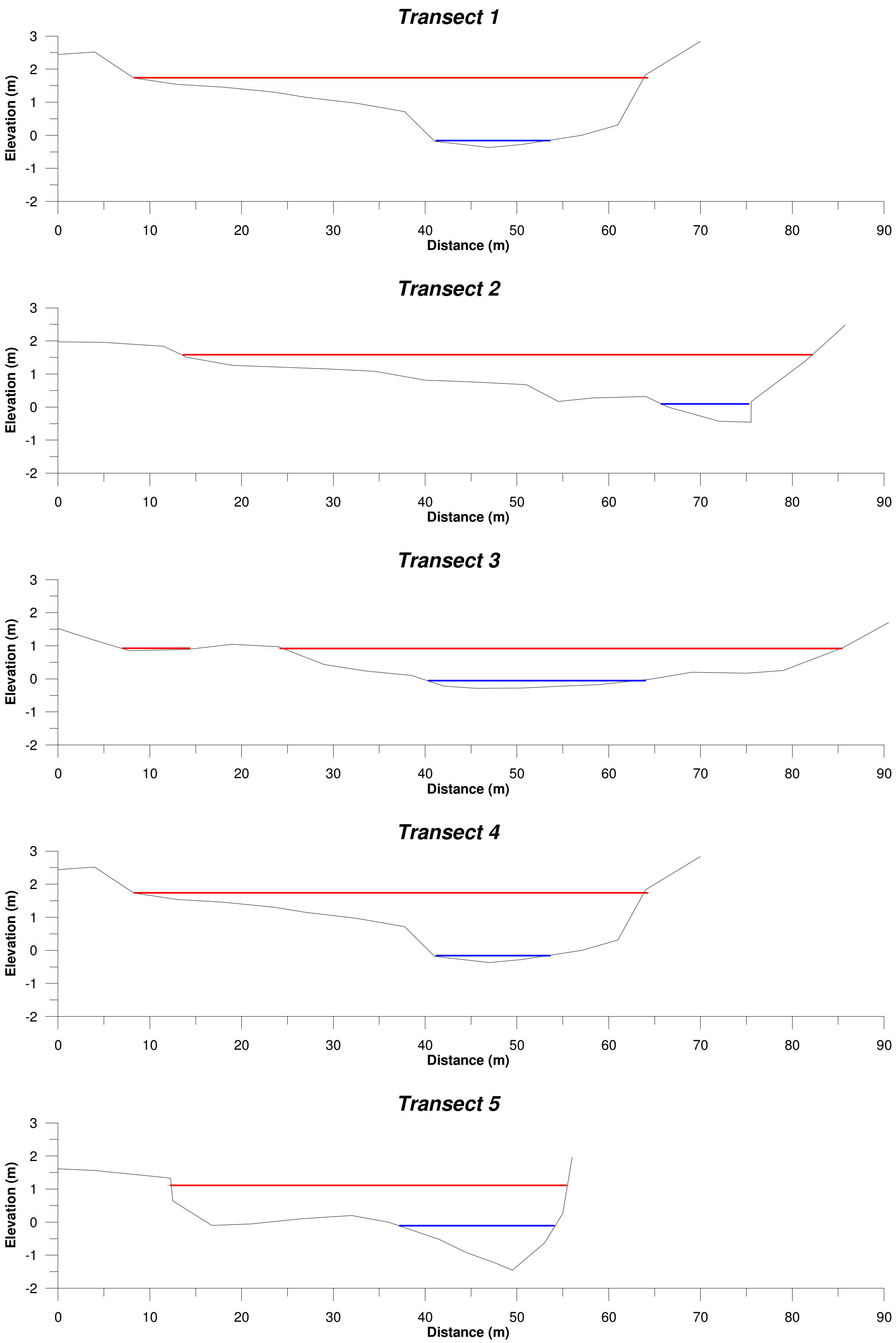

Figure 6. Bathymetry profiles of the Sout Estuary, Transects 1 to 5

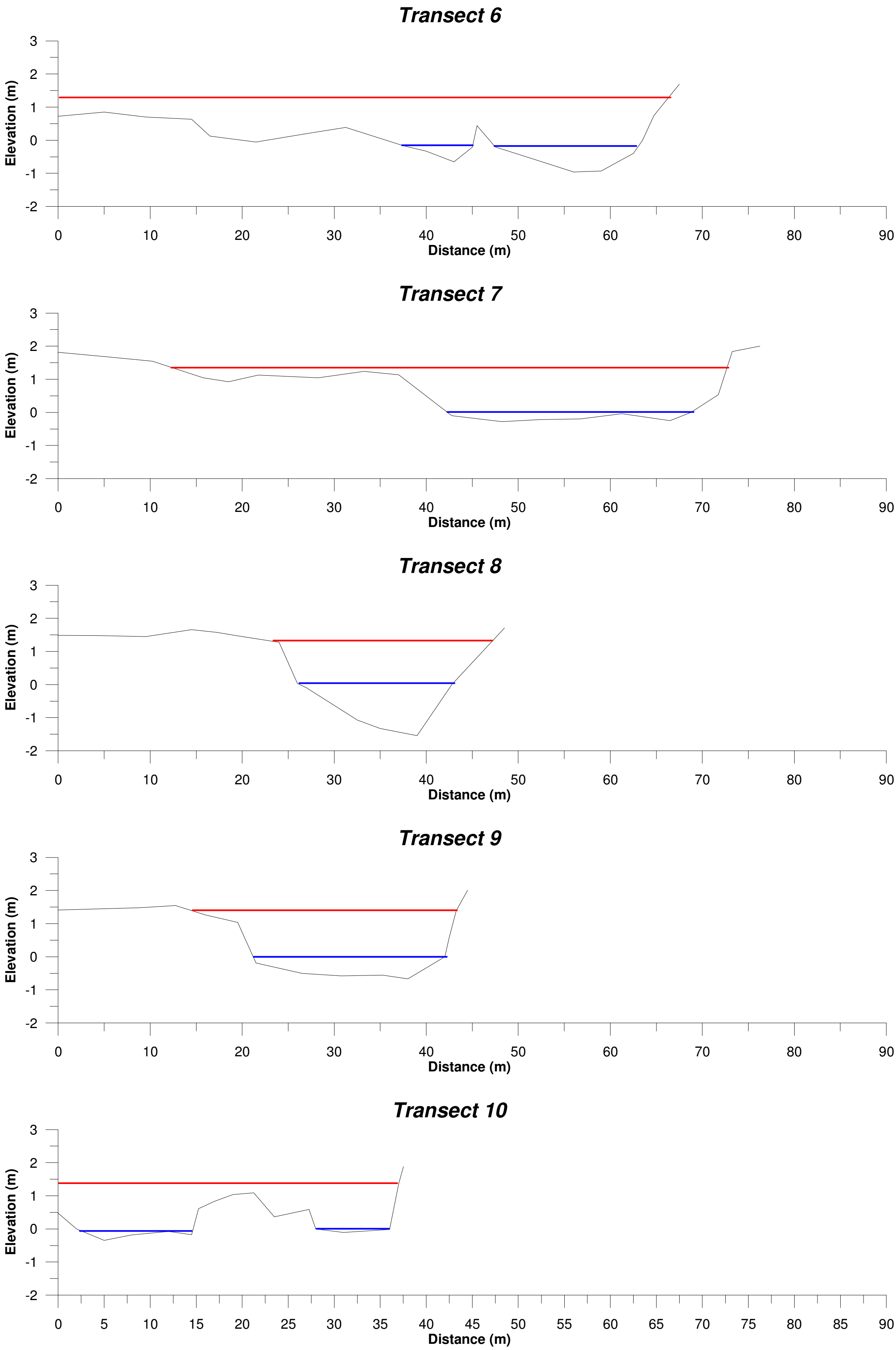

Figure 7. Bathymetry profiles of the Sout Estuary, Transects 6 to 10

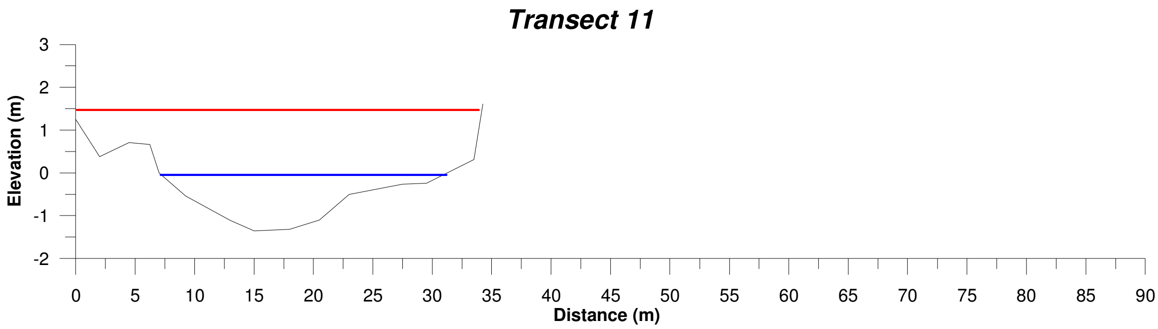

Figure 8. Bathymetry profiles of the Sout Estuary, Transect 11

Additional profile measurements were also taken of the rocky cove at the mouth of the estuary. Transects 1 and 2 extends over the berm area into the cove at the mouth (see **Figure 9**). These transects show a relatively steep beach slope to the sea with a gentle slope leading from the low water mark to the open ocean.

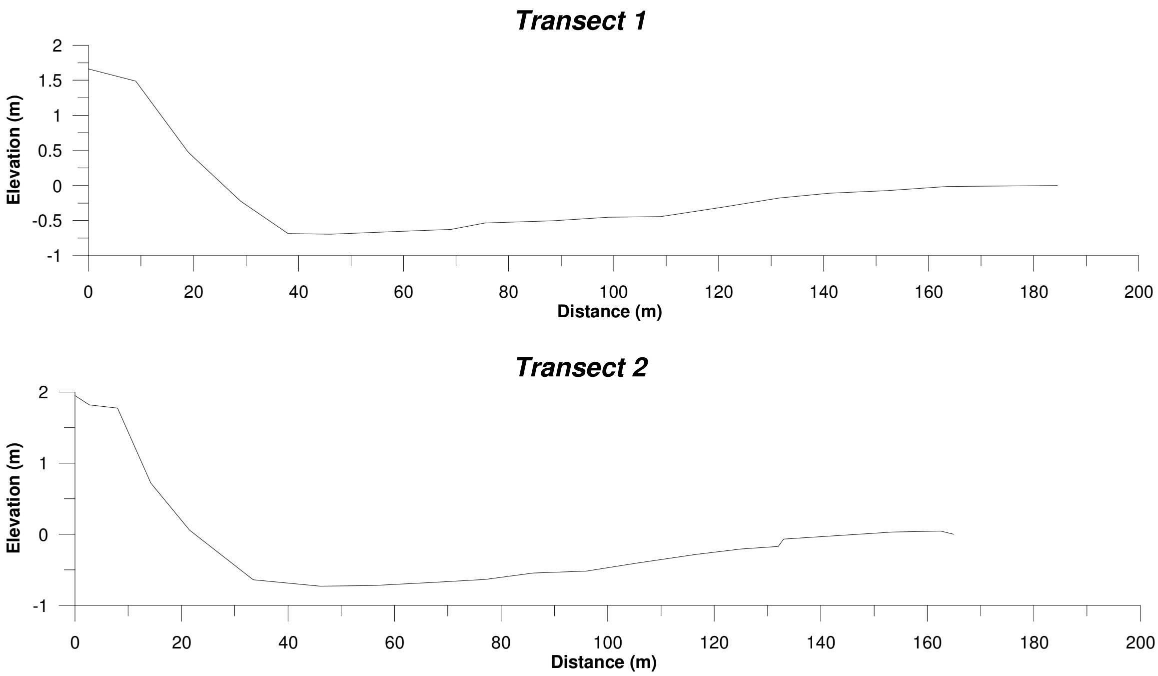

Figure 9. Bathymetry Profile of Sout Estuary berm, Transects 1 and 2

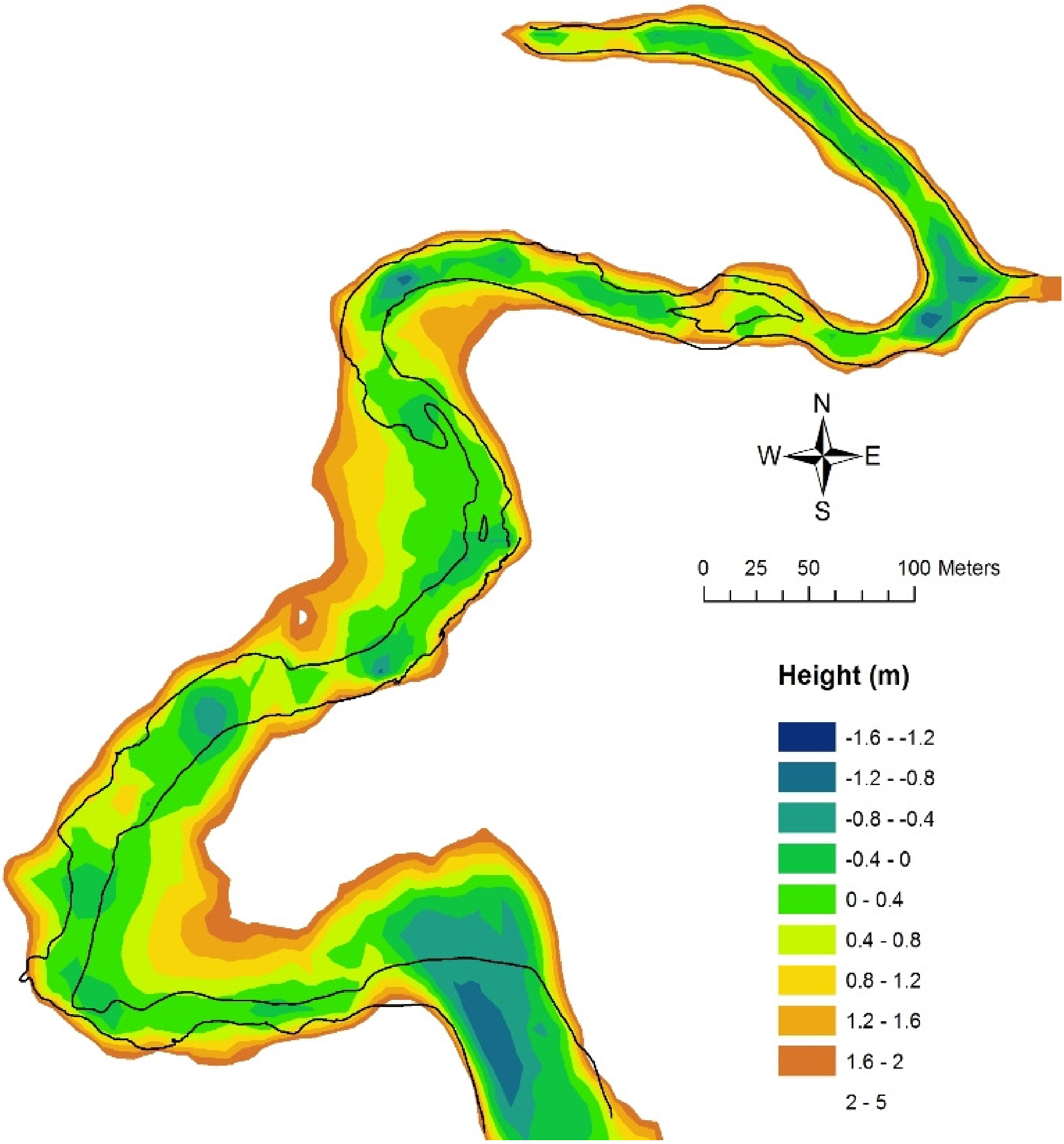

Figure 10. Interpolated surface plot showing the bathymetry of the Sout Estuary

Elevation data was collected using a Dumpy level. Spatial data was collected in the field using a GPS and ArcPad version 7 software. The bathymetric map in Figure 8 was created in ArcGIS version 9.1 using the Kriging method in Geostatistical Analyst.

5 Hydrodynamics

Mouth conditions

The mouth of the Sout Estuary is protected by rocky headlands to the east and the west. The narrow beach on the adjacent coastline indicate limited sediment transport in the marine environment. The estuary is permanently open as result of low closing forces (i.e. small wave action and limited sediment input).

Figure 11. Lower reaches of the Sout Estuary

Marine sediment only penetrates in significant amounts to above the first bend (CSIR 1990). The sediment yield from the Sout River cathment is low and do not contribute significantly to the overall sedimentation rate in the system (CSIR 1983). The confined nature of the estuary channel (steep banks and limited flood plain area) also facilitate efficient scouring of accumulated sediments during flood events which contributes to open mouth conditions.

Table 1 summarises observations based on the Sout Estuary aerial photographic record. The system is permanently open with outflow varying between a trickle through the mouth to significant input of black water to the beach cove at the mouth.

Table 1. An analysis of the Sout Estuary aerial photographs.

Date	Mouth Status	Observation
1936	**Open**	**Some discolouration in marine environment**
1971	**Open**	
1974	**Open**	**Significant flows, black water in marine bay**
1960	**Open**	**Small Channel**
4-12-1972	**Open**	
05-1974	**Open**	**Significant flows**
5-04-1976	**Open**	**Significant flows, black water in marine bay**
8-04-1977	**Open**	**Significant flows, black water in marine bay**
21-04-1979	**Open**	**Some discolouration in marine environment**

Salinity and temperature

Measurements of the salinity penetration into the Sout Estuary were conducted on four occasions:

- April 2007 (this study)
- December 2006 (this study)
- June 1994 (T Harisson, unpublished data)
- April 1981 (NRIO, unpublished data)

March/April 2007

Salinity measurements were taken along 20 hydrographical stations in March and April 2007 (Figure 12 and Table 2) from the mouth (S 0) to 1.13 km (S19) upstream.

Due to the shallow nature of the Sout Estuary it is very susceptible to changes in either river or tidal flows. The system exhibits significant changes in its water column composition (e.g. salinity and temperature) over short periods. For example, during the high spring high tide of 20 March 2007 the Sout Estuary was virtually completely marine dominated (Figure 13). Saline water (>30ppt) was recoded up to 0.8 km from the mouth with very little stratification.

In contrast, measurements taken on the spring low tide on the same day show a brackish system (> 10 ppt) that is freshwater dominated in its upper reaches (Figure 14). Stratification was observed with pockets of more saline water (> 20 ppt) only recorded in the deeper areas (>1.0 m) of the estuary at ~0.5 and 0.7 km from the mouth. The rapid change in the water column composition between the low and high is an indication of rapid flushing and very little retention in the system.

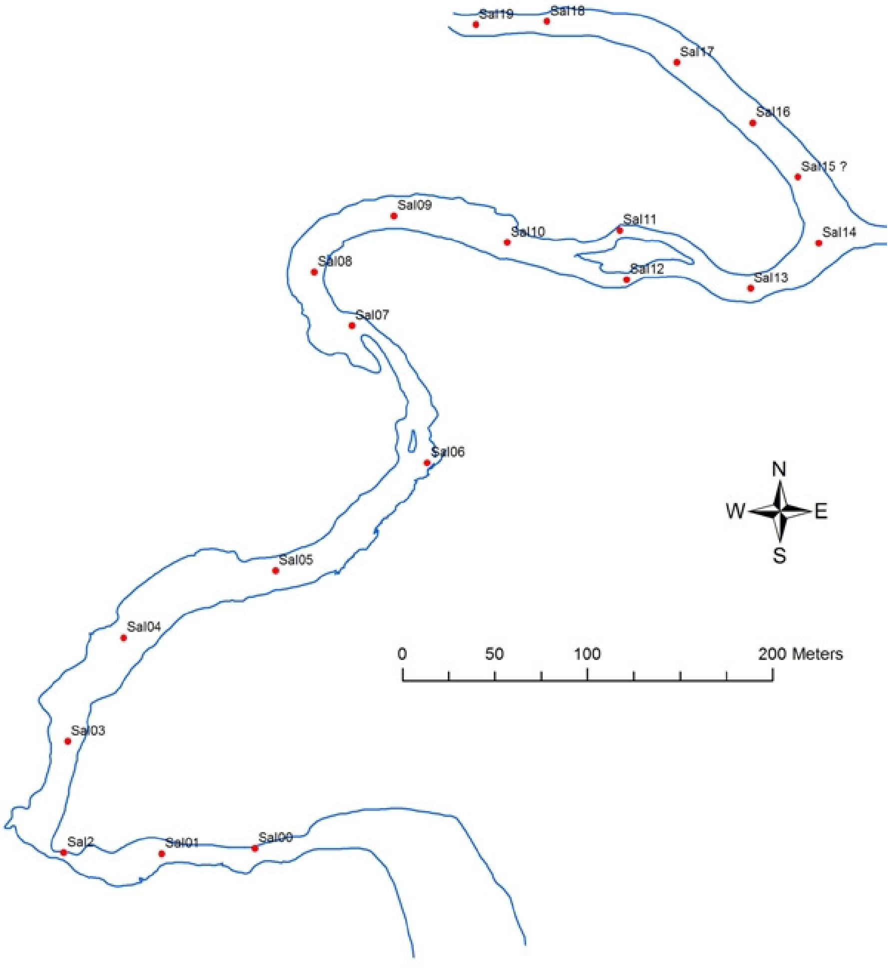

Figure 12. Study site map showing salinity profile stations.

Table 2. Distance from mouth for the Sout Estuary Stations

Station	Distance (m)	Station	Distance (m)	Station	Distance (m)
S00	140	S7	620	S14	900
S1	185	S8	645	S15	940
S2	225	S9	705	S16	980
S3	295	S10	755	S17	1030
S4	360	S11	820	S18	1100
S5	440	S12	820	S19	1135
S6	535	S13	870		

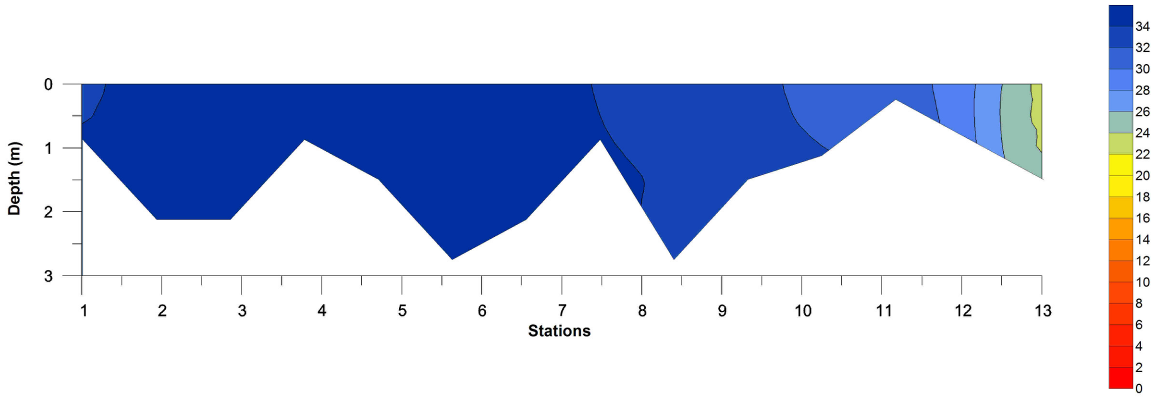

Figure 13. Salinity profile during spring high tide on 20/03/07

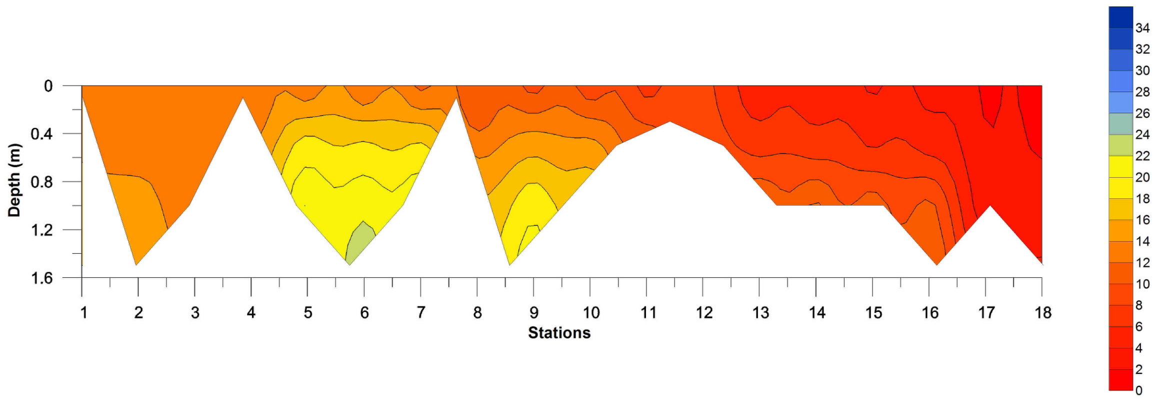

Figure 14. Salinity profile during spring low tide on 20/03/07

During the neap low tide salinity and temperature survey of 10 April 2007 (Figure 143), the Sout Estuary was stratified in areas deeper than 0.5 m. Saline water (>30 ppt) was only measured in the deeper areas of the estuary at ~0.05 and 0.5 km from the mouth. Brackish water (10 – 20 ppt) were recorded in the middle to upper researches of the system, with a pocket of more saline water (> 25 ppt) recorded in the deep section about 0.7 km from the mouth. Fresh water was only measured in the surface layer at the head of the estuary.

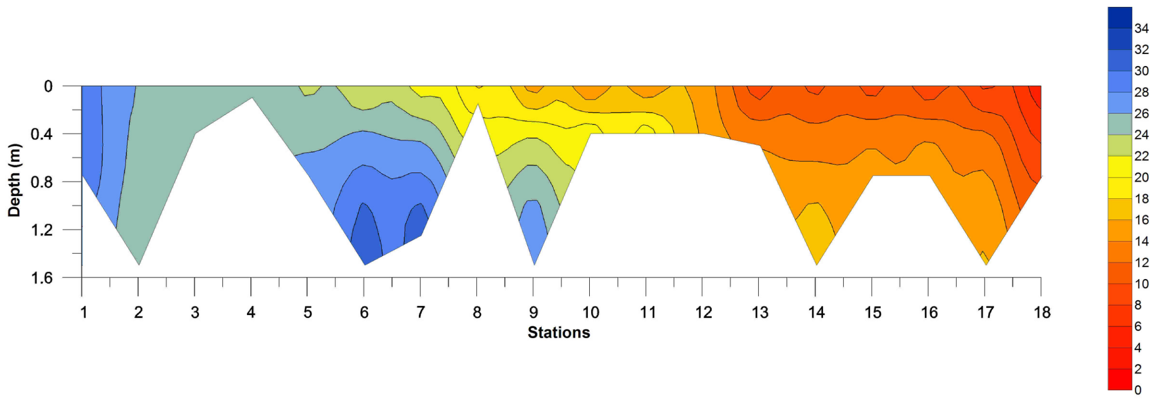

Figure 15. Salinity profile during neap low tide on 10/04/07

December 2006

The Sout Estuary show considerable stratification during both sampling periods. Measurements taken 6 December 2006 (Table 4) indicate that while the surface waters was fresh < 2 ppt, pockets of saline water was detected in areas were the estuary was deeper than 0.5 m. Values greater than 20 ppt was recorded in the bottom waters of the system about 0.35, 0.5 and 0.7 km from the mouth.

Table 3. Salinty data for the Sout Estuary biological stations, 6 December 2006

Station	Depth (m)	Salinity (ppt)
mouth	0	5.0
0.1	0	4.7
0.35	0	1.9
0.35	0.2	15.1
0.35	0.6	23.8
0.5	0	1.4
0.5	0.2	1.3
0.5	0.4	16.5
0.5	1	27.0
0.7	0	0.3
0.7	0.2	16.6
0.7	0.4	20.7
0.7	0.6	21.0
0.9	0	0.1
0.9	0.4	0.1

27 June 1994

Harrison sampled the Sout Estuary once-off in June 1994 (Harrison, unpublished data). The salinity of the system was 23 ppt.

Date	Distance form mouth (km)	Depth (m)	Surface temperature	Bottom temperature	Surface Salinity	Bottom Salinity
27 June 1994	**0.3**	**0.3**	**14**	**14**	**23**	**23**

April 1981

Even though the Sout Estuary is very shallow, stratification was also evident in the deeper pools during the April 1981 NRIO survey (NRIO unpublished data). Tidal seawater penetrates the estuary under the outflowing water, with salinity differentials of 16 and 15 ppt recoded at 0.45 and 0.65 km from the mouth where saline water were tapped in deeper pools.

Date	Distance form mouth (km)	*Depth (m)	Surface temperature	Bottom temperature	Surface Salinity	Bottom Salinity
April 1981	**0.15**	**0.7**	**18.2**	**-**	**25**	**-**
	0.45	**2.0**	**18**	**17.7**	**16**	**32**
	0.65	**-**	**17.7**	**17.3**	**5**	**20**
	0.9	**0.6**	**-**	**-**	**2**	**6**

**Depth inferred from Secchi transparency measurements*

6 Water levels

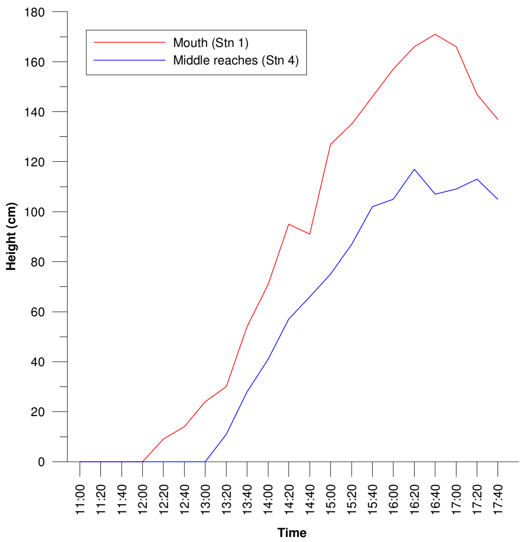

Figure 16. Water level fluctuations at two stations during spring tide on 20/03/07

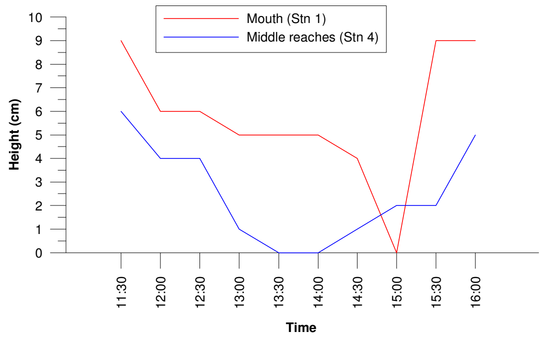

Figure 17. Water level fluctuations at two stations during neap tide on 10/04/07

Water level data was collected during a spring tide on 20 March 2007 and a neap tide on 10 April 2007 (Figure 16 and Figure 17). The Sout Estuary displays surprisingly large tidal amplitude for a small, shallow, perched system. During the spring tide a tidal amplitude of 1.7 m was recoded near the mouth of the system. The difference between the predicted low and high tides for the day were 2.14m, indicating a 0.5 m reduction in the tidal amplitude as it enters the system from the sea. As the tidal wave travel upstream it was dampened by about 0.5 m more to ~ 1.2 m in the middle reaches of the estuary. This significant tidal exchange is supported by the large fluctuations in salinity recorded during the March 2007 survey. Unfortunately the neap tide readings were inconclusive regarding the degree to which tidal exchange occur on a much smaller tide.

7 References

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CSIR 1983. Estuaries of the Cape. Part II. Synopses of available information on individual systems. Report no 19. Groot (Wes) (CMS 23) and Sout (CMS 22).

8 Raw Data

Table 4. Distance from the biological stations to the sea

Distance from the biological stations to the sea	
Station	Distance (m)
S1	**100**
S2	**350**
S3	**500**
S4	**700**
S5	**900**

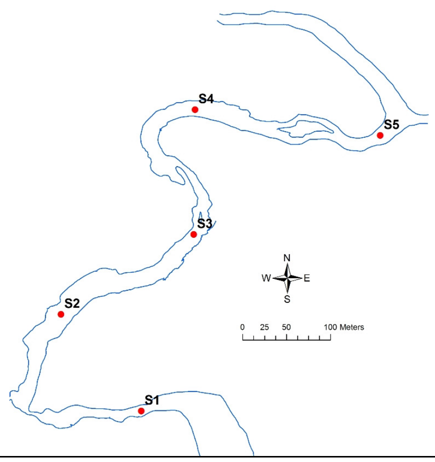

Table 5. Physico-chemical data for the Sout Estuary biological stations, 6 December 2006

Station	Depth (m)	Salinity (ppt)	Conductivity (mS or uS)	Temp (^{o}C)	Secchi (cm)	DO %
mouth		5		20.6		
0.1	0	4.7	8.37	20.5	10	
0.35	0	1.9	3707	20.6		
0.35	0.2	15.1	25.12	19.2	60	
0.35	0.6	23.8	37.59	19.5		
0.5	0	1.4	2531	20.7		
0.5	0.2	1.3	2614	20.3	75	
0.5	0.4	16.5	22.2	18.7		
0.5	1	27	42.28	18.7		
0.7	0	0.3	594	19.9		
0.7	0.2	16.6	20.45	18.8	80	
0.7	0.4	20.7	33.04	18.6		
0.7	0.6	21	33.34	18.6		
0.9	0	0.1	160.4	18.9	40	
0.9	0.4	0.1	161.7	18.4		

Table 6. Physico-chemical data for the Sout Estuary biological stations, 10 April 2007

Station	Depth (m)	Salinity (ppt)	Conductivity (mS or uS)	Temp (°C)	Secchi (cm)	pH	DO %
0.1	0	28.30	43.80	19.52	75 (to bottom)	7.79	93.1
0.1	0.5	28.65	44.27	19.51		7.83	93.0
0.1	0.75	30.11	46.30	19.23		7.87	92.9
0.35	0	23.65	37.23	20.62	100 (to bottom)	7.99	94.5
0.35	0.5	30.40	46.69	19.21		7.85	79.3
0.35	1	33.23	50.57	18.56		7.85	78.8
0.5	0	9.66	16.29	21.90	75 (to bottom)	7.96	93.9
0.5	0.5	30.26	46.50	19.86		7.71	88.9
0.5	1	33.36	50.75	18.83		7.66	96.0
0.7	0	8.49	14.57	21.77	40 (to bottom)	8.24	99.7
0.7	0.4	30.18	46.40	20.12		7.65	85.4
0.9	0	4.16	7.50	19.05	100 (to bottom)	8.38	80.6
0.9	0.5	16.17	26.35	20.51		7.77	96.3
0.9	1	17.71	28.65	20.43		7.7	100

Table 7. Surface water area and volumes at certain elevations above mean spring low water level

Height (m)	Area (m^2)	Volume (m^3)
2	53433.86	83821.07
1.9	52334.48	78642.78
1.8	51168.09	73572.36
1.7	49958.00	68615.95
1.6	48738.29	63776.26
1.5	47520.43	59052.62
1.4	46182.91	54452.17
1.3	44938.33	49975.08
1.2	43596.98	45622.39
1.1	42130.18	41405.51
1	40551.69	37334.16
0.9	38918.65	33419.02
0.8	37256.97	29664.32
0.7	35659.62	26067.76
0.6	34137.61	22622.06
0.5	32620.54	19322.24
0.4	31058.20	16170.73
0.3	29314.54	13178.23
0.2	27251.73	10369.13
0.1	24499.95	7792.56
0	18495.73	5539.47
-0.1	13285.01	3980.83
-0.2	10214.76	2816.22
-0.3	8003.19	1918.82
-0.4	6317.60	1207.41
-0.5	4301.73	676.92
-0.6	2636.51	346.95
-0.7	111.37	147.98
-0.8	449.52	88.01
-0.9	288.01	52.19
-1	184.01	29.39
-1.1	116.35	14.78
-1.2	63.52	6.04
-1.3	25.69	1.75
-1.4	6.90	0.30
-1.5	0.53	0.01

Appendix C

Specialist Report: Water Quality and Microalgae

by

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Introduction

The Sout estuary is located in the Western Cape Province, approximately 20 km east of Plettenberg Bay (33º59'20"S; 23º32'12"E). The Sout River is short, 15 km, and the catchment is small, 35.5 km2. There is little development in the catchment so river flow is regarded to be close to natural (~90% MAR) (Van Niekerk 2007). The climate is warm temperate and the rainfall for the region has neither a summer nor a winter pattern. The highest precipitation generally occurs during late summer (February-March) and during spring (September-November). The land use in the catchment is minimal and the estuary falls within the De Vasselot Forestry Reserve so it is unlikely that there are any significant impacts on water quality. There is a small quantity of water transferred from the Sout River to the Matjies River but the amount is considered to be minimal (Van Niekerk 2007; Appendix A).

The primary aims of this report are to determine the present status of water quality and microalgae (phytoplankton and microphytobenthos) in the Sout estuary, determine how this has changed from before anthropogenic influence (reference condition) and then to predict changes in response to increasing levels of abstraction.

Materials & methods

Study site

Samples for water quality and microalgal analyses were collected at sites located 0, 0.1, 0.35, 0.5, 0.7 and 0.9 km from a sea site located just outside the mouth of the estuary (Fig. 1) during December 2006 and April 2007. It is important to note that the mouth is situated within a cove and that water within the cove does frequently contain brackish water (<35 ppt). The cove can be considered to be an extension of the estuary, particularly during periods of medium to high river flow.

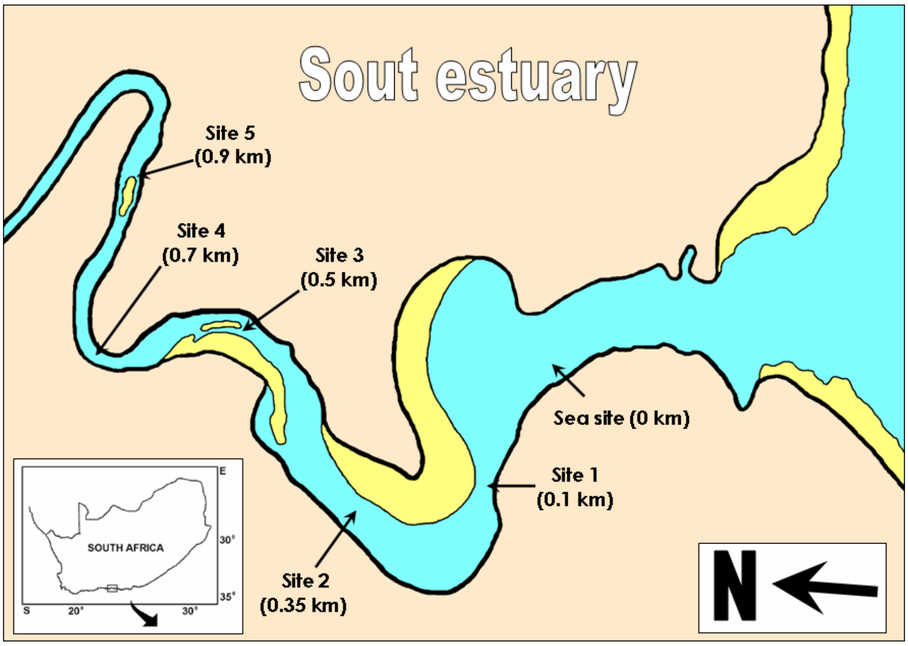

Figure 1. *Map of the Sout estuary showing the locations of the sampling stations (with distance from the mouth) for the study. The sea site falls within a cove and was considered to be the mouth of the estuary in this report.*

WATER QUALITY

Twenty millilitres of filtered water samples (Whatman GF/C) were preserved using 2 drops of 5% $HgCl_2$ then frozen. Water samples were chemically analyzed in the laboratory (NMMU), by manual determinations as described in Grasshof et al. (1983), for total oxidised nitrogen (nitrate + nitrite, measured as NO_2-N after reduction), phosphate measured as dissolved inorganic phosphate (DIP) and ammonium (measured as NH_4^+). Silicate was analysed using the molybdate method described by Strickland & Parsons (1972). Measurements described in this report were replicated, the concentrations averaged and expressed as µmol.L^{-1} (µM).

PHYTOPLANKTON BIOMASS

Replicate water column samples were collected from the surface and bottom and then gravity filtered through plastic Millipore towers using Whatman (GF/C) glass fibre filters. The samples were collected using a 500 ml weighted pop-bottle. The filters were frozen in the field and the chlorophyll *a* was extracted later in the laboratory by placing the filters into glass vials containing 10 ml of 95% ethanol (Merck 4111). The samples were then stored overnight at 1-2°C. The contents of the vials were filtered and the light absorbance at 665 nm of the supernatant was determined, before and after the addition of 0.1N HCL, using a spectrophotometer within 24 hours. The equation used was that of Hilmer (1990), derived from Nusch (1980):

$$\textbf{Chlorophyll } \boldsymbol{a} \textbf{ biomass } (\mu g\ l^{-1}) = (E_{b665} - E_{a665}) \times 29.6 \times (v/(V \times l))$$

Where: E_{b665} = absorbance at 665 nm before acidification

E_{a665} = absorbance at 665 nm after acidification

v = volume of solvent used for the extraction (ml)

V = volume of the sample filtered (l)

L = path of spectrophotometer cuvette (cm)

29.6 = constant calculated from the maximum acid ratio (1.7) and the specific absorption coefficient of chlorophyll-a in ethanol (82g.l^{-l}. cm^{-1})

MICROPHYTOBENTHOS BIOMASS

Microphytobenthos biomass was estimated using benthic chlorophyll *a* content as an index (µg chl-*a* per gram of freeze dried sediment; expressed as µg.g^{-1}). Four surface scrapes of known area, ~2 mm deep, were collected from each site then frozen and kept in the dark before being freeze-dried in a Secfroid Lausanne Suisse freeze-drier. The process of freeze drying eliminates the error related to the water holding capacity of different sediment types and organic content. Once freeze-dried, 4 ml of 95% ethanol (Merck 4111) was added to approximately 100 mg of sample and the pigment was left to extract in a fridge for 24 hours. After extraction the samples were well mixed using a whirlmixer (WM/250/SC/P) and the extract injected into a high performance liquid chromatograph (HPLC) attached to Waters-Lambda-Max 481 LC spectrophotometer and Waters LM-45 solvent delivery system for chlorophyll *a* analysis. A 30% methanol and 70% acetone mixture was used as a carrier. The system was calibrated using the chlorophyll *a* of red seaweed, (*Plocamium collorhiza*) because it contains no chlorophyll *b* that might interfere with the chlorophyll *a* reading. Chlorophyll *a* absorbance was measured at 665 nm. The chlorophyll *a* concentration was determined from the absorbance reading using the modified equation of Nusch (1980):

$$\textbf{Chl-}\boldsymbol{a} \textbf{ biomass } (\mu g\ g^{-1}) = [((E_{Ploc665} - (E_{Ploc665}/1.7)) \times 29.6] \times (V/M) \times E_{HPLC}$$

Where: $E_{Ploc665}$ = *Plocamium collorhiza* chlorophyll *a* absorbance measured using the spectrophotometer at 665 nm (calibration formula in squared brackets)

29.6 = constant calculated from the maximum acid ratio (1.7) and the specific absorption coefficient of chlorophyll *a* in ethanol (82 g l^{-1} cm^{-1})

V = volume of ethanol used to extract pigment (ml)

M = mass of freeze-dried sample (g)

E_{HPLC} = HPLC absorbance value

PHYTOPLANKTON IDENTIFICATION

Surface water (500 ml) was collected from each site and preserved with 1 ml of 25 % Glutaraldehyde solution phytoplankton identification. Two drops of Rose Bengal were added to 60 ml of preserved water samples and poured into a 26.5 mm internal diameter settling chamber (Lund chamber). The cells were left to settle for 24 hours before identification using a Zeiss IM 35 inverted microscope at the maximum magnification of X630. A minimum of 200 cells was counted for each sample and the cells were classified according to different microalgal groups; i.e. flagellates, diatoms, dinoflagellates, cyanophytes (blue-green algae) and chlorophytes (green algae). Cell density was calculated using the formula:

$$\textbf{Cells ml}^{-1} = ((\pi r^2)/A) \times C/V$$

Where: A = area of each frame (mm^2)
C = number of cells in each frame
V = volume of sample in settling chamber (ml)

Results

Salinity (06 December 2006)

Surface salinity along the longitudinal axis of the Sout estuary ranged from 0.1 ppt to 5.0 ppt indicating a strong input of river water (Fig. 1). The flow was not strong enough to mix and flush out more saline water from some of the deeper sites in the middle reaches of the estuary. Salinity in excess of 20 ppt was measured at depths of >0.5 m. The mouth of the estuary is permanently open allowing for strong tidal exchange and a wedge of marine water being forced upstream on the flood tide. This created strong vertical stratification in the estuary and was persistent on the low tide.

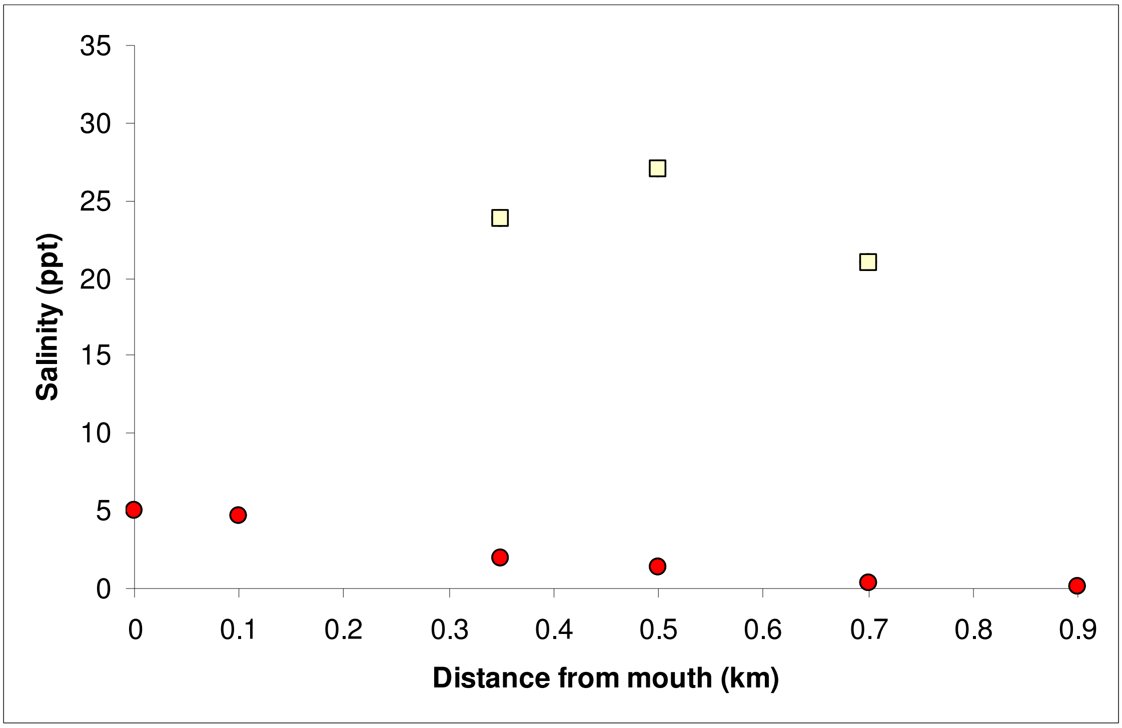

Figure 2. *Salinity along the longitudinal axis of the Sout estuary (06 December 2006). Red circles and yellow squares represent surface and bottom salinity measurements respectively.*

Salinity (10 April 2007)

The Sout estuary was stratified in April 2007, both vertically and longitudinally (Fig. 3). Surface salinity increased from 4.2 ppt near the head of the estuary (0.9 km from the mouth) to 28.3 ppt at the mouth. The salinity gradient indicates lower river flow compared to December 2006. The residence time of water in the estuary increases as river flow decreases but it is important to note that the estuary mouth is permanently open so was still strongly influenced by tidal exchange.

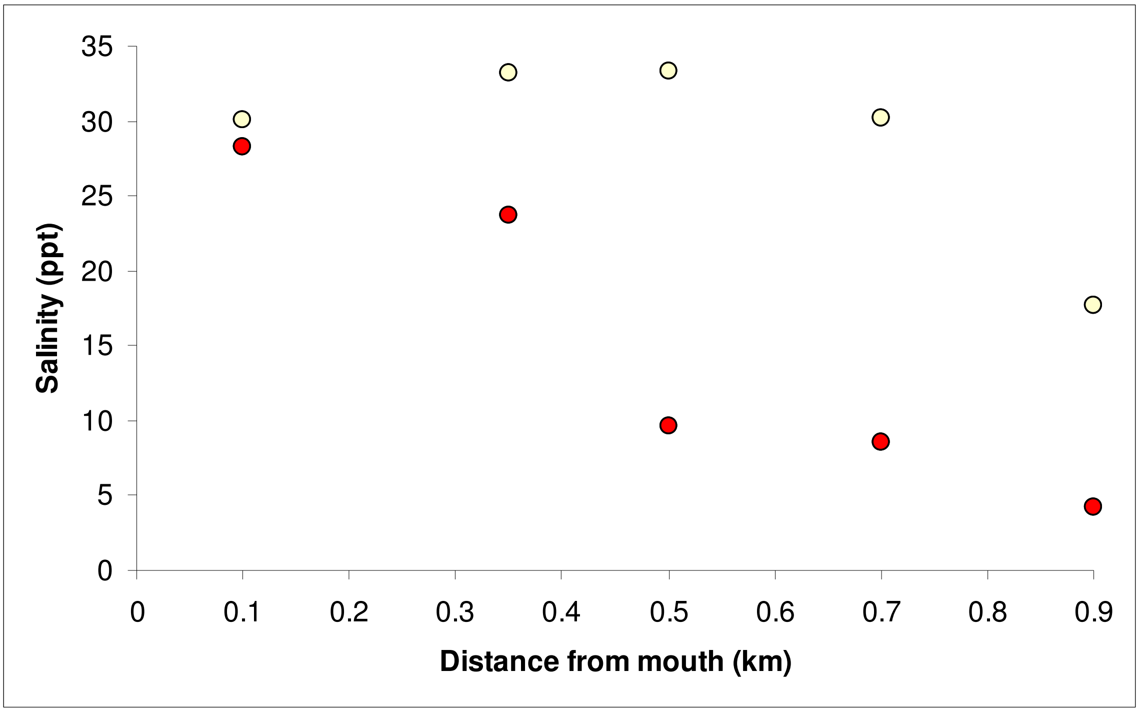

Figure 3. *Salinity along the longitudinal axis of the Sout estuary (10 April 2007). Red circles and yellow squares represent surface and bottom salinity measurements respectively.*

Nutrients (06 December 2006)

Ammonium concentration was low throughout the estuary (<1.0 µM), particularly near to the head of the estuary, indicating that concentration was low in the river water (Fig. 4). The concentration of total oxidised nitrogen (nitrate + nitrite) was evenly mixed throughout the surface water of the estuary and was slightly higher compared to bottom water. This suggests that river water was the primary source of TOxN. TOxN concentration ranged from 8.8 µM to 14.3 µM. Soluble reactive phosphorus (SRP) had a similar spatial pattern to TOxN, also indicating riverine input, and ranged in concentration from 0.9 µM to 1.6 µM. The DIN: DIP ratio was <12 throughout the estuary, which could indicate N-limitation on microalgal growth (a Redfield ratio of 16 is regarded as the optimum). Silicate concentration was low, particularly near the head of the estuary, ranging from 12.1 µM to 20.6 µM. Silicate, together with TOxN, is regarded as a 'new' nutrient, i.e. a nutrient normally imported into estuaries in river water. However, there was no evidence of this in during this sampling session.

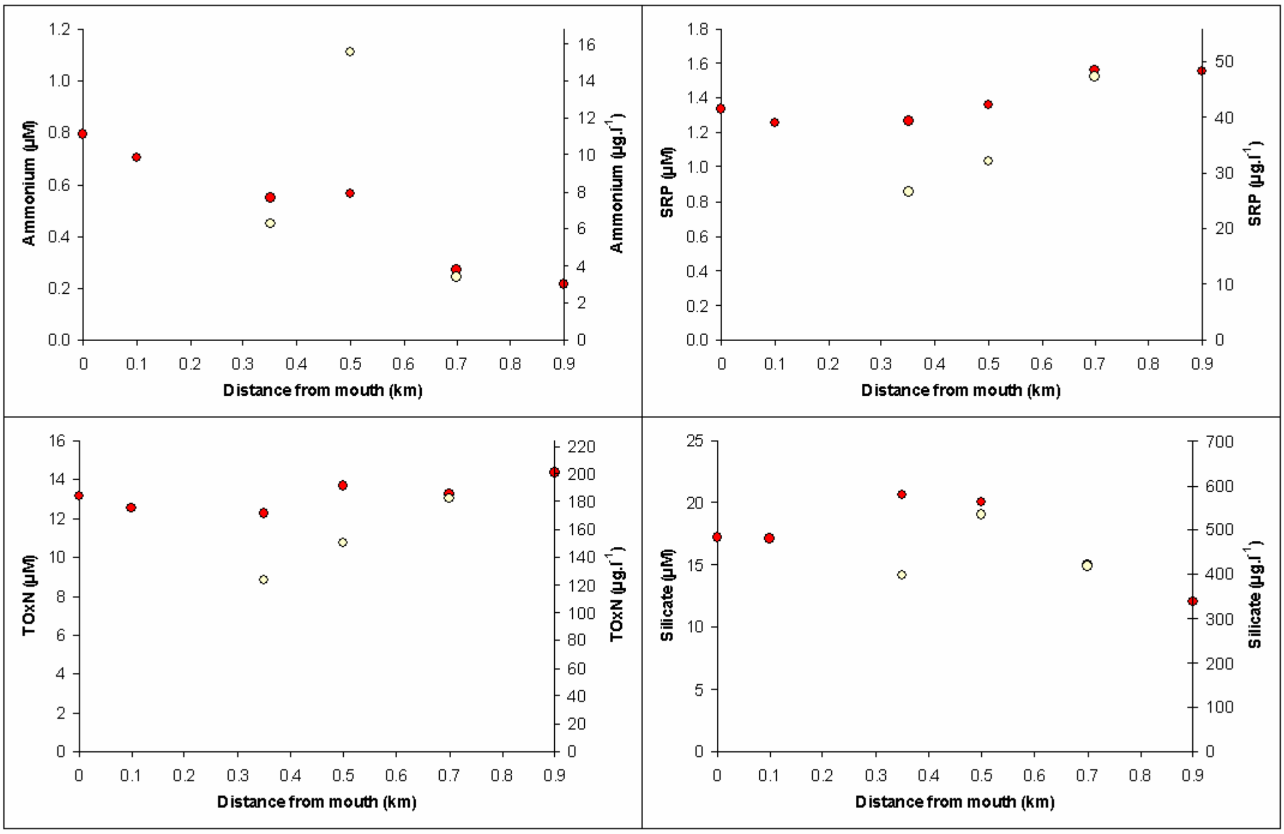

Figure 4. *Water column nutrient concentrations in the Sout estuary (06 December 2006). Red and yellow symbols represent surface and bottom concentrations respectively.*

Nutrients (10 April 2007)

There was no clear spatial pattern of ammonium in the estuary in April 2007 (Fig. 5). Average concentration in April 2007 (3.9 ± 0.6 µM) was significantly higher ($T = 180.0$; $n_{Dec.} = 18$, $n_{April} = 22$; $P < 0.001$) than measured in December 2006 (0.5 ± 0.1 µM). TOxN concentration was generally low, ranging from 1.0 µM to 4.0 µM, and there was no longitudinal gradient suggesting that TOxN concentration was low and similar in concentration to the seawater. SRP concentration was low throughout the estuary, ranging from 1.1 µM near to the head of the estuary (0.9 km) to 0.7 µM at the mouth. The gradual decrease in concentration from the head of the estuary to the mouth indicates that the river was the primary source of phosphorus. The DIN: DIP ratio, as was the case in December 2006, was <12 throughout the estuary, which could indicate N-limitation on microalgal growth. Silicate in the upper reaches of the estuary was much higher compared to December 2006: 132.9 µM compared to 12.1 µM. Silicate concentration decreased from 132.9 µM near the head of the estuary (0.9 km) to 57.4 µM just outside the mouth of the estuary.

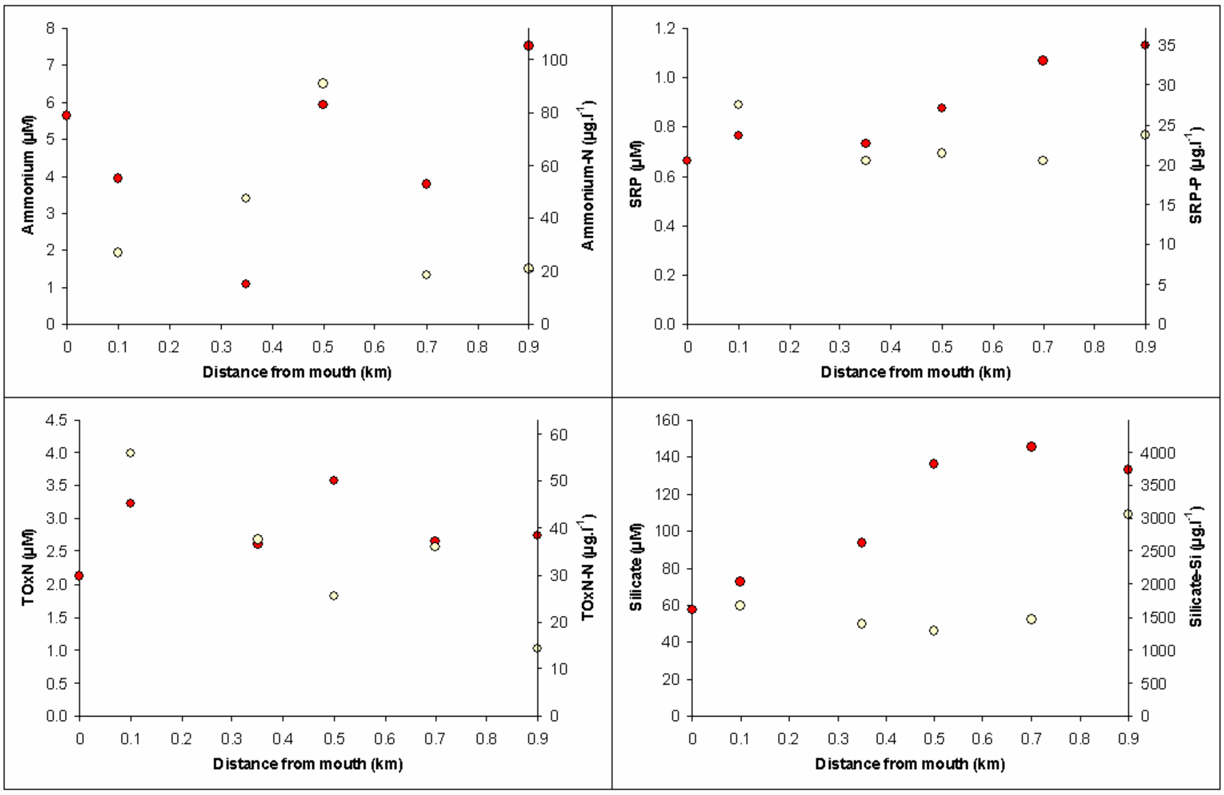

Figure 5. *Water column nutrient concentrations in the Sout estuary (10 April 2007). Red and yellow symbols represent surface and bottom concentrations respectively.*

Phytoplankton biomass

Average phytoplankton chlorophyll *a* was low in December 2006 (0.55 ± 0.12 µg.l^{-1}) and April 2007 (0.47 ± 0.10 µg.l^{-1}) compared to similar studies of other permanently open estuaries within the warm temperate South African coast (Table 1). Concentrations were generally higher in the bottom water compared to the surface (Fig. 6) and could be as a result of a number of factors: resuspension of benthic microalgal cells, a more favourable light environment, release of nutrients from the sediment and a higher retention time of water through the tidal cycle.

TABLE 1. **AVERAGE SALINITY AND PHYTOPLANKTON CHLOROPHYLL a DURING THIS STUDY (BOLD) AND PREVIOUS STUDIES (SNOW *ET AL.* 2000A; SNOW *ET AL* 2000B; SCHARLER *ET AL.* 1997) IN THE KROMME AND GAMTOOS ESTUARIES**

Estuary	Sampling date	Average salinity (‰)	Average phytoplankton chl a (µg.l^{-1}) ± SE
Sout	*6 December 2006*	*9.5 ± 2.5*	*0.55 ± 0.12*
	10 April 2007	*21.9 ± 2.4*	*0.47 ± 0.10*
Kromme	**30 July 2004**	**36.3 ± 0.2**	**3.0 ± 0.2**
	16 November 1998	**34.2 ± 0.1**	**4.2 ± 1.1**
	18 November 1998	**21.5 ± 2.1**	**1.7 ± 0.2**
	20 November 1998	**23.7 ± 1.3**	**2.1 ± 0.2**
	22 November 1998	**29.4 ± 0.6**	**4.4 ± 0.5**
	3 December 1998	**31.9 ± 0.4**	**4.3 ± 0.3**
	17 December 1998	**34.1 ± 0.2**	**5.6 ± 0.3**
	5 January 1999	**35.4 ± 0.1**	**5.2 ± 0.7**
	June 1993 –June	**28.7 ± 0.5**	**4.2 ± 3.3**
Gamtoos	**4 November 1996**	**12.5 ± 2.1**	**17.2 ± 1.6**
	11 February 1997	**9.8 ± 1.9**	**44.8 ± 6.1**
	12 November 1996	**10.8 ± 2.1**	**7.4 ± 0.5**

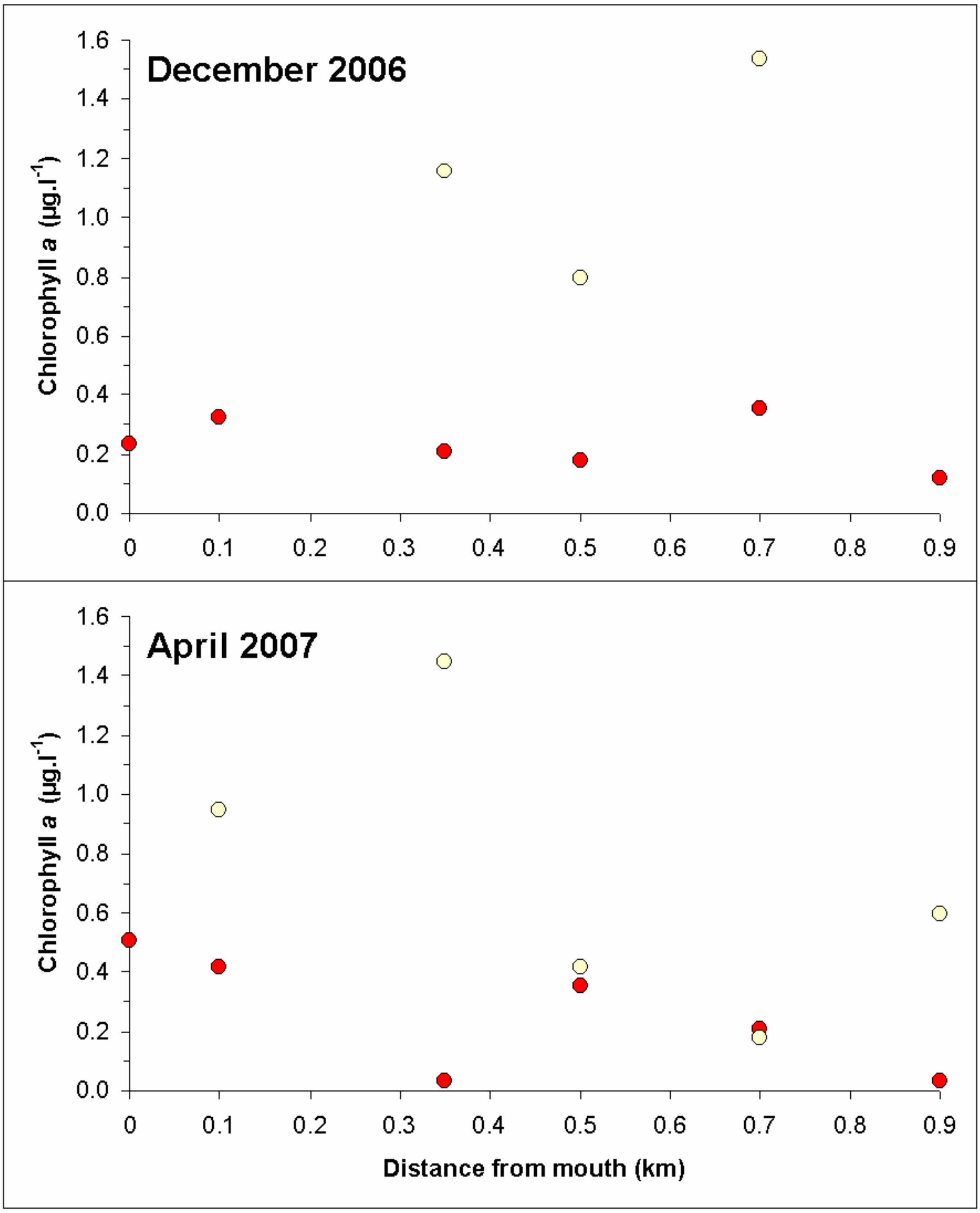

Figure 6. *Phytoplankton chlorophyll a in relation to distance from the mouth in the Sout estuary (6 December 2006 and 10 April 2007). Red and yellow symbols represent surface and bottom concentrations respectively.*

Phytoplankton group distribution (10 April 2007)

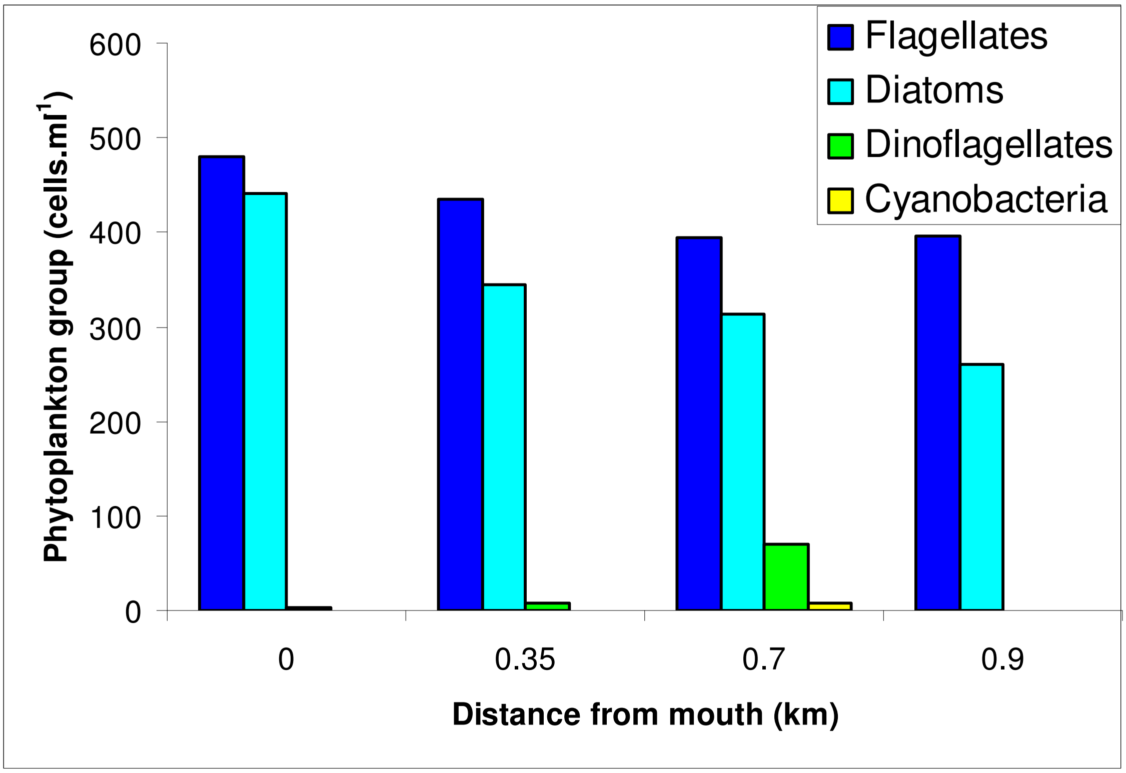

Figure 7. *Phytoplankton group cell density in surface water of the Sout estuary (10 April 2007).*

Water samples were collected from the surface of the Sout estuary in April 2007. There was a strong longitudinal salinity gradient so the phytoplankton present represented a range of marine to freshwater taxa. Flagellates and diatoms were the dominant groups throughout the estuary. Flagellate cell density was highest (480 cells.ml^{-1}) near mouth of the estuary and was lowest in the upper reaches of the estuary (391 cells.ml^{-1}). Diatoms followed a similar distribution pattern, ranging from 442 cells.ml^{-1} at the mouth and decreasing to 261 cells.ml^{-1} 0.9 km from the mouth of the estuary. Dinoflagellate and cyanobacterial cells were also present in the estuary, with highest densities 0.7 km from the mouth. Total cell density can be regarded as low (<1000 cells.ml^{-1}).

Benthic microalgal biomass

Average benthic chlorophyll *a* ranged from 1.0 ± 0.2 µg.g^{-1} (0.1 km, subtidal) to 17.5 ± 2.5 µg.g^{-1} (0.5 km, intertidal) in December 2006 and from 2.7 ± 0.7 µg.g^{-1} (0.1 km, subtidal) to 32.1 ± 1.7 µg.g^{-1} (0.5 km, intertidal) in April 2007 (Fig. 8). The intertidal chlorophyll *a* contents were comparable to contents measured in other permanently open estuaries along South Africa's warm temperate coast (Table 2). The spatial distribution was similar to other permanently open estuaries: lowest at the mouth and head of estuaries and reaching a maximum in the middle reaches where the organic and fine particle content is usually highest.

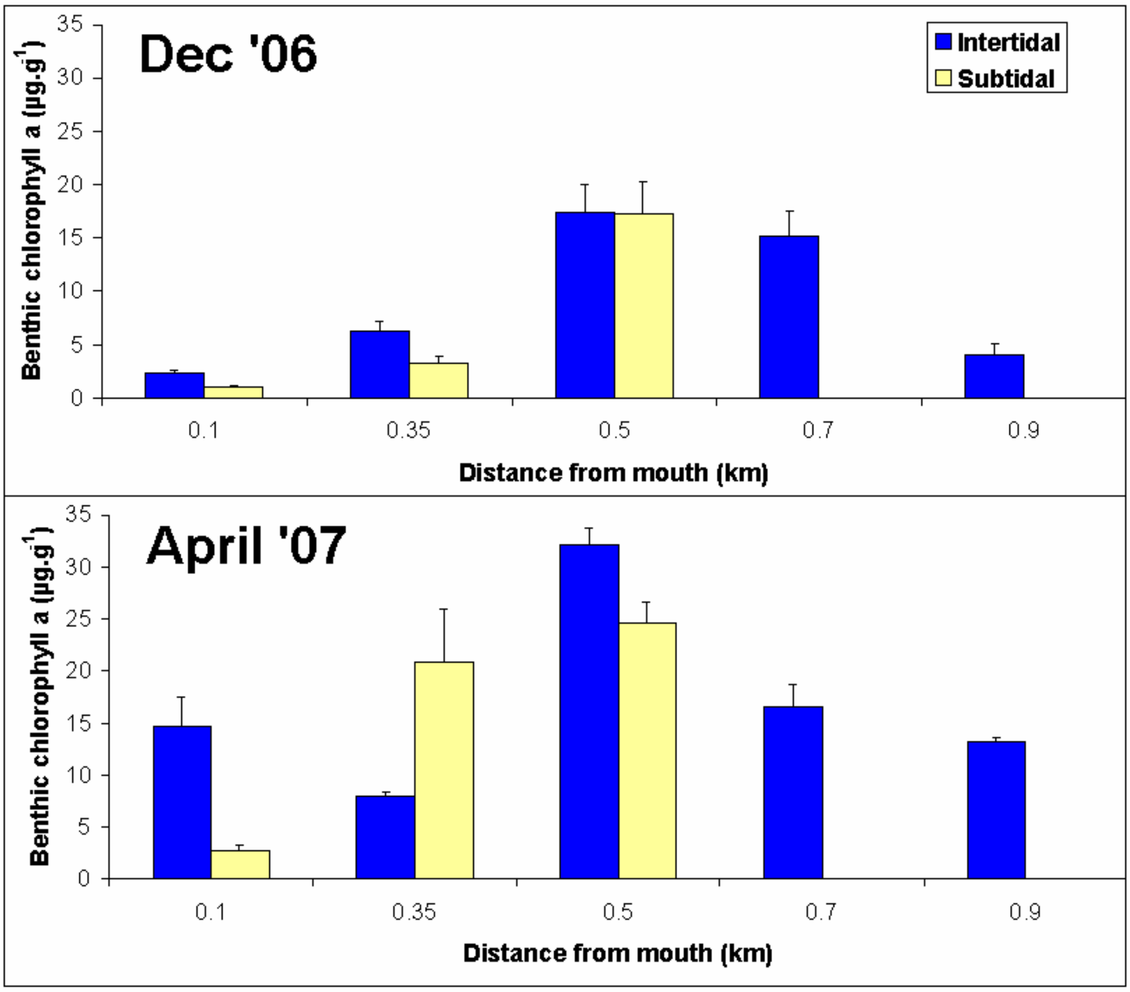

Figure 8. *Intertidal and subtidal benthic chlorophyll a in the Sout estuary (6 December 2006 and 10 April 2007). Vertical bars represent ± SE mean.*

TABLE 2. **AVERAGE INTERTIDAL BENTHIC CHLOROPHYLL A DURING THIS STUDY** (BOLD) **AND STUDIES OF OTHER PERMANENTLY OPEN SOUTH AFRICAN ESTUARIES (SNOW, UNPUBLISHED DATA)**

Estuary	Sampling date	Intertidal Chl *a* ($\mu g.g^{-1}$)
Sout	*6 December 2006*	*9.1 ± 1.7*
	10 April 2007	*16.9 ± 2.0*
Kromme	**30 July 2004**	**4.9 ± 0.4**
Gamtoos	**7 August 2002**	**27.7 ± 3.0**
	21 February 2003	**10.4 ± 0.9**
Keurbooms	**25 August 2002**	**9.5 ± 0.8**
Sundays	**19 February 2003**	**9.1 ± 1.0**
	25 July 2002	**10.2 ± 1.0**
Swartkops	**5 December 2002**	**3.7 ± 0.6**
	12 February 2002	**11.2 ± 0.9**
	15 August 2003	**22.5 ± 1.9**
	28 November 2001	**5.9 ± 0.9**
	30 October 2001	**8.2 ± 0.8**

Discussion

Present state

Typical abiotic states, based on river flow, are as follows (CSIR 2007): Predominantly fresh (river flow >1.0 $m^3.s^{-1}$), strong salinity gradient (river flow between 0.05 and 1.0 $m^3.s^{-1}$) and marine dominated (river flow < 0.05 $m^3.s^{-1}$). There was little reliable river flow data to base the conceptual model that was developed for the abiotic states so the model was of low confidence.

The *predominantly fresh state* is most likely to occur during and shortly after (<1 week) peak flood events. The retention time of the water mass in the estuary is likely to be very short (<1 day) and the estuary water, penetrating up to 200 m into the cove outside the mouth, will be dominated by freshwater (CSIR 2007). Based on December 2006 results, dissolved inorganic nitrogen (DIN), soluble reactive phosphorus (SRP) and silicate concentrations are likely to be >18 µM, >4 µM and <13 µM throughout the estuary respectively. The results should be regarded with caution because the estuary was not sampled during a predominantly fresh state. There was still some saline water (>20 ppt) in deeper reaches of the estuary in December 2006.

The *salinity gradient state* is likely to be the most commonly occurring state in the Sout estuary and retention time is still likely to be very short (<1 week). There is a large difference in volumes of water between the spring high (~60 000 m^3) and spring low tides (~5 500 m^3) so the estuary is likely to be very saline (average salinity >30 ppt) during high tides and reverting to a more brackish stratified system during low tides. During the low tides the upper reaches of the estuary will be freshwater dominated (<10 ppt), with pockets of more saline water (>20 ppt) occurring in deeper areas (>1 m) of the middle estuary (~0.5 km from the mouth) (CSIR 2007).

The relationship between inorganic nutrients and salinity is likely to be as follows during the salinity gradient state (based on the results of the December 2006 and April 2007 results):

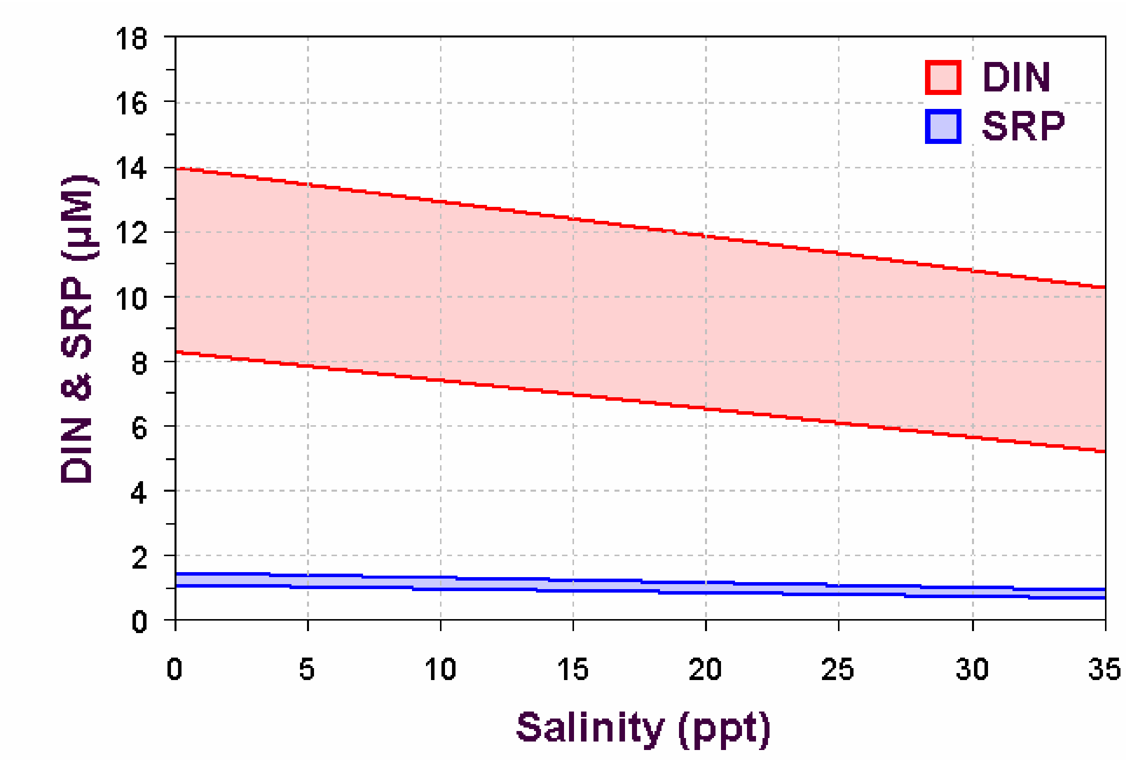

Figure 9. *The relationship between salinity and dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) based on December 2006 and April 2007 results. Upper limits relate to high flow (based on December 2006 data).*

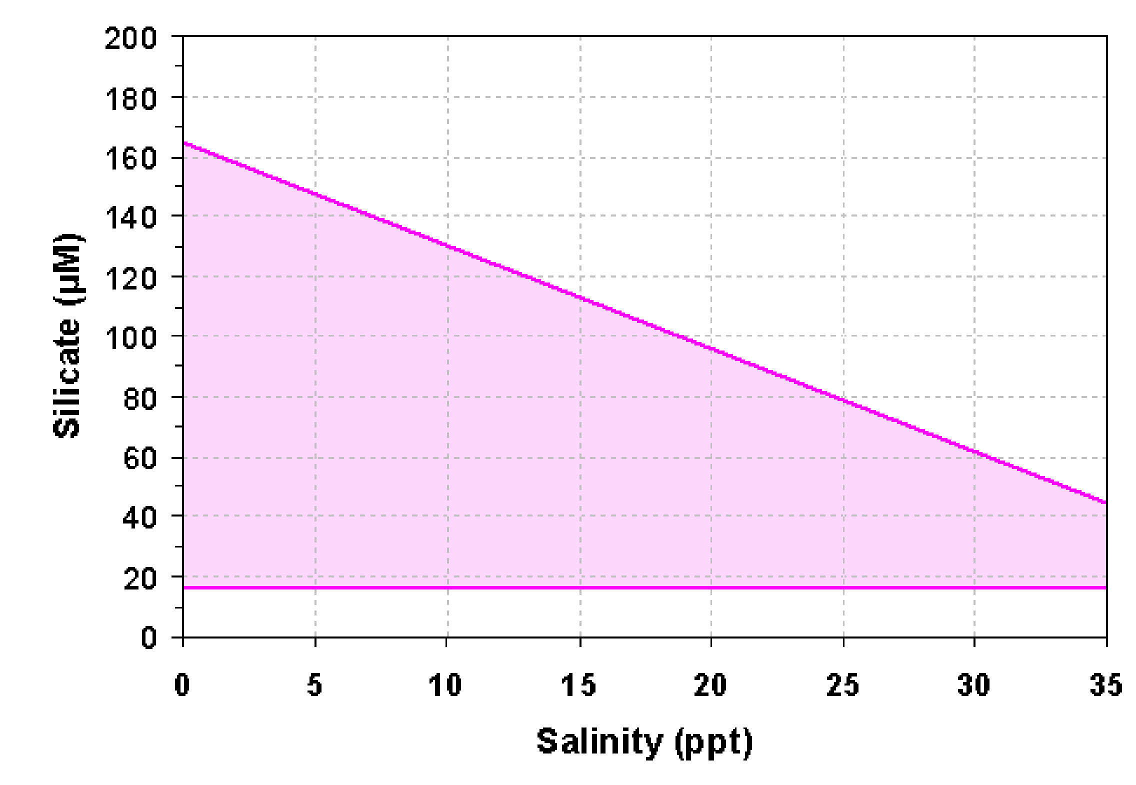

Figure 10. *The relationship between salinity and silicate based on December 2006 and April 2007 results. Upper limit relates to low flow (based on April 2007 data).*

At river flows close to 1.0 $m^3.s^{-1}$, DIN, SRP and silicate concentrations are likely to be approximately 14 µM, 1.5 µM and 20 µM in the fresh upper reaches of the estuary respectively. At lower river flows (flows of ~0.05 $m^3.s^{-1}$) DIN, SRP and silicate concentrations are likely to be 8 µM, 1 µM and 160 µM in the fresh upper reaches of the estuary respectively. There should be a slight decrease in nutrient concentrations as the water becomes more saline nearer to the mouth of the estuary.

It is important to note that Schumann (1999) found that strong southeast winds resulted in the upwelling of cold, nutrient-rich oceanic water along the Agulhas Bank. The study found dramatic drops in water temperature, ~10ºC, in the Knysna embayment with the flood tide. The cold water also introduced elevated concentrations of nitrate; a seven-fold increase from 2.5 µM to 17.5 µM. The Knysna estuary is less than 50 km to the west of the Sout estuary so it is likely that similar events occur in the Sout.

Water in the estuary during the *marine state* is likely to be marine dominated (>30 ppt) on both the high and low tides (CSIR 2007). The river flow should be <0.05 $m^3.s^{-1}$ so retention time will be slightly longer than in the other two states but still less than 2 weeks due to the strong tidal exchange. Water in the cove outside the mouth is likely to totally marine. The concentration of nutrients will be low, similar to seawater, unless an upwelling event has occurred. DIN, SRP and silicate concentrations are likely to be <5 µM, <0.7 µm and <29 µM respectively. However, there has been no study conducted during a marine state so the prediction should be regarded with caution.

The mouth of the estuary is permanently open so system variables such as temperature, pH, dissolved oxygen and turbidity should remain within similar limits during all three abiotic states. Temperature is expected to show a strong seasonal pattern, with summer temperature ranging from 20ºC to 25ºC and winter temperature from 13ºC to 16ºC. The pH in the estuary is expected to remain within the range 7.0 to 8.5. The lower ranges of pH are associated with the fresher upper reaches and the higher ranges with the more saline lower reaches. The estuary is well flushed, shallow and does not appear to have a high organic content so water in the estuary should be well oxygenated (>7 $mg.l^{-1}$). Turbidity in the estuary is likely to be low throughout with the secchi depth generally being greater than water column depth. However, this excludes periods of peak river flow.

The low phytoplankton biomass in the Sout estuary (<2 µg.l^{-1}) is indicative of an oligotrophic system. The water column was dominated by flagellates and diatoms during the strong salinity gradient phase. Water in the Kromme estuary (~100 km east of the Sout estuary) was dominated by flagellates during periods of little to no freshwater input (Snow & Adams 2006). Shortly after a managed freshwater release (~17 days) a diatom bloom developed in the upper reaches but this was short lived and flagellates dominated the phytoplankton by the 31st day. This suggests that flagellates dominate permanently open estuaries during periods of low or no river flow and that freshwater input provides a suitable habitat for the development of a diatom community. The phytoplankton community in the estuary when a strong salinity gradient is present seems to provide a habitat suitable for both flagellates and diatoms.

Benthic microalgae generally do not respond to water quality and quantity directly but are indirectly affected by the organic and fine particulate contents of the estuarine sediment (Snow *unpublished data*). The finer the sediment and the higher the organic content, the higher the microalgal biomass tends to be. A shift in sediment type from coarse to fine, usually associated with a reduction in flow and catchment erosion, is likely to favour a shift in community type from episammic (living on sand) and epilithic (living on rock) to a more epipelic dominated community (living on mud).

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Appendix 1
Sout estuary raw data

Table 3

Nutrients (µM) and phytoplankton chlorophyll *a* (µg.l^{-1}) in the Sout estuary (December 2006).

		Distance	NH4+	SRP	TOxN	Silicate	Chl-a
Sout	Sea	0	0.89	1.44	12.48	17.33	0.24
	Sea	0	0.70	1.23	13.79	17.04	0.24
	1S	0.1	0.71	1.24	12.72	17.04	0.41
	1S	0.1	0.70	1.26	12.32	17.11	0.24
	2S	0.35	0.65	1.29	12.80	20.43	0.12
	2S	0.35	0.45	1.25	11.74	20.76	0.30
	2B	0.35	0.35	0.86	8.84	14.51	1.30
	2B	0.35	0.56	0.86	8.80	13.82	1.01
	3S	0.5	0.68	1.46	13.83	19.77	0.18
	3S	0.5	0.45	1.26	13.53	20.32	0.18
	3B	0.5	1.40	0.99	11.19	17.64	0.59
	3B	0.5	0.82	1.07	10.28	20.41	1.01
	4S	0.7	0.18	1.53	13.75	14.33	0.41
	4S	0.7	0.36	1.58	12.78	15.60	0.30
	4B	0.7	0.17	1.49	12.70	15.00	1.60
	4B	0.7	0.31	1.56	13.31	14.83	1.48
	5S	0.9	0.21	1.60	12.28	13.16	0.12
	5S	0.9	0.22	1.51	16.38	11.00	0.12

Table 4

Nutrients (µM) and phytoplankton chlorophyll *a* (µg.l^{-1}) in the Sout estuary (April 2007).

		Distance	NH4+	SRP	TOxN	Silicate	Chl-a
Sout	Sea	0	2.66	0.701	1.55	57.52	0.414
	Sea	0	8.58	0.621	2.71	57.23	0.592
	1S	0.1	4.44	0.793	3.18	73.92	0.474
	1S	0.1	3.42	0.732	3.27	70.58	0.355
	1B	0.1	2.13	0.930	3.79	58.60	1.184
	1B	0.1	1.72	0.842	4.19	60.62	0.710
	2S	0.35	0.72	0.771	2.67	94.29	0.000
	2S	0.35	1.40	0.688	2.56	92.62	0.059
	2B	0.35	0.91	0.621	2.48	48.36	0.770
	2B	0.35	5.84	0.696	2.89	50.36	2.131
	3S	0.5	7.88	0.917	4.72	141.56	0.474
	3S	0.5	3.94	0.833	2.42	130.93	0.237
	3B	0.5	11.05	0.696	1.87	46.06	0.414
	3B	0.5	1.94	0.688	1.77	45.27	0.414
	4S	0.7	3.30	1.049	1.97	145.15	0.296
	4S	0.7	4.26	1.084	3.33	145.23	0.118
	4B	0.7	1.97	0.652	2.54	52.45	0.237
	4B	0.7	0.71	0.670	2.58	52.08	0.118
	5S	0.9	7.79	1.128	2.78	132.52	0.000
	5S	0.9	7.22	1.133	2.69	133.34	0.059
	5B	0.9	0.88	0.762	0.43	111.70	0.592
	5B	0.9	2.12	0.767	1.61	106.18	0.592

Table 4				
Intertidal (I) and subtidal (S) benthic chlorophyll *a* in the Sout estuary (µg.l^{-1}).				
December 2006				
Distance	**I Chl-a**	**SEM**	**S Chl-a**	**SEM**
0.1	2.35	0.35	1.04	0.20
0.35	6.27	0.85	3.31	0.67
0.5	17.49	2.52	17.33	2.99
0.7	15.26	2.29		
0.9	4.12	0.97		
April 2007				
Distance	**I Chl-a**	**SEM**	**S Chl-a**	**SEM**
0.1	14.74	2.79	2.66	0.66
0.35	7.90	0.47	20.81	5.11
0.5	32.14	1.66	24.63	1.98
0.7	16.53	2.13		
0.9	13.22	0.39		

Appendix D

Specialist Report: Macrophytes

by

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Introduction

The Sout Estuary is a small permanently open estuary situated in close proximity to the large permanently open Keurbooms Estuary and the Temporarily Open/Closed Matjies and Groot Estuaries. The mouth of the Sout Estuary is fixed by two rocky headlands and a "cove" is present between the sea and the mouth of the estuary (Figure 1). The cove was not considered part of the estuary although it forms an important linkage between the sea and the estuary. The Sout Estuary is situated within the De Vasselot Section of the Tsitsikamma National Park and protected in its entirety. The surrounding terrestrial vegetation forms part of the Southern Afrotemperate Forests (Mucina & Geldenhuys 2006). No exotic invasive plant species were observed in and around the estuary.

Figure 1. ***Aerial photo (1998) of the Sout Estuary***

Materials and methods

According to the generic data requirements stipulated for an Intermediate Ecological Reserve Determination (DWAF, 2004a), permanent transects had to be established along which measurements had to be taken of percentage plant cover along the elevation gradient. The small size of the estuary and the lack of available macrophyte habitat made vegetation analyses along transects meaningless in the Sout Estuary. An accurate GIS map the different vegetation types and habitat units would be more useful especially for long term monitoring. Spatial data was collected in the field using a GPS and ArcPad version 7 software. The map was created using ArcGIS version 9.1. A 2004 image of the area downloaded from Google Earth was used as the base raster.

Vegetation and habitat units

The Sout is a small estuary (length: 1.1 km) with steep banks. As a result the total area covered by macrophytes is small (0.67 ha) making up only 12.5% of the total estuarine area (Table 1). The intertidal salt marsh covered 0.35 ha and consisted of the following species: *Cotula coronopifolia*, *Chenolea diffusa*, *Triglochin striata* and *Sarcocornia perennis*. The supratidal salt marsh covered 0.31 ha and was made up of the following species: *Juncus kraussii*, *Samolus porosus*, *Stenotaphrum secundatum* and *Sporobolus virginicus*. In 2006 / 2007 a small area covered by the submerged macrophyte, *Zostera capensis* (eelgrass) was found in the middle reaches of the estuary (Figure 2). *Zostera* is typically found in the intertidal zone of permanently open estuaries. No reeds or sedges were recorded indicating the saline nature of the estuary and the lack of suitable habitat. No filamentous green macroalgae were recorded either. The mobile sands in the "cove" area are colonized by typical foredune vegetation.

Table 1. *Area cover of the different vegetation types and habitat units*

Vegetation/habitat unit	Areas (m^2)
Intertidal salt marsh	**3 561.61**
Supratidal salt marsh	**3 143.46**
Sandy gravel	**5 050.68**
Muddy sand	**880.51**
Sandbanks (coarse marine sediment)	**17 552.06**
Estuary	**23 560.97**
Zostera capensis	**21.26**
Dune vegetation	**907.74**

Zostera capensis was restricted to one small clump (21.26 m^2) in the lower middle reaches as well as two individual plants in the upper middle reaches. The small area covered by this submerged macrophyte is caused by the lack of a suitable substrate (mostly sandy gravel in the middle reaches and pebbles in the upper reaches) and the strong tidal currents. Large quantities of macroalgae are washed into the estuary from sea and are an important source of detritus and nutrients in the estuary that receive oligotrophic (low nutrient) water from the river. The permanently open mouth and the strong tidal currents restrict the growth of nuisance forms of filamentous green algae (prefer nutrient rich calm conditions). The strong tidal currents scour the estuary on every tide, especially spring tide, resulting in a lack of fine sediment in the system. Most estuarine macrophytes prefer silty sediment and as a result the majority of the intertidal and supratidal salt marsh are elevated on tiny islands and on the small floodplain. The intertidal salt marsh is covered during high tide where it plays an important role in trapping suspended fine sediment. The steep sides of the estuary ensure that the entire system is covered in saline marine water thereby preventing the establishment of reeds despite there being sufficient freshwater input from lateral runoff. Salinity varies greatly even over a tidal cycle. Interestingly most of the species present are adapted to brackish conditions. Their survival is therefore dependent on freshwater inflow from the river but probably also lateral flow from the steep banks.

The Sout is in a near natural state with regards to water quantity as it receives close to 90% of natural Mean Annual Runoff (MAR). One can therefore assume that the macrophytes have changed little over time. The small changes that was observed over time is considered natural and mostly related to sediment input (deposition) from the sea or scouring from river floods.

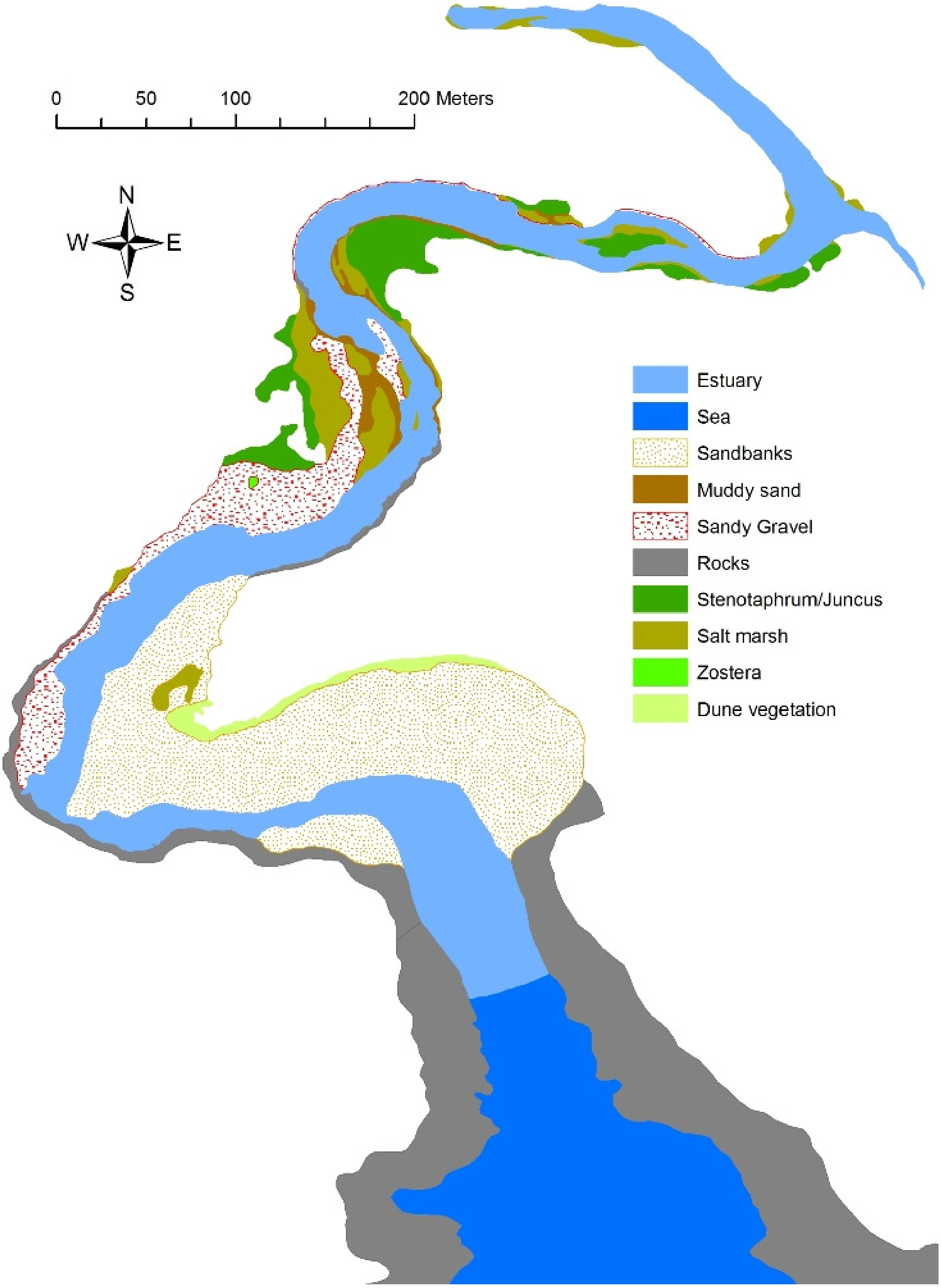

Figure 2. ***Vegetation type and habitat units of the Sout Estuary***

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Appendix E

Specialist Report: Invertebrates

by

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Introduction

The Sout is a relatively small permanently open estuary less than 1 km in length on the Tsitsikamma coast. The catchment lies mostly in the De Vasselot Nature Reserve on the coastal platform and receives rainfall throughout the year. The estuary itself is incised in a deep valley and enters the sea via a cove bounded by steep rocky headlands on both sides. Previous work on invertebrates of the estuary is restricted to two surveys. The Estuarine and Coastal Research Unit (ECRU) surveyed the estuary in 1981 and listed six species (Morant & Bickerton 1983). An earlier study by Gaigher (reported in Morant & Bickerton 1983) focused on the sandprawn *Callianassa kraussi* and the mudprawn *Upogebia africana,* and reported relatively low to medium densities in sandy and muddy substrata respectively.

Topography of the Estuary

The Sout Estuary is small, shallow and isolated and only accessible by hiking (approximately 1.7 km along the coast from Nature's Valley). No boat launching is possible. The estuary consists of a series of pools linked by shallow stony runs. Connection to the sea is via a narrow channel that broadens considerably around high tide. Around low tide, the estuary remains relatively perched, although outflow to the sea is continuous.

Materials and Methods

All benthic samples were collected by wading to selected sampling sites. A hand-held Van Veen type grab was used to collect three replicates from each of four stations. Contents were then sieved through a 500 µm mesh screen bag. The grab has a 200 cm^2 bite that penetrated the sediment down to about 10 cm depth. Animals retained by the sieve were stored in 500 ml plastic bottles and preserved with 10% formaldehyde solution.

Analysis of samples was completed in the laboratory. Final abundance was expressed as the average number of each species per m^2 of substratum at each site, determined from the three replicates respectively. Invertebrates were identified to species level wherever possible and the data analysed using multivariate statistics from the statistical package, PRIMER V.6 (Plymouth Routines in Multivariate Ecological Research). If multivariate techniques were not appropriate, other packages using MS Excel or Statistica for Windows were used.

Results

Twenty subtidal macrobenthic species (Table 1) were recorded in the Sout Estuary, with slightly fewer in December 2006 (15 species) compared to April 2007 (17 species). Crustaceans were the most important group represented in the macrozoobenthos (Table 1, Fig. 1). Amphipods dominated the community sampled on both sampling occasions (84 and 77% respectively), followed by Tanaeids in December (14%) and Polychaete worms in April 2007 (12%).

***Table 1**. Macrobenthicspecies collected in the Sout Estuary in December 2006 (A1 – A4) and in April 2007 (B1 – B4). Data are the mean of three replicates collected at the four sites on each occasion.*

Station	December 2006				April 2007			
	A1	A2	A3	A4	B1	B2	B3	B4
Polychaeta								
Ceratonereis keiskama	0	0	0	0	0	0	1267	101
Desdemona ornata	0	0	0	0	0	0	433	0
Oligochaete sp.	0	0	0	0	0	50	67	0
Prionospio bocki	0	0	0	0	0	0	383	50
Hirudinea								
Hirudinea sp.	0	0	0	0	33	233	83	0
Mysidacea								
Gastrosaccus brevifissura	0	50	0	0	0	17	0	0
Cumacea								
Iphinoe truncata	0	50	0	0	67	383	0	0
Tanaidacea								
Apseudes minutus	0	150	0	0	0	0	0	102
Tanaeid sp.	0	0	3150	1000	0	0	0	0
Isopoda								
Anthurid sp.	0	0	0	100	17	50	733	0
Cyathura estuaria	0	0	150	200	0	0	117	0
Exosphaeroma hylocoetes	25	0	0	0	0	0	0	0
Pontogeloides latipes	25	0	0	0	0	0	0	0
Amphipoda								
Corophium triaenonyx	0	0	5100	3050	0	0	6801	650
Grandidierella chelata	50	1450	0	0	17	183	0	0
Grandidierella lignorum	0	0	0	13250	0	33	5217	0
Grandidierella lutosa	0	0	1000	1000	0	0	901	302
Talorchestia quadrispinosa	0	0	0	50	0	0	0	0
Urothoe serrulidactylus	0	450	0	0	367	667	0	0
Insectivora								
Chironomid larvae	0	0	0	50	0	0	117	0

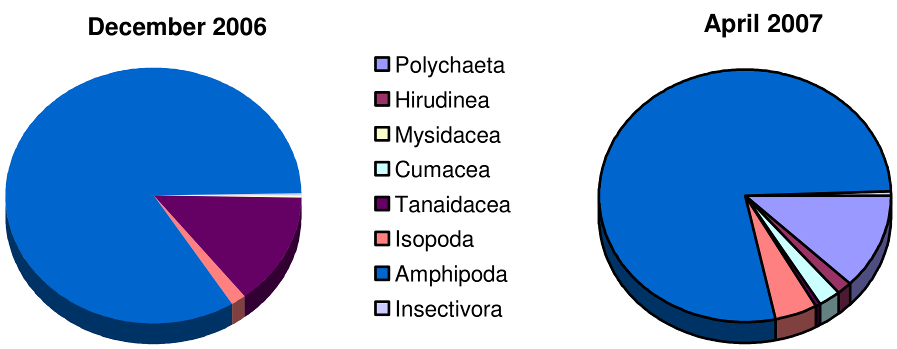

***Figure 1.** Major taxa represented in the macrozoobenthos in December 2006 and April 2007.*

No species was present at all sites sampled. Polychaete worms and the amphipods *Corophium triaenonyx* and *Grandidierella lignorum* characterized muddy sites in upper estuarine reaches, while sand-associated species such as *Gastrosaccus brevifissura* and *G. chelata* were only recorded at the lower two sampling stations. Group linkages shown by Bray Curtis Similarity clustering based on composition and abundance of the macrozoobenthos using group average mode on square-root transformed data indicated two major clusters at a similarity level of <5% (Fig. 2). These two clusters represent sand and mud-associated communities. The similarity profile test (SIMPROF) indicated that the split between the groups was significant (p<0.5). Within the two groups, no significant community substructures were apparent (p>0.05).

Non-metric multi-dimensional scaling (MDS) of all sites sampled over (Fig. 3) reflects the same pattern shown in Fig. 3, with the two major groupings at the 10% level. The low stress level (0.01) reflects high confidence in the data.

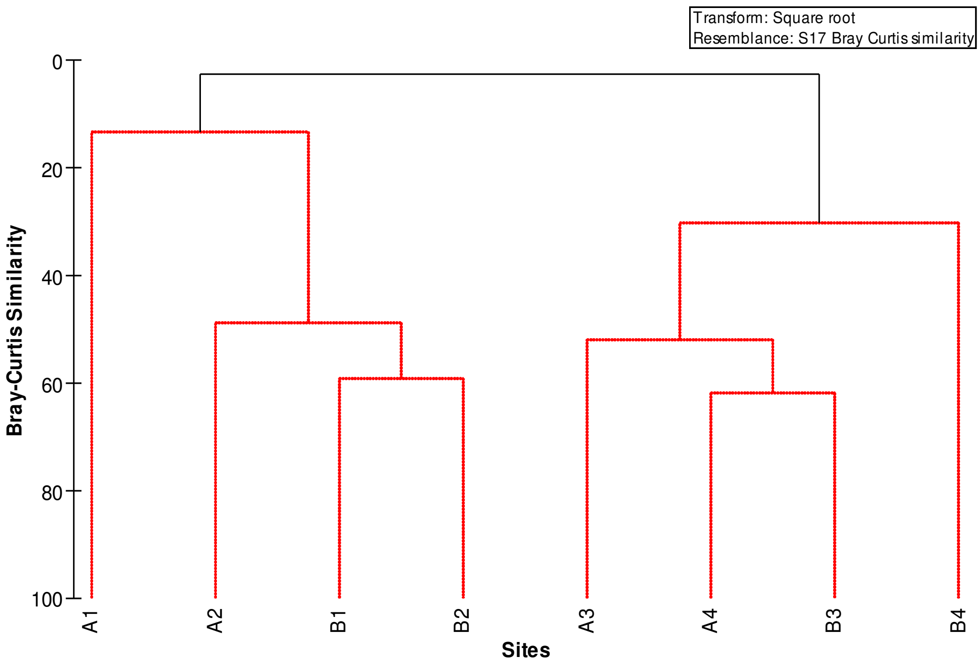

Figure 2. *Bray-Curtis Similarity dendrogram based on macrobenthic composition and abundance at each sampling site in the Sout Estuary. Data represent two sampling trips (A = December 2006, Sites 1 – 4; B = April 2007, Sites 1 – 4). The red hatched lines indicate those sites that do not vary significantly from each other in multivariate structure (p>0.5%).*

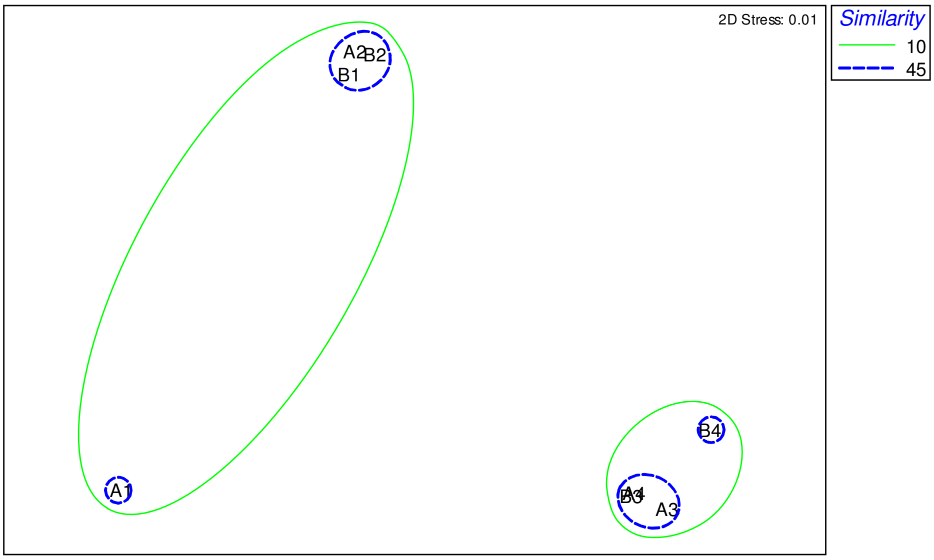

Figure 3. *MDS plot based on macrobenthic composition and abundance at each sampling site in the Sout Estuary. (A = December 2006, Sites 1 – 4; B = April 2007, Sites 1 – 4). Sites that are closer together represent a greater similarity in community composition compared to sites that are more distant from each other. Blue lines group sites that are 45% similar in community structure; green lines group sites that are 10% similar.*

References

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Appendix F

Specialist Report: Ichthyofauna

by

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EXECUTIVE SUMMARY

A total of 19 fish species from 10 families have been recorded from the Sout Estuary. Five of these species are dependent on estuaries for breeding purposes, and include resident taxa such as the Cape silverside *Atherina breviceps* and prison goby *Caffrogobius gilchristi*. A total of three marine species, including the Cape stumpnose *Rhabdosargus holubi* and white steenbras *Lithognathus lithognathus*, are dependent on estuaries as nursery areas. A further seven marine species (e.g. blacktail *Diplodus capensis* and southern mullet *Liza richardsonii*) are at least partially dependent on estuaries as nursery areas. Two of the remaining taxa were stenohaline marine species (evileye blaasop *Amblyrhynchotes honckenii* and zebra *Diplodus cervinus*) that occur in the lower and/or middle reaches where full seawater salinities prevail.

Based on their distributional ranges, 14 (74%) of the fish species recorded in the Sout Estuary are southern African endemics. The high degree of endemism can be attributed to the locality of the Sout 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 although the bandit blenny *Omobranchus banditus* has seldom been recorded in South African estuaries, possibly because of its rocky habit selection.

This study has shown that:

(1) The Sout Estuary supports an ichthyofauna dominated by 0+ juvenile marine fishes that utilize the almost pristine system as a nursery area.
(2) The input of macrodetritus from both the river catchment and adjacent coastal zone appear to be important drivers of the food web within this estuary, especially the zoobenthos.
(3) Most of the fish species found within the estuary are associated with the benthos, feeding either on the microphytobenthos and detritus in the case of mugilids or the zoobenthos in the case of carnivorous sparids and gobies.
(4) Poor planktonic food resources as a result of clear, nutrient poor river inflow have contributed to low abundance, biomass and diversity of planktivorous fish species within this system.
(5) Reduced river flow is likely to result in marine conditions penetrating further upstream, resulting in expanded marine migrant and marine straggler fish components within the system.

1. INTRODUCTION

The state of knowledge of the Sout Estuary fish fauna is very limited. Three brief surveys have been conducted, one by ECRU (CSIR) in April 1981, one by Harrison (CSIR) in September 1994, and one by Whitfield (SAIAB) in April 2007. All three 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 estuary is a small system situated in an incised valley and is fed by a river 15 km long that drains a catchment of approximately 3360 ha (Morant & Bickerton 1983). The permanently open mouth state is probably a function of the protected rocky embayment in which the estuary is situated (Figure 1.1), together with tidal scour and perennial river flow.

The river drains hard sandstones in the catchment and has a low pH and characteristic clear dark brown colour (Morant & Bickerton 1983) 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.

Salinity stratification within the estuary appears to be a common feature, especially when tidal seawater penetrates upstream under the outflowing river water. Where saline water is trapped in the deeper pools within the estuary, vertical salinity differentials in excess of 15 psu have been recorded (Morant & Bickerton 1983).

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 moderate when compared to similar estuaries within the warm-temperate region. 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 Sout Estuary Intermediate 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 Sout River flow.

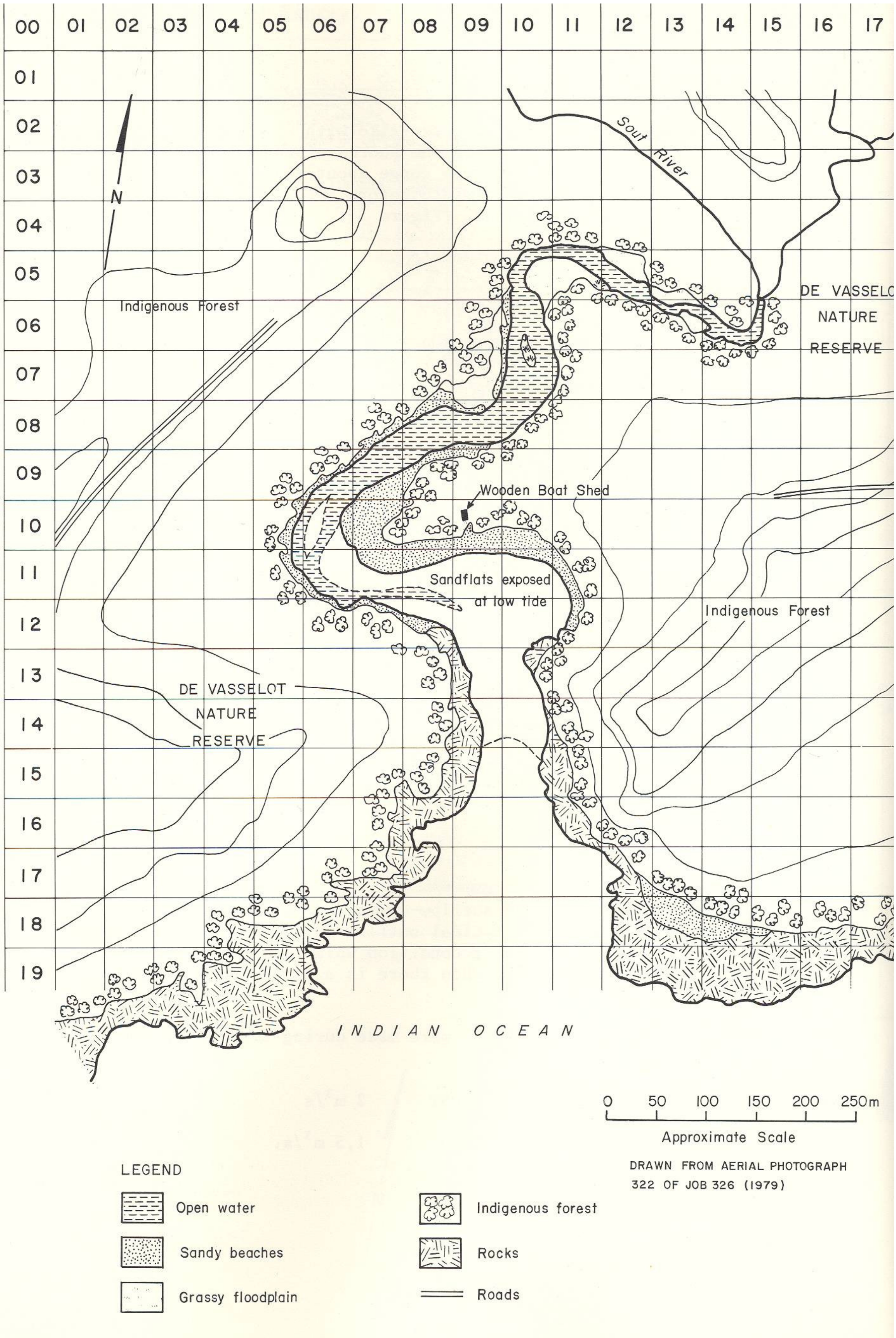

Figure 1.1 *Map of the Sout Estuary (after Morant & Bickerton 1983).*

2. FISH COMMUNITY

2.1 The Sout Estuary ichthyofauna

A total of 19 fish species from 10 families, analysed using the categories outlined in Table 2.1, have been recorded from the Sout Estuary (Table 2.2). Five of these species are dependent on estuaries for breeding purposes, and include resident taxa such as the Cape silverside *Atherina breviceps* and prison goby *Caffrogobius gilchristi*. A total of three marine species, including the Cape stumpnose *Rhabdosargus holubi* and white steenbras *Lithognathus lithognathus*, are dependent on estuaries as nursery areas. A further seven marine species (e.g. blacktail *Diplodus capensis* and southern mullet *Liza richardsonii*) are at least partially dependent on estuaries as nursery areas. Two of the remaining taxa were stenohaline marine species (evileye blaasop *Amblyrhynchotes honckenii* and zebra *Diplodus cervinus*) that occur in the lower and/or middle reaches where full seawater salinities prevail.

An analysis of the fish species groupings in the Sout 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, marine stragglers and then catadromous taxa. Catadromous taxa are represented by the freshwater mullet which is able to survive in the estuary if the river is unavailable for colonisation. Although it is probable that the catadromous anguillid eel *Anguilla mossambica* uses the Sout Estuary as a conduit to the river catchment, no specimens were sampled.

Fish species groupings in the Sout Estuary analysed according to relative abundance indicated that once again marine immigrant species are dominant followed by estuarine residents (Harrison & Whitfield data unpublished). Marine stragglers contribute little to the overall fish abundance in the system. 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, 14 (74%) of the fish species recorded in the Sout Estuary are southern African endemics. The high degree of endemism can be attributed to the locality of the Sout 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 although the bandit blenny *Omobranchus banditus* has seldom been recorded in South African estuaries, possibly because of its rocky habit selection.

The food web structure of the Sout Estuary fish community appears to be dominated by mugilids feeding on microphytobenthos and macrophytic detritus generated from catchment forests and nearshore marine macroalgae. The clear estuarine waters appear to support very low populations of zooplanktivorous fish species (e.g. *Atherina breviceps*) and the estuarine roundherring *Gilchristella aestuaria* appears to be absent from this system.

The limited amount of submerged and emergent macrophyte 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 benthic dominated food web structure with many fish species feeding predominantly on zoobenthos associated with the detritus food web. There is also a spatial separation of the family Gobiidae, with the Knysna sandgoby *Psammogobius knysnaensis* occupying sandy areas in the lower and middle reaches, with *Caffrogobius gilchristi* and *Caffrogobius natalensis* found mainly in amongst the boulders and pebbles of the middle reaches.

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 Sout 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
Ariidae	*Galeichthys feliceps**	White seacatfish	IIb
Atherinidae	*Atherina breviceps**	Cape silverside	Ib
Blenniidae	*Omobranchus banditus**	Bandit blenny	Ia
Gobiidae	*Caffrogobius gilchristi**	Prison goby	Ib
Gobiidae	*Caffrogobius natalensis**	Baldy	Ib
Gobiidae	*Psammogobius knysnaensis**	Speckled sandgoby	Ib
Monodactylidae	*Monodactylus falciformis*	Oval moony	IIa
Mugilidae	*Liza dumerili*	Groovy mullet	IIb
Mugilidae	*Liza richardsonii**	Southern mullet	IIc
Mugilidae	*Liza tricuspidens**	Striped mullet	IIb
Mugilidae	*Mugil cephalus*	Flathead mullet	IIa
Mugilidae	*Myxus capensis**	Freshwater mullet	Vb
Pomatomidae	*Pomatomus saltatrix*	Elf	IIc
Soleidae	*Heteromycteris capensis**	Cape sole	IIb
Sparidae	*Diplodus hottentotus**	Zebra	III
Sparidae	*Diplodus capensis**	Blacktail	IIc
Sparidae	*Lithognathus lithognathus**	White steenbras	IIa
Sparidae	*Rhabdosargus holubi**	Cape stumpnose	IIa
Tetraodontidae	*Amblyrhynchotes honckenii*	Evileye blaasop	III

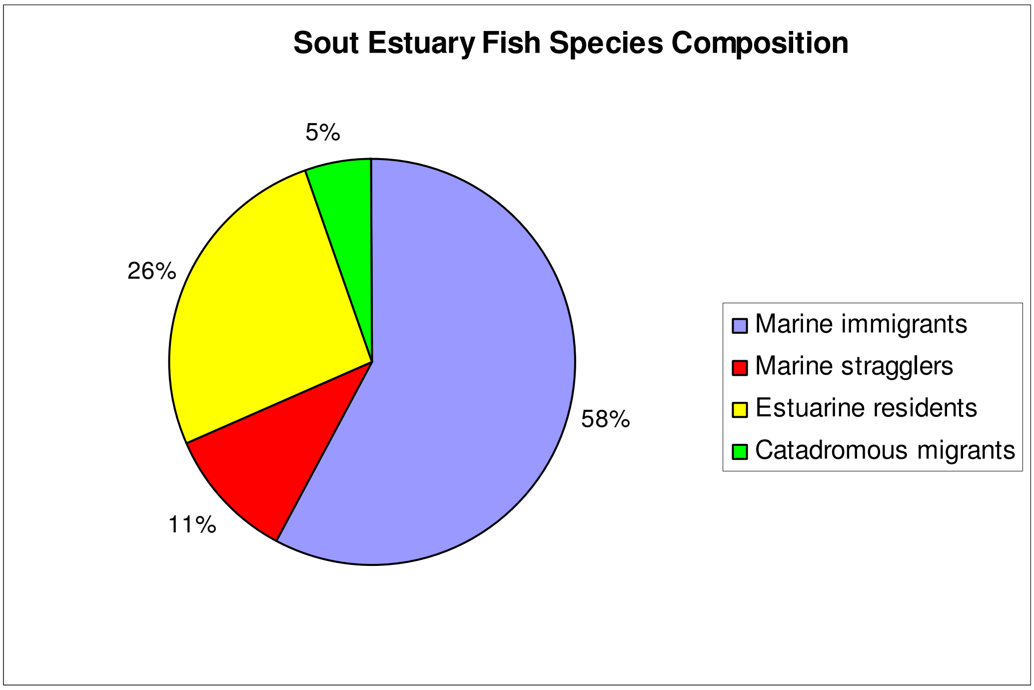

Figure 2.1 *Fish species groupings in the Sout Estuary analysed according to life history traits of the various taxa (data from Harrison unpublished).*

2.2 Conclusions

Based on this review, the following conclusions can be reached:

(1) The Sout Estuary supports an ichthyofauna dominated by 0+ juvenile marine fishes that utilize the almost pristine system as a nursery area.
(2) The input of macrodetritus from both the river catchment and adjacent coastal zone appear to be important drivers of the food web within this estuary, especially the zoobenthos.
(3) Most of the fish species found within the estuary are associated with the benthos, feeding either on the microphytobenthos and detritus in the case of mugilids or the zoobenthos in the case of carnivorous sparids.
(4) Poor planktonic food resources as a result of clear, nutrient poor river inflow have contributed to low abundance, biomass and diversity of planktivorous fish species within this system.
(5) Reduced river flow is likely to result in marine conditions penetrating further upstream, resulting in expanded marine migrant and marine straggler fish components within the system.

2.3 Further studies

Our current understanding of the ichthyofauna of the Sout Estuary is limited to three brief fish surveys. More detailed studies would provide additional information on the structure and functioning of fish assemblages within the estuary 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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Appendix G

Specialist Report: Birds

by

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The Avifauna

Although only few surveys have focused on the birds of the Sout Estuary (Underhill 1980, Morant & Bickerton 1983), the avifauna is not well represented. Morant and Bickerton (1983) ascribe this to a low surface area of exposed sediment along the shoreline that is regularly covered by the high tide. Water-associated birds probably forage widely, utilizing the Sout Estuary at intermittent intervals. At high spring tide, only a narrow (metres) non-vegetated band is exposed before merging with the steep-sided, forest covered slopes. Water birds associated with the Sout Estuary are likely to move between adjacent feeding habitats that include the larger Groot Estuary a short distance to the East. Thus, most bird species utilizing the shoreline or water column are probably highly transient. Species such as the Kingfishers and Cape Wagtails are probably more resident compared to other water associated birds.

Table 1. *List of birds recoded from the Sout Estuary (from Underhill 1980, Morant & Bickerton 1983).*

Species	Number recorded
Whitebreasted Cormorant	**2**
Black Oystercatcher	**4**
Fish Eagle	**2**
Whitefronted Plover	**7**
Whimbrel	**1**
Kelp Gull	**11**
Giant Kingfisher	**1**
Halfcollared Kingfisher	**1**
Cape Wagtail	**2**

In terms of trophic class (Figure 1), piscivores and invertebrate feeders dominate, although some species also feed across different classes.

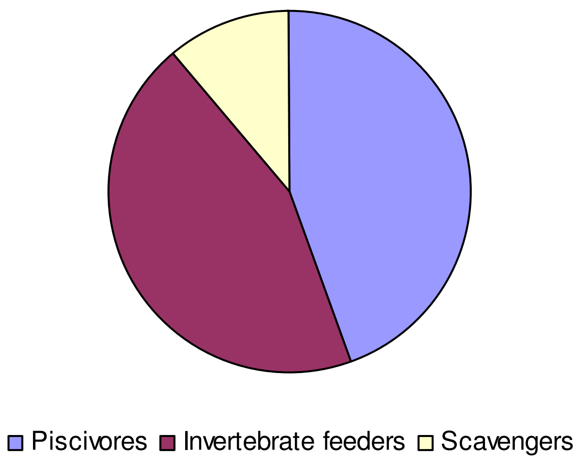

Figure1. *Trophic position of bird species feeding at the Sout Estuary.*

The Sout Estuary is also a popular area visited by hikers or other recreationalists on a daily basis from the nearby holiday resort of Nature's Valley. Given the size of the Sout Estuary, disturbance is likely to be significant and this will further lead to birds leaving the estuary area.

Appendix H

Proposed changes to RDM methodology for estuaries

Proposed changes to RDM methodology for estuaries

The following changes were proposed during the Sout Estuary Intermediate 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**.