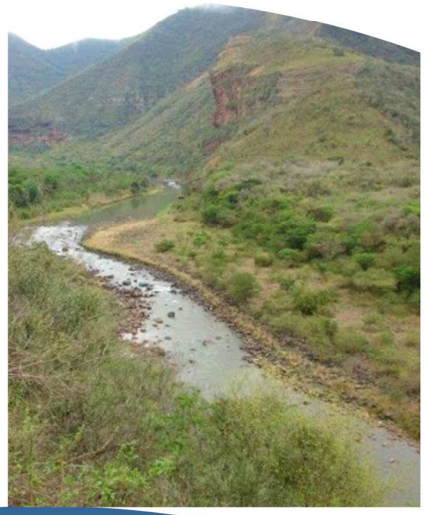
REPORT NO: RDM/WMA11/00/CON/CLA/0614

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

PROJECT NUMBER: WP 10679

VOLUME 2B:
SUPPORTING INFORMATION ON THE DETERMINATION OF WATER RESOURCE CLASSES - uMKHOMAZI (U1) ESTUARY EWR AND ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS



DECEMBER 2014

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

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3	Report Number: RDM/WMA11/00/CON/CLA/0213	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **River Resource Units and EWR sites**
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6	Report Number: RDM/WMA11/00/CON/CLA/0212	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **BHNR**
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9.3	Report Number: RDM/WMA11/00/CON/CLA/0515	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 3: Groundwater RQOs**
9.4	Report Number: RDM/WMA11/00/CON/CLA/0615	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 4: Estuary RQOs**
10	Report Number: RDM/WMA11/00/CON/CLA/0715	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Implementation Report**
11	Report Number: RDM/WMA11/00/CON/CLA/0815	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Main Report**
12	Report Number: RDM/WMA11/00/CON/CLA/0116	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Closing Report**

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

VOLUME 2B: SUPPORTING INFORMATION ON THE DETERMINATION OF WATER RESOURCE CLASSES – uMKHOMAZI (U1) ESTUARY EWR AND ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

Approved for RFA by:

……. ……

Delana Louw — Date

Project Manager

DEPARTMENT OF WATER AND SANITATION (DWS)

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REPORT SCHEDULE

Version	Date
First draft	October 2014
Second draft	30 November 2014
Third draft	2 December 2014
Forth draft	March 2015
Final	September 2015

EXECUTIVE SUMMARY

STUDY AREA

The uMkhomazi Estuary is situated 50 km south-west of Durban and is one of only two estuarine systems within the eThekwini Municipal boundary classified as Permanently Open and one of only five between uThukela and Mtamvuna. In effect, this classification is not totally rigid and a number of closures have been recorded in the last few decades. With a catchment area of *ca.* 4 300 km^2 it is one of Kwazulu-Natal's largest rivers. At present the Sappi weir above the old metal bridge and 6 km from the mouth sets an artificial and absolute limit on tidal and to some extent saline penetration. For the purposes of this EWR study, the geographical boundaries of the estuary are defined as follows:

Downstream boundary:	Estuary mouth 30°12'4.45" S 30°48'8.65"E
Upstream boundary:	30°10'25.64"S 30°44'51.42"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Geographical boundaries of the uMkhomazi Estuary based on the Estuary Functional Zone

PRESENT ECOLOGICAL STATE

The uMkhomazi Estuary in its present state is 69% similar to the natural condition, which translates into a Present Ecological State (PES) of a C Ecological Category and attributed to the following factors:

- The weir in the upper reaches reducing the connectivity between the river and estuary and contributing to loss of estuarine habitat;
- Sandmining that has taken away the sandbanks in the upper reaches (Zone C), resulting in loss of intertidal areas and backwater refuge areas. It has also impacted on access to cattle grazing areas as the river cannot be crossed in this section anymore;
- Recreational activities (e.g. boat launching) in the lower reaches affecting bird abundance;
- Over exploitation of living resources (e.g. cast netting and line fishing); and
- Agricultural activities and disturbance in the Estuary Functional Zone (EFZ) causing loss of estuarine habitat.

Estuarine Health Score for the uMkhomazi Estuary

Variable	Estuarine health score		
	Overall	**Excluding flow related pressures**	**Conf***
Hydrology	66.8	67	Medium
Hydrodynamics and mouth condition	95	95	Medium/High
Water quality	66.6	66.6	Medium
Physical habitat alteration	78	78	Medium
Habitat health score	**76**	**76**	**Medium**
Microalgae	90	99	Medium
Macrophytes	21	84	Medium
Invertebrates	75	78	High
Fish	60	70	Medium
Birds	60	70	Medium
Biotic health score	**61**	**80**	**Medium**
ESTUARY HEALTH SCORE	**69**	**78**	
PRESENT ECOLOGICAL STATE (PES)	**C**	**B**	
OVERALL CONFIDENCE	**Medium**	**Low**	

* Confidence level: L – Low; M – Medium; H - High

RELATIVE CONTRIBUTION OF FLOW AND NON-FLOW RELATED IMPACTS ON HEALTH

Using estimates of the contribution of non-flow related impacts on the level of degradation of each component led to an increase in the PES health score from 69 to 78, which would raise the health score to a B Category. This suggests that both flow and non-flow related impacts have played a role in the degradation of the estuary to a C.

The highest priority is to address the quality of influent water. Of the non-flow-related impacts, habitat loss (within the 5 m contour and above the Sappi weir) along with water quality problems because of the high nutrient load associated with the Waste Water Treatment Works (WWTWs) were the most important factors influencing ecological health of the system. The excess nutrients in the inflowing water are an important factor to consider with increased abstraction from the system. Retention of these high concentrations of nutrients could lead to nuisance algal growth, low dissolved oxygen in the water and reduced habitat quality.

ESTUARY IMPORTANCE

The Estuary Importance Score (EIS) takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account. Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. Estuary Importance was estimated at 85, i.e. the estuary is rated as "Highly Important".

Estuarine Importance scores for the uMkhomazi Estuary

Criterion	Weight	Score
Estuary Size	15	80
Zonal Rarity Type	10	30
Habitat Diversity	25	60
Biodiversity Importance	25	91.5
Functional Importance	25	100
Weighted Estuary Importance Score		**85**

The functional Importance of the uMkhomazi Estuary is very high. It serves as an important nursery for exploited fish stock and plays a very important role from a fish egg production perspective. In addition, it is also an important movement corridor for eels (CITES listed species).

The functional importance of uMkhomazi Estuary is also very high for the nearshore marine environment. It is one of five key systems (Mfolozi, Mvoti, uMngeni, uMkhomazi, and Umzimkulu) that supply sediment, nutrients and detritus to the coasts. The sediment load from the uMkhomazi is especially important as it is habitat forming and plays an important role in maintaining the beaches and near shore habitat along this coast.

The impact of further dam development on the nearshore marine environment was not assessed as part of this study, but should be evaluated to ensure that all ecological processes and related ecosystem services (e.g. nearshore pelagic and prawn fishery) are addressed.

The uMkhomazi forms part of the core set of priority estuaries identified in the National Estuary Biodiversity Plan in need of protections to meet biodiversity targets under the Biodiversity Act and National Estuarine Management Protocol promulgated under the Integrated Coastal Management Act. The National Estuary Biodiversity Plan requires that the uMkhomazi Estuary be partially protected (e.g. no-take fishing zone and 25% of riverine area left untransformed) with a Recommended Ecological Category (REC) of B.

RECOMMENDED ECOLOGICAL CATEGORY

The REC represents the level of protection assigned to an estuary. The PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection or desired protection of a particular estuary. The PES for the uMkhomazi Estuary is a C, but the Estuary is rated as "Very Important" from a biodiversity perspective and should therefore be in a B Category.

Estuary protection status and importance, and the basis for assigning a REC

Protection status and importance	REC	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 Category.**
Important	PES + 1, min C	Important estuaries should be in an A, B or C Category.
Of low to average importance	PES, min D	Estuaries to remain in a D Category.

* Best Attainable State

In addition, the system also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan and the National Biodiversity Assessment (NBA) 2011 (Turpie *et al*., 2013; Van Niekerk and Turpie, 2012). The NBA 2011 recommends that the minimum Category for the uMkhomazi should be a B, it be granted full no-take protection, and that 25 % of the estuary margin be undeveloped.

Taking into account the current conditions (PES = C), the reversibility of the impacts, the ecological importance and the conservation requirements of the uMkhomazi Estuary the REC for the system is a B Category.

Ecological Categories associated with scenarios

The individual Estuarine Health Index (EHI) scores, as well as the corresponding Ecological Category (EC) under different scenarios are provided below. The estuary is currently in a C Category. Under Scenario Group B (MK21 and 42) and Group C (MK22, 23, and 43) the uMkhomazi Estuary will decline slightly in health, as a result of more closed mouth conditions, but is expected to remain in a C Category. Under Scenario Group A (MK2, and 4), D (MK31) and E (MK32, 33) the estuary will deteriorate further in health by about 14%, 8% and 9% respectively as a result of increase closed mouth conditions.

To test the sensitivity of the estuary to the increased nutrient load associated with a 20 ML/d WWTWs, Scenario Group F (based on inflows generated for Scenario Group B) was evaluated in more detail. Under this scenario, the uMkhomazi Estuary declines in health by 13% (MK21b) because of a decline in water quality (nutrients and oxygen) which drives increased primary production and a decline in estuary biota. Of special concern are periods when the estuary mouth closes and retention becomes high. Similar responses are expected for any of the future scenarios with this high level of nutrient input. (It should be noted that this is a low confidence assessment as no numerical modelling was done to test the tidal effects on lateral discharges or the effect of entrainment).

For the uMkhomazi Estuary, none of the scenarios achieved the REC of a B Category. Therefore Scenario H (Group B (MK21 and MK42), in conjunction with a number of management interventions, is the recommended ecological flow scenario. Scenario Group C (MK22, 23 and 43) will also achieve the REC. The following management interventions are required to achieve the uMkhomazi REC:

- Remove sandmining from the upper reaches below the Sappi Weir to increase natural function , i.e. restore intertidal area;

- Restoration of vegetation in the upper reaches and along the northern bank in the middle and lower reaches, e.g. remove alien vegetation and allow disturbed land to revert to natural land cover (is already on upwards trajectory);
- Curb recreational activities in the lower reaches through zonation and improved compliance;
- Reduce/remove castnetting in the mouth area through estuary zonation or increased compliance; and
- Relocate upstream, or remove, the Sappi Weir to restore upper 15% of the estuary.

Since these scenarios include the construction of a new dam, the relocation or removal of the Sappi Weir is regarded as a medium to long-term recommendation. In the short term, a combination of the PES and the REC is recommended. The improvements required to meet the REC are mostly non-flow related measures. **The non-flow related (or anthropogenic) measures required to improve the estuary (apart from the removal or changing of the SAPPI weir location) can be applied and should improve the estuary to a B/C in a relatively short time frame.**

uMkhomazi EHI scores and corresponding ECs under the different runoff scenarios

Variable	Weight	Scenario Group								
		Present	A (MK2, 4)	B (MK21, 42)	C (MK22, 23, 43)	D (MK31)	E (MK32, 33)	F (MK21, 42) + WWTW	G MK21, 42 –Anth but with weir	H MK21, 42 – Anth & Weir
Hydrology	25	66.8	**45**	63	62	59	57	63	63	63
Hydrodynamics and mouth condition	25	95	**75**	95	95	38	38	95	95	97
Water quality	25	66.6	**61**	66	67	66	67	34	66	66
Physical habitat alteration	25	78	**70**	75	75	75	75	75	84	90
Habitat health score		**76**	**63**	**75**	**75**	**60**	**59**	**67**	**77**	**79**
Microalgae	20	80	**65**	80	80	80	80	50	80	90
Macrophytes	20	21	**20**	26	31	33	34	15	46	46
Invertebrates	20	75	**60**	75	75	70	70	50	85	90
Fish	20	60	**35**	60	60	60	55	50	70	75
Birds	20	60	**50**	55	55	55	55	50	57	65
Biotic health score		**59**	**46**	**59**	**60**	**60**	**59**	**43**	**68**	**73**
ESTUARY HEALTH SCORE		**68**	**54**	**67**	**67**	**60**	**59**	**55**	**72**	**76**
ECOLOGICAL STATUS		**C**	**D**	**C**	**C**	**D**	**D**	**D**	**B/C**	**B**

OVERALL CONFIDENCE

Confidence levels were medium to high for most of the abiotic components. Four of the biotic components had enough data to yield medium-high confidence assessments. The overall confidence of the study was MEDIUM.

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ACRONYMS AND ABBREVIATIONS

BAS	Best Attainable State
Conf	Confidence
CSIR	Centre of Scientific and Industrial Research
CWAC	Coordinated Waterbird Counts
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
DRS	Dissolved Reactive Silicate
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EC	Ecological Category
EFZ	Estuary Functional Zone
EHI	Estuarine Health Index
EIS	Estuarine Importance Score
EWR	Ecological Water Requirement
H	High
KZN	KwaZulu Natal
L	Low
M	Medium
MCM	Million Cubic Metres
MPB	microphytobenthos
MSL	Mean Sea Level
NBA	National Biodiversity Assessment
nMAR	Natural Mean Annual Runoff
NWA	National Water Act (1998)
OCD	Off-channel Dam
PES	Present Ecological State
pMAR	Present Mean Annual Runoff
pMAR	Present Mean Annual Runoff
ppt	Parts per thousand
PSD	Particle size Distribution
PSU	Practical Salinity Units
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
TPC	Thresholds of potential concern
uMWP-1	uMkhomazi Water Project Phase 1
WRPM	Water Resource Planning Model
WWTW	Waste Water Treatment Work

1 INTRODUCTION

1.1 BACKGROUND

There is an urgency to ensure that water resources in the Mvoti to Umzimkulu Water Management Area (WMA) are able to sustain their level of uses and maintained at their desired states. The determination of the Water Resource Classes of the significant water resources in Mvoti to Umzimkulu WMA will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised are maintained and adequately managed within the economic, social and ecological goals of the water users (DWA, 2011a). The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives (RQOs) in the Mvoti to Umzimkulu WMA.

The objective of this task was to describe and document the EWR and scenario consequences for the uMkhomazi estuary. The output of this task will serve as input to the RQO, implementation, monitoring and Legal Notice.

1.2 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs (DWA, 2012a) are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).
2	Initiation of stakeholder process and catchment visioning (on-going).
3	**Quantify the Ecological Water Requirements and changes in non-water quality ecosystem.**
4	**Identification and evaluate scenarios within the Integrated Water Resource Management process.**
5	Evaluate the scenarios with stakeholders and determine Water Resource Classes.
6	Develop draft RQOs and numerical limits.
7	Gazette and implement the class configuration and RQOs.

This task forms ***part*** of Step 3 and 4, i.e. the determination of EWRs and consequences of scenarios.

1.3 ECOLOGICAL WATER REQUIREMENT METHOD FOR ESTUARIES

Methods to determine the environmental flow requirement of estuaries were established soon after the promulgation of the National Water Act (NWA) in 1998. The so-called “Preliminary Reserve Method” involves setting a Recommended Ecological Category (REC) (i.e. desired state), recommended Ecological Reserve (i.e. flow allocation to achieve the desired state) and recommended Resource Quality Objectives (RQOs) for a resource on the basis of its present health status and its ecological importance. The approach follows a generic methodology that can be carried out at different levels of effort (e.g. rapid, intermediate or comprehensive). The official method for estuaries (Version 2), is documented in DWA (2008). In 2013, a Version 3 of the method was published, as part of a Water Research Commission study (Turpie *et al*., 2012). The

study reported upon in this document was initiated in 2012 and Version 2 of the methodology (DWA, 2008) is therefore applied, but with consideration of obvious improvements proposed in Version 3 for the evaluation of abiotic processes such as water quality (Turpie *et al*., 2012). Currently, the official suite of "Preliminary Reserve Methods" for estuaries does not include a desktop assessment method. However, a desktop approach for assessing estuary health in data poor environments was applied recently successfully in South Africa's 2012 **National Biodiversity Assessment** (NBA) (Van Niekerk and Turpie, 2012). This method has since been refined in a Water Research Commission study (Van Niekerk *et al*., in prep) and was also applied in this Mvoti to Umzimkulu WMA study, where considered appropriate.

This report presented the EcoClassification of the uMkhomazi Estuary that included a field measurement programme and specialists reports.

The generic steps of the official "Ecological Reserve Method" for estuaries were applied as follows:
Step 1: Initiate study defining the study area, project team and level of study (confirmed in the **inception report** of this study).
Step 2: Delineate the geographical boundaries of the resource units (confirmed in the **delineation report** of this study).
Step 3a: Determine the **Present Ecological State** (PES) of resource health (water quantity, water quality, habitat and biota) assessed in terms of the degree of similarity to the reference condition (referring to natural, unimpacted characteristics of a water resource, and must represent a stable baseline based on expert judgement in conjunction with local knowledge and historical data). An Estuarine Health Index (EHI) is used to evaluate the current condition of the estuary (Table 1.1).

Table 1.2 Estuarine Health Index (EHI) scoring system

Variable	Score	Weight	Weighted score
Hydrology	…	25	…
Hydrodynamics and mouth condition	…	25	…
Water quality	…	25	…
Physical habitat alteration	…	25	…
Habitat health score			**…**
Microalgae	…	20	…
Macrophytes	…	20	…
Invertebrates	…	20	…
Fish	…	20	…
Birds	…	20	…
Biotic health score			**…**
Estuary Health Score Mean (Habitat health, Biological health)			**…**

In the case of this assessment the EHI scoring of the various variables is based on a review of historical data, as well as data collected during a field monitoring programme in 2013 (refer to Appendices for specialist reports).

The estuarine health score is translated into one of six Ecological Categories provided below in Table 1.2.

Table 1.3 Translation of EHI scores into Ecological Categories

EHI score	PES	General Description
91 – 100	A	Unmodified, or approximates natural condition; the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used
76 – 90	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. Only a small risk of modifying the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
61 – 75	C	Moderately modified. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the wellbeing and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
41 – 60	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred. Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota depending on (the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.
21 – 40	E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 – 20	F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Step 3b: Determine the **Estuary Importance Score (EIS[1])** that takes account the size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (Table 1.3 and Table 1.4).

Table 1.4 Estuary Importance scoring system

Criterion	Score	Weight	Weighted Score
Estuary Size	…	15	**…**
Zonal Rarity Type	…	10	**…**
Habitat Diversity	…	25	**…**
Biodiversity Importance	…	25	**…**
Functional Importance	…	25	**…**
Weighted Estuary Importance Score			**…**

[1] Note that EIS does not have the same meaning as EIS for rivers, which refer to Ecological Importance and Sensitivity.

Table 1.5 Estuarine Importance rating system

EIS	Importance rating
81 – 100	Highly important
61 – 80	Important
0 – 60	Of low to average importance

Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) flowing the guidelines listed in Table 1.5.

Table 1.6 Guidelines to assign REC, based on protection status and importance, and PES of an estuary

Protection Status and Importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health.
Desired Protected Area (based on complementarity)		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B Category.
Important	PES + 1, min C	Important estuaries should be in an A, B or C Category.
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D Category.

* Best Attainable State

An estuary cannot be allocated an REC below a Category "D". Therefore systems with a PES in Categories 'E' or 'F' needs to be managed towards achieving at least a REC of "D".

Step 4: **Quantify the ecological consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the reference condition.

Step 5: Quantify the (recommended) **Ecological Water Requirements (EWR)**, which represent the lowest flow scenario that will maintain the resource in the REC.

Step 6: Estimate (recommended) **Resource Quality Objectives (Ecological Specification)** for the REC, as well as future **monitoring requirements** to improve the confidence of the EWR.

1.4 DEFINITION OF CONFIDENCE LEVELS

The level of available historical data in combination with the level of effort expended during the assessment determines the level of confidence of the study. Three levels of study have been recognised in the past in terms of the effort expended during the assessment – rapid, intermediate and comprehensive. In this study, effort lay somewhere between an intermediate and comprehensive study, in that some field data collection was carried out, but the long-term river inflow data needed to benchmark the abiotic processes were not available. Nevertheless, as a result of the availability of historical data and the relative uncomplicated nature of the estuarine processes meant that we expected the confidence of the study to be low. This is a situation that can only be remedied with some comprehensive and long term data collection on the system. Criteria for the confidence limits attached to statements in this study are:

Confidence level	Situation
Low	Limited data available
Medium	Reasonable data available
High	Good data available

1.5 ASSUMPTIONS AND LIMITATIONS FOR THIS STUDY

The following assumptions and limitations should be taken into account:

- The accuracy and confidence of an Estuarine Ecological Water Requirements study is strongly dependent on the quality of the hydrology. The overall confidence in the hydrology supplied to the estuarine study team is of a medium level, with a particular concern regarding the accuracy of the simulated base flows during the low flow period into the estuary.
- Inflow data were only available at the head of the estuary for limited periods, which only allowed for a medium level confidence in the correlation between mouth state and water quality characteristics.

1.6 STRUCTURE OF THIS REPORT

The report is structured as follows:

Chapter 1: Introduction
An overview of EWR methods and confidence of the study is provided.

Chapter 2: Background Information
This Chapter summarises important background information related to the hydrological characteristics, catchment characteristics and land-use, as well as human pressures affecting the estuary.

Chapter 3: Delineation of Estuary
The geographical boundaries of the study area are defined, as well as the zoning and typical abiotic states adopted for this estuary.

Chapter 4: Ecological Baseline and Health Assessment
This chapter provides a baseline ecological and health assessment of the estuary. It describes each of the abiotic and biotic aspects of the estuary - from hydrology to birds – describing an understanding of the present situation and estimation of the reference condition. The health state of each component is determined using the Estuarine Health Index (EHI).

Chapter 5: Present Ecological Status
Describes the overall state of health (or present ecological status) of the estuary. It also summarises the overall confidence of the study and the degree to which non-flow factors have contributed to the degradation of the system.

Chapter 6: The Recommended Ecological Category
The EHI score combined with the Estuarine Importance Score (EIS) for the system determines the Recommended Ecological Category, which is provided in this chapter.

Chapter 7: Consequences of Alternative Scenarios
This chapter describes the ecological consequences of various future flow scenarios, and determines the Ecological Category for each of these using the EHI.

Chapter 8: Conclusions and Recommendations
Recommendations on the ecological water requirements for the estuary are provided, including the recommended resource quality objectives (ecological specifications). Finally, monitoring requirements to improve the confidence of the EWR assessment are recommended.

Chapter 9: References
Report references are listed.

Chapter 10: Appendix A: Report Comments
Comments from reviewers are listed.

2 BACKGROUND INFORMATION

2.1 HYDROLOGICAL CHARACTERISTICS

The uMkhomazi River is one of KwaZulu Natal's (KZN) largest rivers and the estuary 30°12'S, 30°49'E is situated approximately 50 km south of central Durban. The suburb of Umkomaas lies on the south bank of the estuary. The uMkhomazi River rises in the Drakensberg with a length of 298 km (Begg, 1978; Perry, 1989). Cited catchment areas range from 4 222 to 4 389 km^2 (Begg, 1978) and 4 310 km^2 (Perry, 1989) to 4 315 km^2 (Day, 1981). The Present Mean Annual Runoff (pMAR) is estimated at 943.4 Million m^3. With its length and large catchment (second only to the Thukela in KZN), the river has historically been subject to major flood events.

The estuary was classified as a permanently open estuary by Whitfield (2000). It is relatively straight for much of its length only undulating around the headland on which the Sappi Saiccor factory is located. It is a wide shallow system, with a mouth that very seldom closes. There are two existing bridges, *viz.* the combined road and rail bridge at the mouth and the newer N2 freeway bridge further upstream. The old steel bridge is above the present limit of estuarine penetration.

2.2 CATCHMENT CHARACTERISTICS AND LAND-USE

A broad overview of the land-use in the uMkhomazi catchment indicated that:

- About 47% of the catchment is natural grasslands and <1% planted grasslands, with about 6% classified as degraded grassland.
- About 25% of the catchment is thicket and bushland.
- Nearly 13% of the catchment is forest plantation (comprising eucalyptus, pine, acacia and clear felled land); and
- Sugar cane is estimated at less than 1% of the catchment, while cultivated commercial farming is estimated at 3%, and cultivated temporarily subsistence dryland were estimated at 4%.

2.3 HUMAN ACTIVITIES AFFECTING THE ESTUARY (PRESSURES)

Table 2.1 provides a summary of significant flow related pressures on the uMkhomazi Estuary, while Table 2.2 summarises key non-flow related pressures.

Table 2.1 Pressures related to flow modification

Activity	Present	Description of Impact
Water abstraction and dams (including farm dams)	✓	N/A
Augmentation/Inter-basin transfer schemes		N/A
Infestation by invasive alien plants	✓	N/A

Table 2.2 Pressures, other than modification of river inflow presently affecting estuary

Activity	Present	Description of Impact
Agricultural and pastoral run-off containing fertilisers, pesticides and herbicides.	✓	Some sugar cane in the floodplain areas.
SAPPI Paper Mill effluent disposal (just above N2 bridge).	✓	Industrial effluent from paper mill (high organic content and possibly toxic substances).
Municipal Waste Water Treatment Work (WWTW).	✓	Umkomaas WWTW (Capacity 1Ml/day, operation at 49% in 2012) discharging in Zone A.
Ushukela Sugar Mill.	✓	Industrial effluent (high organic content).
Bridge(s).	✓	There are two existing bridges, the combined road and rail bridge at the mouth and the newer N2 freeway bridge further upstream.
Artificial breaching.	✓	Yes, but breaching level unknown.
Bank stabilisation and destabilisation.		Extensive sand mining in the upper reaches.
Low-lying developments.	✓	Sugar cane fields and possibly the Sappi pump station.
Migration barrier in river.	✓	Sappi Saiccor intake weir in the upper estuary.
Recreational fishing.	✓	Limited. Mostly targets the beach.
Commercial/Subsistence fishing (e.g. gillnet fishery).	✓	High levels of marginal line fishing (unknown if subsistence).
Illegal fishing (Poaching).		N/A
Bait collection.	✓	Cast netting for juvenile mullet occurs to support rock and surf anglers.
Grazing and trampling of salt marshes.		N/A
Translocated or alien fauna and flora.		N/A
Recreational disturbance of waterbirds.	✓	High intensity use of mouth area for launching, recreational beach users and fishers.

3 DELINEATION OF ESTUARY

3.1 GEOGRAPHICAL BOUNDARIES

The mouth of the uMkhomazi River is approximately 50 km south of Durban. The uMkhomazi Estuary is classified as a "*Permanently open*" estuary, but the marine influence upstream of the inlet is limited for a large part of the year (Whitfield, 1992). The uMkhomazi estuary is relatively straight for much of its length only undulating around the headland on which the Sappi Saiccor factory is located. It is a wide shallow system with a mouth that very seldom closes.

For the purposes of this EWR study, the geographical boundaries of the estuary are defined as follows (Figure 3.1):

Downstream boundary:	Estuary mouth: 30°12'4.45" S 30°48'8.65"E
Upstream boundary:	30°10'25.64"S 30°44'51.42"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 3.1 Geographical boundaries of the uMkhomazi Estuary based on the Estuary Functional Zone

The true extent of the upper boundary (marked in dark blue in Figure 3.1) of the uMkhomazi Estuary is not known as the full extent of tidal penetration is currently constrained by a weir. However, for the purpose of this study the upper reaches were taken as about 1.7 km upstream of the weir, based on channel and vegetation features. This boundary may well be significantly further upstream. The positioning of the uMkhomazi Estuary's upper boundary is further confounded by back flooding above the weir, which decreases flow velocities that in turn leads to localised sedimentation in this zone under normal flow conditions. Topographical survey information is needed to accurately determine the upper boundary of this system.

3.2 ZONATION OF THE uMKHOMAZI ESTUARY

For the purposes of this study, the uMkhomazi Estuary is sub-divided into four distinct zones, primarily based on bathymetry (Figure 3.2).

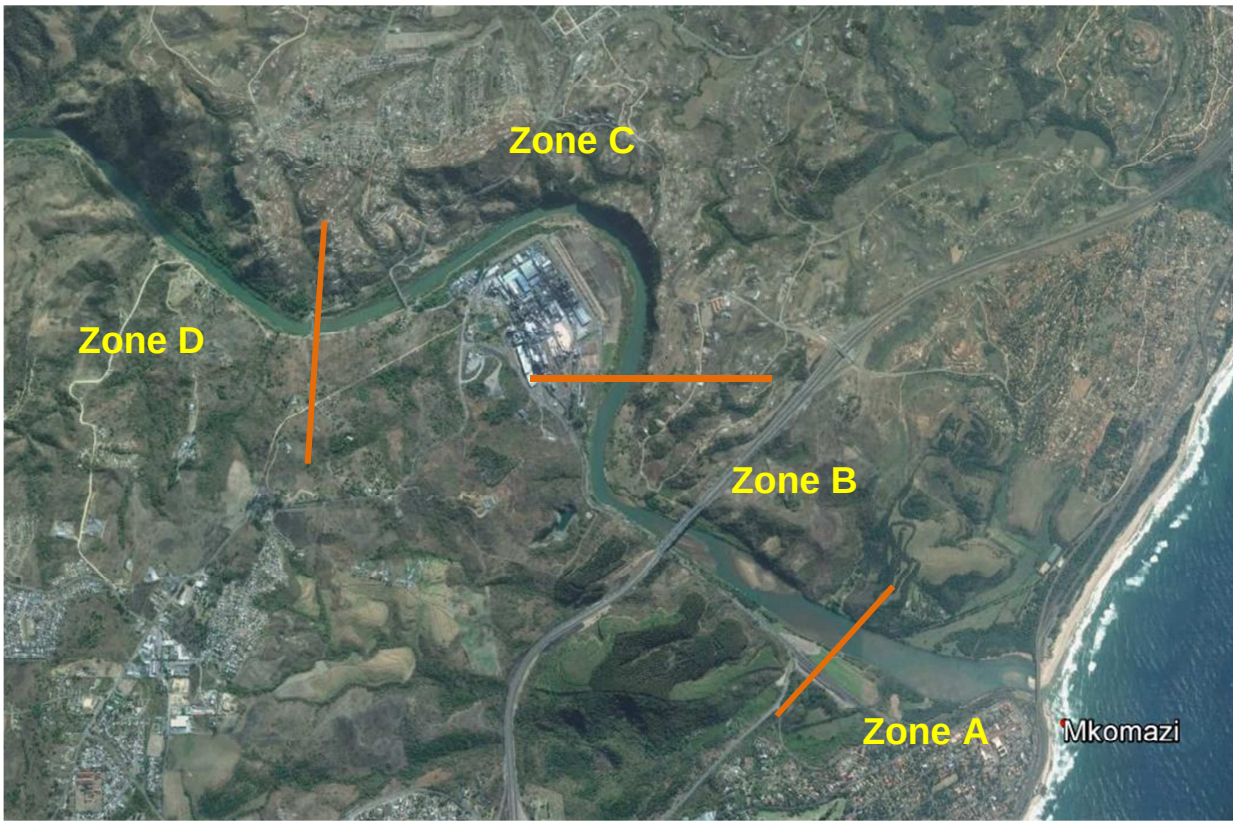


Figure 3.2 Zonation of the uMkhomazi Estuary

Table 3.1 below lists some of the key features of the uMkhomazi Estuary zonation that were used to determine the weighting of scores.

Table 3.1 Key features of the uMkhomazi Estuary zonation

	Zone A: Lower	Zone B: Middle	Zone C: Upper	Zone D: Historical upper
Area (ha)	26.5	20.1	16.1	9.4
Maximum depth (to MSL)	-0.5 to -1.0	-1.5 to - 2.0	-2.0 to -3.0	1.0 – 2.0 deep (at about -1. m MSL)

3.3 TYPICAL ABIOTIC STATES

Based on available literature, a number of characteristic 'states' can be identified for the uMkhomazi Estuary, related to mouth condition, tidal exchange, salinity distribution and water quality. These are primarily determined by river inflow patterns, water level and duration since last breaching. The different states are listed in Table 3.2.

Table 3.2 Summary of the abiotic states that can occur in the uMkhomazi Estuary

State	Flow range (m^3/s)	Description
State 1: Closed, brackish	< 1.0	The estuary mouth is closed for weeks to months. Zones A, B, and C are well mixed and salinity is brackish throughout. Zones A, B and C have salinity of about 20, 20 and 10 respectively, Zone D is fresh.
State 2: Open, full salinity gradient	1.0 – 2.0	The system shows a marine influence due to reduced freshwater inflow and regular breaching. Zones A, B and C have salinity of about 25, 15 and 10 respectively, Zone D is fresh.
State 3: Open, limited salinity gradient	2.0 – 5.0	Zones C and D are fresh, with limited saline intrusion into Zone B (salinity ~10). Zones A have salinity of about 20, with strong tidal flucuations been tween 30 on the high tide and 10 on the low tide.
State 4: Open fresh	> 5	All zones are fresh.

The transition between the different states will not be instantaneous, but will take place gradually. To assess the occurrence and duration of the different abiotic states selected for the estuary during the different scenarios, a number of techniques were used:

- Colour coding (indicated above) was used to visually highlight the occurrence of the various abiotic states between different scenarios.
- Summary tables of the occurrence of different flows at increments of 10%iles are listed separately to provide a quick comprehensive overview; and

A summary of the typical physical and water quality characteristics of different abiotic states in the uMkhomazi is provided in Chapter 4. For more detail on the underlying data and assumptions, refer to the Abiotic Specialist Report (Part of Report 8.3; Report Number: RDM/WMA11/00/CON/CLA/0714).

4 ECOLOGICAL BASELINE AND HEALTH ASSESSMENT

4.1 HYDROLOGY

4.1.1 Baseline description

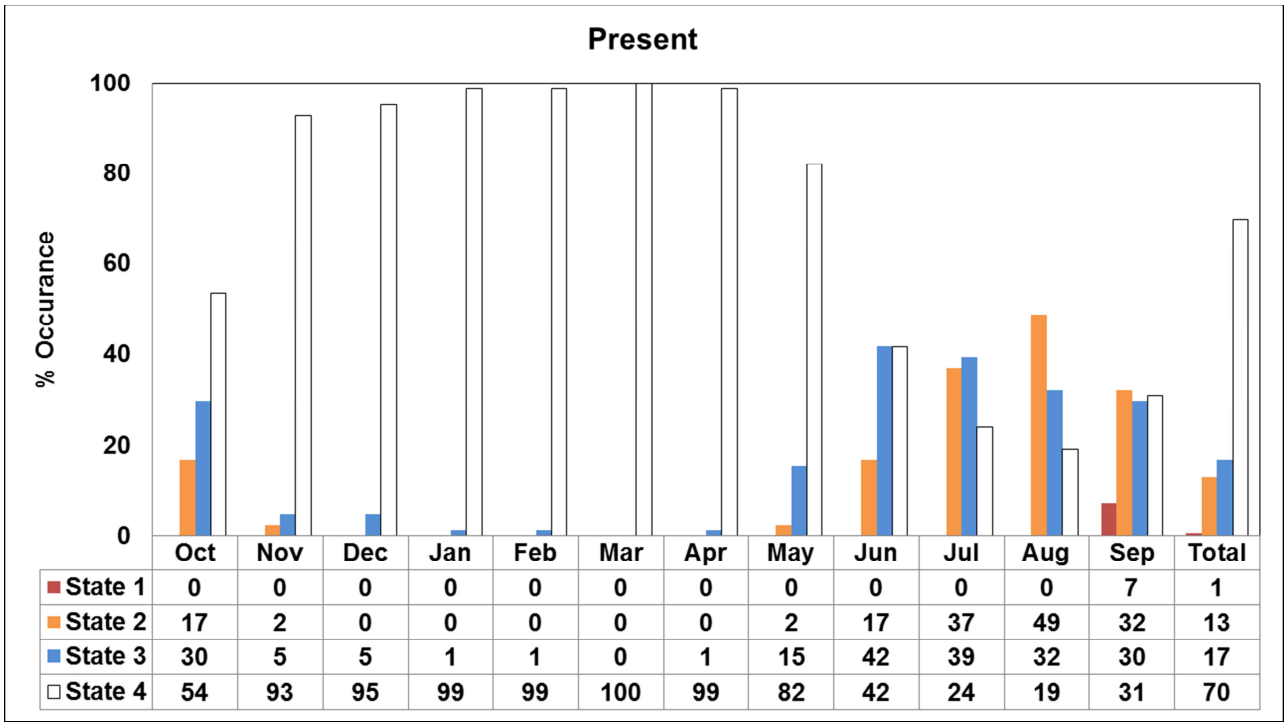
According to the hydrological data provided for this study, the pMAR into the uMkhomazi Estuary is 943.39 10^6 m^3 Million Cubic Metres (MCM). This is a decrease of 12% compared to the natural MAR (nMAR) of 1 077.74 10^6 m^3 MCM. The occurrences of flow distributions (mean monthly flows in m^3/s) for the Present State and Reference Condition of the uMkhomazi Estuary, derived from the 84-year simulated data set, are provided in Table 4.1 and Table 4.2. A graphic representation of the occurrence of the various abiotic states is presented in Figure 4.1 and Figure 4.2. The full 84-year series of simulated monthly runoff data for the present state and Reference Condition is provided in Table 4.3 and Table 4.4.

Table 4.1 A summary of the monthly flow (in m^3/s) distribution under the Present State

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	203.4	133.8	186.6	205.1	245.6	251.5	136.6	130.8	89.2	44.9	40.9	248.4
99	83.5	131.6	146.0	203.1	221.2	226.4	115.9	103.2	48.2	29.5	32.8	92.0
90	23.6	55.2	95.9	119.6	138.4	111.1	66.7	23.6	12.2	14.2	8.2	12.1
80	15.9	34.5	70.1	92.7	112.3	81.9	47.4	15.3	8.7	5.7	4.7	7.6
70	12.2	28.8	55.9	74.8	87.3	63.7	34.5	14.3	6.2	4.1	3.7	5.1
60	8.1	22.8	47.0	64.7	76.8	58.6	31.5	10.9	5.2	3.3	2.9	3.6
50	5.9	19.1	41.2	52.5	65.9	49.7	29.2	9.7	4.8	2.7	2.3	2.5
40	4.3	14.3	32.2	44.4	58.0	45.7	24.5	8.6	4.1	2.2	1.6	2.0
30	3.4	10.3	26.0	37.5	46.7	41.0	18.4	7.4	3.3	1.6	1.3	1.6
20	2.8	8.8	16.1	29.2	39.8	37.6	15.4	5.3	2.3	1.3	1.1	1.3
10	1.6	6.6	8.7	22.8	26.5	28.6	10.9	3.7	1.6	1.1	1.0	1.1
1	1.1	1.3	3.0	5.5	9.1	12.0	4.9	1.7	1.1	1.0	1.0	1.0
0.1	1.0	1.2	2.6	5.0	4.7	10.0	4.5	1.3	1.0	1.0	1.0	1.0

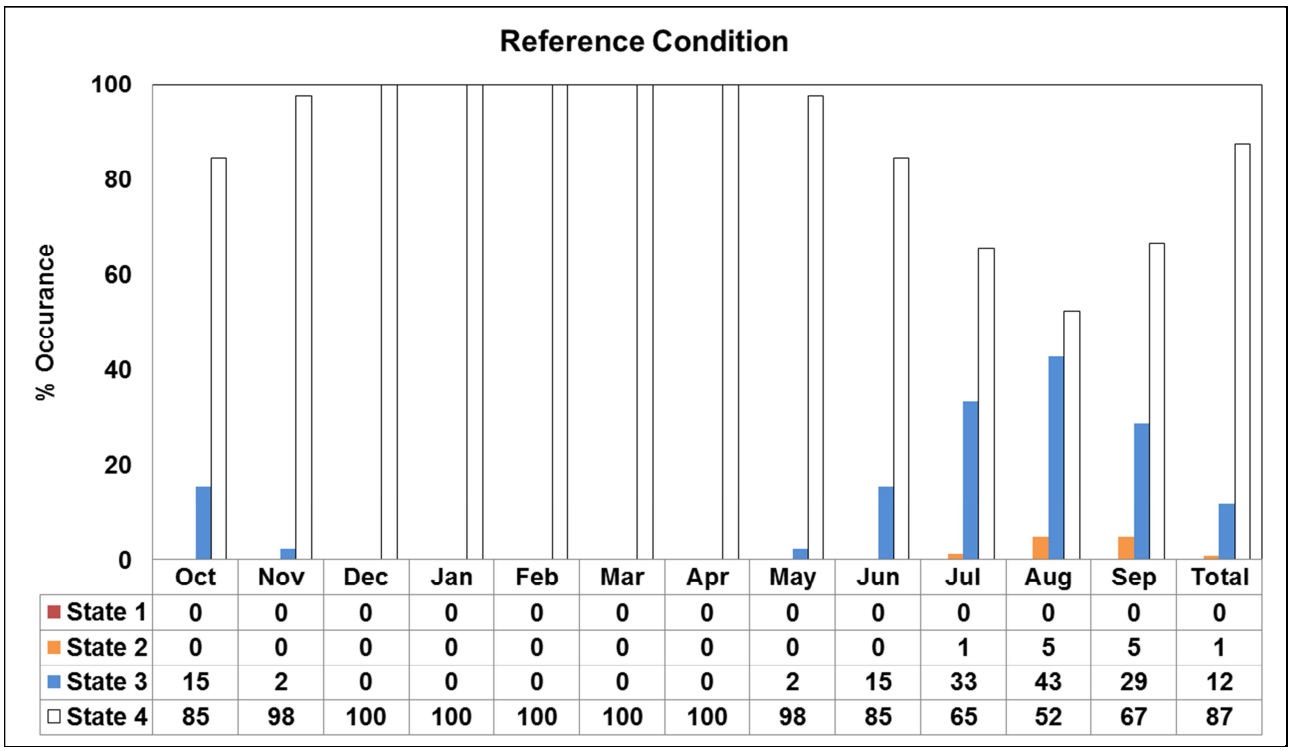
Table 4.2 A summary of the monthly flow (in m^3/s) distribution under the Reference State

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	209.5	145.4	204.5	217.6	255.8	260.3	148.6	142.2	94.6	51.7	48.7	269.7
99	91.6	133.7	160.6	216.8	233.4	236.9	122.2	109.0	55.2	36.0	38.1	101.3
90	27.8	61.9	104.8	126.3	149.3	119.9	73.4	25.6	16.0	16.5	12.2	15.8
80	19.6	39.4	78.1	100.9	122.3	85.3	52.5	19.2	12.2	9.0	8.5	11.5
70	15.6	33.3	61.8	82.8	94.7	68.0	38.6	17.0	9.6	7.3	6.9	8.8
60	11.7	26.9	51.6	70.7	82.1	62.7	35.0	14.4	8.6	6.4	6.1	7.2
50	9.1	23.7	45.2	57.8	71.2	54.9	32.2	13.4	8.0	5.9	5.4	6.0
40	7.7	18.5	36.3	48.7	63.1	49.2	28.5	12.5	7.3	5.3	4.5	5.2
30	6.5	14.1	29.7	41.6	50.3	46.2	23.6	10.9	6.3	4.5	3.8	4.8
20	5.7	12.3	19.2	33.9	44.5	40.7	19.1	8.9	5.3	3.6	3.2	4.1
10	4.3	10.1	11.0	25.6	29.3	32.3	14.5	6.8	4.4	2.8	2.5	2.9
1	2.8	3.8	5.5	8.3	11.9	14.9	8.4	4.8	3.0	2.1	1.8	1.6
0.1	2.6	3.7	5.4	7.8	7.1	12.4	7.8	4.0	2.8	2.0	1.8	1.6



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	7	1
State 2	17	2	0	0	0	0	0	2	17	37	49	32	13
State 3	30	5	5	1	1	0	1	15	42	39	32	30	17
State 4	54	93	95	99	99	100	99	82	42	24	19	31	70

Figure 4.1 **Graphic presentation of the occurrence of the various abiotic states under the Present State**



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	1	5	5	1
State 3	15	2	0	0	0	0	0	2	15	33	43	29	12
State 4	85	98	100	100	100	100	100	98	85	65	52	67	87

Figure 4.2 **Graphic presentation of the occurrence of the various abiotic states under the Reference Condition**

Table 4.3 Present State simulated monthly flows (in m^3/s) to the uMkhomazi Estuary

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	15.4	11.0	11.3	17.7	23.6	30.5	18.4	5.6	4.5	2.8	1.2	12.5
1926	20.4	21.5	52.9	57.7	47.4	88.0	55.1	9.7	1.7	1.1	3.7	4.0
1927	10.9	13.3	47.4	105.6	79.5	53.9	30.1	6.8	2.3	1.1	1.3	1.8
1928	7.2	10.3	31.5	52.5	37.4	47.4	33.0	12.2	19.9	21.5	12.3	13.8
1929	18.0	37.3	46.7	75.5	66.3	45.5	24.9	6.0	2.6	1.5	2.4	3.4
1930	5.0	10.0	42.8	70.2	59.6	40.4	24.8	8.6	2.2	4.3	4.4	1.6
1931	2.1	4.0	8.2	26.7	84.4	59.6	18.3	5.7	4.2	2.3	1.1	1.5
1932	5.9	21.5	32.0	19.8	20.4	24.3	15.8	5.2	1.3	1.0	1.0	1.0
1933	1.0	54.9	107.4	148.3	101.7	40.9	29.4	20.6	10.7	5.8	4.8	4.1
1934	8.0	65.8	109.7	61.1	38.3	32.2	22.3	11.4	38.9	26.1	7.1	2.1
1935	1.4	1.3	3.0	26.3	82.9	71.7	31.1	18.0	12.3	4.3	1.2	1.3
1936	4.4	75.0	54.4	42.7	77.2	47.0	15.6	3.4	1.1	1.0	1.0	1.0
1937	1.5	9.9	19.3	55.6	108.3	55.8	33.1	18.6	6.3	3.4	4.1	3.1
1938	22.7	31.9	68.6	61.4	166.6	110.5	30.3	8.3	3.3	1.5	1.4	7.5
1939	15.2	33.3	43.6	45.8	46.6	48.8	30.4	37.2	34.6	14.8	4.4	2.4
1940	7.0	31.1	119.4	102.0	78.1	48.3	22.8	7.7	1.9	1.1	1.0	1.0
1941	3.4	7.9	15.0	64.2	136.2	120.4	63.9	21.6	6.6	2.3	2.5	2.8
1942	11.3	59.4	126.6	120.7	86.7	48.9	139.0	96.9	27.0	15.5	30.9	21.2
1943	56.0	134.1	121.6	74.6	65.1	58.8	30.2	5.5	1.9	1.4	1.1	12.7
1944	18.3	14.1	7.3	23.1	43.6	103.5	66.8	14.3	4.0	1.2	1.0	1.0
1945	1.2	1.2	4.3	19.1	40.3	39.0	25.0	10.0	2.7	1.0	1.0	1.0
1946	1.2	21.8	26.1	33.3	89.1	96.4	48.9	13.6	11.5	8.8	4.0	1.6
1947	4.3	34.4	55.7	77.7	75.0	70.6	46.5	14.8	4.9	1.2	1.0	1.0
1948	3.2	8.6	17.0	27.6	48.1	51.0	29.6	8.7	2.2	1.0	1.0	1.4
1949	4.1	17.1	41.1	34.1	62.4	111.4	73.2	23.2	9.0	4.2	9.3	8.9
1950	3.9	6.9	59.2	103.2	73.3	28.2	14.1	5.4	1.3	1.0	3.3	6.8
1951	12.2	8.7	25.0	64.8	88.8	45.6	20.2	10.4	4.8	2.4	2.4	1.9
1952	2.9	16.5	27.6	38.3	72.7	39.3	10.7	3.1	1.3	1.0	1.3	4.4
1953	12.3	25.3	52.9	59.8	90.2	63.5	24.4	11.6	8.4	3.4	1.2	2.2
1954	26.9	34.8	33.9	135.8	178.6	82.7	28.0	10.5	5.2	2.0	1.1	1.1
1955	1.9	5.1	38.8	29.7	110.6	139.4	66.3	11.3	2.6	1.1	1.1	1.4
1956	5.0	29.4	136.8	152.2	87.1	75.3	52.3	15.4	4.9	1.6	2.9	26.6
1957	48.2	38.6	41.3	74.5	91.1	43.8	29.4	16.2	5.0	1.2	1.0	1.2
1958	2.9	12.7	63.9	74.8	64.4	34.5	15.5	133.9	93.7	14.9	4.1	2.3
1959	4.4	21.9	33.1	24.4	32.3	46.1	39.3	17.9	6.0	1.3	1.0	1.4
1960	2.9	20.0	87.3	49.4	46.7	67.2	100.6	29.3	8.6	3.5	1.6	1.9
1961	1.7	12.1	30.8	51.7	83.6	58.7	23.7	9.7	3.7	1.6	1.9	2.8
1962	2.7	25.9	47.1	117.0	48.5	108.5	34.4	10.1	6.5	24.5	6.0	2.8
1963	10.7	55.4	58.1	101.0	45.3	30.2	14.4	7.4	13.1	6.6	3.2	7.8
1964	14.5	44.5	34.5	60.5	69.2	12.5	7.6	3.2	15.9	10.3	5.4	12.6
1965	15.3	29.7	15.4	84.4	90.2	13.4	6.0	6.1	3.1	1.7	1.4	2.5
1966	2.0	29.2	31.8	43.2	139.4	142.2	111.2	24.2	10.6	8.3	5.0	2.7
1967	2.9	29.0	26.6	22.7	21.9	40.7	33.4	7.6	3.6	2.3	2.9	2.0
1968	1.3	8.2	25.5	5.0	12.0	65.6	42.7	10.7	5.2	3.4	1.9	3.4
1969	24.0	14.8	48.5	39.1	64.3	16.3	4.5	2.9	1.5	1.5	14.6	8.4
1970	56.3	23.3	22.6	27.3	66.2	33.5	25.9	15.2	5.8	5.6	22.1	7.6
1971	16.5	25.3	59.5	99.6	130.3	124.3	35.7	13.5	7.4	4.4	3.1	1.7
1972	4.0	17.5	13.7	11.0	65.0	46.9	79.8	23.8	4.9	2.7	3.7	5.1
1973	17.7	28.6	30.1	142.5	215.6	146.0	77.7	24.2	12.0	8.3	4.6	2.4
1974	3.3	13.4	29.4	88.1	114.7	61.5	25.7	8.1	4.3	2.7	1.8	7.4
1975	5.1	13.6	88.4	202.7	248.3	254.3	91.5	23.7	9.8	6.9	5.3	4.1
1976	35.6	20.3	16.7	44.2	63.0	63.5	34.7	9.2	4.2	2.9	2.0	2.3
1977	7.3	10.2	16.5	84.7	65.6	57.4	41.5	15.0	6.3	3.6	2.5	5.8
1978	17.2	24.1	88.1	34.5	46.5	49.5	17.3	9.2	4.1	4.1	4.5	6.1
1979	4.3	8.9	11.5	31.8	39.0	44.8	11.2	3.0	1.6	1.3	1.1	7.6
1980	10.7	8.2	35.6	68.3	117.5	44.3	8.4	4.8	3.0	1.6	1.6	11.1
1981	3.7	9.1	15.2	17.6	10.1	60.2	17.8	4.9	3.2	1.7	1.2	1.4
1982	1.4	9.0	6.4	5.6	4.3	9.7	5.0	1.2	1.0	1.0	1.1	1.1
1983	3.5	18.4	79.1	69.8	26.5	62.5	53.4	9.7	4.8	3.4	2.2	2.0
1984	4.7	7.1	6.5	52.5	171.3	44.3	8.2	3.6	2.3	1.5	1.1	1.1
1985	8.0	63.1	90.0	76.4	51.3	44.6	15.1	7.7	4.0	2.1	1.7	3.6
1986	9.9	39.9	42.4	45.0	26.1	52.6	16.9	5.6	3.6	2.6	6.1	265.7
1987	216.7	131.1	44.0	37.7	176.0	220.7	60.1	14.5	8.8	12.8	5.8	4.6

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1988	4.6	17.0	80.7	103.1	152.2	66.8	22.2	14.9	7.0	5.2	2.6	1.7
1989	2.0	95.7	98.4	34.8	29.8	59.0	58.4	10.3	4.8	3.1	2.9	5.1
1990	5.9	8.1	39.0	79.7	133.9	55.8	18.3	7.7	4.6	2.9	1.6	2.0
1991	18.2	21.1	33.8	35.1	26.5	19.5	5.8	1.8	1.2	1.0	1.0	1.0
1992	1.1	3.0	3.1	10.0	33.0	35.6	19.2	3.6	1.3	1.0	1.0	1.0
1993	15.1	19.8	45.4	109.3	120.0	39.3	11.2	5.0	2.6	2.6	3.1	1.6
1994	3.5	4.3	7.8	39.3	19.2	40.1	32.2	9.7	5.8	3.3	41.8	56.4
1995	33.3	16.9	191.1	205.3	175.1	109.9	32.0	11.0	6.1	46.6	15.7	7.8
1996	8.1	17.3	68.2	122.6	47.4	81.3	43.0	14.7	14.8	17.4	8.6	7.5
1997	11.4	44.6	72.2	69.2	125.7	67.6	29.1	9.9	5.7	3.4	3.2	2.4
1998	2.9	9.1	47.9	45.9	74.6	27.1	8.6	3.7	1.9	1.3	1.1	1.0
1999	8.7	13.8	113.3	150.1	83.9	145.7	76.9	24.8	8.9	5.2	3.1	7.4
2000	6.1	24.6	61.1	65.7	42.5	29.3	37.0	11.5	5.0	2.9	1.8	20.0
2001	14.1	71.2	67.8	48.9	51.6	39.8	11.7	5.2	5.8	15.0	14.8	10.3
2002	4.3	5.6	10.0	26.1	52.3	33.9	24.0	9.0	4.3	2.2	1.2	2.1
2003	1.4	9.1	13.6	42.3	57.6	49.9	14.8	4.2	1.6	2.2	2.8	3.9
2004	8.1	28.8	82.3	84.4	42.8	41.0	31.6	7.9	3.7	2.3	1.5	1.2
2005	1.6	4.3	2.6	37.5	74.6	58.3	29.0	14.9	5.3	3.1	4.3	4.0
2006	30.5	23.0	48.5	28.5	38.1	21.5	13.2	4.5	3.5	4.1	1.4	1.2
2007	14.4	38.2	41.7	51.3	43.0	45.1	31.9	14.3	6.2	2.9	1.4	1.7
2008	2.0	6.5	20.0	37.1	135.9	99.5	32.8	9.7	3.4	1.4	2.0	1.3

Table 4.4 Reference Condition simulated monthly flows (in m^3/s) to the uMkhomazi Estuary

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	15.5	14.6	14.0	21.3	26.8	34.2	23.6	9.1	7.6	6.2	3.6	15.9
1926	24.4	26.1	57.5	63.4	50.6	98.5	62.2	12.6	4.6	3.2	6.9	7.9
1927	14.5	17.4	53.1	117.4	84.8	56.2	34.1	10.2	5.3	3.0	3.7	5.0
1928	10.6	14.1	35.5	56.9	40.6	53.3	39.3	16.0	23.0	26.1	16.9	17.7
1929	21.8	41.8	51.5	83.4	70.6	48.1	28.9	9.7	5.6	4.6	5.6	7.1
1930	8.6	13.4	46.1	78.1	65.5	43.3	29.0	12.5	5.2	7.3	8.5	5.0
1931	5.0	7.4	10.6	30.1	92.1	65.7	23.3	8.9	7.4	5.5	3.2	4.2
1932	9.0	25.4	35.9	23.9	23.1	27.1	20.5	9.1	3.8	2.7	2.6	2.0
1933	2.6	62.4	121.8	159.5	104.4	42.2	33.0	24.5	14.5	9.1	8.5	7.7
1934	11.4	71.3	120.4	66.7	40.3	35.3	25.8	15.5	46.3	32.4	10.7	5.6
1935	4.1	3.9	5.5	29.5	96.3	82.0	35.4	20.6	16.7	7.9	3.7	3.8
1936	7.7	88.0	61.8	45.0	84.8	51.9	19.2	6.5	3.0	2.1	1.8	1.7
1937	4.1	13.5	22.4	62.9	120.1	61.7	36.1	23.5	9.8	6.5	7.5	6.6
1938	26.4	36.6	72.8	65.5	179.9	115.8	31.4	11.7	6.9	4.5	4.3	11.5
1939	19.4	38.8	49.0	50.5	50.4	53.0	34.6	41.4	39.1	19.2	8.1	5.6
1940	10.3	35.8	131.4	109.3	80.1	50.2	26.2	11.7	5.0	3.0	2.4	2.4
1941	6.4	11.6	18.3	68.9	147.1	130.6	68.6	24.3	10.1	5.4	5.6	6.3
1942	15.0	67.2	138.3	126.0	87.4	50.9	151.6	101.4	28.4	19.0	35.7	26.7
1943	64.7	146.7	127.5	76.7	66.8	62.1	34.2	9.1	4.8	4.1	3.1	16.3
1944	22.7	18.4	10.2	25.7	47.5	116.2	74.9	17.1	7.3	3.4	2.1	1.6
1945	3.3	3.7	6.5	22.6	46.1	44.3	30.2	13.9	5.8	2.7	1.8	1.6
1946	3.2	25.9	29.6	37.9	97.2	106.9	55.3	17.0	14.4	13.1	7.9	4.8
1947	7.5	39.4	60.3	82.8	79.2	75.1	50.7	18.7	8.2	3.5	1.9	1.7
1948	6.1	12.7	20.3	31.8	51.9	55.9	34.5	12.5	5.3	2.7	2.5	4.1
1949	7.3	22.7	45.6	38.1	68.2	120.6	78.3	26.1	12.5	7.3	12.9	13.2
1950	7.4	10.2	66.9	113.5	76.2	29.7	18.5	8.9	3.8	2.0	6.2	10.7
1951	16.2	13.1	27.5	71.2	94.6	48.2	23.7	14.8	8.4	5.7	5.5	5.0
1952	5.9	19.9	31.2	42.7	80.1	44.8	14.4	6.3	3.7	2.6	3.8	8.2
1953	16.2	30.1	59.1	66.2	95.9	66.9	27.5	14.9	12.2	6.8	3.6	5.4
1954	31.9	39.5	37.5	148.7	191.9	85.0	29.9	14.2	8.6	5.2	3.1	3.1
1955	4.8	8.5	42.8	34.5	122.2	153.4	69.7	13.6	5.7	3.3	3.2	4.2
1956	8.4	34.1	150.6	162.7	87.7	80.4	56.4	18.9	8.3	4.5	5.8	31.2
1957	55.2	44.0	44.8	79.2	98.3	48.1	31.9	20.6	8.5	3.5	2.0	3.5
1958	5.9	15.8	72.6	85.1	71.1	37.6	18.9	145.9	99.0	16.5	7.6	5.9
1959	7.8	26.0	37.4	28.6	34.6	51.6	44.7	22.2	9.5	4.0	2.8	4.1
1960	6.0	24.6	97.8	56.8	50.0	74.2	109.8	32.8	11.8	6.6	4.5	4.8
1961	4.8	15.7	34.6	56.9	92.2	66.7	28.4	13.5	6.8	4.3	4.6	6.1
1962	5.6	30.6	51.6	126.4	53.2	118.0	39.0	13.8	9.8	27.8	10.2	6.6
1963	14.3	60.7	61.8	110.6	49.8	33.0	17.9	11.3	16.1	10.5	6.7	11.5

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1964	18.0	50.0	37.6	65.5	73.1	15.5	11.1	6.3	18.9	14.9	9.0	17.5
1965	18.6	34.9	18.9	94.1	99.1	16.5	9.4	9.2	6.5	5.0	4.3	6.0
1966	5.3	33.3	36.1	48.0	149.7	153.2	116.2	25.3	14.1	12.0	8.9	6.3
1967	5.8	33.4	30.0	25.5	24.6	44.7	38.3	11.3	6.7	5.3	6.0	5.3
1968	4.2	11.7	29.7	7.7	13.9	73.4	49.6	14.0	8.6	6.6	5.0	6.7
1969	28.4	19.1	53.5	43.7	68.9	19.4	7.7	5.9	4.2	4.4	18.1	12.7
1970	63.1	27.1	25.5	31.3	70.2	36.3	30.4	18.7	9.6	9.0	26.3	12.2
1971	19.9	29.2	63.6	107.5	138.1	130.6	37.6	16.9	11.0	7.9	6.6	4.9
1972	7.1	21.9	17.7	13.6	71.3	54.0	88.0	25.8	7.9	5.5	6.5	8.7
1973	22.8	32.5	33.7	156.6	228.3	150.1	80.3	26.1	15.8	12.0	8.1	5.8
1974	6.5	16.8	32.9	96.6	122.3	64.5	28.9	11.9	7.5	5.9	4.8	10.9
1975	9.2	17.6	95.4	216.6	258.3	262.9	87.9	25.9	14.0	11.1	9.2	7.7
1976	40.6	24.6	19.5	48.6	68.5	66.9	38.6	13.1	7.3	6.1	5.0	5.1
1977	10.8	13.9	19.4	93.2	71.4	62.7	45.8	19.4	9.7	6.9	5.7	9.3
1978	21.4	29.7	95.6	38.4	50.4	53.4	20.5	13.1	7.6	7.4	8.0	9.8
1979	7.7	12.1	13.9	35.6	43.5	49.0	14.6	6.3	4.4	3.5	2.9	10.7
1980	15.2	11.5	41.4	74.9	125.1	46.7	11.5	8.1	6.2	4.6	4.2	15.5
1981	6.9	12.3	18.7	21.5	13.0	65.7	23.9	8.5	6.3	4.7	3.7	4.1
1982	3.8	13.2	9.1	8.5	6.5	12.1	8.5	3.9	2.8	2.4	3.1	3.1
1983	6.6	22.8	88.7	80.8	29.4	67.8	56.9	13.1	8.1	6.4	5.2	5.2
1984	7.0	11.1	9.5	58.7	188.6	48.9	11.6	6.6	5.1	4.2	3.1	3.0
1985	12.4	74.0	99.1	83.2	53.4	48.6	19.5	10.9	7.0	5.2	4.4	7.2
1986	13.0	45.7	47.5	49.5	29.2	58.8	22.0	9.0	6.6	5.9	9.4	288.5
1987	222.6	131.1	45.8	40.9	188.7	231.6	60.0	16.5	12.3	16.5	9.4	8.0
1988	7.9	20.9	91.0	111.4	160.3	70.5	24.7	18.9	10.8	8.6	6.0	4.8
1989	4.8	112.9	107.2	36.0	32.4	65.5	65.2	13.7	8.1	6.4	6.0	9.2
1990	9.0	12.4	42.8	86.8	145.6	59.2	21.8	11.0	8.0	6.3	4.8	5.1
1991	22.4	25.9	37.2	38.4	29.2	22.6	9.6	4.9	3.2	2.3	2.0	2.1
1992	2.9	6.2	5.9	13.1	36.2	40.1	23.4	7.2	4.0	2.7	2.5	2.9
1993	19.4	25.9	51.1	118.3	126.3	41.1	15.9	8.3	5.5	5.5	6.6	5.0
1994	6.5	7.8	10.2	43.9	23.4	43.8	38.0	13.3	8.8	6.7	49.9	63.0
1995	35.7	19.8	209.4	217.7	180.7	114.4	34.5	14.5	9.4	53.4	22.1	11.8
1996	11.2	20.3	77.7	132.8	48.5	85.7	45.9	18.4	18.1	22.0	12.9	11.8
1997	14.8	52.3	78.8	76.0	134.9	70.2	32.4	13.5	9.2	6.6	6.4	5.8
1998	5.8	12.6	52.6	50.4	82.5	31.9	12.2	6.7	4.5	3.6	3.0	2.6
1999	11.6	17.3	130.8	164.6	86.1	151.1	78.9	27.0	12.6	8.8	6.4	10.8
2000	9.7	28.5	67.6	72.8	45.2	33.0	40.3	15.4	8.3	6.0	4.7	24.2
2001	19.0	82.0	75.9	52.5	56.3	42.8	15.1	8.7	9.3	18.6	19.0	15.3
2002	7.9	9.0	12.1	30.0	56.1	37.0	27.7	12.8	7.7	5.3	3.6	5.0
2003	4.2	12.1	16.3	47.0	62.5	55.8	18.9	7.5	4.4	5.1	6.1	7.3
2004	11.7	35.6	92.7	91.8	47.4	46.3	38.0	11.1	6.7	5.4	4.3	3.6
2005	4.3	7.8	5.4	41.7	80.7	62.6	32.6	19.0	8.7	6.3	7.3	7.7
2006	36.5	28.0	54.7	33.0	41.3	25.0	18.6	8.1	6.3	7.8	4.4	3.5
2007	18.0	49.3	47.8	55.6	47.8	48.6	35.1	18.7	9.5	6.3	4.3	4.6
2008	5.1	10.0	24.0	42.8	148.3	109.1	36.1	13.2	6.4	4.0	4.7	4.1

4.1.2 Low flows

Winter inflows never decrease below 1.0 m^3/s and less than 1% below 2 m^3/s under the Reference condition (Table 4.5), thereby maintaining open mouth conditions and ingress of salinity into the middle and upper reaches of the estuary. Under the Reference Condition, monthly flow exceeded 5 m^3/s for 87% of the time, while under the Present State river inflow exceeds 5 m^3/s for 70% of the time.

Table 4.5 Summary of the change in low flow conditions to the uMkhomazi Estuary from the Reference Condition to the Present State

Percentile	Monthly flow (m^3/s)		% Remaining
	Natural	Present	
30%ile	8.5	5.0	58.6
20%ile	6.3	3.1	48.8
10%ile	4.4	1.6	35.8
% Similarity in low flows			**47.7**

Confidence: High

4.1.3 Flood regime

To provide an indication of the change in flood regime from the Reference Condition to the Present State the ten highest simulated monthly flow volumes were compared for the 84-year period (summarised Table 4.6). The analysis of the simulated monthly flow data indicate that under Reference Conditions floods were about 6% higher than at present, depending on the size class.

Table 4.6 Summary of the ten highest simulated monthly volumes to the uMkhomazi Estuary under Reference Condition and Present State

Date	Monthly Volume ($x10^6$ m^3/month)		% Remaining
	Natural	Present	
Sep 1987	92.1	688.8	88.8
Mar 1976	96.7	681.1	91.3
Feb 1976	96.1	606.1	85.0
Mar 1988	95.3	591.0	88.0
Oct 1987	97.3	580.5	72.5
Jan 1996	94.3	550.0	66.6
Jan 1976	93.5	542.8	80.7
Dec 1995	91.3	511.8	90.2
Feb 1974	94.4	526.4	77.2
Feb 1955	93.1	436.0	71.5
% Similarity in floods			**94.4**

Confidence: Medium

4.1.4 Hydrological health

Table 4.7 provides a summary of the hydrological health of the uMkhomazi Estuary.

Table 4.7 Calculation of the hydrological health score, giving examples in italics

Variable	Summary of change	Score	Conf*
a.% Similarity in period of low flows		48	H
b.% Similarity in mean annual frequency of floods	The simulated monthly flow data indicate that under Reference Conditions floods were about 20 % higher than at present, depending on the size class.	95	M
Hydrology score		**66.8**	**M**

* Confidence level: L – Low; M – Medium; H - High

4.2 PHYSICAL HABITAT

4.2.1 Baseline description

Sedimentary deposits and processes in the uMkhomazi Estuary are predominantly fluvial in nature and the system is classified as a river-dominated estuary (Cooper, 1994). The greatest geomorphological impacts in the channel and sand berm at the mouth are caused by extreme river floods. Sedimentary processes show significant changes in response to river inflow variation. Within the normal range of discharge variation the channel varies in dimension and morphology but no major long-term build-up of sediment is evident in the floodplain or channel. Minor floods deposit muddy overbank deposits. During such floods, the channel depth and gradient is increased by mouth breaching, but the high wave energy along this coast rapidly leads to a more constricted mouth post flood event. Superimposed on these short-term changes is a cyclic pattern driven by major floods which cause lateral channel erosion and overbank deposition. Post-flood recovery involves progressive channel confinement and stabilisation as flow reverts to a single or braided channel and the floodplain is re-vegetated.

Under the Reference Condition there would have been less sediments coming from the catchment. Poor land-use practises are at present leading to more sediment, especially finer fractions, entering the system. The reduction in major floods and loss of minor resetting events would have resulted in a slowdown of the natural erosion-depositional cycle, leading to the estuary being more in the shallow constricted phase of the cycle because of the loss of resetting events. In addition, there has been some loss of intertidal and subtidal area above the Sappi Weir.

Sand mining in the floodplain in the river reach just above the estuary is reducing historical depositional areas and removing some of the medium sand fractions from the system.

4.2.2 Physical habitat health

Table 4. 8 provides a summary of the hydrological health of the uMkhomazi Estuary.

Table 4.8 Calculation of the physical habitat score and adjusted score (net of non-flow impacts)

Variable		Score[1]	Motivation	Conf
1. Resemblance of <u>intertidal sediment</u> structure and distribution to Reference condition				
1a	% Similarity in intertidal area exposed	80	Sedimentation processes are similar to Reference conditions, but there is some loss of intertidal habitat due to deposition and infilling of the intertidal habitat. There has been some loss of intertidal area above the Sappi weir. During States 1 and 2 there is also less exposed intertidal habitat to increased mouth closure and greater mouth restriction.	M
1b	% Similarity in sand fraction relative to total sand and mud	80	Information is lacking on changes in % similarity in sand fraction relative to total sand and mud, but the score of 80 is based on an increase in clay and silt fractions experienced in similar systems, especially in Zone B, C and D. Sand mining will also change grain size distribution in the system.	M

Variable		Score[1]	Motivation	Conf
2	% Similarity in subtidal components: depth, bed or channel morphology	80	There has been some infilling of sub-tidal areas as a result of the decrease/loss in resetting floods and increased sediment yield from the catchment. Under the Reference Condition, floods would have scoured the system to mean sea level before the natural deposition cycle caused infilling. Under the Present State resetting events have been somewhat reduced and infilling is maintaining the more constricted equilibrium state. There has been about a 10% loss of subtidal area due to the Sappi weir. There are also indications that the bridges are causing localise changes in bathymetry.	M
	Physical habitat score	**80**		

[1] $Score = \frac{mean(1a\ to\ 1b)+2.}{2}$

Variable	Score	Motivation	Conf
Anthropogenic influence:			
Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary.	70	Poor agricultural practises and developments in the catchment are causing degradation and changes in sedimentation- this is especially relevant. This is offset to some extend by sand mining	M
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.	70	Poor agricultural practises and developments in the catchment are causing degradation and changes in sedimentation.	M

4.3 HYDRODYNAMICS

4.3.1 Baseline description

Table 4.9 provides a summary of the hydrodynamics characteristics associated the typical abiotic states occurring in the uMkhomazi Estuary.

Table 4.9 Summary of the abiotic states, and associated hydrodynamic characteristics

Parameter	State 1: Closed, brackish	State 2: Open, full salinity gradient	State 3: Open, limited salinity gradient	State 4: Open, fresh
Flow range (m^3/s)	<1	1 - 2	2 - 5	>5
Mouth condition	Closed	Closed <7 days	Open	Open
Water level (m to MSL)	1.5 - 2.0 (can reach ~3 m MSL but artificially breached)	1.5	1.5	1.5, but can increase significantly during floods to 3 m MSL
Inundation	Yes, back flooding during closed state	N/A	N/A	Yes, during floods
Tidal range (m)	0	0.3 - 0.5	0.5 -1.0	2.0 m, suppressed during floods
Dominant circulation process	Wind	Tides	Tides and river	River
Retention	Weeks to months	1 - 2 weeks	<1 week	<1 day

4.3.2 Hydrodynamic health

Table 4.10 provides a summary of the hydrodynamic health of the uMkhomazi Estuary.

Table 4.10 Calculation of the hydrodynamics score

Variable	Summary of change	Score	Conf
Hydrodynamics and mouth conditions score	Mouth closure occurs for about 1% of the time under the Present State, while the estuary was permanently open under the Reference Condition. Artificial breaching at low levels is disguising the actual frequency at which this is occurring as the system is artificially breached as soon as the mouth becomes constricted. Note: Mouth closure is scored conservatively following an exponential curve (DWAF, 2008).	95	H
Hydrodynamic score		**95**	**H**

4.4 WATER QUALITY

4.4.1 Baseline description

Table 4.11 presents a summary of the water quality characteristics for the various states, in each of the four zones. This summary derives from available information on the estuary as presented in the Abiotic Specialist Report. The future scenarios with WWTW assumed effluent discharges at General limits (General authorisation).

Table 4.11 Summary of water quality characteristics of different abiotic states in the uMkhomazi Estuary (differences in state between reference condition and present state and future scenarios – due to anthropogenic influences other than flow - are indicated)

Parameter	State 1: Closed, brackish	State 2: Open, full salinity gradient	State 3: Open, limited salinity gradient	State 4: Open, fresh
Salinity	20 | 20 | 10 | 0	30 | 20 | 10 | 0	25 | 10 | 0 | 0	0 | 0 | 0 | 0
Temperature (°C)	Summer: 26 - 30 Winter: 14 - 23	Summer: 26 - 30 Winter: 14 - 23	Summer: 26 - 30 Winter: 14 - 23	Summer: 26 - 30 Winter: 14 - 23
pH	7.5 – 8.5	7.5 – 8.5	7.5 – 8.5	7.5 – 8.5
DO[1] (mgl/l)	Reference/Present/Future: 6 | 6 | 4 | 6 Future with WWTW: 6 | 6 | 2 | 4	Reference/Present/Future: 6 | 6 | 4 | 6 Future with WWTW: 6 | 6 | 2 | 4	6 | 6 | 6 | 6	6 | 6 | 6 | 6
Turbidity (NTU)	Reference: 10 | 10 | 10 | 10 Present/Future: 10 | 10 | 10 | 10	Reference: 10 | 10 | 10 | 10 Present/Future: 10 | 10 | 10 | 10	Reference: 10 | 10 | 10 | 10 Present/Future: 10 | 10 | 10 | 10	Reference: >200 | >200 | >200 | >200 Present/Future: >200 | >200 | >200 | >200

NOTE: For the purposes of this assessment the estuary was sub-divided into three zones representing from left to right: Zone A (lower), Zone B (middle), Zone C (upper) and Zone D (historical upper) (Figure 3.1).
1 Dissolved Oxygen

Parameter	State 1: Closed, brackish	State 2: Open, full salinity gradient	State 3: Open, limited salinity gradient	State 4: Open, fresh
DIN[1] (µg/l)	Reference: 80 80 80 80 Present/Future: 150 150 150 200 Future with WWTW: 2200 2200 3500 5000	Reference: 80 80 80 80 Present/ uture: 100 150 150 200 Future with WWTW: 500 1600 2200 3500	Reference: 80 80 80 80 Present/Future: 100 150 200 200 Future with WWTW: 500 1200 1600 1600	Reference: 100 100 100 100 Present/Future: 250 250 250 250 Future with WWTW: 500 500 500 500
DIP[2] (µg/l)	Reference: 10 10 10 10 Present Future: 10 10 10 10 Future with WWTW: 1000 1000 1600 2400	Reference: 10 10 10 10 Present/Future: 10 10 10 10 Future with WWTW: 240 700 1000 1600	Reference: 10 10 10 10 Present/Future: 10 10 15 15 Futu e with WWTW: 200 500 700 700	Reference: 10 10 10 10 Present/Future: 20 20 20 20 Future with WWTW: 140 140 140 140
DRS[3] (µg/l)	800 800 2000 6000	200 800 4000 6000	200 4000 6000 6000	6000 6000 6000 6000

NOTE: For the purposes of this assessment the estuary was sub-divided into three zones representing from left to right: Zone A (lower), Zone B (middle), Zone C (upper) and Zone D (historical upper see Figure 3.1)
1 Dissolved Inorganic Nitrogen 2 Dissolved Inorganic Phosphate 3 Dissolved Reactive Silica

Calculation of River inflow quality assuming a WWTW effluent discharge in Future Scenarios:

Future Scenarios (with WWTW Effluent at General Limits)

STATE	Flow (m3/s)			DIN (ug/l)				DIP (ug/l)			
	Total	WWTW	River Fraction	WWTW	RIVER	Inflow	Estimate	WWTW	River	Inflow	Estimate
1	1	0.24	0.76	21000	200	5192	**5000**	10000	10	2408	**2400**
2	1.5	0.24	1.26	21000	200	3528	**3500**	10000	10	1608	**1600**
3	3.5	0.24	3.26	21000	200	1626	**1600**	10000	15	700	**700**
4	20	0.24	19.76	21000	250	499	**500**	10000	20	140	**140**

A summary of the water quality characteristics under the various flow scenarios is provided for each zone in Table 4.12.

A summary of the water quality scores under the various flow scenarios is provided for each zone in Table 4.13.

Table 4.12 Summary of average changes in water quality from Reference Condition to Present State within each of the various

Parameter	Summary of change	Zone	Reference	Present
Salinity	Due to decrease in the baseflows to the system (i.e. an increase in the occurrence of monthly flows below 3 m^3/s).	A: Lower	4	9
		B: Middle	3	6
		C: Upper	1	3
		D: Upper (H)	0	0
DIN (µg/ℓ)	Due to increased nutrient input from anthropogenic sources in the catchment concentrations in the estuary increased under Present state (and future scenarios) compared with reference.	A: Lower	97	207
		B: Middle	97	222
		C: Upper	97	230
		D: Upper (H)	97	237
DIP (µg/ℓ)	Due to increased nutrient input from anthropogenic sources in the catchment concentrations in the estuary increased slightly under Present state (and future scenarios) compared with reference.	A: Lower	10	17
		B: Middle	10	17
		C: Upper	10	18
		D: Upper (H)	10	18
Turbidity (NTU)	System becomes less turbid under Present and Future scenarios due to reduction in State 4.	A: Lower	175	143
		B: Middle	175	143
		C: Upper	175	143
		D: Upper (H)	175	143
DO (µg/ℓ)	No marked changes in dissolved oxygen, system remains well flushed in general.	A: Lower	6	6
		B: Middle	6	6
		C: Upper	6	6
		D: Upper (H)	6	6
Toxic substances	Industrial and urban development (e.g. Sappi) may have introduced toxic substances into the estuary, but only assumed to be limited, 85% for present.	85% similarity between Reference and Present.		

4.4.2 Water quality health

The similarity in each parameter (e.g. DO) to reference condition was scored as follows:

- Define zones along the length of the estuary (Z) (i.e. Zones A, B, C and D).
- Volume fraction of each zone (V) (i.e. Lower = 0.5; Middle = 0.2; Upper = 0.3).
- Different abiotic states (S) (i.e. States 1 to 4).
- Define the flow scenarios (i.e. Reference, Present, Future scenarios.)
- Determine the % occurrence of abiotic states for each scenario.
- Define **WQ concentration range (C)** (e.g. 6 mg/l; 4 mg/l; 2 mg/l).

Similarity between Present State, or any Future Scenarios, relative to the Reference Condition was calculated as follows:

- Calculate Average concentration for each Zone for Reference and Present/Future Scenarios, respectively:

- Average Conc (ZA) = [({∑% occurrence of states in C1}*C1)+ ({∑% occurrence of states in C2}*C2)+({∑% occurrence of states in Cn}*Cn)] divided by 100.
- Calculate similarity between Average Conc's Reference and Present/Future Scenario for each Zone using the Czekanowski's similarity index: ∑(min(ref,pres)/(∑ref + ∑pres)/2.
- For the final scores, a weighted average of the similarity scores of different zones was computed using the volume fractions.

Table 4.13 Summary of changes and calculation of the water quality health score

Variable		Summary of change	Score[1]	Conf
1	**Salinity**			
	Similarity in salinity	⇧ due to increase in low flows	66	M
2	**General water quality in estuary**			
a	DIN and DIP concentrations	⇧ due to nutrient enrichment in catchment	67	M
b	Turbidity (transparency)	⇩ due to reduction in high flow state (State 4)	90	M
c	Dissolved oxygen (mg/l)	No marked changes, remains well flushed	99	M
d	Toxic substances	⇧ industrial and urban inputs	85	M
Water quality health score[1]				**M**
% of impact non-flow related			**50**	**H**
Adjusted score				

[1] $\text{Score} = (0.6 * \text{S} + 0.4 * (\min(\text{a to d}))$

4.5 MICROALGAE

4.5.1 Overview

The microalgae component comprises the autotrophic microorganisms, i.e. those that contain chlorophyll and, as a result, are able to convert sunlight into living material. In this capacity they are at the base of the food chain and responsible for most of the food consumed by the primary consumers. This is especially important in that they provide the food resources for the juvenile fish and benthic microorganisms, including those that, in the adult form, are found in the sea and play an important role in the South African economy.

i) *Main grouping and baseline description*

They are grouped into two main types, the planktonic and the benthic. The planktonic group are the phytoplankton (plants in the water column) while the benthic group comprise the microphytobenthos (small plants found mostly attached to sediment particles (mud, sand, gravel, rocks). The true phytoplankton usually have flagellae which enable them to maintain a position in the water column, while the microphytobenthos are not flagellated and are therefore unable to maintain a position in the water column.

These organisms are greatly influenced by the amount of water flowing through the estuary as well as the way it passes through the estuary, i.e. they are sensitive to the hydrology and the hydrodynamic flows. The amount of water in the system and the continuity of flow determine the volume available and thus the absolute maximum amount of material available, while the hydrodynamic factor influences the stability of the system and especially the microphytobenthos (MPB). Estuaries with a large Mean Annual Runoff (MAR) are open more often, are usually larger and therefore are in the open mouth state for longer than those with a smaller MAR. Estuaries with

a large MAR tend to be less sensitive to flow variation than do those with a small MAR. The importance of the hydrodynamic flow is that the flooding regime influences the state of the mouth, (open or closed- faunal recruitment or not).

The MPB are very important both when they are attached to sediment particles but also when they are attached to submerged or emergent plants (epiphytes), thus the status of the macrophyte community also impacts on the state of the microalgal community and whether or not the juvenile fish have an available food source in a protected environment, i.e. they have a measure of protection plus a source of food in amongst the living plant material.

Microalgae respond to the nutrient status of the water column. Under reference conditions, the nitrogen and phosphorus contents are usually low, but might occasionally be raised by an abundance of large terrestrial animal excreta. Thus, the reference condition is considered to be one of low nutrient status to which the microalgae respond by having a high diversity of species. Where pollution raises the nutrient levels, the biomass rises but the species diversity is lowered, but only under extreme conditions.

The flagellate components of the microalgal community are able to maintain themselves in the water column using their flagellae and they are usually numerically dominant when counts are made. They are made up of both autotrophic and heterotrophic organisms, the latter being consumers rather than photosynthetically productive. Despite this, they are still components that are ingested and are therefore part of the food available to larger consumers and especially fish.

The cyanophytes (blue-green microalgae) are a group of non-flagellated photosynthetic bacteria that can make up a large component of both the planktonic and benthic microalgal community. They can be important in that under certain conditions (including anaerobic) they can utilise gasses such as hydrogen sulphide in order to grow. Some species are able to fix nitrogen and can become important under conditions where the water column is oligotrophic. Certain species of cyanophytes can produce toxins which are able to be harmful if present in high concentration.

The green microalgae are a very diverse group that can be present in estuary waters in fairly high proportions. They are included mostly in the flagellated group and because of the flagellum they are able to maintain their presence within the water column rather than sink to the sediment surface as do the diatoms. The phytoplankton are more sensitive to extreme floods than are the MPB which are only lost from the system under very strong flooding conditions. All records appear to show that the microalgae are a very resilient group of organisms.

Under reference conditions, the flagellate community would be relatively small while under polluted conditions the heterotrophic component of the flagellate community would be expected to be high because of a high organic component in the water.

ii) Description of factors influencing microalgae

Table 4.14 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings

Variable	Grouping	
	Phytoplankton	Microphytobenthos (MPB)
Open water area	Proportional reduction with loss of open water area (37 - 16).	Proportional reduction with loss of open water area (43% remaining).
Salinity	Very little effect when >5 psu[1]. When < 5 PSU there can be a few freshwater species present. Very seldom that freshwater diatoms appear in an estuary sample.	Very little salinity effect with estuary MPB. This was established during at prolonged survey at St. Lucia where salinity rose from normal to ~150 PSU.
Mouth condition	Mouth open - Biomass maximum at ~15 PSU. Vertical salinity gradient.	Mouth never closed - MPB elevated at low flows.
Water flow rate	Under water high flow rates, most of the microalgae are suspended in the water column.	Many diatoms that are commonly benthic (epipelic) are found in the water column. This is especially the case where the fine sediment fraction is suspended due to turbulence
Water retention time	Phytoplankton biomass elevated at long retention time with diatoms on the sediment.	MPB biomass elevated at long retention time.
Floods	Only temporary reduction in phytoplankton biomass as a result of flooding. Consumer population also reduced - therefore little effect	Only temporary reduction in MPB biomass as a result of flooding. Consumer population also reduced - therefore little effect.
Turbidity	Because high turbidity occurs at the time of flooding there is very little effect on phytoplankton	Possible small reduction in MPB productivity.
Water quality	Low nutrient content - maximum species diversity. Diversity decreases at high nutrient levels.	No evidence of a species change at high nutrient levels
Toxins	Literature indicates that there is an unspecified adverse effect with certain toxins	No information
Macrophyte community structure	Diatom phytoplankton exchange onto and off submerged aquatic surfaces.	MPB high with high density of rooted aquatic macrophytes. Food availability to juvenile fauna increases - also security.
Oxygen levels	No effect on phytoplankton.	No effect on MPB.

1 Practical Salinity Units

Table 4.15 Summary of Microalgae responses to different abiotic states

State	Response
State 1 closed (1%)	Very little adverse response if only closed for very short periods.
State 2 Intermittently closed (1 - 2 weeks)	Very little adverse response if only closed for short periods.
State 3 Tidal (<7 days)	Productivity and biomass would be maximal under these conditions.
State 4 Freshwater (<1 day)	90% of the phytoplankton and 80% of the MPB would be lost but the recovery would be quick.

iii) Reference condition

Table 4.16 Summary of relative changes from Reference Condition to Present state

Key drivers	Change
Open water area	10% reduction in subtidal area
Closed mouth conditions	1% reduction (with artificial opening)
Nutrient increases	10% increase in biomass (compensation)
Toxic substances	Likely 0% reduction
TOTAL CHANGE	**10%**

4.5.2 Microalgae health

Table 4.17 Microalgae component health score

Variable	Summary of change	Score	Conf
1. Species richness	Unlikely to be any significant changes	95	H
2. Abundance	Some increase in biomass for much of the year	90	M
3. Community composition	Likely a very small shift in community structure	95	M
Biotic component health score		**90**	
% of impact non-flow related		**95**	**M**
Adjusted score		**99**	

4.6 MACROPHYTES

4.6.1 Overview

i) Main grouping and baseline description

uMkhomazi Estuary has historically supported limited estuarine vegetation. However, these macrophytes are important as they add to the aesthetic appearance of the lower reaches, filter sediments and nutrients and stabilize the banks. From a site visit in July 2014, mapping and assessment of past aerial photographs updated information on the macrophytes is provided in Table 4. 18. Swamp forest with coastal or lagoon Hibiscus (*Hibiscus tiliaceus)* was the most abundant habitat. Reeds and sedges, covered the second largest area and fringed both banks of the estuary. A stand of black mangroves, *Bruguiera gymnorrhiza,* and a few large white mangrove, *Avicennia marina,* trees were located on the south bank along the Impisini stream inlet close to the mouth of the estuary. A few tall *B. gymnorrhiza* trees were also located amongst a stand of invaded coastal forest on the north bank near the mouth. Common reed (*Phragmites australis),* bush tick berry (*Chrysanthemoides monilifera*), morning glory creeper (*Ipomoea pes-capre)* and inkberry (*Scaevola plumieri)* were visible amongst this invaded stand.

A small patch of coastal forest occurred on the sloping north bank in the middle reaches. A steep rock face, vegetated with *Acacia natalensis,* was present in the middle reaches, opposite the SAPPI SAICCOR Factory. Hygrophilous grasses interspersed the reeds and sedges in the middle reaches of the estuary. Grasses present were antelope grass (*Echinocloa pyramidalis)*, *Panicum maximum,* broad-leaved bristle grass *(Setaria megaphylla),* buffalo grass *(Stenotaphrum secundatum)* and the exotic *Paspalum dilatum* and *Paspalum urvillei.* A number of invasives were present in the estuary including Spanish/giant reed (*Arundo donax),* black wattle (*Acacia mearnsii*), beefwood (*Casuarina cunninghamiana),* Brazilian pepper tree (*Schinus terebinthifolius)* peanut butter bush (*Senna didymobotrya)* and syringa (*Melia azedarach).*

Some areas previously cultivated have been colonised by opportunistic grasses, weeds and exotic species. Species present in these disturbed areas were pennywort (*Centella asiatica),* climbing/spreading dayflower (*Commelina diffusa), Conyza scabrida,* prickly lettuce (*Lactuca serriola),* River nettle (*Laportea penduncularis), Persicaria decipiens* and bulrush (*Typha capensis*). Sediment in the reed areas was soft and muddy and no macroalgae were visible. No submerged macrophytes were found. There was no evidence to suggest the historical occurrence of any Red Data List species. Species composition of uMkhomazi Estuary, including exotics are provided in the specialist report (Part of Report 8.3; Report Number: RDM/WMA11/00/CON/CLA/0714).

Table 4.18 Macrophyte habitats and functional groups recorded in the estuary (spp. examples in italics)

Habitat type	Distribution
Open surface water area	Serves as a possible habitat for phytoplankton.
Intertidal sand and mudflats	Intertidal zone consisting of sand/mud banks that provide a possible area for microphytobenthos to inhabit.
Swamp forest	Swamp forest fringed both banks in the lower reaches of the estuary. Near the mouth a single row of *H. tiliaceus* trees occurred in front of a concrete bank. Wild date palm (*Phoenix reclinata)* was conspicuous in this macrophyte habitat, particularly on the north bank at the mouth. *S. terebinthifolius* has replaced some swamp forest habitat and creepers, such as *Ipomea* species, were abundant.
Mangroves	Mangroves were present in the lower reaches of uMkhomazi Estuary, mostly on the south bank. The mangroves occurred along the narrow Impisini stream inlet, near the old ski boat slipway. This stand consisted almost entirely of *B. gymnorrhiza* trees that were set back from the water channel by a fringe of reeds and sedges. A few large *A. marina* trees occurred further inland of this stand. The area was polluted with litter and debris that was wrapped around the mangrove trunks. Wood harvesting was evident on some of the individuals present on the north bank. A few older individuals of *B. gymnorrhiza* were sparsely distributed along the north bank of uMkhomazi Estuary close to the mouth, as indicated by the points in Figure 4.3. These tall individuals were situated in a disturbed area of coastal dune forest.
Reeds and sedges	Reed and sedge habitat extended along the length of the estuary as a thin, disjointed fringe on both banks of the water channel (Figure 4.3). Species present were: *Cyperus natalensis, Juncus effuses, Juncus kraussii, Phragmites australis, Phragmites mauritianus, Schoenoplectus scirpoides* and *Typha capensis.*

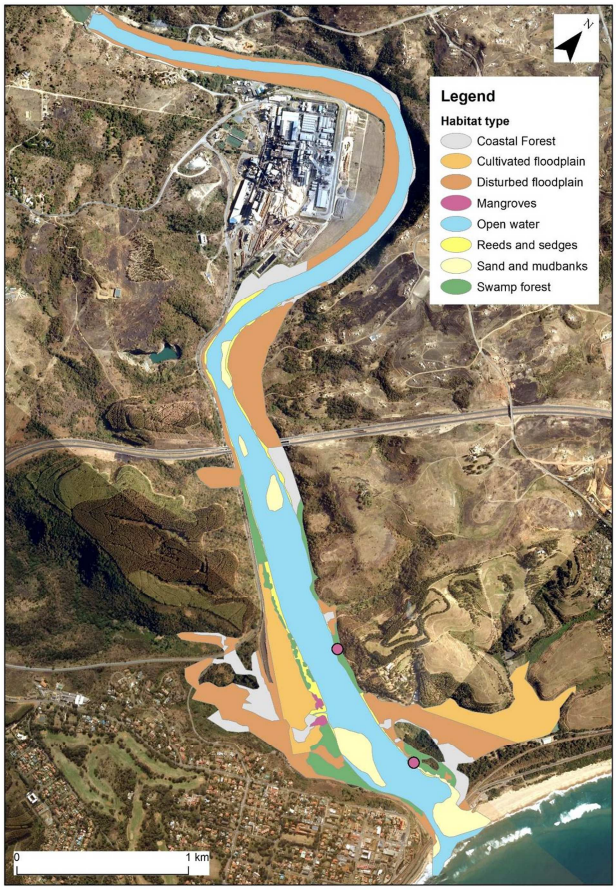


Figure 4.3 Macrophyte habitat distribution at uMkhomazi Estuary in 2013

ii) Description of factors influencing macrophytes

Table 4.19 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings

Variable	Grouping		
	Reeds and sedges	Swamp forest	Mangroves
Mouth conditions	Open mouth conditions and high river inflow prevent the establishment of submerged macrophytes and macroalgae.		
Retention times of water masses	Under natural and present conditions the estuary remains permanently open. If the estuary were to remain closed for an extended period of time, which is highly unlikely, the increased water levels may cause waterlogging and dieback of macrophytes.		
Flow velocities (e.g. tidal velocities or river inflow velocities)	High river inflow prevents the establishment of submerged macrophytes and macroalgae.		
Total volume and/or estimated volume of different salinity ranges	Longitudinal salinity gradient present along the estuary increases macrophyte diversity.		
Floods	There has been some reduction in floods and re-resetting events that would result in a more stable system allowing macrophyte encroachment. Under natural conditions floods would flush out excess nutrients and sediment from the estuary and prevent reed encroachment.		
Salinity	Although the estuary has become more saline over time, the brackish conditions enable the proliferation of reeds, sedges and swamp forest.		Due to reduced baseflows salinity has increased from natural conditions enabling the growth and expansion of mangrove habitat.
Turbidity	High turbidity as a result of high flows and catchment disturbance prevents the establishment of submerged macrophytes.		
Dissolved oxygen	This would not influence the macrophytes.		

Variable	Grouping		
	Reeds and sedges	Swamp forest	Mangroves
Nutrients	High nutrients levels encourage the proliferation of *Phragmites* spp. and other macrophytes.		
Sediment characteristics (including sedimentation)	Sedimentation increases the available habitat for the establishment of reeds, sedges and swamp forest.		Accumulation of sediments in the mangrove habitat could smother seedlings thus causing a decline in the population.
Other biotic components	Little natural floodplain remains due to surrounding developments and sugarcane cultivation. Invasive species are abundant replacing natural vegetation.		

Table 4.20 Summary of Macrophyte responses to different abiotic states

State	Response
State 1: Closed, brackish	Mouth closure is infrequent under current conditions. Should the mouth remain closed for an extended period, which is unlikely, the open water area will increase potentially displacing some macrophytes.
State 2: Open, full salinity gradient	Saline conditions would favour the growth and expansion of mangrove habitat.
State 3: Open, limited salinity gradient	This state favours the growth of reeds and sedges.
State 4: Open fresh	This is the dominant state under both natural and present conditions. Flooding events would reset the estuary by removing macrophyte habitat.

ii) Reference condition

Development and sugarcane cultivation has removed macrophyte habitat since natural conditions with large areas of reeds and sedges, swamp forest, mangrove and coastal forest lost. Table 4.21 provides the areas (ha) mapped for 1937 and 2013. These data assist with the assessment of changes over time from natural to present (Table 4.22). A stand of reeds described by Day (1981) and Begg (1984) located above the steep south bank near the mouth of the estuary has been lost. Begg (1984) suggested that the construction of the R102 road and rail bridge at the mouth led to the loss of most of the mangrove population that naturally occurred on the north bank. The mangrove community on the south bank was in poor condition due to impeded drainage and inadequate tidal exchange. Adams and Bate (1998) described a few scattered *A. marina* and *B. gymnorrhiza* trees on both banks at the mouth.

Mangrove habitat was not distinguishable in the 1937 aerial photographs, but the last reported area of mangroves at uMkhomazi Estuary was 2 ha (Ward & Steinke, 1982; Rajkaran *et al.,* 2009). Thus, the area of mangrove habitat in 2013 has halved since 2006. In 2013 swamp forest had increased by 3 ha from 1937 (Table 4.21). The increase may be inaccurate due to the difficulty in distinguishing swamp forest from interspersed invasive plants such as *S. terebinthifolius* as well as coastal forest. A similar difficulty was encountered for the mapping of the area covered by mangroves. In 2013 cultivated land occupied less area than in 1937; this disturbed habitat has been colonised by reeds, grasses and invasive species.

Under natural conditions, the dominance of the open, fresh State 4 would have been unfavourable for mangroves. Mangroves have likely been opportunistic in the estuary, as conditions have become more saline. The naturally fresh conditions would have encouraged the proliferation of reeds and sedges, which covered large areas of the uMkhomazi Estuary floodplain.

Table 4.21 Comparison of area (ha) for the different macrophyte habitats at uMkhomazi Estuary under reference (1937) and present (2013) condition

Macrophyte habitat	1937	2013
Open water	36	47
Natural floodplain	8	12
Disturbed floodplain	3	44
Cultivation	63	19
Sand and mudbanks	14	10
Reeds and sedges	14	4
Swamp forest	7	10
Mangroves	0	1

Table 4.22 Comparison of area (ha) for the different macrophyte habitats at uMkhomazi Estuary under natural and present (2013) conditions

Macrophyte habitat	Natural	Present
Open water	50	64
Natural floodplain	34	15
Disturbed floodplain	0	47
Cultivation	0	19
Sand and mudbanks	20	9
Reeds and sedges	45	4
Swamp forest	25	10
Mangroves	0	1
Alien vegetation	0	5
TOTAL	**174**	**174**

Table 4.23 Summary of relative changes from Reference Condition to Present state

Key drivers	Change
Removal of habitat due to development and sugarcane cultivation.	⇩ floodplain habitat, reeds, sedges, mangroves and swamp forest.
⇧ nutrients from catchment activities.	⇧ growth of all macrophytes, in particular reed, sedge and grass expansion.
⇩ flow 5 $m^3 s^{-1}$ for 70% time and ⇩ floods.	⇧ reeds and sedges due to sediment deposition and infilling of intertidal habitats.
⇧ catchment and floodplain disturbance.	⇧ invasive species.
TOTAL CHANGE	**Loss of all macrophyte habitats due to development and cultivation. The flow related changes are small compared to this greater loss of habitat.**

4.6.2 Macrophyte health

The data in Table 4.22 were used to inform the changes in the macrophyte habitats over time. The health of the macrophytes was assessed in terms of species richness, abundance and community composition using the methods described in RDM draft Version 3 (2010). Change in species richness was measured as the loss in the average species richness expected during a sampling event, excluding species thought to not have occurred under Reference conditions. Abundance

was measured as the change in area cover of macrophyte habitats. The following was used to measure change: % similarity = 100 x present area cover / reference area cover. Change in community composition was assessed using a similarity index (Table 4.24 and 25) which is based on estimates of the area cover of each habitat in the reference and present state (Czekanowski's similarity index: $\sum(\min(ref,pres) / (\sum ref + \sum pres)/2)$.

Invasive species have become more prevalent in the estuary and have likely displaced native species. Thus an alien plant subgroup was added for the calculation of the community composition Table 4.24). In 2013 only 30 ha were covered with macrophyte habitats (including natural floodplain). Reeds and mangrove habitat has been lost since natural conditions. This represents a similarity of 21 % in macrophyte habitat abundance. Based on these changes the 2013 macrophyte community composition has a resemblance of 51 % to that of natural conditions.

Table 4.24 Area (ha) covered by macrophyte habitats and calculation of the similarity in community composition

Macrophyte habitat	Natural area (ha)	2013 area	Minimum score
Open water	50	64	50
Natural floodplain	34	15	15
Disturbed floodplain	0	47	0
Cultivation	0	19	0
Sand and mudbanks	20	9	9
Reeds and sedges	45	4	4
Swamp forest	25	10	10
Mangroves	0	1	0
Alien vegetation	0	5	0
SUM	**174**	**175**	**88**
	=88/174		
	51% similarity to reference		

Table 4.25 Macrophyte component health score

Variable	Summary of change	Score	Conf
1. Species richness	Species have been lost due to floodplain transformation increased salinity and displacement by invasive species.	80	M
2. Abundance	Sugarcane cultivation and development has removed macrophyte habitat, particularly reeds and swamp forest. Mangrove habitat has been lost due to decreased inundation and disturbance. Sand mining and disturbance in the upper reaches has also resulted in habitat loss.	21	M
3. Community composition	Invasive species have colonised disturbed areas. Grasses and invasive species have interspersed into reed habitat. Swamp forest habitat in the lower reaches has been reduced by development (roads, canalisation, railway line and pipe lines).	51	M
Biotic component health score		**21**	
% of impact non-flow related		**80**	**M**
Adjusted score		**38**	

4.7 INVERTEBRATES

4.7.1 Overview

i) Main grouping and baseline description

Benthic invertebrate communities are generally separated into two major size classes. The meiofauna are organisms (metazoans plus foraminiferans) that typically range from 63 to 500 mm in size, and the macrofauna are all of the larger organisms greater than 500 mm in size. Both groups include species that are considered to be either epifauna because they reside primarily on the surface of the sediments and other substrata, or infauna because they burrow or live beneath the surface of the sediment water interface. A brief description of the invertebrate community assemblages from the estuarine and freshwater areas of the uMkhomazi is provided as a baseline description below.

The invertebrate community of the uMkhomazi estuary has a naturally low diversity and abundance at any one time. For the purposes of this EWR the estuary was sampled for invertebrates, at six sites from the mouth to the upper estuary, during the low flow winter and high flow summer periods. There was a strong contrast between the diversity and abundance of the macrobenthos in August - September 2013, when 27 taxa were recorded, and February 2014 when this number dropped to 12 (Figure 4.4). The numbers of taxa at each site in August 13-September 14 were lowest at the two upper sites (6), increasing to 12 - 13 at the N2 bridge, skiboat and mouth with a maximum of 16 in the Mpisini stream. The fauna at the three upper sites was totally dominated by amphipod crustaceans. This changed to a dominance of the polychaete *Desdemona ornata* at the skiboat site. The tanaid crustacean *Apseudes digitalis* was numerically dominant in the muddy Mpisini stream but the small crab *Paratylodiplax blephariskios*, a typical inhabitant of this area, made the major biomass contribution. As indicated above, the diversity and particularly the abundance, crashed in February after the high summer flows with a maximum of five species recorded at the N2 bridge site. The only species that retained any of their winter abundance were the tanaid *A.digitalis* and the crab *P.blephariskios*, both in the relatively physically stable Mpisini stream. This is in keeping with current understanding of benthic invertebrate communities which will be disturbed and depressed by repeated strong river flows and depositional events.

All the physico-chemical parameters measured during this particular study period, and when seen in conjunction with data accumulated during the past decade (MER, 2002 - 2013) as well as the historical records (Day, 1981; Begg, 1978, 1984) characterise the uMkhomazi estuary as a naturally highly variable environment which has arguably been further modified by the actions of extensive sand mining between the N2 bridge and the weir. The variability is derived from seasonal flow fluctuations coupled with periodic major flood events such as last occurred in 1987.

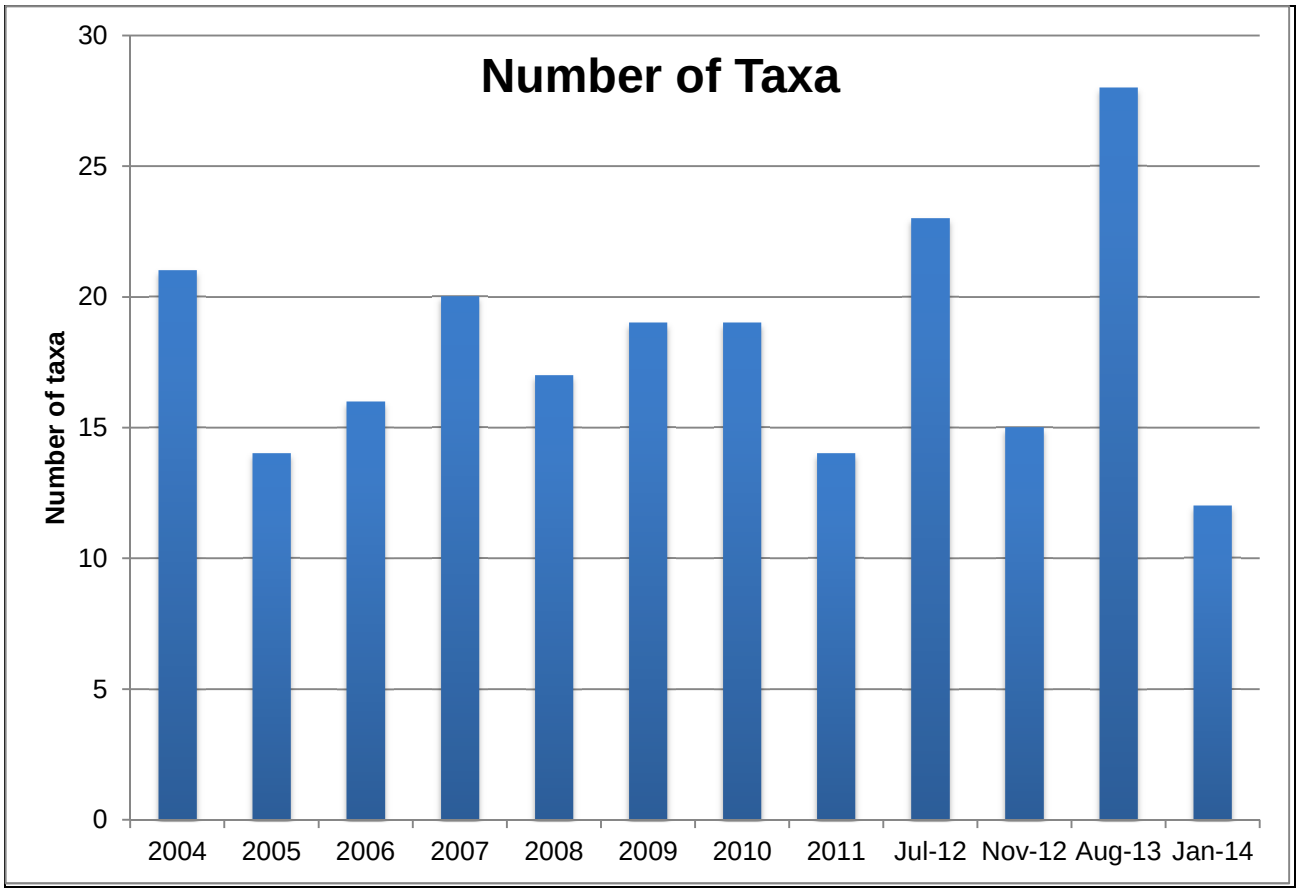


Figure 4.4 The number of taxa recorded in the uMkhomazi annually during the low flow period 2004 – 2011 and during low flow and high flow 2012 - 2014

The seasonal variations are enough to alter sediment distribution, salinity gradients, temperature and turbidity, all of which have spin off effects on the biota. These are aptly demonstrated by the above comparison of the benthos under winter and summer conditions and between years which exhibit different flow regimes. From an estuarine status or health point of view, the variable nature of the benthic macrofauna can be attributed directly to the natural physico-chemical variability of the system.

On a broader scale, it is worth noting that the species making up the benthos are largely small in comparison with other known estuarine benthic taxa such as bivalves and the larger burrowing crustaceans such as the sandprawn *Callianassa (Callichirus) kraussi* and the mudprawn *Upogebia africana.* There are no records of *C. kraussi* and rare incidences of bivalves although individuals of *U. africana* do appear in muddy samples. The absence of *C. kraussi* and rarity of bivalves can be attributed to sediment instability and periodic high flows while the appearance of *U. africana* can be linked to the existence of a marine larval phase in this species, which will allow recruitment from other estuaries.

Superimposed on this is the question of the long term impact of sand winning on the macrobenthos of the estuary which is difficult to quantify. In ways dredging disturbance could be equated with major flood events; the latter however would naturally be followed by a stable period during which recovery of the benthos could occur. In the context of the uMkhomazi estuary, with its flood history and the consequent dominance of the macrobenthos by short lived, opportunistic species, short term sand winning is less likely to have a major impact here than in systems occupied by larger, longer lived species.

The different abiotic states which occur in response to varying runoff conditions in the uMkhomazi (Table 4.26) are strong drivers of the invertebrate community, with increases in State 1 producing higher abundance and diversity than state 4 (Figure 4.5).

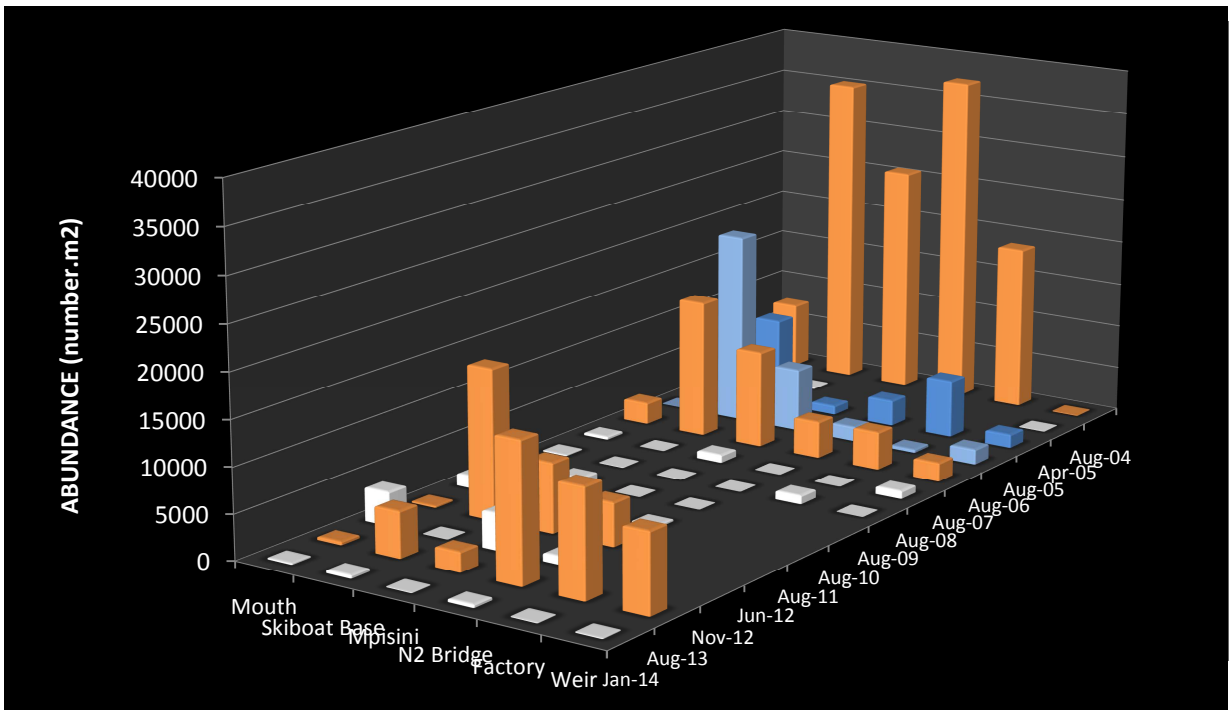


Figure 4.5 Benthic invertebrate abundance at six sites during low flow and high flow conditions. Colours correspond to the described states

Table 4.26 Summary of Invertebrate responses to different abiotic states

State	Response
State 1: Closed, brackish	Freshwater community changes, increases in abundance with stability and increases in food resources, increased light penetration - likely to reach higher levels of abundance.
State 2: Open, full salinity gradient	Numbers of species recorded increases as survival increases and rarer species are more likely to be found, increases in abundance with stability and increases in food resources, increased light penetration.
State 3: Open, limited salinity gradient	Estuarine invertebrates confined to the lower parts of the system, high flows and mobile sediments exclude most species other than those areas away from main flows.
State 4:Open fresh	Highly dynamic and excludes most estuarine species leaving only resilient freshwater tolerant species.

iii) Reference condition

Table 4.27 Summary of relative changes from Reference Condition to Present state

Key drivers	Change
⇧ in State 2 and addition of state 3	Changes in estuarine invertebrate distribution with extension into zones B and C. Increased abundance relative to reference due to increased retention times within the system and more suitable salinity conditions.
⇧ in nutrients	Perhaps a minor effect as a result of an increase in micro-algal food resources.
TOTAL CHANGE	Decreases in flow and concomitant increases in salinity and retention times have increased diversity and abundance of estuarine and marine species.

4.7.2 Invertebrate health

Table 4.28 Invertebrate component health score

Variable	Summary of change	Score	Conf
1. Species richness	No driver to eliminate species - 5% precautionary for the ones which may have been eliminated but not recorded.	95	M
2. Abundance	Increase in abundance of estuarine invertebrates as a result of the extension of state 1, 2 and 3 temporally (extended low flow conditions) and spatially into zones B and C. Increased nutrients may increase food organisms.	75	M
3. Community composition	The changes in conditions i.e. increased salinity and stability may favour species previously depressed by strong outflows, sediment instability and low salinity.	80	M
Biotic component health score		**75**	
% of impact non-flow related		**10**	**M**
Adjusted score		**78**	

4.8 FISH

4.8.1 Overview

i) Main grouping and baseline description

Fishes with a variety of life histories use South African estuaries and several estuarine association guilds have been applied to categorise the estuarine ichthyofauna. Most widely used has been that of Whitfield (1994, see below), although more recent refinements have applied (e.g. Harrison and Whitfield, 2008) based on functional use categories more globally applicable (e.g. Elliot *et al*., 2007).

Table 4.29 Classification of South African fish fauna according to their dependence on estuaries (Whitfield, 1994)

Category	Description
I	Truly estuarine species, which breed in southern African estuaries; subdivided as follows:
Ia	Resident species which have not been recorded breeding in the freshwater or marine environment.
Ib	Resident species which have marine or freshwater breeding populations.
II	Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries; subdivided as follows:
IIa	Juveniles dependent of estuaries as nursery areas.
IIb	Juveniles occur mainly in estuaries, but are also found at sea.
IIc	Juveniles occur in estuaries but are more abundant at sea.
III	Marine species which occur in estuaries in small numbers but are not dependent on these systems.
IV	Euryhaline freshwater species that can penetrate estuaries depending on salinity tolerance. Includes some species which may breed in both freshwater and estuarine systems.
V	Obligate catadromous species which use estuaries as transit routes between the marine and freshwater environments. Includes the following subcategories:
Va	Obligate catadromous species.
Vb	Facultative catadromous species.

For the purposes of this assessment Whitfield's categorisation (above) was used as a basis to classify fishes as:

- Estuarine resident: Species that complete their life cycles in South African estuaries (Whitfield's categories Ia and Ib).
- Estuarine dependent marine: Species that breed at sea with the juveniles dependent on South African estuaries (Whitfield's categories IIa, IIb and Vb).
- Marine: Species that use South African estuaries opportunistically, but are not dependent upon these systems to complete their life cycles (Whitfield's categories IIc and III).
- Freshwater: Species that can (and mostly do) complete their life cycles in fresh water (Whitfield's category IV).
- Catadromous: Anguillid eels, which use estuaries only as transit routes between the marine and freshwater environments (Whitfield's category Vb).

There are of course other ways of categorising, or grouping, components of estuarine fish assemblages. Feeding guilds are another common approach and in this respect most South African species can be assigned to categories as being:

- Detritivores: Species that feed predominantly on detritus, deriving nutrition from bacteria on decaying vegetation and microphytobenthos.
- Zooplanktivores: Species that feed on zooplankton, mostly small crustaceans.
- Zoobenthivores: Species that feed on benthic invertebrates living on, or in the sediments.
- Piscivores: Species that prey upon other fishes.

A wide variety of fishes has been sampled in the system (60 distinct species) and this is reflective of reference conditions. Comparative few dominate the assemblage numerically, however. This is typical of estuarine fish assemblages. Estuarine dependent marine species, followed by estuarine resident fishes, dominate the fish fauna by both numbers of species and abundance of individuals. The relative abundance of estuarine dependent marine species across indicates the nature of the uMkhomazi to be strongly estuarine and that the system is an important nursery area for these fishes. Marine taxa are more abundant than freshwater species, a fact suggestive of regular saltwater penetration under present day conditions. Under reference condition marine taxa would have occurred with less frequency and in lower abundances. Catadromous fishes (Anguillid eels) transit through the estuary, rather than spending significant time in it.

Trophically, the fish assemblage has typically been dominated by zoobenthivores and detritivores. On average zooplanktivores and piscivores contribute very little to the abundance of fishes in the system. The paucity of zooplanktivores is likely the result of poorly developed zooplankton biomass. The relative abundance of benthivores is atypical of KZN estuaries, which are usually dominated by detritivores (mullet in particular contributing high abundances). Zoobenthic feeders form a significant component of the fish assemblage. This is likely to be reflective of reference conditions.

Overall, estuarine dependent marine fishes dominate the uMkhomazi fish assemblage in terms of frequency of occurrence, number of species and relative abundance. This is brought about by an abundance of juveniles of euryhaline marine fishes that are strongly dependent on estuaries (Whitfield's category IIa fish). While mullet play an important role in this, several other perciform fishes contribute significantly. These fishes occur in highest abundances the lower sections of Zone C of the estuary. This area of the estuary is where fine sediments are deposited naturally under the influence of flow and flocculation. Muddy sandbanks with stratified overlying waters (5 - 20 PSU) are strongly favoured habitat for several key estuarine as well as estuarine dependent marine fish species.

The estuarine plume in coastal waters off the uMkhomazi is an important feature of the system, playing a role in the recruitment of marine spawned fishes as well as acting as estuarine habitat during periods of high flow. In the uMkhomazi where salinity can fluctuate widely over the tidal cycle, even during normal flows, some fishes are likely to use estuarine plume waters on a tidal basis, occurring in the brackish turbid coastal waters at low tide and following them into the estuary as they are pushed back with incoming high tides. Under reference conditions tidal freshwaters would have occurred upstream of the Sappi Saiccor weir. This section of the estuary would have been favoured habitat for a number of estuarine and estuarine dependent marine fishes.

ii) Description of factors influencing fish

The main flow related factors influencing fish in the uMkhomazi estuary are listed below (Table 4.30). A summary of fish responses to different estuarine states is given in Table 4.31.

Table 4.30 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings

Grouping			
Estuarine resident	**Estuarine dependent marine**	**Marine**	**Freshwater**
Mouth condition: Mouth closure			
Most resident species proliferate under closed mouth conditions.	Recruitment of marine spawning fishes is reduced by mouth closure. Short periods of closure may benefit fishes (more so the estuarine dependent than marine species) that are already in the system. However, prolonged closure, especially if associated with reduced salinity, negatively impacts this component of the ichthyofauna. Numbers of species and abundance therefore declines with prolonged mouth closure. Category IIc and III fishes especially become increasingly less common and abundant.		Increase in abundance if salinity is low. *Oreo mossambicus* especially becomes abundant through both breeding in the estuary as well as recruitment from freshwater reaches.
Salinity			
Resident and estuarine dependent marine species are generally tolerant of a wide range in salinity, often from fresh- to sea water. Species distribute themselves across the estuarine gradient according to salinity preferences (and other factors).		Inhabit waters close to 35 PSU and become stressed at salinities under 20 PSU.	Highly variable. Most species are likely to avoid waters where salinities are > 1 PSU. *O. mossambicus* capable of much surviving much higher levels.
Dissolved oxygen			
Most resident and estuarine dependent marine species are stressed when oxygen drops below 4 mg/l.		Little tolerance to low oxygen levels.	Respond variously. Some species tolerant of low oxygen.
River flow			
During spates these species may be washed out to sea but many return as flood waters recede.	Also susceptible to being washed out to sea in flood waters, but recruit back following the receding flood front. Juvenile marine and catadramous species use river flows (and flood waters) as a cue for locating and migrating into the estuary. Major river flooding associated with high sediment loads can cause gill clogging for fishes. Marine fishes are most sensitive to this.		Some individuals may be washed out to sea where mortalities occur because of osmoregulatory shock. Very high water levels and floodplain inundation promotes spawning of some freshwater species.

Table 4.31 Summary of fish responses to different abiotic states

State	Response
State 1: Closed, brackish	No estuarine plume ("offshore estuary") exists. Marine spawning fishes cannot recruit into the estuary, with the exception of a very limited number of species which recruit during wave overwash events. Abundance and species diversity of estuarine dependent and marine species declines. Nearly all species that are in the system at the time of closure survive however, unless severe cold snaps occur. Food availability improves for most species and estuarine residents that are zooplanktivorous become more abundant. Oxygen concentrations might limit abundance of some estuarine and estuarine dependent taxa however, notably in Zone C of the estuary, which is important nursery habitat. This would be much more problematic in nutrients loads into the estuary were high (e.g. from treated wastewater).
State 2: Open, full salinity gradient	Good conditions within the estuary for marine, estuarine dependent and estuarine fishes. The offshore plume does not develop to its full potential but recruitment of estuarine dependent species is unaffected by mouth closure. Marine species use the lower reaches of the estuary, some on a tidal basis. Zone C is a particularly important nursery are for estuarine dependent species.
State 3: Open, limited salinity gradient	Good conditions within the estuary for estuarine dependent and estuarine fishes. The offshore plume does not develop to its full potential but recruitment of estuarine dependent species is unaffected by mouth closure. Marine species use the lower reaches of the estuary but mostly on a tidal basis. Some estuarine dependent species migrate freely between estuarine and turbid coastal waters with the tide.
State 4: Open fresh	The offshore plume develops to its full potential and acts as a strong recruitment cue for estuarine dependent species as well as catadromous eels. Marine species do not occur in the estuary, and several estuarine dependent marine fishes are limited to the systems lower reaches. Many use the estuary on a tidal basis. Even some estuarine species migrate freely between estuarine and turbid coastal waters with the tide. Freshwater fishes occur all the way down the estuary, but these are generally limited to a few taxa.

iii) Reference condition

Under reference conditions, the uMkhomazi estuary occurred in a fresh water state over much of the high flow season (summer). A well-developed estuarine plume occurred in the nearshore coastal waters off the systems mouth. These waters would have been used by estuarine dependent fishes (and probably, to a limited extent, also by estuarine resident species). Under flood conditions, this water was brackish, turbid and extended a considerable distance offshore and even further along the coast. These waters acted as a strong recruitment cue for estuarine dependent marine fishes, which would have entered the system in large abundances. Flows dissipated naturally during the dry season and the estuary was increasingly tidal during winter with a greater occurrence of a limited salinity gradient. This benefitted fishes that had recruited into the system and good nursery habitat existed in the form of gently sloping sand and mud banks. The best nursery area would have occurred in the upper reaches of Zone B and lower reaches of Zone C. Tidal freshwaters would have extended all the way into Zone D. These would have been used as preferential habitat by a variety of estuarine and estuarine dependent species. Under these conditions all fish categories would have occurred in the estuary, although marine species only sporadically so when river flows dropped below 2 m^3/s.

A summary of present day changes compared to reference conditions are given in Table 4.32 below.

Table 4.32 Summary of relative changes from Reference Condition to Present state

Key drivers	Change
Salinity gradients (estuarine state)	Under reference conditions a higher frequency of open fresh conditions (State 4), and lower frequency of full salinity gradient conditions occurred, especially during the low flow (winter) months. Present day conditions in the estuary during winter are more favourable for estuarine, estuarine dependent and marine fishes. A better developed "offshore estuary" existed under reference conditions however, and this also served as a recruitment cue for marine spawning species. There was a much stronger link, and high functional connectivity, between the estuary proper and these offshore transitional waters.
Connectivity with tidal fresh waters	The Sappi Saiccor weir cuts across the functional estuary. Under reference conditions Zone D was tidal fresh water that was used as preferential habitat by a variety of estuarine and estuarine dependent species.
Nursery habitat	Key nursery area for estuarine dependent species under reference conditions occurred as sand- and mud banks in the upper reaches of Zone B and lower reaches of Zone C. Under present day conditions Zone C has the most favourable salinity and flow characteristics. Sand- and mud banks in this zone of the estuary are impacted negatively by sand mining and this reduces the systems value as a nursery for key fish species.

4.8.2 Fish health

The PES of the uMkhomazi fish assemblage is described and scored in Table 4.33 below.

Table 4.33 Fish component health score

Variable	Summary of change	Score	Conf
1. Species richness	A similar number of species uses the estuary as was the case under reference conditions. Increased marine straggler component probably offset losses in species numbers that might have occurred.	95	H
2. Abundance	Some species are markedly reduced in abundance in the estuary. These include estuarine residents and some estuarine dependent marine species in the reduced tidal freshwaters (flow related) as well as some specialist turbid water species such as cob (flow related, overfishing) and grunter (overfishing). The loss of offshore transitional waters (flow related) contributes to reduced recruitment and reduced flood buffer, and also leads to reduced abundance of species compared to reference.	60	M
3. Community composition	Species composition remains similar to reference conditions with the exception that some estuarine and estuarine dependent marine species have been replace by marine stragglers.	75	M
Biotic component health score		**60**	
% of impact non-flow related		**25**	**M**
Adjusted score		**70**	

4.9 BIRDS

4.9.1 Overview

i) Main grouping and baseline description

The avifaunal investigation done as part of this study (see Avifaunal Specialist Report - (Part of Report 8.3; Report Number: RDM/WMA11/00/CON/CLA/0714) confirmed that the uMkhomazi Estuary does not support a particularly rich diversity, or large numbers, of waterbird species. The estuary also does not appear to support significant habitat for any Red Data waterbird species and the only two such species to have been recorded during counts are the Pink-backed Pelican and Woolly-necked Stork, both recorded only on single occasions. The configuration of the mouth, the bridges present there and, especially, the high level of human disturbance precludes the use of the area by large numbers of roosting terns and gulls. The reason for this relatively depauperate waterbird community is likely the absence under normal circumstance of particularly attractive waterbird habitats, e.g. there are no extensive, natural floodplain habitats associated with the estuary.

The October 2014 field survey coincided with a period of peak back-flooding of the estuary, with the mouth closed and high inflow from the river. Relatively high numbers of a wide diversity of waterbirds were noted exploiting the ephemerally flooded areas on both the north and south banks of the estuary. This opportunistic observation demonstrates the particular value of the estuary to waterbird populations during these temporarily ideal conditions.

Table 4.34 Waterbird feeding guilds and their defining features and typical/dominant species

Main foraging guilds	Defining features and typical/dominant species
Swimming piscivores	This group, which favours expanses of open, deep water, essentially comprises the cormorants, although the African Darter will also enter estuaries when and where these are dominated by freshwater condition, as well as the pelicans. The two most common cormorants are the White-breasted and Reed cormorants, although small numbers of Cape Cormorants will also seasonally enter some systems during the winter-spring period. As a major river, the uMkhomazi offers fairly substantial habitat suitable for cormorants.
Aerial piscivores	The primary aerial piscivores (species hunting from the wing, or elevated perches, over open water) in estuaries are terns (primarily Caspian, Swift, Lesser Crested, Sandwich, Common and Little terns), aquatic raptors (African Fish Eagle and Osprey) and kingfishers (mainly Pied, Giant and Malachite kingfishers). Many terns often use open sandbanks in estuaries for roosting but the mouth of the uMkhomazi Estuary is too disturbed to support any major tern roosts.
Large wading piscivores	The primary large wading piscivores are the herons and egrets (especially Goliath, Grey, Purple and Black-crowned Night herons and Little Egret). These species are characteristic of wetland shorelines and their ability to extend their hunting range into inundated areas depends primarily on their size/leg-length. Storks (essentially the Woolly-necked Stork in this region) and African Spoonbill are additional large wading piscivores. Salinity militates against the abundance of amphibians (frogs) and hence the large wading predatory waterbirds that tend to specialise on these animals, e.g. Hamerkop and Yellow-billed Egret, unless there is extensive back-flooding during closed-mouth conditions as observed at the uMkhomazi Estuary.
Small wading invertebrate feeders	The main groups here are the shorebirds (e.g. sandpipers, plovers, stints, thick-knees, etc.), i.e. the migratory Palaearctic waders and their resident counterparts. These species feed on benthic macroinvertebrates. Like the large wading piscivores, many of these species are characteristic of wetland shorelines but many also exploit inter-tidal sand- and mud-flats. Indeed these inter-tidal areas are often the most important habitat for many of the Palaearctic waders and some a wholly reliant on these habitats on their non-breeding grounds. Such suitable inter-tidal habitat, however, is rare at uMkhomazi Estuary. A large diversity of species characterises this group, e.g. sandpipers, plovers, lapwings, stilts, oystercatchers and thick-knees. Ibises, essentially African Sacred and Hadeda

Main foraging guilds	Defining features and typical/dominant species
	ibises, are likely also best placed in this group despite their size, although both species likely obtain the bulk of their food outside estuaries, indeed wetlands generally, as in the case of the Egyptian Goose (see below).
Swimming herbivorous waterfowl	Salinity also militates against the growth of higher vegetation in most estuaries, limiting the food supply for herbivorous waterfowl (ducks and geese) in many instances. It also severely curtails the abundance of the otherwise ubiquitous Red-knobbed Coot, and some other rallids, in these habitats. Waterfowl, however, do occur when and where estuaries are dominated by freshwater conditions, e.g. African Black Ducks – river specialists, typically occur in the upper reaches of estuaries where rivers enter these systems. Some waterfowl, however, feed on a mixture of plant material and invertebrate food such as small crustaceans. These birds, like terns, are also attracted to roost at estuaries. The Egyptian Goose is a particularly abundant, and increasing, estuarine waterfowl but it likely obtains most of its food in surrounding dryland habitats, e.g. lawns, pastures and cropfields. The same applies to the Spur-winged Goose.
Carnivorous and scavenging gulls	Gulls, primarily the Kelp and Grey-headed gulls along the KZN coastline, have an unparalleled dietary breadth as carnivores, feeding on both vertebrate and invertebrate matter both live and dead (scavenged). Their breadth of foraging strategies is equally broad. Gulls, like terns, often also use estuaries as roosting sites, coming in from the nearby coastline for this purpose. Gulls are rare at uMkhomazi Estuary, however, which offers little in the way of foraging or roosting habitat for these birds.

iii) Description of factors influencing birds

The table below lists the effects of various abiotic and biotic factors on the different waterbird feeding guilds present at the uMkhomazi Estuary.

Table 4.35 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings (generalist gulls excluded from consideration due to their overall resilience, unpredictability and adaptability)

Grouping			
Swimming and large wading piscivores	**Aerial piscivores**	**Swimming herbivorous waterfowl**	**Small wading invertebrate feeders**
Mouth condition			
Indirectly, through influence on water level and fish – can be positive when extensive back-flooding accompanies mouth closure.		Indirectly, through influence on macrophytes – can be positive when extensive back-flooding accompanies mouth closure.	Mouth closures have negative effect on preferred inter-tidal sandbanks in lower estuary. Can also affects roosting terns (not relevant at uMkhomazi)
Salinity			
Indirectly, through influence on fish.		Prefer lower salinities	Some Palaearctic waders reliant on seawater conditions
Turbidity			
Negatively affects visibility for foraging.		Negatively affects submerged aquatic plants.	Only if impacts benthic macroinvertebrates
Intertidal area			
Indirectly, through influence on fish.	Indirectly, through influence on fish. Shallow water at high tide likely valuable as foraging area.	Only important for this group if exposes submerged food plants, e.g. *Zostera*, at low tide. Roosting habitat also exposed at low tide.	Critically important habitat for waders which rely mostly on intertidal areas for feeding.
Sediment characteristics (including sedimentation)			
Indirectly, through influence on fish.		Can enhance macrophyte growth, e.g. reeds.	Most waders prefer medium to fine sand; a few prefer coarse

Grouping			
Swimming and large wading piscivores	**Aerial piscivores**	**Swimming herbivorous waterfowl**	**Small wading invertebrate feeders**
			sand and mud. Sedimentation can smother benthic macroinvertebrates.
Primary productivity			
Indirectly though influence on food supply.			
Submerged macrophytes abundance			
Indirectly, through influence on fish (food and cover)		Has positive influence on herbivorous waterfowl numbers.	Indirectly, if affects benthic macroinvertebrates.
Abundance of reeds and sedges			
Indirectly, through influence on fish (food and cover). Encroaches on roosting habitat of terns.		Has positive influence on some herbivorous waterfowl species.	Encroachment of macrophytes largely at expense of open habitats required by waders.
Abundance of zooplankton			
Indirectly, through influence on fish.		Assumed positive for some omnivorous species.	
Benthic invertebrate abundance			
Indirectly, through influence on fish.			Primary food source for invertebrate-feeding waders.
Fish biomass			
Piscivores will increase with increasing numbers of small to medium-sized fish.			Indirectly, if fish compete for benthic macroinvertebrates

Table 4.36 Summary of bird responses to different abiotic states

State	Response
State 1: Closed	The deep water conditions of a closed-mouth state increase habitat for swimming piscivores and, possibly, aerial piscivores. Where this results in back-flooding into the floodplain as observed at uMkhomazi Estuary, it can also increase habitat for wading piscivores and herbivorous waterfowl, indeed for waterbirds generally. The lack of tidal conditions though results in reduced habitat for many key small invertebrate-feeding waders, and likely also reduces potentially suitable exposed sandbanks for roosting waterbirds.
State 2: Tidal, intermittently closed	A condition intermittent between that described directly above and below.
State 3: Tidal	Where this is associated with extensive inter-tidal sand flats and mudflats, it can provide key habitat for key small invertebrate-feeding waders. Exposed sandflats and mudflats are also favoured by roosting waterbirds.
State 4: Freshwater dominated	Probably the least productive scenario from a waterbird perspective under normal circumstances and the likely typical condition of this relatively waterbird-poor estuary.

iv) Reference condition

Evidence from earlier waterbird counts dating back to the 1980s and synthesised in the Avian Specialist Report suggest that waterbird species richness and abundance have remained relatively constant since at least that time. The major ecological perturbations to the estuary had likely already manifested by that time, however, and our knowledge of the reference waterbird condition at the estuary can only be a matter for conjecture. The system was clearly much deeper in its original state, as evidenced by sea-faring vessels once having been able to penetrate far upstream.

Known threats that operate to shift the system away from its reference condition include: habitat loss (including bridge construction, incursions into the floodplain and sand-mining in the upper estuary), water pollution and eutrophication (especially from the Umkomaas WWTW), and water extraction (including from the SAPPI SAICCOR weir and further upstream in the catchment) (Forbes and Demetriades, 2008). Lesser threats include chemical contamination (including from dive boats), litter and debris, and over-fishing. These threats can be expected to translate into negative impacts on waterbird populations.

Table 4.37 Summary of relative changes from Reference Condition to Present state

Key drivers	Change
Siltation	Loss of deep-water conditions. Increased turbidity negatively affects visual predatory piscivores.
Disturbance at the mouth	Precludes large numbers of roosting terns and gulls.
Agriculture and other anthropogenic modifications in the floodplain	Reduction in estuarine habitat.
Water pollution and eutrophication	Impact on food chain. Increased growth of alien plants.
Angling	Reduction in food and entanglement danger to waterbirds from discarded tackle.

4.9.2 Bird health

Waterbird species richness and abundance appear stable at present.

Table 4.38 Bird component health score

Variable	Summary of change	Score	Conf
1. Species richness	Likely retains majority of species ancestrally present.	80	M
2. Abundance	Fairly significant loss in overall waterbird abundance probable, due to habitat destruction in the floodplain, and, perhaps especially, disturbance of the mouth area, precluding roosting by large numbers of terns and gulls.	60	M
3. Community composition	Probably still retains basic structure of original waterbird community composition with the greatest changes likely related to coastal and marine species now excluded from the estuary by shallowing brought about by siltation and gross disturbance in the mouth area.	70	M
Biotic component health score		**60**	**M**
% of impact non-flow related		**80**	**M**
Adjusted score		**92**	

5 PRESENT ECOLOGICAL STATE

5.1 OVERALL ESTUARINE HEALTH INDEX SCORE

The uMkhomazi Estuary in its present state is estimated to be 69% similar to natural condition, which translates into a PES of a C Category. This is mostly attributed to the following factors:

- The weir in the upper reaches severing connectivity with the catchments.
- Sandmining that have taken away the sandbanks in the upper reaches (Zone C), resulting loss of intertidal areas and backwater refuge areas. It has also impacted on access to grazing areas as the river cannot be crossed in this section anymore.
- Recreational activities (e.g. boat launching) in the lower reaches affecting birds abundance.
- Over exploitation of living resources (e.g. cast netting and line fishing); and
- Agricultural activities in the EFZ causing loss of estuarine habitat.

Table 5.1 Estuarine Health Score (EHI) for the uMkhomazi Estuary

Variable	Estuarine health score		
	Overall	Excluding flow related pressures	Conf
Hydrology	66.8	67	M
Hydrodynamics and mouth condition	95	95	M/H
Water quality	66.6	66.6	M
Physical habitat alteration	78	78	M
Habitat health score	**76**	**76**	**M**
Microalgae	90	99	M
Macrophytes	21	84	M
Invertebrates	75	78	H
Fish	60	70	M
Birds	60	70	M
Biotic health score	**61**	**80**	**M**
ESTUARY HEALTH SCORE	**69**	**78**	
PRESENT ECOLOGICAL STATUS (PES)	**C**	**B**	
OVERALL CONFIDENCE	**M**	**L**	

5.2 RELATIVE CONTRIBUTION OF FLOW AND NON-FLOW RELATED IMPACTS ON HEALTH

Estimates of the contribution of non-flow related impacts on the level of degradation of each component led to an increase in the health score from a PES of 69 to 78, which would raise the health score to a B Category. This suggests that non-flow related impacts have played some in the degradation of the estuary to a C, but that flow-related impacts are also driving degradation.

The highest priority is to address the quality of influent water. Of the non-flow-related impacts, habitat loss within the 5m contour and the vegetation integrity of these areas along with water quality problems as a result of the high nutrient load associated with the WWTWs were the most important factors influencing ecological health of the system. The excess nutrients in the inflowing water is considered to be an important factor to consider with increased abstraction from the system. Retention of these high concentrations of nutrients will lead to nuisance algal growth, low dissolved oxygens and reduced habitat quality.

5.3 OVERALL CONFIDENCE

Confidence levels were medium to high for most of the abiotic components. Four of the biotic components had enough data to yield medium-high confidence assessments. The overall confidence of the study was MEDIUM.

6 THE RECOMMENDED ECOLOGICAL CATEGORY

6.1 CONSERVATION IMPORTANCE

The Estuary Importance Score (EIS) takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (Table 1.3). Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its present state. The scores have been determined for all South African estuaries (DWA, 2014), apart from functional importance, which is scored by the specialists in the workshop (Table 6.1). The Estuary Importance scores for five components and the importance rating (Table 1.4) is presented in Tables 6.2 and 6.3, respectively.

Table 6.1. Estimation of the functional importance score of the uMkhomazi Estuary

Functionality	Score
a. Estuary: Input of detritus and nutrients generated in estuary	20
b. Nursery function for marine-living fish	100
c. Movement corridor for river invertebrates and fish breeding in sea	100
d. Migratory stopover for coastal birds	20
e. Catchment detritus, nutrients and sediments to sea	100
f. Coastal connectivity (way point) for fish	100
Functional importance score - Max (a to f)	**100**

The functional Importance of the uMkhomazi Estuary is very high. It serves as an important nursery for exploited fish stock and plays a very important role from a fish egg production perspective. In addition it is also an important movement corridor for eels (CITES listed species).

The functional importance of uMkhomazi Estuary is very high for the nearshore marine environment. It is one of five key systems (Mfolozi, Mvoti, uMngeni, uMkhomazi, Umzimkulu) that supply sediment, nutrients and detritus to the coasts. The sediment load from the uMkhomazi is especially important as it is habitat forming and plays an important role in maintain the beaches and near shore habit along this coast.

The impact of further dam development on the nearshore marine environment was not assessed as part of this study, but should be assessed to ensure that all ecological processes and related ecosystem services (e.g. nearshore) are addressed.

Table 6.2 EIS for the uMkhomazi Estuary

Criterion	Weight	Score
Estuary Size	15	80
Zonal Rarity Type	10	30
Habitat Diversity	25	60
Biodiversity Importance	25	91.5
Functional Importance	25	100
Weighted Estuary Importance Score		**85**

The uMkhomazi estuary forms part of the core set of priority estuaries identified in the National Estuary Biodiversity Plan in need of protections to meet biodiversity targets under the Biodiversity Act and National Estuarine Management Protocol promulgated under the Integrated Coastal Management Act. The National Estuary Biodiversity Plan requires that the uMkhomazi Estuary be partially protected (e.g. no-take fishing zone and 25% of riverine area left untransformed) with a REC of B.

6.2 RECOMMENDED ECOLOGICAL CATEGORY

The REC represents the level of protection assigned to an estuary. The PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection or desired protection of a particular estuary. The PES for the uMkhomazi Estuary is a C, but the Estuary is rated as "Very Important" from a biodiversity perspective and should therefore be in a B Category.

In addition, the system also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the NBA (Turpie *et al*., 2013). The NBA 2011 (Van Niekerk and Turpie, 2012) recommends that the minimum category for the uMkhomazi estuary should be a B, it be a granted full no-take protection, and that 25 % of the estuary margin be undeveloped.

Taking the current conditions (PES =C), the reversibility of the impacts, the ecological impotence and the conservation requirements of the uMkhomazi Estuary the REC for the system is a B Category.

7 CONSEQUENCES OF ALTERNATIVE SCENARIOS

7.1 DESCRIPTION OF SCENARIOS

The proposed scenarios for the Mvoti system are summarised in Table 7.1 and each scenario and its associated variables are described in the sub-sections that follow. Detailed scenario description are provided in DWS RDM/WMA11/00/CON/CLA/0514.

Table 7.1 Summary of the uMkhomazi Scenarios

Scenario	Scenario Variables				
	Update Water Demands	Ultimate Development Demands & Return Flows (2040)	EWR[1]	uMWP-1[2]	Ngwadini OCD[3]
MK1	Yes	No	No	No	No
MK2	Yes	Yes	No	Yes	Yes (no support)
MK21	Yes	Yes	REC tot[4] (Mk_I_EWR2)	Yes	Yes (no support)
MK22	Yes	Yes	REC low[5] (Mk_I_EWR2)	Yes	Yes (no support)
MK23	Yes	Yes	REC low+[6] (Mk_I_EWR2)	Yes	Yes (no support)
MK31	Yes	Yes	REC tot[4] (Mk_I_EWR3)	Yes	Yes (no support)
MK32	Yes	Yes	REC low[5] (Mk_I_EWR3)	Yes	Yes (no support)
MK33	Yes	Yes	REC low+[6] (Mk_I_EWR3)	Yes	Yes (no support)
MK4	Yes	Yes	No	Yes	Yes (with support)
MK41	Yes	Yes	REC tot[4] (Mk_I_EWR2)	Yes	Yes (with support)
MK42	Yes	Yes	REC low[4] (Mk_I_EWR2)	Yes	Yes (no support)

1 Ecological Water Requirement for river sites
2 uMkhomazi Water Project Phase 1
3 Off-channel Dam
4 REC (Total Flows)
5 REC (Low Flows)
6 REC (Total Flows for Jan, Feb, Mar and Low Flows remaining months)

7.1.1 Scenario MK2: Ultimate Development, uMkhomazi Water project (uMWP-1) and Ngwadini OCD (No uMWP-1 Support)

This scenario will include estimates of increased water use and return flows for the domestic sector due to population growth and improved service delivery for the ultimate development scenario, developed in accordance with the EThekwini Spatial Development Framework and Umgeni Water Planning.

The uMWP-1 is also included in the scenario as proposed by the DWS Water Reconciliation Strategy Study for the KwaZulu-Natal Coastal Metropolitan Areas as a required augmentation option to meet the projected future water requirements of the uMngeni River System. The uMWP-1 will impact directly on the flows of the uMkhomazi due to the Smithfield Dam impoundment and abstraction to support the eThekwini municipalities projected water requirements and will hence contribute to projected increase in return flows of the uMkhomazi WWTW and also in neighbouring rivers that the eThekwini WWTW discharge into. The projected requirements was sourced from the uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study Raw Water.

Umgeni Water has recently commissioned the Lower uMkhomazi Bulk Water Supply Scheme: Service Provider for the Detailed Feasibility Study and Preliminary Design that includes the Ngwadini OCD in the lower uMkhomazi River. This option is also included in the scenarios and will

also impact directly on the flows of the uMkhomazi due to the proposed weir construction and abstraction. The Ngwadini OCD was configured in the Water Resource Planning Model (WRPM) in such a way that no support is provided from Smithfield Dam. The projected water requirements was sourced directly from the uMngeni Water feasibility study.

The purpose of this scenario is to assess the flows at the EWR sites for the ultimate development level with uMWP-1 and Ngwadini OCD (with no support from Smithfield Dam) in place.

7.1.2 Scenario MK21, MK22, MK23: Ultimate Development, REC EWR (Mk_I_EWR2), uMWP-1 and Ngwadini OCD (No uMWP-1 support)

These scenarios are based on Scenario MK2 where the flows at the EWR sites will be assessed for the following EWR flows:

- Total flow EWRs (Mk_I_EWR2) set to achieve the REC (**MK21**).
- Low flow EWRs (Mk_I_EWR2) set to achieve the REC (**MK22**).
- Total Flows for January, February, March and Low Flows remaining months (Mk_I_EWR2) set to achieve the REC (**MK23**).

The purpose of these scenarios is to determine to what degree the total flow, low flow and the in between flow EWRs together with the dam spills and tributary inflows from the dam will achieve the REC at Mk_I_EWR2. The 'cost' of releasing an EWR from the future Smithfield Dam can also be determined as an impact on the current socio-economics.

7.1.3 Scenarios MK31, MK32, MK33: Ultimate Development, REC EWR (Mk_I_EWR3), uMWP-1 and Ngwadini OCD (No uMWP-1 Support)

These scenarios are based on Scenario MK2 where the flows at the EWR sites will be assessed for the following EWR flows:

- Total flow EWRs (Mk_I_EWR3) set to achieve the REC (**MK31**).
- Low flow EWRs (Mk_I_EWR3) set to achieve the REC (**MK32**).
- Total flows for January, February, March and low flows remaining months (Mk_I_EWR3) set to achieve the REC (**MK33**).

The purpose of these scenarios is to determine to what degree the total flow, low flow and the in between flow EWRs together with the dam spills and tributary inflows from the dam will achieve the REC at Mk_I_EWR3. The 'cost' of releasing an EWR from the future Smithfield Dam can also be determined as an impact on the current socio-economics.

7.1.4 Scenario MK4: Ultimate Development, uMWP-1 and Ngwadini OCD (No uMWP-1 Support)

This scenario is based on **MK2** with the only change being that the Ngwadini OCD was configured in the WRPM in such a way that support is provided from Smithfield Dam

The purpose of this scenario is to assess the flows at the EWR sites for the ultimate development level with MWP and Ngwadini OCD (with support provided from Smithfield Dam) in place.

7.1.5 Scenarios MK41 and MK42: Ultimate Development, REC EWR (Mk_I_EWR2), MWP and Ngwadini OCD (With uMWP-1 Support)

These scenarios are based on Scenario **MK2** where the flows at the EWR sites will be assessed for the following EWR flows:

- Total flow EWRs (Mk_I_EWR2) set to achieve the REC (**MK41**).

- Low flow EWRs (Mk_I_EWR2) set to achieve the REC (**MK42**).

The purpose of these scenarios is to determine to what degree the total flow and low flow EWRs (Mk_I_EWR2) together with the dam spills and tributary inflows from the dam will achieve the REC at EWR sites. The 'cost' of releasing an EWR from the future Isithundu Dam (and possibly Imvutshane Dam) can also be determined as an impact on the current socio-economics.

The above mentioned water resource development scenarios were then grouped into five groups (Group A to E) based on how the simulated runoff would affect the uMkhomazi Estuary (Table 7.2).

Table 7.2 Summary of flow scenarios applicable to the uMkhomazi estuary

Scenarios		Description	MAR ($X10^6$ m^3)	% Remaining
Reference		Natural Flow	1077.74	100
Present		Present	943.39	88
Group A	MK2	Ultimate Development, uMkhomazi Water project (uMWP-1) and Ngwadini OCD (No uMWP-1 Support).	719.12	67
Group B	MK21	Ultimate Development, REC EWR (Mk_I_EWR2), uMWP-1 and Ngwadini OCD (No uMWP-1 Support), Total flow EWRs at Mk_I_EWR2.	779.09	72
Group C	MK22	Ultimate Development, REC EWR (Mk_I_EWR2), uMWP-1 and Ngwadini OCD (No uMWP-1 Support), Low flow EWRs at Mk_I_EWR2.	770.76	72
Group C	MK23	Ultimate Development, REC EWR (Mk_I_EWR2), uMWP-1 and Ngwadini OCD (No uMWP-1 Support), Total Flows for Jan to Mar and Low Flows for remainder at Mk_I_EWR2.	771.25	72
Group D	MK31	Ultimate Development, REC EWR (Mk_I_EWR3), uMWP-1 and Ngwadini OCD (No uMWP-1 Support), Total flow EWRs at Mk_I_EWR3.	773.14	72
Group E	MK32	Ultimate Development, REC EWR (Mk_I_EWR3), uMWP-1 and Ngwadini OCD (No uMWP-1 Support), Low flow EWRs at Mk_I_EWR3.	761.64	71
Group E	MK33	Ultimate Development, REC EWR (Mk_I_EWR3), uMWP-1 and Ngwadini OCD (No uMWP-1 Support), Total flows for Jan to Mar and low flows remainder (EWR at Mk_I_EWR3).	761.64	71
Group A	MK4	Ultimate Development, MWP and Ngwadini OCD (No uMWP-1 Support).	728.25	68
Group B	MK41	Ultimate Development, REC EWR (Mk_I_EWR2), uMWP-1 and Ngwadini OCD (With uMWP-1 Support), Total flow EWRs at Mk_I_EWR2.	788.11	73
Group C	MK42	Ultimate Development, REC EWR (Mk_I_EWR2), uMWP-1 and Ngwadini OCD (With uMWP-1 Support), Low flow EWRs at Mk_I_EWR2.	779.81	72

7.2 VARIABILITY IN RIVER INFLOW

The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future Scenarios of the uMkhomazi Estuary, derived from a 84-year simulated data set are provided in Table 7.3 to Table 7.7 and Figure 7.1 to Figure 7.5. The full sets 84-year series of simulated monthly runoff data for the future Scenarios are provided in Table 7.8 to Table 7.12.

Table 7.3 Summary of the monthly flow (in m^3/s) distribution under Scenario Group A

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	196.6	127.3	179.6	198.7	239.0	245.8	130.5	125.1	81.5	36.2	32.3	228.3
99	76.7	124.8	131.1	196.3	214.5	219.9	109.2	96.3	41.8	21.8	25.5	80.1
90	8.4	34.8	82.6	112.8	131.4	104.5	59.1	16.3	5.1	6.3	1.6	1.9
80	2.8	17.9	60.9	86.2	105.6	75.3	40.4	8.3	1.8	1.2	1.2	1.2
70	1.3	11.0	43.4	67.7	80.4	56.5	27.0	7.0	1.3	1.2	1.2	1.2
60	1.2	5.8	32.3	54.1	67.4	50.4	24.0	3.8	1.2	1.1	1.0	1.2
50	1.2	2.5	21.0	42.8	58.6	42.8	22.1	2.5	1.2	1.0	0.8	1.0
40	1.2	1.5	9.8	32.7	51.0	39.2	17.2	1.5	1.2	0.8	0.7	0.8
30	1.2	1.3	4.6	21.4	40.1	34.6	10.8	1.3	1.1	0.7	0.6	0.7
20	1.0	1.3	2.6	13.4	32.1	27.5	7.9	1.2	0.9	0.6	0.6	0.6
10	0.8	1.2	1.3	3.3	17.7	19.4	3.6	1.0	0.6	0.5	0.5	0.5
1	0.6	0.6	0.9	0.8	1.2	1.3	1.1	0.6	0.5	0.5	0.4	0.4
0.1	0.5	0.6	0.6	0.5	0.6	1.2	0.9	0.6	0.5	0.4	0.4	0.4

Table 7.4 Summary of the monthly flow (in m^3/s) distribution under Scenario Group B

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	198.0	129.1	174.9	200.2	240.4	247.5	132.3	126.9	82.9	32.4	32.3	226.7
99	78.4	126.7	131.5	197.8	215.7	221.7	110.9	98.2	39.5	22.3	27.0	79.9
90	12.3	32.9	77.8	112.8	133.2	106.1	60.6	18.0	7.2	7.8	4.5	4.1
80	9.5	21.0	55.6	80.7	105.1	76.8	42.1	11.6	6.2	4.7	3.9	3.8
70	8.0	17.8	39.2	68.0	81.9	58.3	28.7	10.6	5.6	4.0	3.4	3.5
60	6.8	14.3	27.1	52.3	69.3	52.0	25.7	9.5	5.1	3.6	3.0	3.1
50	5.7	12.5	20.2	39.9	60.0	44.0	24.1	8.5	4.7	3.0	2.3	2.5
40	4.6	10.5	16.3	29.6	46.7	40.3	19.0	7.1	3.8	2.5	1.7	2.0
30	3.8	8.2	12.0	22.0	41.6	36.4	12.7	5.8	3.1	1.9	1.5	1.7
20	2.8	5.6	8.2	13.9	32.9	28.8	10.0	4.5	2.2	1.5	1.4	1.5
10	1.6	3.1	3.8	8.1	19.6	21.3	6.6	3.5	1.8	1.3	1.3	1.3
1	1.3	1.6	1.9	3.3	4.5	7.9	5.2	2.0	1.4	1.2	1.2	1.2
0.1	1.3	1.6	1.9	2.9	2.1	6.5	4.7	1.6	1.3	1.2	1.2	1.2

Table 7.5 Summary of the monthly flow (in m^3/s) distribution under Scenario Group C

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	197.7	128.9	178.3	199.9	240.1	247.3	132.1	126.7	82.7	31.6	32.2	225.4
99	78.1	126.4	131.9	197.6	215.5	221.4	110.6	97.9	39.0	22.0	26.8	79.7
90	9.7	33.4	82.5	114.3	132.9	105.8	60.4	17.8	7.2	7.8	4.5	4.1
80	5.7	16.9	61.1	87.8	107.1	76.5	41.8	11.6	6.2	4.7	3.9	3.8
70	4.9	10.4	43.6	69.2	82.0	58.0	28.5	10.6	5.6	4.0	3.4	3.5
60	4.1	7.5	30.9	55.6	69.0	51.7	25.4	9.5	5.1	3.6	3.0	3.1
50	3.4	6.3	19.9	43.4	59.7	43.7	23.8	8.5	4.7	3.0	2.3	2.5
40	2.9	4.8	10.8	34.0	48.2	40.7	18.8	7.1	3.8	2.5	1.7	2.0
30	2.2	3.5	6.9	22.9	41.6	36.1	12.4	5.8	3.1	1.9	1.5	1.7
20	1.8	3.1	5.1	12.6	32.7	29.0	9.4	4.5	2.2	1.5	1.4	1.5
10	1.5	2.5	3.4	6.6	19.3	21.3	6.4	3.5	1.8	1.3	1.3	1.3
1	1.3	1.6	1.9	3.3	4.5	7.9	5.2	2.0	1.4	1.2	1.2	1.2
0.1	1.3	1.6	1.9	2.9	2.1	6.5	4.7	1.6	1.3	1.2	1.2	1.2

Table 7.6 Summary of the monthly flow (in m^3/s) distribution under Scenario Group D

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	197.8	128.9	177.9	200.0	240.2	247.4	132.1	126.7	82.9	34.5	32.5	228.1
99	78.2	126.5	131.9	197.6	215.6	221.5	110.7	98.0	41.1	22.6	26.9	80.3
90	10.5	35.2	82.9	114.3	133.0	105.9	60.5	17.8	5.9	6.4	2.8	2.5
80	6.6	19.6	58.2	85.5	107.2	76.6	41.9	9.9	4.7	3.5	2.7	2.4
70	6.1	14.6	44.4	69.3	81.7	58.1	28.5	8.7	4.3	3.0	2.4	2.3
60	5.5	13.0	29.4	54.7	69.3	51.8	25.5	7.9	4.1	2.8	2.3	2.2
50	4.9	11.6	18.1	40.4	60.3	43.8	23.9	7.1	3.8	2.5	1.8	2.0
40	4.3	10.3	15.4	30.5	46.5	40.3	18.9	6.0	3.2	2.1	1.6	1.8
30	3.6	8.4	12.1	19.3	41.6	36.2	12.5	5.1	2.8	1.8	1.5	1.6
20	2.4	5.5	7.8	14.0	32.7	29.1	9.8	4.1	2.1	1.5	1.3	1.5
10	1.5	2.2	3.0	6.6	19.0	22.2	5.5	3.5	1.8	1.3	1.3	1.3
1	1.3	1.5	1.9	3.3	3.8	6.5	4.7	1.8	1.3	1.1	1.0	1.0
0.1	1.3	1.5	1.9	2.9	1.9	4.4	4.3	1.6	1.3	1.1	1.0	1.0

Table 7.7 Summary of the monthly flow (in m^3/s) distribution under Scenario Group E

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	197.4	128.6	180.0	199.6	239.9	247.0	131.8	126.4	82.5	33.5	32.4	226.3
99	77.8	126.1	132.0	197.3	215.2	221.2	110.4	97.6	40.4	22.1	26.6	79.9
90	9.9	35.8	83.8	114.0	132.6	105.5	60.1	17.5	5.8	6.1	2.8	2.5
80	3.4	18.4	62.3	87.5	106.8	76.2	41.5	9.6	4.7	3.5	2.7	2.4
70	3.3	10.8	44.6	69.0	81.7	57.7	28.2	8.6	4.3	3.0	2.4	2.3
60	2.9	5.6	34.3	55.3	68.9	51.5	25.2	7.9	4.1	2.8	2.3	2.2
50	2.4	4.8	23.4	44.0	60.0	44.0	23.5	7.1	3.8	2.5	1.8	2.0
40	2.1	3.5	10.8	34.2	51.1	40.4	18.5	6.0	3.2	2.1	1.6	1.8
30	1.9	2.8	5.9	22.8	41.3	35.8	12.1	5.1	2.8	1.8	1.5	1.6
20	1.6	2.3	3.9	15.1	33.4	28.7	9.1	4.1	2.1	1.5	1.3	1.5
10	1.5	2.0	2.7	5.5	18.9	21.8	5.4	3.5	1.8	1.3	1.3	1.3
1	1.3	1.5	1.9	3.3	3.8	6.2	4.7	1.8	1.3	1.1	1.0	1.0
0.1	1.3	1.5	1.9	2.9	1.9	4.4	4.3	1.6	1.3	1.1	1.0	1.0

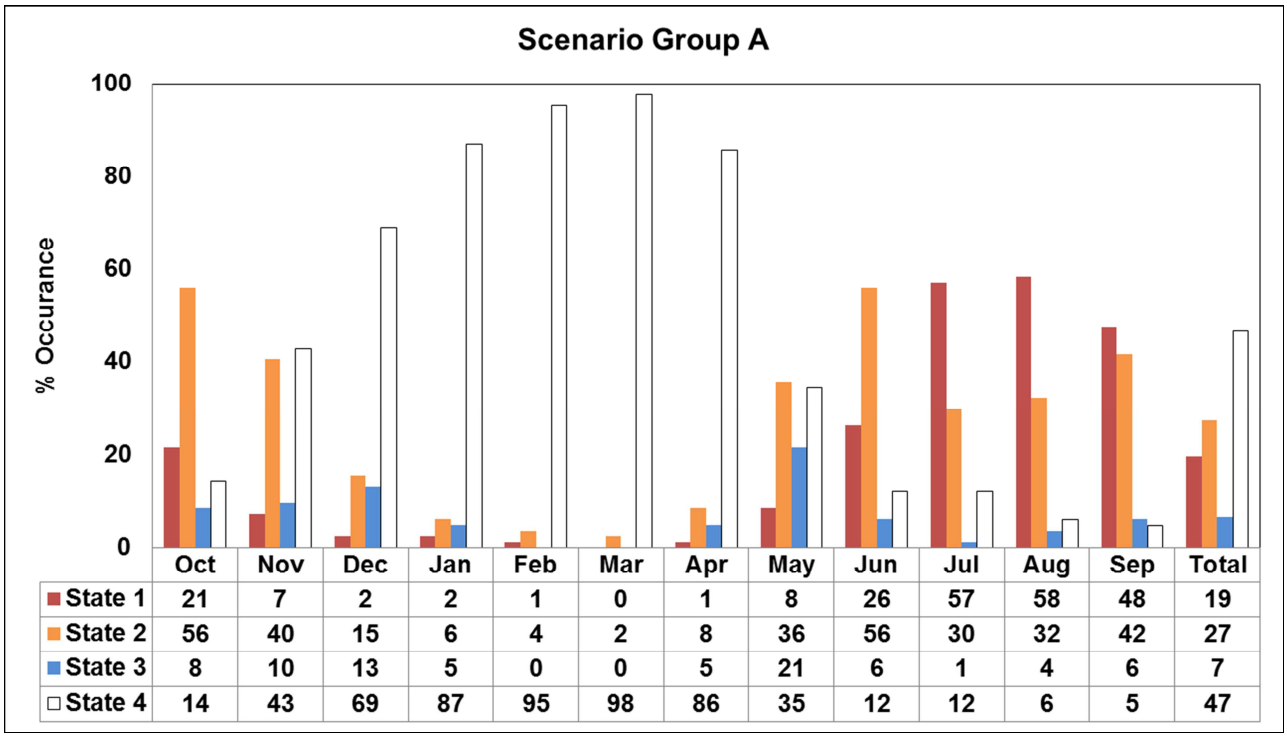
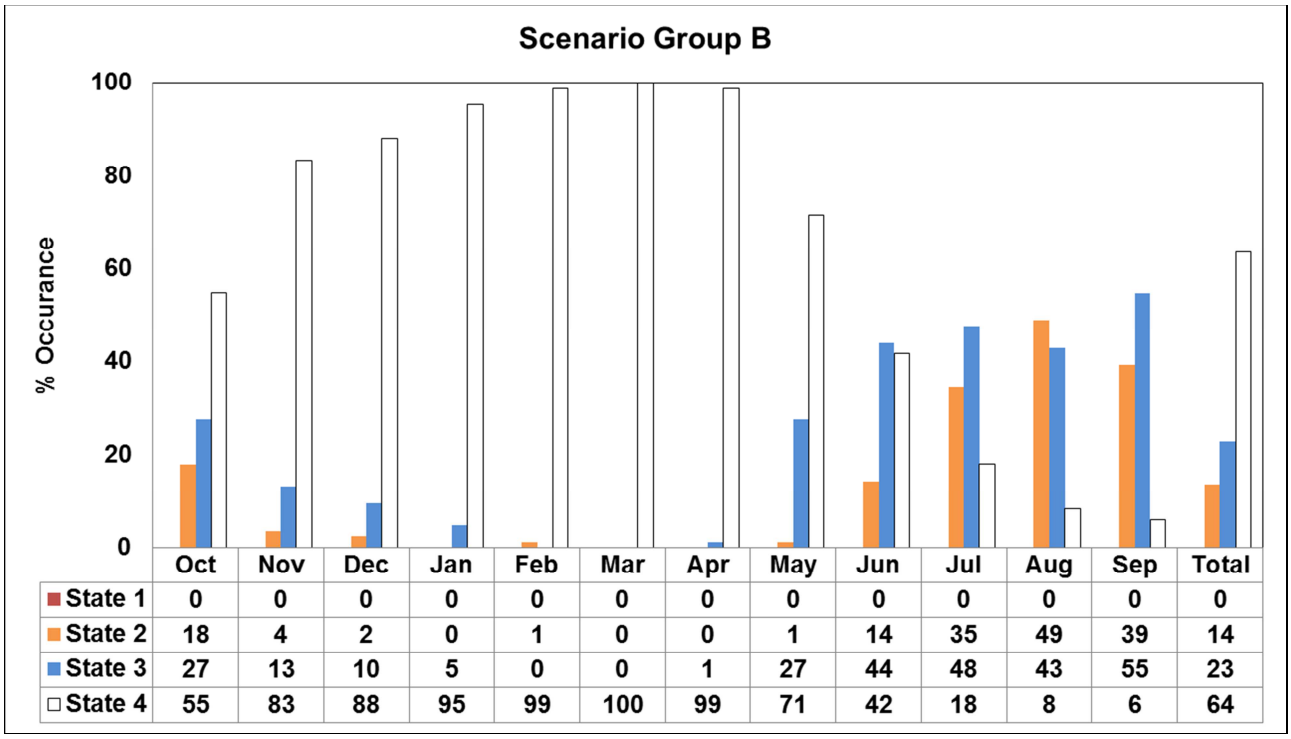
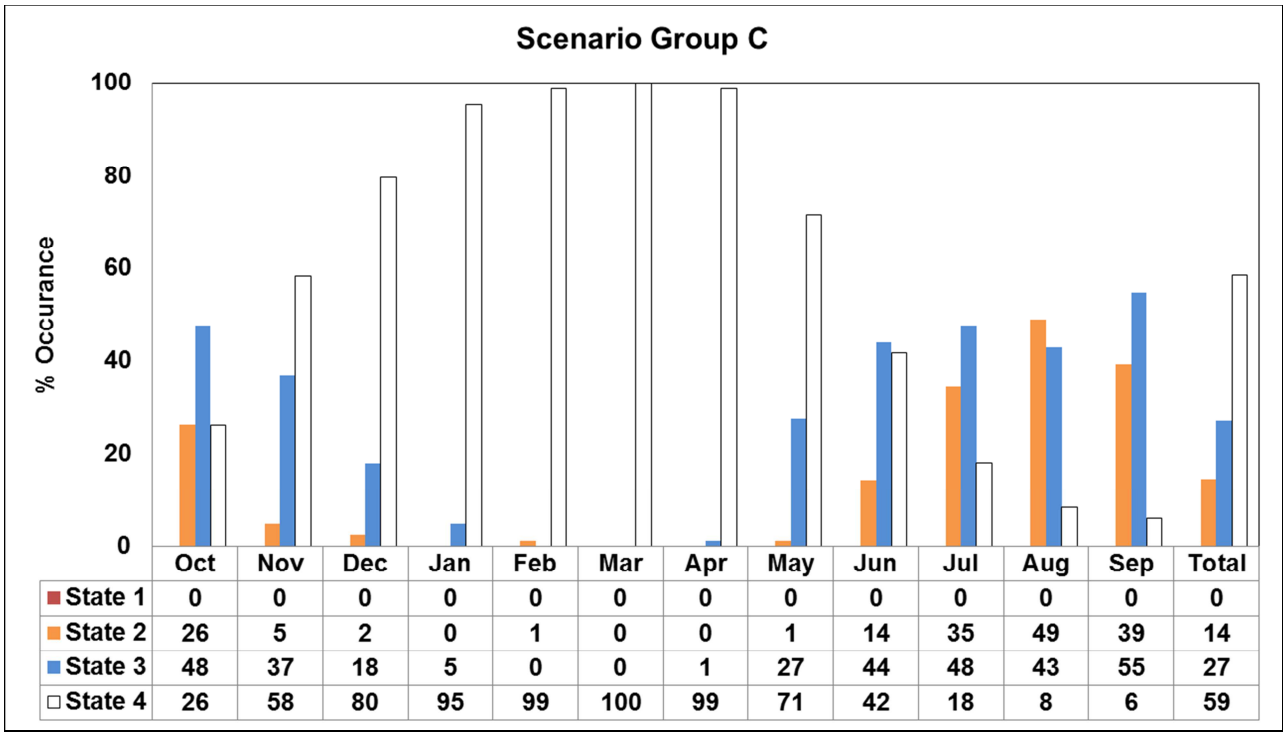


Figure 7.1 Graphic presentation of the occurrence of the various abiotic states under the Scenario Group A



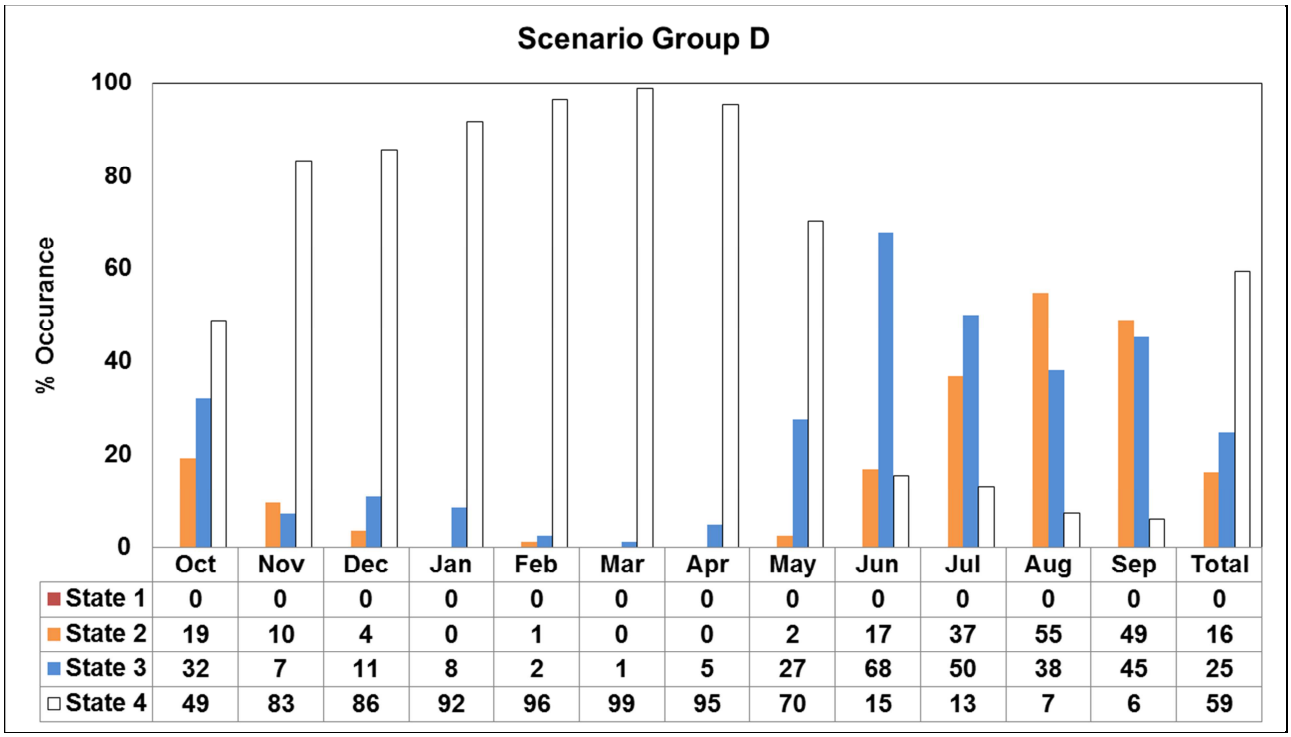
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	18	4	2	0	1	0	0	1	14	35	49	39	14
State 3	27	13	10	5	0	0	1	27	44	48	43	55	23
State 4	55	83	88	95	99	100	99	71	42	18	8	6	64

Figure 7.2 Graphic presentation of the occurrence of the various abiotic states under Scenario Group B



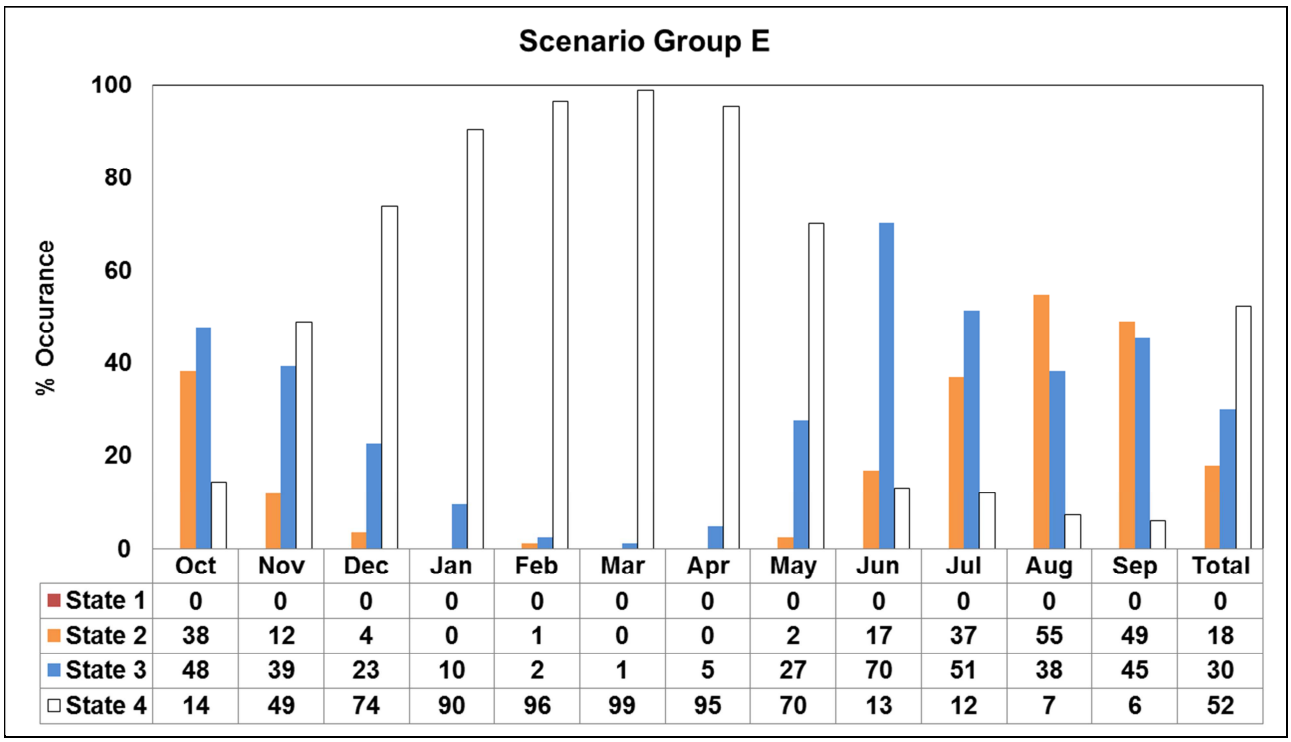
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	26	5	2	0	1	0	0	1	14	35	49	39	14
State 3	48	37	18	5	0	0	1	27	44	48	43	55	27
State 4	26	58	80	95	99	100	99	71	42	18	8	6	59

Figure 7.3 Graphic presentation of the occurrence of the various abiotic states under Scenario Group C



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	19	10	4	0	1	0	0	2	17	37	55	49	16
State 3	32	7	11	8	2	1	5	27	68	50	38	45	25
State 4	49	83	86	92	96	99	95	70	15	13	7	6	59

Figure 7.4 **Graphic presentation of the occurrence of the various abiotic states under Scenario Group D**



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	38	12	4	0	1	0	0	2	17	37	55	49	18
State 3	48	39	23	10	2	1	5	27	70	51	38	45	30
State 4	14	49	74	90	96	99	95	70	13	12	7	6	52

Figure 7.5 **Graphic presentation of the occurrence of the various abiotic states under Scenario Group E**

Table 7.8 Simulated monthly flows (m^3/s) to the uMkhomazi Estuary for Scenario Group A

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	8.5	3.9	4.6	11.0	16.8	24.0	10.8	1.2	1.2	0.8	0.6	1.0
1926	1.4	11.5	46.1	50.4	40.6	82.1	47.6	2.4	1.0	0.6	1.2	1.2
1927	1.2	1.3	24.7	98.8	72.6	47.6	22.5	1.2	0.7	0.5	0.6	0.7
1928	1.2	1.3	1.4	42.0	30.5	40.8	25.4	5.1	13.3	14.3	4.7	6.8
1929	10.8	30.3	40.0	69.1	59.3	39.0	17.4	1.3	1.2	1.0	1.2	1.2
1930	1.2	1.5	8.0	63.1	52.8	33.9	17.6	1.5	1.1	1.2	1.2	0.9
1931	1.1	1.2	1.3	3.8	61.1	52.6	10.6	1.4	1.2	0.9	0.6	0.5
1932	1.2	1.4	8.7	12.6	13.9	17.7	8.5	1.2	0.7	0.5	0.5	0.5
1933	0.5	7.1	97.3	141.8	94.6	34.3	22.6	13.6	3.5	1.3	1.2	1.2
1934	1.2	47.6	102.7	54.2	32.0	25.8	15.4	4.2	32.8	18.6	2.1	1.2
1935	1.0	0.6	0.6	1.2	66.1	64.8	23.7	11.4	5.1	1.3	0.8	0.7
1936	1.2	44.2	46.9	36.2	70.9	40.0	8.2	1.1	0.6	0.5	0.5	0.5
1937	0.8	1.2	2.6	16.3	101.1	49.0	26.5	11.0	1.4	1.2	1.2	0.8
1938	1.5	22.6	61.8	54.6	161.4	103.4	23.0	1.6	1.2	1.0	0.8	1.3
1939	4.1	10.2	36.4	39.3	40.1	42.1	23.1	30.8	27.6	7.4	1.3	0.9
1940	1.2	12.4	112.8	94.9	71.3	41.6	15.7	1.4	1.0	0.6	0.5	0.5
1941	1.2	1.3	1.3	28.0	129.0	113.2	56.7	14.5	1.3	0.9	1.0	1.1
1942	1.3	35.8	120.0	113.8	80.0	42.3	132.9	89.8	19.8	8.8	24.0	13.5
1943	49.4	127.6	114.9	67.7	58.7	52.4	22.8	1.3	0.9	0.6	0.5	1.2
1944	1.3	1.5	1.3	11.4	36.8	96.8	59.2	7.1	1.2	0.6	0.5	0.4
1945	0.7	0.6	1.2	2.0	8.0	19.1	17.7	2.6	1.0	0.5	0.5	0.4
1946	0.7	1.3	2.7	18.4	82.4	89.4	42.2	6.4	4.9	1.6	1.2	0.9
1947	1.2	11.3	48.7	71.1	68.5	64.0	39.3	7.5	1.2	0.6	0.5	0.4
1948	1.2	1.3	3.0	3.1	33.1	44.3	22.4	1.3	0.8	0.5	0.5	0.6
1949	1.2	7.0	9.7	22.3	55.9	105.0	66.1	16.2	1.8	1.2	1.2	1.2
1950	1.2	1.2	43.1	96.3	66.4	21.8	6.9	1.2	0.6	0.5	0.9	1.2
1951	1.3	1.3	2.0	53.6	81.7	38.5	13.4	3.2	1.3	1.0	0.7	0.6
1952	0.9	1.3	4.6	29.7	66.0	32.2	3.5	1.0	0.6	0.5	0.9	1.2
1953	1.5	3.7	33.0	52.8	83.8	56.5	17.1	4.9	1.3	1.1	0.6	0.8
1954	11.4	17.7	27.2	129.9	172.1	76.0	21.1	3.3	1.3	0.9	0.6	0.6
1955	1.1	1.3	2.7	17.9	104.3	132.5	58.7	4.1	1.2	0.8	0.7	0.8
1956	1.2	1.6	119.0	145.4	80.3	69.1	45.3	8.1	1.3	0.7	0.7	4.4
1957	40.8	31.4	34.8	67.9	84.5	36.8	23.0	8.7	1.3	0.7	0.5	0.6
1958	0.8	1.6	29.6	67.6	57.9	27.8	8.4	128.3	85.9	7.7	1.3	1.2
1959	1.2	6.0	20.3	17.4	26.1	39.7	32.5	10.5	1.3	0.7	0.6	0.6
1960	1.2	2.3	60.9	42.6	40.1	61.2	93.8	21.8	1.8	1.0	0.6	0.8
1961	1.0	1.3	3.3	44.8	76.6	52.0	16.6	2.4	1.1	0.5	0.7	0.6
1962	1.2	5.1	25.8	110.2	41.1	102.2	26.9	2.8	1.3	15.9	1.3	1.2
1963	1.2	41.3	51.2	94.8	38.2	23.8	7.4	1.3	5.1	1.2	1.0	1.2
1964	4.0	32.6	27.9	53.8	62.4	5.4	1.2	0.9	5.3	1.5	1.2	2.1
1965	7.9	23.0	8.5	78.2	83.2	6.0	1.3	1.5	1.2	1.0	0.9	1.2
1966	1.0	2.4	8.8	36.8	132.2	135.8	104.4	16.8	3.5	1.9	1.3	1.2
1967	1.2	10.2	15.1	15.9	15.2	34.1	26.2	1.3	1.0	0.8	1.2	1.1
1968	0.9	1.0	2.5	0.5	1.5	46.3	35.0	3.6	1.2	0.9	0.8	1.0
1969	4.2	4.8	38.5	31.9	57.7	9.1	0.9	1.0	0.6	0.7	1.3	1.2
1970	33.1	16.3	16.2	20.3	59.4	26.9	18.6	8.5	1.2	1.2	9.5	1.4
1971	8.2	18.3	53.0	93.1	123.7	117.5	28.1	6.5	1.5	1.2	1.2	0.8
1972	1.1	1.3	3.1	1.8	51.3	39.9	72.7	16.3	0.8	0.6	0.6	1.2
1973	2.1	14.0	23.3	136.5	208.9	139.4	70.5	17.2	4.8	1.6	1.2	0.9
1974	1.2	1.2	11.5	81.5	107.6	54.5	18.7	1.4	1.2	1.0	0.8	1.2
1975	1.2	1.7	65.2	195.8	241.7	248.7	84.3	16.6	5.8	4.8	2.9	1.3
1976	21.0	4.2	8.8	37.6	55.9	57.0	27.4	1.8	1.1	1.0	0.7	0.5
1977	1.2	1.2	2.9	64.7	58.6	50.7	34.8	7.6	1.3	1.2	1.1	1.2
1978	3.7	8.1	81.2	27.6	40.4	42.8	10.2	2.0	1.2	1.2	1.2	1.2
1979	1.2	0.9	1.3	11.0	32.2	37.8	3.9	1.1	0.5	0.5	0.5	1.2
1980	1.3	1.4	6.6	59.2	110.3	37.1	1.2	1.2	1.0	0.7	0.5	1.3
1981	0.8	1.5	1.5	3.8	1.7	46.6	10.1	1.2	1.1	0.7	0.6	0.7
1982	0.9	1.3	1.4	0.8	0.6	1.2	1.2	0.5	0.5	0.5	0.6	0.6
1983	0.6	1.3	9.9	50.5	20.1	55.4	46.2	2.5	1.2	0.7	0.6	0.6
1984	1.2	1.2	1.2	20.1	163.8	36.8	1.3	0.9	0.7	0.6	0.6	0.5
1985	1.3	21.8	83.1	69.6	44.5	38.4	8.1	0.7	1.0	0.7	0.6	1.1
1986	1.2	13.1	35.2	38.0	19.7	46.1	9.5	1.2	1.2	1.1	1.2	244.8
1987	210.0	124.3	37.2	30.7	169.8	214.0	52.8	7.3	1.9	5.6	1.2	1.0
1988	1.2	1.3	71.7	96.2	146.2	59.6	15.2	7.6	3.5	1.2	1.0	0.9
1989	1.0	62.5	91.1	28.0	23.3	52.9	50.8	2.9	1.2	1.2	1.2	1.2
1990	1.3	1.7	14.1	70.2	127.5	49.2	10.8	1.5	1.2	1.2	1.0	1.0
1991	1.6	4.8	22.6	28.3	20.2	12.6	1.2	0.7	0.5	0.4	0.4	0.4
1992	0.7	1.0	1.2	1.0	1.3	1.3	6.4	1.2	0.6	0.5	0.5	0.6
1993	2.4	2.6	19.4	101.7	112.5	32.6	3.8	1.0	0.8	0.9	1.1	0.7

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1994	1.2	1.2	1.3	1.4	8.1	33.9	24.9	2.4	1.2	1.0	33.1	46.4
1995	24.5	6.6	185.0	198.9	168.7	103.2	24.7	3.9	1.2	37.8	8.0	1.4
1996	1.3	9.1	61.6	115.8	40.4	74.8	36.0	7.6	8.3	10.2	1.8	3.8
1997	1.4	36.8	65.3	62.4	119.3	60.9	21.9	2.6	1.3	1.2	1.2	1.1
1998	0.9	0.8	17.2	39.3	67.7	20.0	1.2	0.6	0.5	0.5	0.5	0.5
1999	1.1	0.6	80.8	142.5	77.3	140.0	69.8	17.6	1.7	1.2	1.1	1.2
2000	1.2	5.1	54.2	58.9	35.6	22.5	30.0	4.3	1.2	0.8	0.8	2.1
2001	3.4	63.5	61.0	43.0	44.7	33.1	4.4	1.2	1.3	6.6	5.3	2.1
2002	1.2	1.2	1.2	13.5	45.6	27.0	17.1	1.7	1.0	0.7	0.5	0.6
2003	0.6	1.2	1.3	13.3	50.9	42.8	7.5	0.7	0.8	0.8	0.8	1.2
2004	1.3	11.0	59.5	78.2	36.1	34.7	24.1	1.3	1.1	1.0	0.6	0.6
2005	0.6	1.0	0.9	2.0	55.8	51.4	21.9	7.6	1.1	0.9	1.0	1.2
2006	7.2	15.6	41.7	21.5	31.2	15.3	5.9	1.2	1.2	1.2	0.7	0.6
2007	1.3	23.2	21.6	45.0	36.1	38.4	25.2	7.0	1.3	1.1	0.6	0.6
2008	1.2	1.3	5.6	9.3	129.4	92.7	25.5	2.5	0.9	0.5	0.5	0.7

Table 7.9 Simulated monthly flows (m^3/s) to the uMkhomazi Estuary for Scenario Group B

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	10.4	8.7	5.6	11.0	18.7	25.9	12.7	4.6	4.3	3.4	1.4	3.4
1926	9.4	13.5	39.8	52.4	42.5	83.3	48.9	7.2	2.0	1.4	3.5	3.3
1927	7.6	9.9	22.8	92.5	74.1	49.3	24.4	5.3	2.2	1.4	1.5	1.8
1928	6.5	7.7	13.7	27.3	32.4	42.8	27.4	9.8	12.3	16.1	6.6	8.7
1929	12.7	32.2	41.7	70.8	60.9	40.8	19.2	4.8	2.6	1.9	2.4	3.2
1930	5.2	6.2	18.2	53.5	54.6	35.7	19.4	7.0	2.2	4.2	3.8	1.7
1931	2.0	2.3	3.6	8.0	59.2	54.5	12.5	4.5	4.0	2.7	1.4	1.5
1932	5.7	12.9	14.8	6.0	8.6	19.5	10.4	4.5	1.6	1.3	1.3	1.3
1933	1.3	21.2	91.5	143.2	96.0	36.0	24.4	15.4	6.2	4.7	3.9	3.2
1934	6.6	43.1	104.4	56.0	33.8	27.5	17.2	10.5	29.6	20.0	4.8	2.2
1935	1.5	1.6	1.9	8.2	66.0	66.2	25.3	13.2	7.2	4.3	1.5	1.5
1936	4.7	45.5	48.5	38.0	72.6	41.8	10.1	3.3	1.4	1.2	1.2	1.2
1937	1.5	7.8	9.1	23.0	93.8	50.7	28.2	12.9	5.6	3.7	3.6	2.8
1938	9.6	18.2	60.7	56.5	162.5	105.0	24.9	6.4	3.4	1.9	1.6	4.0
1939	9.7	20.9	24.8	41.2	41.9	43.9	24.9	32.5	29.3	9.2	4.0	2.3
1940	6.1	18.3	107.7	96.6	73.1	43.4	17.5	6.3	2.2	1.4	1.3	1.3
1941	3.7	4.6	7.6	25.2	131.1	114.7	58.3	16.3	5.7	2.5	2.4	2.8
1942	7.7	32.1	121.6	115.6	81.9	44.1	134.7	91.6	21.7	10.6	25.8	15.4
1943	51.2	129.4	116.8	69.5	60.6	54.2	24.6	4.5	2.0	1.7	1.3	3.7
1944	9.1	10.4	3.3	5.8	34.5	98.6	60.8	10.5	3.8	1.5	1.2	1.2
1945	1.4	1.6	2.4	5.2	13.3	21.0	19.6	9.1	2.6	1.3	1.2	1.2
1946	1.4	13.3	11.7	13.1	74.5	91.0	43.7	11.1	7.2	5.6	3.9	1.7
1947	4.6	20.6	37.4	73.0	70.2	65.7	41.0	10.8	4.8	1.5	1.2	1.2
1948	3.3	5.4	8.3	9.4	24.6	46.2	24.3	7.4	2.2	1.3	1.3	1.5
1949	4.3	13.4	20.0	14.5	53.4	106.5	67.7	18.0	6.0	4.0	4.1	3.9
1950	4.3	3.6	39.2	98.1	68.0	23.5	8.7	4.4	1.6	1.2	3.1	3.6
1951	8.0	5.8	11.0	41.8	83.7	40.4	15.2	9.8	4.8	2.8	2.4	1.9
1952	3.1	10.9	12.7	16.4	64.2	34.0	6.6	3.1	1.6	1.3	1.5	3.5
1953	8.0	15.1	25.9	51.8	85.5	58.2	19.0	9.6	6.0	3.7	1.4	2.2
1954	15.2	22.3	20.0	131.2	172.5	77.0	22.7	9.2	5.2	2.4	1.3	1.4
1955	1.8	2.7	16.2	10.6	102.4	133.8	60.3	8.5	2.6	1.5	1.4	1.5
1956	5.2	16.0	108.5	147.1	82.1	71.0	47.1	11.7	4.7	1.9	2.8	4.2
1957	42.4	33.1	36.5	69.8	86.2	38.6	24.9	11.5	5.0	1.5	1.2	1.4
1958	3.1	9.2	28.2	67.8	59.4	29.5	10.3	130.1	87.8	9.6	3.9	2.5
1959	4.7	14.4	18.4	15.6	27.9	41.5	34.2	12.4	5.6	1.6	1.3	1.5
1960	3.0	12.3	56.3	44.3	41.8	62.7	95.5	23.6	6.4	3.7	1.7	1.8
1961	1.7	9.2	13.4	32.9	78.4	53.5	18.2	8.2	3.5	1.8	1.8	2.6
1962	2.6	15.8	23.0	106.3	42.9	103.8	28.7	8.8	5.6	11.3	4.1	3.0
1963	7.4	38.3	53.0	96.4	39.9	25.6	9.3	6.2	7.2	4.9	3.3	3.8
1964	9.4	25.2	29.8	55.7	64.2	8.2	5.9	3.2	8.4	5.7	3.7	4.6
1965	10.5	21.0	8.8	75.9	84.7	9.0	5.8	4.7	3.1	2.2	1.6	2.8
1966	2.2	15.9	14.6	22.6	134.1	137.1	106.0	18.6	7.2	5.6	4.1	2.9
1967	2.9	19.1	12.0	12.5	17.0	35.9	27.9	6.2	3.4	2.5	2.9	2.0
1968	1.5	5.0	11.6	2.9	5.2	36.9	37.0	9.3	5.1	3.6	1.9	3.0
1969	11.3	11.8	25.1	34.0	59.4	10.9	4.6	2.9	1.8	1.8	4.2	3.9
1970	33.7	18.1	18.0	22.2	61.2	28.7	20.4	11.3	5.4	4.6	7.0	4.0
1971	10.3	19.3	54.6	94.8	125.2	118.9	29.8	10.9	6.0	4.2	3.4	1.8
1972	4.2	11.5	7.0	4.6	34.8	41.7	73.9	18.0	4.7	2.9	3.1	3.4
1973	9.4	16.7	16.3	137.9	210.1	141.1	72.3	19.0	7.1	5.4	3.9	2.5
1974	3.4	9.9	14.0	73.9	109.2	56.2	20.5	6.5	4.1	3.1	1.9	3.8
1975	5.6	10.0	55.1	197.3	243.2	250.4	86.1	18.4	8.5	6.7	5.1	3.5
1976	21.1	13.2	8.8	34.8	57.7	58.7	29.2	7.8	4.0	3.2	2.0	2.2

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1977	6.5	8.2	8.0	51.6	60.5	52.3	36.5	10.9	5.6	3.8	2.5	3.6
1978	9.9	16.3	68.7	29.5	42.1	44.5	12.0	7.8	4.1	4.1	3.8	3.5
1979	4.6	5.7	5.4	11.5	22.0	39.6	6.6	3.1	1.8	1.5	1.3	3.7
1980	7.7	4.5	16.4	49.3	112.4	39.0	5.9	4.0	2.9	1.9	1.7	4.0
1981	4.0	5.0	7.7	5.3	5.0	38.6	12.0	4.1	3.0	2.0	1.5	1.5
1982	1.5	6.2	3.2	3.4	1.8	6.4	5.3	1.6	1.3	1.3	1.3	1.4
1983	3.9	11.8	27.4	29.3	21.6	57.4	48.1	8.5	4.7	3.5	2.1	2.1
1984	4.4	4.2	3.1	20.4	159.7	38.5	6.1	3.4	2.2	1.8	1.3	1.3
1985	7.2	24.6	80.4	71.2	46.2	40.1	9.9	6.1	3.6	2.4	1.7	3.1
1986	7.2	17.8	27.7	40.1	21.6	47.7	11.3	4.5	3.3	3.0	3.8	243.0
1987	211.3	126.1	39.1	32.7	171.6	215.8	54.6	11.6	6.5	5.7	3.8	3.2
1988	4.8	11.2	60.4	97.9	148.0	61.4	17.1	13.0	6.9	4.6	2.8	1.7
1989	1.8	61.6	91.5	29.9	25.1	54.7	52.6	8.6	4.7	3.6	2.9	3.7
1990	5.7	4.8	20.3	58.7	128.7	50.8	12.7	5.8	4.5	3.4	1.8	1.9
1991	9.2	13.9	15.0	25.6	22.1	14.4	5.6	2.1	1.4	1.3	1.2	1.3
1992	1.4	1.9	2.3	3.8	8.6	14.2	10.7	3.8	1.7	1.3	1.3	1.4
1993	9.0	12.7	21.4	81.6	114.6	34.6	7.2	4.0	2.4	2.7	3.3	1.8
1994	3.8	2.2	3.4	15.6	5.6	26.6	26.8	8.9	5.3	3.7	32.8	46.6
1995	24.7	12.0	179.8	200.4	170.6	105.1	26.5	9.7	5.5	33.5	9.8	3.9
1996	6.7	12.4	58.0	117.6	42.2	76.6	37.8	11.4	8.5	11.6	4.6	5.4
1997	7.6	33.4	67.1	64.2	121.2	62.7	23.8	8.5	5.5	3.8	3.3	2.5
1998	2.9	7.0	19.8	30.6	69.6	21.9	5.9	3.4	1.9	1.5	1.3	1.3
1999	6.6	9.7	71.6	144.7	79.0	141.8	71.6	19.5	6.2	4.6	3.3	3.7
2000	6.1	14.1	41.9	60.7	37.3	24.3	31.8	9.6	5.0	3.3	1.8	4.7
2001	10.0	54.7	62.5	44.7	46.5	34.9	7.2	4.4	5.5	8.3	6.5	4.7
2002	4.7	2.5	4.3	9.5	47.5	28.9	19.0	8.3	4.4	2.5	1.4	1.9
2003	1.5	5.7	6.6	16.6	41.8	44.8	9.4	3.6	1.9	2.4	3.0	3.1
2004	6.8	19.6	51.6	80.0	38.0	36.4	25.8	6.1	3.4	2.6	1.6	1.4
2005	1.6	2.0	1.9	14.6	48.9	53.3	23.9	9.8	5.1	3.5	3.4	3.3
2006	13.1	15.0	39.0	23.5	33.2	17.3	8.0	4.1	3.1	4.3	1.7	1.4
2007	8.5	27.5	22.9	39.7	37.9	40.2	26.9	10.2	5.6	3.4	1.6	1.7
2008	2.0	2.9	10.6	16.7	121.5	93.9	27.1	8.2	3.1	1.7	1.8	1.5

Table 7.10 Simulated monthly flows (m^3/s) to the uMkhomazi Estuary for Scenario Group C

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	10.1	5.5	6.2	12.6	18.4	25.6	12.4	4.6	4.3	3.4	1.4	3.4
1926	5.1	7.5	47.8	52.2	42.2	83.1	48.7	7.2	2.0	1.4	3.5	3.3
1927	4.6	4.3	21.2	100.3	73.8	49.0	24.1	5.3	2.2	1.4	1.5	1.8
1928	3.8	3.6	6.7	38.7	32.2	42.5	27.1	9.8	11.7	15.8	6.3	8.4
1929	12.4	31.9	41.4	70.5	60.7	40.5	19.0	4.8	2.6	1.9	2.4	3.2
1930	3.2	3.2	10.4	63.8	54.3	35.4	19.1	7.0	2.2	4.2	3.8	1.7
1931	1.7	2.2	3.5	5.9	59.1	54.2	12.2	4.5	4.0	2.7	1.4	1.5
1932	3.1	6.3	8.0	12.8	15.5	19.3	10.1	4.5	1.6	1.3	1.3	1.3
1933	1.3	10.3	99.9	143.0	95.8	35.8	24.1	15.2	6.2	4.7	3.9	3.2
1934	3.9	44.3	104.1	55.7	33.5	27.3	17.0	10.5	29.1	19.8	4.8	2.2
1935	1.5	1.6	1.9	5.5	67.0	66.0	25.0	12.9	7.2	4.3	1.5	1.5
1936	2.9	45.7	48.3	37.8	72.4	41.5	9.8	3.3	1.4	1.2	1.2	1.2
1937	1.5	3.3	5.2	20.6	102.7	50.4	28.0	12.6	5.6	3.7	3.6	2.8
1938	5.1	18.1	63.5	56.3	162.2	104.7	24.6	6.4	3.4	1.9	1.6	4.0
1939	6.2	12.1	34.8	40.9	41.6	43.6	24.6	32.3	29.1	9.0	4.0	2.3
1940	3.4	12.9	114.2	96.4	72.9	43.2	17.2	6.3	2.2	1.4	1.3	1.3
1941	2.2	2.9	4.3	29.2	130.8	114.4	58.1	16.0	5.7	2.5	2.4	2.8
1942	4.7	33.6	121.3	115.3	81.6	43.9	134.4	91.3	21.4	10.3	25.6	15.1
1943	50.9	129.1	116.5	69.3	60.3	53.9	24.4	4.5	2.0	1.7	1.3	3.7
1944	5.0	4.5	3.2	9.5	38.4	98.3	60.5	10.5	3.8	1.5	1.2	1.2
1945	1.4	1.6	2.4	5.2	10.1	21.2	19.3	9.1	2.6	1.3	1.2	1.2
1946	1.4	6.3	6.1	14.0	84.1	90.8	43.4	11.1	7.2	5.6	3.9	1.7
1947	2.8	11.5	45.8	72.7	70.0	65.4	40.7	10.8	4.8	1.5	1.2	1.2
1948	2.1	3.1	4.8	6.5	32.4	46.0	24.0	7.4	2.2	1.3	1.3	1.5
1949	2.7	7.4	12.5	23.0	57.5	106.3	67.4	17.7	6.0	4.0	4.1	3.9
1950	2.6	2.5	40.1	97.9	67.8	23.2	8.5	4.4	1.6	1.2	3.1	3.6
1951	4.9	3.1	5.6	50.7	83.4	40.2	15.0	9.8	4.8	2.8	2.4	1.9
1952	1.8	4.8	7.0	23.6	67.7	33.7	6.6	3.1	1.6	1.3	1.5	3.5
1953	4.9	7.7	31.0	54.4	85.2	58.0	18.7	9.6	6.0	3.7	1.4	2.2
1954	11.7	14.8	28.7	130.9	172.3	76.8	22.4	9.2	5.2	2.4	1.3	1.4
1955	1.6	2.6	8.7	12.6	105.9	133.6	60.1	8.5	2.6	1.5	1.4	1.5
1956	3.0	7.2	117.0	146.9	81.9	70.7	46.8	11.7	4.7	1.9	2.8	4.2
1957	40.8	32.9	36.3	69.6	85.9	38.4	24.6	11.5	5.0	1.5	1.2	1.4
1958	1.8	4.2	30.6	69.2	59.2	29.2	10.0	129.9	87.5	9.3	3.9	2.5
1959	3.0	8.0	21.2	19.1	27.7	41.2	34.0	12.1	5.6	1.6	1.3	1.5

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	1.9	6.0	61.8	44.1	41.5	62.4	95.2	23.4	6.4	3.7	1.7	1.8
1961	1.6	4.0	6.6	42.7	78.1	53.3	18.0	8.2	3.5	1.8	1.8	2.6
1962	1.8	8.6	22.9	111.8	42.6	103.5	28.4	8.8	5.6	10.9	4.1	3.0
1963	4.4	39.9	52.7	96.2	39.7	25.3	9.0	6.2	7.2	4.9	3.3	3.8
1964	6.1	26.7	29.5	55.4	63.9	8.2	5.9	3.2	8.4	5.7	3.7	4.6
1965	7.3	16.3	10.1	79.5	84.5	9.0	5.8	4.7	3.1	2.2	1.6	2.8
1966	1.7	7.4	7.7	35.3	133.8	136.8	105.8	18.3	7.2	5.6	4.1	2.9
1967	1.8	11.7	13.0	17.5	16.7	35.6	27.7	6.2	3.4	2.5	2.9	2.0
1968	1.5	2.4	6.1	2.9	5.1	42.1	36.7	9.3	5.1	3.6	1.9	3.0
1969	6.8	6.2	32.9	33.7	59.1	10.6	4.6	2.9	1.8	1.8	4.2	3.9
1970	31.8	17.9	17.7	21.9	61.0	28.4	20.2	11.3	5.4	4.6	6.6	4.0
1971	8.3	19.8	54.3	94.5	124.9	118.6	29.5	10.9	6.0	4.2	3.4	1.8
1972	2.5	5.2	4.5	4.5	43.2	41.4	73.6	17.8	4.7	2.9	3.1	3.4
1973	5.5	10.0	25.0	137.6	209.9	140.8	72.1	18.8	7.1	5.4	3.9	2.5
1974	2.2	4.2	9.3	83.3	109.0	55.9	20.2	6.5	4.1	3.1	1.9	3.8
1975	3.3	4.4	60.6	197.0	242.9	250.1	85.8	18.2	8.5	6.7	5.1	3.5
1976	21.1	6.9	8.4	39.3	57.4	58.4	28.9	7.8	4.0	3.2	2.0	2.2
1977	3.8	3.5	4.7	59.8	60.2	52.0	36.2	10.9	5.6	3.8	2.5	3.6
1978	6.1	9.6	76.9	29.2	41.8	44.2	11.7	7.8	4.1	4.1	3.8	3.5
1979	2.9	2.5	3.8	6.6	31.5	39.4	6.4	3.1	1.8	1.5	1.3	3.7
1980	4.6	3.0	9.2	58.6	112.1	38.7	5.8	4.0	2.9	1.9	1.7	4.0
1981	2.3	3.2	4.3	5.2	5.0	42.4	11.7	4.1	3.0	2.0	1.5	1.5
1982	1.5	3.1	3.2	3.4	1.8	6.4	5.3	1.6	1.3	1.3	1.3	1.4
1983	2.2	5.5	15.8	45.8	21.9	57.1	47.8	8.5	4.7	3.5	2.1	2.1
1984	2.7	2.9	3.0	15.7	165.4	38.3	6.0	3.4	2.2	1.8	1.3	1.3
1985	4.4	20.8	84.5	71.0	45.9	39.8	9.6	6.1	3.6	2.4	1.7	3.1
1986	4.2	8.8	37.2	39.8	21.3	47.5	11.0	4.5	3.3	3.0	3.8	241.6
1987	211.0	125.8	38.8	32.4	171.3	215.6	54.3	11.6	6.5	5.7	3.8	3.2
1988	2.9	5.0	66.2	97.7	147.8	61.2	16.8	13.0	6.9	4.6	2.8	1.7
1989	1.6	61.6	89.7	29.6	24.8	54.4	52.3	8.6	4.7	3.6	2.9	3.7
1990	3.4	3.1	13.6	67.2	128.4	50.5	12.4	5.8	4.5	3.4	1.8	1.9
1991	5.1	7.5	18.6	30.0	21.8	14.2	5.6	2.1	1.4	1.3	1.2	1.3
1992	1.4	1.9	2.3	3.8	6.5	10.3	8.7	3.8	1.7	1.3	1.3	1.4
1993	5.4	6.2	13.6	101.5	114.3	34.3	7.0	4.0	2.4	2.7	3.3	1.8
1994	2.2	2.2	3.4	8.7	5.6	32.5	26.6	8.9	5.3	3.7	32.8	46.6
1995	24.7	6.1	183.5	200.2	170.3	104.8	26.3	9.7	5.5	32.7	9.6	3.9
1996	4.0	8.9	63.0	117.3	41.9	76.3	37.6	11.4	8.5	10.8	4.6	5.4
1997	4.6	35.4	66.8	64.0	120.9	62.4	23.5	8.5	5.5	3.8	3.3	2.5
1998	1.8	2.7	12.3	41.1	69.3	21.6	5.9	3.4	1.9	1.5	1.3	1.3
1999	3.8	3.7	77.9	144.4	78.7	141.5	71.4	19.2	6.2	4.6	3.3	3.7
2000	3.5	6.9	49.7	60.4	37.1	24.0	31.5	9.6	5.0	3.3	1.8	4.7
2001	6.5	56.5	62.3	44.5	46.3	34.7	7.1	4.4	5.5	8.3	6.5	4.7
2002	3.0	2.4	3.1	9.9	47.2	28.6	18.7	8.3	4.4	2.5	1.4	1.9
2003	1.5	2.7	4.1	9.7	52.3	44.5	9.1	3.6	1.9	2.4	3.0	3.1
2004	4.1	12.0	59.5	79.8	37.7	36.2	25.6	6.1	3.4	2.6	1.6	1.4
2005	1.5	2.0	1.9	8.2	53.1	53.0	23.6	9.8	5.1	3.5	3.4	3.3
2006	8.6	13.0	43.4	23.3	32.9	17.0	7.6	4.1	3.1	4.3	1.7	1.4
2007	4.9	22.6	22.2	46.5	37.6	40.0	26.7	10.2	5.6	3.4	1.6	1.7
2008	1.7	2.9	6.6	10.9	129.8	93.7	26.9	8.2	3.1	1.7	1.8	1.5

Table 7.11 Simulated monthly flows (m^3/s) to the uMkhomazi Estuary for Scenario Group D

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	10.2	8.7	4.7	11.3	18.5	25.7	12.5	4.2	3.4	2.7	1.4	2.4
1926	6.7	12.5	44.8	52.3	42.3	83.2	48.8	6.1	1.9	1.4	2.4	2.3
1927	5.8	9.8	18.5	100.4	73.9	49.1	24.2	4.7	2.1	1.4	1.5	1.7
1928	5.2	8.5	13.6	27.3	32.2	42.6	27.2	8.3	13.4	15.9	6.4	8.5
1929	12.5	32.0	41.5	70.6	60.8	40.6	19.1	4.5	2.3	1.8	1.9	2.2
1930	4.7	7.3	16.1	55.6	54.4	35.5	19.2	6.0	2.1	3.0	2.7	1.7
1931	1.8	1.8	2.8	6.9	64.0	54.3	12.3	4.1	3.3	2.2	1.3	1.5
1932	4.8	12.1	13.8	4.4	12.9	19.4	10.2	4.2	1.5	1.3	1.3	1.2
1933	1.3	16.7	94.7	143.0	95.9	35.9	24.2	15.2	5.2	3.5	2.7	2.3
1934	5.4	47.7	104.2	55.8	33.6	27.3	17.0	8.3	31.6	19.9	2.8	1.9
1935	1.5	1.6	1.9	6.5	69.0	66.1	25.1	13.0	6.7	3.2	1.5	1.4
1936	4.3	46.5	48.3	37.8	72.5	41.6	9.9	3.3	1.3	1.1	1.0	1.1
1937	1.5	7.5	8.8	19.4	97.0	50.5	28.1	12.7	4.4	2.8	2.6	2.1
1938	6.8	20.7	63.6	56.4	162.3	104.8	24.7	5.5	3.0	1.8	1.6	2.4
1939	6.5	15.2	34.9	41.0	41.7	43.7	24.7	32.4	29.1	9.1	2.7	1.9
1940	5.1	14.6	113.0	96.4	72.9	43.2	17.3	5.6	2.0	1.3	1.2	1.2
1941	3.5	4.4	7.0	25.5	130.9	114.5	58.2	16.1	4.4	2.1	1.9	2.1
1942	5.9	35.8	121.4	115.4	81.7	44.0	134.5	91.4	21.5	10.4	25.6	15.2

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1943	51.0	129.2	116.6	69.3	60.4	54.0	24.4	4.2	1.9	1.7	1.3	2.4
1944	6.6	10.2	2.7	5.3	38.5	98.4	60.6	8.7	3.2	1.5	1.2	1.0
1945	1.4	1.5	2.1	4.3	11.6	24.5	19.4	7.5	2.4	1.3	1.0	1.0
1946	1.3	12.3	11.6	11.2	78.0	90.8	43.5	8.6	5.9	3.8	2.6	1.6
1947	4.2	15.3	48.1	72.8	70.0	65.5	40.8	9.2	3.9	1.5	1.1	1.1
1948	3.0	6.0	8.0	7.8	27.4	46.0	24.1	6.0	2.1	1.3	1.2	1.5
1949	4.1	11.4	16.1	16.6	57.6	106.4	67.5	17.8	4.7	3.0	2.8	2.4
1950	4.1	2.4	44.3	97.9	67.9	23.3	8.5	4.1	1.5	1.1	2.3	2.4
1951	6.1	6.8	10.7	43.9	83.5	40.2	15.0	8.0	4.0	2.4	1.9	1.7
1952	2.6	10.6	12.2	16.3	67.8	33.8	5.5	3.1	1.5	1.3	1.5	2.3
1953	6.1	13.4	27.3	54.5	85.3	58.1	18.8	8.0	4.7	2.9	1.5	1.9
1954	11.8	19.4	28.8	131.0	172.4	76.8	22.5	7.8	4.1	2.0	1.3	1.3
1955	1.7	1.9	15.4	10.0	106.0	133.7	60.2	7.3	2.4	1.4	1.3	1.5
1956	4.6	14.1	110.8	146.9	81.9	70.8	46.9	9.8	4.0	1.8	2.0	6.6
1957	42.5	33.0	36.3	69.6	86.0	38.4	24.7	10.4	4.1	1.5	1.2	1.4
1958	2.7	9.2	27.6	69.3	59.2	29.3	10.1	129.9	87.6	9.4	2.6	2.0
1959	4.4	12.4	17.7	19.2	27.7	41.3	34.0	12.2	4.3	1.6	1.3	1.5
1960	2.8	11.7	57.1	44.2	41.6	62.5	95.3	23.5	4.7	2.8	1.6	1.6
1961	1.7	9.1	13.3	34.3	78.2	53.3	18.1	7.2	3.0	1.7	1.6	2.0
1962	2.3	13.6	20.5	111.9	42.7	103.6	28.5	7.5	4.4	13.4	2.8	2.1
1963	5.8	41.4	52.8	96.3	39.7	25.4	9.1	5.3	4.9	3.6	2.4	2.4
1964	6.3	33.8	29.6	55.5	64.0	7.0	5.1	3.1	5.5	4.0	2.7	2.5
1965	9.6	24.5	10.2	79.6	84.6	7.6	4.9	4.3	2.8	1.9	1.6	2.1
1966	2.0	14.0	13.8	27.2	133.9	136.9	105.8	18.4	5.2	3.8	2.8	2.1
1967	2.5	14.1	16.4	17.6	16.8	35.7	27.7	5.3	2.9	2.1	2.2	1.9
1968	1.5	4.6	11.6	2.9	4.3	38.6	36.8	7.6	4.1	2.8	1.7	2.1
1969	7.0	10.5	33.6	33.8	59.2	10.7	4.2	2.7	1.7	1.8	2.8	2.4
1970	35.9	17.9	17.8	22.0	61.0	28.5	20.2	10.2	4.3	3.5	9.6	2.4
1971	10.6	19.9	54.4	94.6	125.0	118.7	29.6	8.6	4.5	3.1	2.4	1.7
1972	4.0	11.1	6.7	3.7	41.1	41.5	73.7	17.9	3.7	2.3	2.4	2.3
1973	6.7	13.8	24.1	137.7	209.9	140.9	72.1	18.9	6.5	3.8	2.7	2.0
1974	3.5	9.5	12.8	77.9	109.1	56.0	20.3	5.6	3.4	2.6	1.7	2.4
1975	4.9	9.9	58.1	197.1	243.0	250.2	85.9	18.2	5.9	5.0	3.1	2.3
1976	21.0	11.8	11.5	39.4	57.5	58.5	29.0	6.8	3.2	2.6	1.7	1.8
1977	5.3	8.1	7.6	54.7	60.3	52.1	36.3	9.3	4.3	2.9	2.0	2.3
1978	6.6	13.4	78.9	29.3	41.9	44.3	11.8	6.7	3.4	3.0	2.6	2.3
1979	4.3	5.1	4.6	9.8	29.2	39.6	5.6	3.1	1.8	1.5	1.3	2.4
1980	5.9	4.3	15.2	53.0	112.2	38.8	5.1	3.9	2.6	1.8	1.6	2.4
1981	3.9	5.4	7.2	4.2	4.3	41.1	11.8	4.0	2.7	1.8	1.5	1.5
1982	1.4	7.0	2.5	3.4	1.7	4.1	4.8	1.5	1.3	1.2	1.3	1.3
1983	3.7	11.3	22.8	35.5	20.2	57.2	47.9	6.8	3.9	2.8	1.8	1.8
1984	3.9	3.7	2.6	18.6	165.4	38.4	5.1	3.4	2.0	1.7	1.3	1.3
1985	5.6	21.4	84.6	71.0	46.0	39.9	9.7	5.1	3.0	2.0	1.6	2.2
1986	5.6	15.6	32.9	39.9	21.4	47.5	11.1	4.1	2.9	2.5	2.7	244.5
1987	211.1	125.9	38.9	32.5	171.4	215.7	54.4	9.0	4.7	6.3	2.7	2.3
1988	4.4	10.8	65.1	97.7	147.8	61.2	16.9	9.2	4.6	3.4	2.2	1.6
1989	1.7	67.1	92.7	29.7	24.9	54.5	52.4	7.4	3.8	2.8	2.2	2.4
1990	4.8	5.5	15.6	66.9	128.5	50.6	12.5	5.2	3.7	2.8	1.7	1.8
1991	6.6	12.4	15.4	30.0	21.9	14.3	4.9	1.9	1.4	1.2	1.1	1.2
1992	1.3	1.7	2.0	3.6	7.8	10.0	9.9	3.6	1.6	1.3	1.3	1.3
1993	6.5	12.3	17.5	94.0	112.5	34.3	6.2	3.9	2.2	2.2	2.4	1.7
1994	3.6	1.8	2.7	14.1	5.0	30.6	26.5	7.0	4.2	2.9	33.1	46.6
1995	24.7	10.6	183.0	200.2	170.4	104.9	26.4	7.9	4.3	35.9	9.7	2.4
1996	5.3	10.8	61.6	117.4	42.0	76.4	37.6	9.2	9.9	11.9	2.9	4.0
1997	5.9	37.6	66.9	64.0	121.0	62.5	23.6	7.3	4.2	2.9	2.4	2.0
1998	2.5	6.0	17.8	37.1	69.4	21.7	5.2	3.4	1.8	1.5	1.3	1.3
1999	5.4	9.7	71.8	144.5	78.8	141.6	71.5	19.3	4.8	3.4	2.4	2.4
2000	5.0	13.1	47.5	60.5	37.2	24.1	31.6	8.2	3.9	2.6	1.6	2.7
2001	6.4	62.5	62.3	44.6	46.3	34.7	6.1	4.0	4.3	6.4	5.5	4.1
2002	4.4	1.9	3.6	15.4	47.3	28.7	18.8	6.4	3.5	2.1	1.4	1.7
2003	1.5	5.2	5.9	15.3	46.2	44.6	9.2	3.7	1.8	2.0	2.3	2.2
2004	5.5	14.6	58.3	79.9	37.8	36.2	25.6	5.2	2.9	2.1	1.6	1.4
2005	1.5	1.8	1.9	13.3	50.6	53.1	23.7	9.4	4.1	2.8	2.5	2.3
2006	9.0	17.4	43.4	23.3	33.0	17.1	7.6	3.9	2.7	3.1	1.6	1.4
2007	6.3	22.5	23.4	46.6	37.7	40.1	26.8	8.7	4.3	2.8	1.6	1.6
2008	1.9	2.1	9.4	13.8	128.7	93.8	26.9	6.9	2.8	1.6	1.6	1.5

Table 7.12 Simulated monthly flows (m^3/s) to the uMkhomazi Estuary for Scenario Group E

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1925	9.8	5.2	6.0	12.3	18.1	25.3	12.1	4.2	3.4	2.7	1.4	2.4
1926	3.4	10.2	47.5	51.9	41.9	82.8	48.4	6.1	1.9	1.4	2.4	2.3
1927	3.1	3.2	24.7	100.0	73.5	48.8	23.8	4.7	2.1	1.4	1.5	1.7
1928	2.7	2.8	5.5	40.0	31.9	42.2	26.8	8.3	12.7	15.6	6.1	8.1
1929	12.2	31.6	41.2	70.2	60.4	40.2	18.7	4.5	2.3	1.8	1.9	2.2
1930	2.3	2.6	10.6	64.7	54.0	35.1	18.8	6.0	2.1	3.0	2.7	1.7
1931	1.5	1.8	2.6	4.9	62.7	53.9	11.9	4.1	3.3	2.2	1.3	1.5
1932	2.4	4.4	8.2	14.1	15.2	19.0	9.8	4.2	1.5	1.3	1.3	1.2
1933	1.3	7.6	100.7	142.7	95.5	35.5	23.9	14.9	4.8	3.5	2.7	2.3
1934	2.8	48.4	103.8	55.4	33.2	27.0	16.7	8.3	30.8	19.5	2.8	1.9
1935	1.4	1.6	1.9	4.7	68.2	65.7	24.7	12.6	6.4	3.2	1.5	1.4
1936	2.1	46.9	48.0	37.5	72.1	41.3	9.5	3.3	1.3	1.1	1.0	1.1
1937	1.5	2.6	4.0	20.4	102.4	50.1	27.7	12.3	4.4	2.8	2.6	2.1
1938	3.4	22.0	63.2	56.0	161.9	104.4	24.3	5.5	3.0	1.8	1.6	2.4
1939	3.4	12.2	38.0	40.6	41.3	43.3	24.4	32.0	28.8	8.7	2.7	1.9
1940	2.6	14.3	113.9	96.1	72.6	42.9	17.0	5.6	2.0	1.3	1.2	1.2
1941	1.8	2.2	3.5	29.5	130.5	114.1	57.8	15.8	4.4	2.1	1.9	2.1
1942	3.2	36.4	121.0	115.0	81.3	43.6	134.2	91.1	21.1	10.1	25.3	14.8
1943	50.6	128.9	116.2	69.0	60.0	53.6	24.1	4.2	1.9	1.7	1.3	2.4
1944	3.3	3.3	2.6	12.1	38.1	98.0	60.2	8.6	3.2	1.5	1.2	1.0
1945	1.4	1.5	2.0	4.2	7.3	24.7	19.1	7.5	2.4	1.3	1.0	1.0
1946	1.3	4.6	4.8	16.5	83.9	90.5	43.1	8.6	5.2	3.8	2.6	1.6
1947	2.0	13.4	50.0	72.4	69.7	65.1	40.5	8.8	3.9	1.5	1.1	1.1
1948	1.7	2.4	3.8	5.0	36.7	45.7	23.7	6.0	2.1	1.3	1.2	1.5
1949	2.0	6.9	9.9	25.9	57.2	106.0	67.1	17.4	4.7	3.0	2.8	2.4
1950	2.0	2.0	44.3	97.6	67.5	23.0	8.2	4.1	1.5	1.1	2.3	2.4
1951	3.3	2.5	4.5	53.8	83.1	39.9	14.7	8.0	4.0	2.4	1.9	1.7
1952	1.7	3.5	5.1	28.0	67.4	33.4	5.4	3.1	1.5	1.3	1.5	2.3
1953	3.3	5.2	34.9	54.1	84.9	57.7	18.4	8.0	4.7	2.9	1.5	1.9
1954	11.7	16.9	28.4	130.6	172.0	76.5	22.1	7.8	4.1	2.0	1.3	1.3
1955	1.5	1.9	6.5	15.8	105.6	133.3	59.8	7.3	2.4	1.4	1.3	1.5
1956	2.2	5.3	118.8	146.6	81.6	70.4	46.6	9.4	4.0	1.8	2.0	5.1
1957	42.1	32.6	36.0	69.3	85.6	38.1	24.3	10.0	4.1	1.5	1.2	1.4
1958	1.7	3.0	32.0	68.9	58.9	29.0	9.7	129.6	87.2	9.0	2.6	2.0
1959	2.1	5.6	24.8	18.8	27.4	40.9	33.7	11.8	4.3	1.6	1.3	1.5
1960	1.7	4.2	63.0	43.8	41.2	62.1	95.0	23.1	4.7	2.8	1.6	1.6
1961	1.5	3.0	5.4	45.4	77.9	53.0	17.7	7.2	3.0	1.7	1.6	2.0
1962	1.6	5.6	26.0	111.6	42.3	103.2	28.1	7.5	4.4	12.3	2.8	2.1
1963	3.1	42.7	52.4	95.9	39.4	25.1	8.7	5.3	4.9	3.6	2.4	2.4
1964	3.5	34.2	29.2	55.1	63.6	6.6	5.1	3.1	5.4	4.0	2.7	2.5
1965	7.2	24.1	9.8	79.3	84.2	7.2	4.9	4.3	2.8	1.9	1.6	2.1
1966	1.6	5.3	7.9	38.3	133.5	136.6	105.5	18.1	4.9	3.8	2.8	2.1
1967	1.6	10.3	18.8	17.3	16.5	35.3	27.4	5.3	2.9	2.1	2.2	1.9
1968	1.5	2.1	4.9	2.9	4.3	44.0	36.3	7.6	4.1	2.8	1.7	2.1
1969	4.8	4.9	38.2	33.4	58.8	10.3	4.2	2.7	1.7	1.8	2.8	2.4
1970	33.4	17.6	17.4	21.7	60.7	28.1	19.9	9.8	4.3	3.5	8.5	2.4
1971	9.9	19.5	54.1	94.2	124.6	118.3	29.2	8.6	4.5	3.1	2.4	1.7
1972	1.9	3.7	3.5	3.7	50.8	41.1	73.4	17.5	3.7	2.3	2.4	2.3
1973	3.4	14.0	24.7	137.4	209.6	140.6	71.8	18.5	6.2	3.8	2.7	2.0
1974	1.8	3.1	13.0	83.0	108.7	55.6	19.9	5.6	3.4	2.6	1.7	2.4
1975	2.5	3.2	64.1	196.7	242.6	249.9	85.5	17.9	5.9	5.0	3.1	2.3
1976	21.0	9.4	11.4	39.0	57.1	58.1	28.7	6.8	3.2	2.6	1.7	1.8
1977	2.7	2.7	3.7	63.1	59.9	51.8	35.9	8.9	4.3	2.9	2.0	2.3
1978	3.8	9.7	82.8	29.0	41.5	43.9	11.4	6.7	3.4	3.0	2.6	2.3
1979	2.1	2.2	3.0	9.0	33.5	39.2	5.4	3.1	1.8	1.5	1.3	2.4
1980	3.2	2.2	6.6	63.0	111.8	38.4	5.1	3.9	2.6	1.8	1.6	2.4
1981	1.9	2.3	3.6	4.2	4.3	45.5	11.4	4.0	2.7	1.8	1.5	1.5
1982	1.4	2.6	2.4	3.4	1.7	4.1	4.8	1.5	1.3	1.2	1.3	1.3
1983	1.9	3.9	10.7	52.6	20.7	56.8	47.6	6.8	3.9	2.8	1.8	1.8
1984	1.9	2.1	2.5	19.0	165.1	38.0	5.1	3.4	2.0	1.7	1.3	1.3
1985	3.0	21.1	84.2	70.7	45.6	39.5	9.4	5.1	3.0	2.0	1.6	2.2
1986	3.0	11.2	36.9	39.6	21.0	47.2	10.7	4.1	2.9	2.5	2.7	242.6
1987	210.7	125.5	38.5	32.1	171.0	215.3	54.1	8.6	4.7	5.6	2.7	2.3
1988	2.1	3.6	72.6	97.4	147.5	60.9	16.5	8.9	4.6	3.4	2.2	1.6
1989	1.5	65.1	92.3	29.3	24.5	54.1	52.0	7.4	3.8	2.8	2.2	2.4
1990	2.4	2.3	12.9	71.8	128.2	50.3	12.1	5.2	3.7	2.8	1.7	1.8
1991	3.4	4.7	23.2	29.7	21.5	13.9	4.9	1.9	1.4	1.2	1.1	1.2
1992	1.3	1.7	2.0	3.6	6.0	7.4	7.6	3.6	1.6	1.3	1.3	1.3
1993	3.4	4.6	16.7	102.1	114.1	34.1	5.8	3.9	2.2	2.2	2.4	1.7

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1994	1.9	1.8	2.6	7.0	5.9	34.8	26.3	7.0	4.2	2.9	33.0	46.6
1995	24.7	5.4	185.3	199.9	170.0	104.5	26.0	7.9	4.3	34.8	9.3	2.4
1996	2.8	10.8	62.7	117.1	41.6	76.0	37.3	8.9	9.5	11.5	2.9	3.8
1997	3.3	39.1	66.5	63.7	120.6	62.1	23.2	7.3	4.2	2.9	2.4	2.0
1998	1.7	2.3	15.3	40.8	69.1	21.3	5.2	3.4	1.8	1.5	1.3	1.3
1999	2.9	3.1	77.6	144.1	78.4	141.2	71.1	18.9	4.8	3.4	2.4	2.4
2000	2.6	5.1	55.2	60.2	36.8	23.7	31.2	8.2	3.9	2.6	1.6	2.6
2001	3.6	62.9	62.0	44.2	46.0	34.4	5.7	4.0	4.3	6.3	5.4	2.5
2002	2.1	1.9	2.8	16.9	46.9	28.3	18.4	6.4	3.5	2.1	1.4	1.7
2003	1.5	2.2	3.3	11.7	52.3	44.2	8.8	3.7	1.8	2.0	2.3	2.2
2004	2.9	10.5	61.9	79.5	37.4	35.9	25.3	5.2	2.9	2.1	1.6	1.4
2005	1.5	1.8	1.9	6.7	54.2	52.6	23.3	9.0	4.1	2.8	2.5	2.3
2006	7.5	16.7	43.1	23.0	32.6	16.7	7.3	3.9	2.7	3.1	1.6	1.4
2007	3.3	22.3	23.7	46.2	37.3	39.7	26.4	8.7	4.3	2.8	1.6	1.6
2008	1.6	2.0	4.9	13.7	130.3	93.4	26.6	6.9	2.8	1.6	1.6	1.5

7.3 ABIOTIC COMPONENTS

7.3.1 Hydrology

Table 7.13 and Table 7.14 provide a summary of the changes in low flow and floods that have occurred under the different scenarios.

Table 7.13 Summary of the change in low flow conditions to the uMkhomazi Estuary under a range of flow scenarios

Percentile	Monthly flow (m^3/s)						
	Reference	Present	A	B and F	C	D	E
30%ile	8.5	5.0	1.2	4.0	3.6	3.2	2.7
20%ile	6.3	3.1	1.0	3.0	2.7	2.3	2.1
10%ile	4.4	1.6	0.7	1.7	1.7	1.6	1.6
% Similarity in low flows		**47.7**	**15.1**	**44.6**	**41.7**	**37.0**	**34.0**

Confidence: High

Table 7.14 Summary of the ten highest simulated monthly volumes to the uMkhomazi Estuary under Reference Condition, Present State and a range of flow scenarios

Date	Monthly volume ($x10^6$ m^3/month)						
	Reference	Present	A	B & F	C	D	E
Sep 1987	747.67	688.8	634.5	629.8	626.2	633.68	628.81
Mar 1925	704.19	681.1	666.0	670.7	670.0	670.2	669.22
Mar 1976	630.39	606.1	590.0	593.5	592.8	593.04	592.14
Oct 1987	620.40	591.0	573.3	578.1	577.4	577.6	576.62
Feb 1985	596.34	580.5	562.3	565.8	565.1	565.35	564.37
Feb 1932	582.99	550.0	532.8	536.8	536.1	536.34	535.35
Mar 1988	580.22	542.8	524.5	528.4	527.7	527.91	526.93
Apr 1925	560.76	511.8	495.6	481.5	491.4	490.24	496.43
Apr 1943	557.29	526.4	509.9	512.9	512.2	512.44	511.54
Mar 1927	468.49	436.0	420.1	421.1	420.5	420.69	419.79
% Similarity in floods		**94.4**	**91.1**	**91.3**	**91.3**	**91.4**	**91.3**

Confidence: Medium

A summary of the hydrology scores is provided in Table 7.15.

Table 7.15 EHI scores for hydrology under different scenarios

Variable	Scenario Group						
	Present	A	B & F	C	D	E	Conf
a. Similarity in low flows	48	15	45	42	37	34	M
b. Similarity floods	95	91	91	91	91	91	M
Hydrology score	**66.8**	**45.4**	**63.4**	**61.6**	**58.6**	**56.8**	

7.3.2 Hydrodynamics and mouth condition

This section provides a description of the changes in the occurrences of mouth conditions for each of the scenarios.

Present	Mouth closure did not occur the Reference Condition. At present mouth closure occurs for about 1% of the time for relatively short periods.
Scenario Group A to F	Mouth closure is not expected to occur for weeks at a time under Scenario Group B to F, but as flows do decrease below 2.0 m^3/s intermitted closures may occur for short periods (i.e. 1- 2 weeks). Mouth closures for weeks to months at a time are a significant feature under Scenario Group A, with flow less than 1.0 m^3/s occurring for about 20% of the time. Note: Mouth closure is scored conservatively.

Table 7.16 provides a summary of the hydrodynamics and mouth condition scores for the uMkhomazi Estuary.

Table 7.16 EHI scores for hydrodynamics and mouth condition under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
Hydrodynamics and mouth conditions score	95	75	95	95	95	95	95	**M**

7.3.3 Water quality

Table 7.17 Occurrence of the abiotic states under the different scenario groups

Abiotic State	Reference	Present	Scenario Group				
			A	B & F	C	D	E
State 1: Closed mouth	0	1	19	0	0	0	0
State 2: Tidal with intermitted mouth closure	1	13	27	14	14	16	18
State 3: Tidal	12	17	7	23	27	25	30
State 4: Freshwater dominated	87	70	47	64	59	59	52

Table 7.18 Estimated changes in water quality in different zones under different scenarios

Zones in Estuary	Volume weighting for Zone	Estimated SALINITY concentration based on distribution of abiotic states under a range of Scenario Groups							
		Reference	Present	A	B	C	D	E	F
A: Lower	0.4	4	9	14	11	12	12	13	11
B: Middle	0.3	3	6	11	7	7	8	9	7
C: Upper	0.2	1	3	7	3	3	3	4	3
D: Upper (H)	0.1	0	0	0	0	0	0	0	0

Zones in Estuary	Volume weighting for Zone	Estimated DIN concentration (µg/l) based on distribution of abiotic states under a range of Scenario Groups							
		Reference	Present	A	B	C	D	E	F
A: Lower	0.4	97	207	180	197	189	189	178	505
B: Middle	0.3	97	222	197	216	209	209	202	820
C: Upper	0.2	97	230	201	227	223	222	217	996
D: Upper (H)	0.1	97	237	224	234	230	230	226	1178

Zones in Estuary	Volume weighting for Zone	Estimated DIP concentration (µg/l) based on distribution of abiotic states under a range of Scenario Groups							
		Reference	Present	A	B	C	D	E	F
A: Lower	0.4	10	17	15	17	16	16	15	169
B: Middle	0.3	10	17	15	17	16	16	15	243
C: Upper	0.2	10	18	15	18	17	17	17	391
D: Upper (H)	0.1	10	18	15	18	17	17	17	475

Zones in Estuary	Volume weighting for Zone	Estimated TURBIDITY (NTU based on distribution of abiotic states under a range of Scenario Groups							
		Reference	Present	A	B	C	D	E	F
A: Lower	0.4	175	143	99	132	122	122	109	132
B: Middle	0.3	175	143	99	132	122	122	109	132
C: Upper	0.2	175	143	99	132	122	122	109	132
D: Upper (H)	0.1	175	143	99	132	122	122	109	132

Zones in Estuary	Volume weighting for Zone	Estimated DISSOLVED OXYGEN concentration (mg/l) based on distribution of abiotic states under a range of Scenario Groups							
		Reference	Present	A	B	C	D	E	F
A: Lower	0.4	6	6	6	6	6	6	6	6
B: Middle	0.3	6	6	6	6	6	6	6	6
C: Upper	0.2	6	6	5	6	6	6	6	6
D: Upper (H)	0.1	6	6	6	6	6	6	6	6

Table 7.19 Summary of water quality changes under different scenarios

Parameter	Summary of changes
Changes in longitudinal salinity gradient and vertical stratification	⇧ due to increase in low flow States 1 and 2.
Inorganic nutrients in estuary	⇧ due to nutrient enrichment in catchment. Nutrient slightly improve in upper reaches in Future Scenarios as a result of reduction in high flows (State 4) compared with Present State. ⇧⇧ for Scenario B+WWTW as a result of WWTW input at General Limits (0.24 m^3/s).
Turbidity in estuary	⇩ due to reduction in high flow state (State 4).
Dissolved oxygen in estuary	No marked changes, remains well flushed.
Toxic substances in estuary	⇧ industrial and urban inputs. ⇧⇧more for Scenario F which include WWTW effluent.

Table 7.20 EHI scores for water quality under different scenarios

Variable		Scenario Group							
		Present	A	B	C	D	E	F	Conf
1	**Salinity**								
	Similarity in salinity	66	45	61	59	58	54	61	M
2	**General water quality in the estuary**								
A	N and P concentrations	67	74	69	70	70	72	16	M/l
B	Turbidity	90	72	86	82	82	77	77	M/L
C	Dissolved oxygen	99	98	99	100	99	99	99	M/L
D	Toxic substances	75	75	75	75	75	75	60	L
Water quality score*		**67**	**61**	**66**	**67**	**66**	**67**	**34**	**M/L**

* $Score = (0.4 * 1. + 0.6 * (\min(2a. \; to \; 2d.))$

7.3.4 Physical habitats

Table 7.21 Summary of physical habitat changes under different scenarios

Parameter		Scenario Group
1a	% Similarity in intertidal area exposed	Sedimentation processes under Scenario Group A to E are similar to the Present State, with some loss of intertidal habitat due deposition and infilling of the intertidal habitat. There is also a loss of intertidal area above the Sappi Weir. Under Scenario A, State 2 increases by 20% reducing exposed intertidal habitat due to intermitted mouth closure and greater mouth restriction.
1b	% Similarity in sand fraction relative to total sand and mud	Information is lacking on changes in % similarity in sand fraction relative to total sand and mud, but the score of 80 is based on increase in clay and silt fractions experienced in similar systems, especially in Zone B to D. Sand mining is also changing grains size distribution in the system.

Parameter		Scenario Group
2	% Similarity in intertidal area: depth, bed or channel morphology	There has been some infilling of sub-tidal areas as a result of the decrease/loss in resetting floods and increase sediment yield from the catchment. Under the Reference conditions floods would have scoured the system to mean sea level before the natural deposition cycle causes infilling. There is also a loss of intertidal area above the Sappi Weir. Under the future Scenarios resetting events have been somewhat reduced and infilling is maintaining a more constricted equilibrium state.

Table 7.22 EHI scores for physical habitat under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
1a. Intertidal areas and sediments	70	50	70	70	70	70	70	M
1b.Similarity in sand fraction	80	80	80	80	80	80	80	M
2. Subtidal area and sediments	80	75	75	75	75	75	75	M
Physical habitat score	**78**	**70**	**75**	**75**	**75**	**75**	**75**	**M**

7.4 BIOTIC COMPONENT

7.4.1 Microalgae

Table 7.23 Summary of change in microalgae component under different scenarios

Scenario	Summary of Changes
A	Under this scenario the open water area is increased which will allow more volume in which the microalgae can proliferate. At the same time there is some nutrient enrichment which will result in an increase in both phytoplankton and MPB biomass. This compensates for the loss of intertidal sand and mudflats. There is a big loss of area in reed and swamp vegetation which will have an overall negative effect. The changes in area of forest, mangroves floodplain are not relevant to the microalgae scores. Only small changes in salinity appear and these to levels that will be unlikely to adversely affect microalgae.
B to E	The changes in these scenarios are so similar to those in A that the end condition is likely to produce a similar effect.
F	Species richness is expected to increase with increased nutrient loading. Abundance/biomass will increase due to high nutrient loading, but as there is not a significant increase in retention this will be capped during the high flow season. There would be a shift in community composition to blue-green species as a result of the high nutrients.

Table 7.24 EHI scores for microalgae component under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
1. Species richness	95	90	95	95	95	95	80	M
2 Abundance	90	75	90	90	90	90	60	M
3. Community composition	95	90	95	95	95	95	60	M
Biotic component score	**90**	**75**	**90**	**90**	**90**	**90**	**60**	**M**

7.4.2 Macrophytes

Table 7.25 Summary of change in macrophyte component under different scenarios

Scenario	Summary of Changes
A	Worst case scenario where drastically reduced base flow causes the mouth to close. This will result in an increase in open water area thereby reducing area for reeds and sedges to occupy. Higher salinity will reduce reed and sedge growth. Salinity at times will be 30 in Zone A, 20 in Zone B and 10 in Zone C. Reeds, sedges and swamp forest grow best at salinity less than 15. Saline conditions would encourage the growth and expansion of mangroves, with a possible increase from 1 to 2 ha. Some change (15 % lower than present) in species and community composition in response to salinity change expected. The decline in open fresh state (State 4), which was dominant under natural conditions would impact the offshore marine habitats.
B	Lower and middle reaches slightly more saline than under present conditions. Some change (5 % lower than present) in species and community composition in response to salinity change expected. Monthly flows 3 % lower than present condition which may increase reed habitat.
C & D	Lower and middle reaches more saline. Some change (10 % lower than present) in species and community composition in response to salinity change expected. Reduced base flows and decreased flooding events will lead to infilling of the estuary, creating more habitat for colonisation by reeds and sedges.
E	Increased salinity in the lower and middle reaches of the estuary. Some change (10 % lower than present) in species and community composition in response to salinity change expected. Reduced base flows and decreased flooding events will lead to infilling of the estuary, creating more habitat for colonisation by reeds, sedges and grasses.
F	Scenario B plus 0.24 m^3/s of wastewater input. This causes a significant increase in nutrients and together with low flow will result in a eutrophic estuary particularly during closed mouth conditions. Invasive aquatic plants will increase in abundance and all macrophytes will grow and expand in open sand and mudflat areas. Macroalgal blooms are expected on exposed sand and mudflats.
Significant negative changes in macrophytes occur in Scenario A due to an increase in salinity and Scenario F due to an increase in nutrients. There is a decrease in low flow conditions for all scenarios and therefore an increase in reed and sedge habitat due to more stable conditions. This replaces some of this habitat lost due to historical disturbance and therefore changes in the scores between scenarios are not large.	

Table 7.6 EHI scores for macrophyte component under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
1. Species richness	80	65	75	70	70	75	60	M
2 Abundance	21	20	26	31	33	34	15	M
3. Community composition	51	47	52	54	55	55	45	M
Biotic component score	**21**	**20**	**26**	**31**	**33**	**34**	**15**	**M**

7.4.3 Invertebrates

Table 7.26 Summary of change in invertebrates component under different scenarios

Scenario	Summary of Changes
A	Increase in mouth closure, especially during winter. Reduced river flows, higher water retention and increased zooplankton and benthic invertebrate community diversity and abundance. Loss of intertidal habitat and intertidal microphytobenthos reduces food availability for some species. Overall numbers of species don't change but total abundance likely to be very reduced, and community composition changes markedly.
B	Very similar to present for both species diversity, composition and abundance. Reduced flows result in an increase of States 2 and 3 and decrease in the dominant (under natural) State 4. Changes in the middle reaches and particularly zone C influence the overall invertebrate community standing stock.
C	
D	

Scenario	Summary of Changes
E	
F	Treated wastewater inputs will increase nutrient levels in the estuary. This will impact the trophic status, and cause low dissolved oxygen concentrations particularly in the middle to upper reaches. The most important benthic productivity area in the estuary is likely to be the most impacted by degraded water quality. This has influences species composition, carry capacity and the relative proportions of species within the system.

Table 7.27 EHI scores for invertebrates component under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
1. Species richness	95	95	95	95	95	95	65	M
2. Abundance	75	60	75	75	75	75	50	M
3. Community composition	80	60	75	75	70	70	60	M
Biotic component score	**75**	**60**	**75**	**75**	**70**	**70**	**50**	**M**

7.4.4 Fish

Table 7.28 Summary of change in fish component under different scenarios

Scenario	Summary of Changes
A	Flow reductions cause a significant increase in mouth closure, especially in late winter and early spring. This impacts recruitment of many of the main (and important) estuarine dependent marine fishes. Increased occurrence on State 1 and State 2 might results in depressed oxygen concentrations in Zone C of the estuary, an important nursery area for estuarine dependent marine species. Most of these species will undergo population reductions despite salinities in the estuary being conducive to the use of the whole system. Reduced river flows, higher water retention and increased zooplankton productivity will benefit the estuarine resident component of the fish assemblage. Detritivores are also likely to benefit from lower flows and increased detrital productivity. Loss of intertidal habitat and intertidal microphytobenthos reduces food availability for some mullet species. Overall numbers of species and total fish abundance is likely to be reduced, and community composition changes markedly.
B	Flow and habitat changes are unlikely to result in fish assemblages that are different to those under present day conditions.
C	Flow and habitat changes are unlikely to result in fish assemblages that are different to those under present day conditions.
D	Flow and habitat changes are unlikely to result in fish assemblages that are different to those under present day conditions.
E	Increased occurrence of States 2 and 3 occur at the expense of State 4 occurrence. A consequence of this is an increased occurrence of reduced oxygen levels in the lower sections of Zone C of the estuary. Given the importance of this area for the estuary's fish fauna losses in fish abundance can be expected. Reduced base flows and flooding events will also lead to some infilling of the estuary and consequent loss of fish habitat, causing further loses in fish abundance in the system. Overall numbers of species and total fish abundance is likely to be reduced, and community composition changes.
F	Treated wastewater inputs will result in marked changed in nutrient levels in the estuary and a changed trophic base and status, with mullet in particular benefitting. Significant negative consequences also occur. Wastewater nutrients cause depressed oxygen concentrations in Zone C of the system. The most important nursery area in the estuary is likely to be the most impacted by degraded water quality. This will result in losses of some fish species from the estuary as well as losses in fish abundance and an impacted species composition.

Table 7.29 EHI scores for fish component under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
1. Species richness	95	55	95	95	95	85	80	M
2. Abundance	60	35	60	60	60	55	50	M
3. Community composition	75	40	75	75	75	75	70	M
Biotic component score	**60**	**35**	**60**	**60**	**60**	**55**	**50**	**M**

7.4.5 Birds

Table 7.30 Summary of change in bird component under different scenarios

Scenario	Summary of Changes
A	This scenario and scenario F are considered to take the system the furthest from reference (and present) state. Mouth closure would increase, with increased back-flooding (which was observed during this study to have positive impacts on the aquatic avifauna). There would be increased salinity in the estuary and the possibility of enhanced development of inter-tidal sandbanks and mudflats to the possible advantage of small invertebrate-feeding waders. Back-flooding and increased salinity would have a negative impact on macrophytes but this would likely have little impact on waterbirds. Low flows would be to the detriment of swimming piscivores, a major component of the relatively impoverished waterbird avifauna, during open-mouth conditions but would be to their benefit during closed-mouth, deeper-water conditions.
B, C, D & E	These four scenarios were considered likely to have similar impacts on the waterbird community and only relatively slightly further away from reference than the present state. Expected changes would include reduced base flows (and hence increased mouth closures) and flooding events, increased siltation, salinity and macrophyte growth.
F	Reduced base flows and Increased eutrophication through greater waste-water input resulting in spread of macrophytes, including alien species.

Table 7.31 EHI scores for bird component under different scenarios

Variable	Scenario Group							
	Present	A	B	C	D	E	F	Conf
1. Species richness	80	70	75	75	75	75	70	M
2. Abundance	60	50	55	55	55	55	50	M
3. Community composition	70	60	65	65	65	65	60	M
Biotic component score	**60**	**50**	**55**	**55**	**55**	**55**	**50**	**M**

7.5 ECOLOGICAL CATEGORIES ASSOCIATED WITH SCENARIOS

The individual EHI scores, as well as the corresponding ecological category under different scenarios are provided below. The estuary is currently in a C Category. Under Scenario Group B (**MK21** and **42**) and Group C (**MK22**, **23**, **43**) the uMkhomazi Estuary will decline slightly in health, as a result of more closed mouth conditions, but is expected to remain in a C Category. While, under Scenario Group A (**MK2**, **4**), D (**MK31**) and E (**MK32**, **33**) the estuary will deteriorate further in health by about 14%, 8% and 9% respectively as a result of increase closed mouth conditions.

To test the sensitivity of the estuary to the increased nutrient load associated with a 20 ML/d WWTW, Scenario Group F (based on inflows generated for Scenario Group B) was evaluated in more detail. Under this scenario, the uMkhomazi estuary declines in health by 13% (**MK21b**) as a result of a decline in water quality (nutrients and oxygen) which drives increased primary production and a decline in estuary biota. Of special concern are periods when the estuary mouth

closes and retention becomes high. Similar responses are expected for any of the future scenarios with this high level of nutrient input. (It should be noted that this is a low confidence assessment as no numerical modelling was done to test the tidal effects on lateral discharges or the effect of entrainment).

Table 7.32 EHI score and corresponding Ecological Categories under the different runoff scenarios

Variable	Weight	Scenario Group								
		Present	A (MK2, 4)	B (MK21, 42)	C (MK22, 23, 43)	D (MK31)	E (MK32, 33)	F (MK21, 42) + WWTW	G MK21, 42 –Anth but with weir	H MK21, 42 – Anth & Weir
Hydrology	25	66.8	**45**	63	62	59	57	63	63	63
Hydrodynamics and mouth condition	25	95	**75**	95	95	38	38	95	95	97
Water quality	25	66.6	**61**	66	67	66	67	34	66	66
Physical habitat alteration	25	78	**70**	75	75	75	75	75	84	90
Habitat health score		**76**	**63**	**75**	**75**	**60**	**59**	**67**	**77**	**79**
Microalgae	20	80	**65**	80	80	80	80	50	80	90
Macrophytes	20	21	**20**	26	31	33	34	15	46	46
Invertebrates	20	75	**60**	75	75	70	70	50	85	90
Fish	20	60	**35**	60	60	60	55	50	70	75
Birds	20	60	**50**	55	55	55	55	50	57	65
Biotic health score		**59**	**46**	**59**	**60**	**60**	**59**	**43**	**68**	**73**
ESTUARY HEALTH SCORE		**68**	**54**	**67**	**67**	**60**	**59**	**55**	**72**	**76**
ECOLOGICAL STATUS		**C**	**D**	**C**	**C**	**D**	**D**	**D**	**B/C**	**B**

For the uMkhomazi Estuary, none of the scenarios achieved the REC of a B Category. Therefore, Scenario H (Group B (**MK21** and **MK42**) in conjunction with a number of management interventions) is the recommended ecological flow scenario. Scenario Group C (**MK22**, **23** and **43**) will also achieve the REC. The following management interventions are required to achieve the uMkhomazi REC:

- Remove sandmining from the upper reaches below the Sappi Weir to increase natural function, i.e. restore intertidal area.
- Restoration of vegetation upper reaches and along the northern bank, e.g. remove aliens and allow disturbed land to revert to natural land cover (is already on upwards trajectory).
- Curb recreational activities in the lower reaches through zonation and improve compliance.
- Reduce/remove castnetting in the mouth area through estuary zonation or increase compliance; and
- Relocate upstream, or remove, the Sappi Weir to restore upper 15% of the estuary.

Since these scenarios include the construction of a new dam, relocation or removal of the Sappi Weir is seen as a medium to long term recommendation. In the short term, a combination of the PES and the REC will be recommended. The improvements required to meet the REC are mostly non-flow related measures. **The non-flow related (or anthropogenic) measures required to improve the estuary (apart from the removal or changing of the SAPPI weir location) can be applied and should improve the estuary to a B/C in a relatively short time frame.**

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Ecological Water Requirements

The **'recommended Ecological Water Requirement' scenario,** is defined as the flow scenario (or a slight modification thereof to address low-scoring components) that represents the highest change in river inflow that will still maintain the estuary in the recommended Ecological Category.

Where any component of the health score is less than 40, then modifications to flow and measures to address anthropogenic impacts must be found that will rectify this. The REC for the uMkhomazi Estuary should be an Ecological Category B.

The flow requirements for the estuary are the same as those described for Group B (MK 21 and MK 42) and are summarised in Table 8.1.

Table 8.1 Summary of the monthly flow (in m^3/s) distribution simulated for Scenario Group B

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	198.0	129.1	174.9	200.2	240.4	247.5	132.3	126.9	82.9	32.4	32.3	226.7
99	78.4	126.7	131.5	197.8	215.7	221.7	110.9	98.2	39.5	22.3	27.0	79.9
90	12.3	32.9	77.8	112.8	133.2	106.1	60.6	18.0	7.2	7.8	4.5	4.1
80	9.5	21.0	55.6	80.7	105.1	76.8	42.1	11.6	6.2	4.7	3.9	3.8
70	8.0	17.8	39.2	68.0	81.9	58.3	28.7	10.6	5.6	4.0	3.4	3.5
60	6.8	14.3	27.1	52.3	69.3	52.0	25.7	9.5	5.1	3.6	3.0	3.1
50	5.7	12.5	20.2	39.9	60.0	44.0	24.1	8.5	4.7	3.0	2.3	2.5
40	4.6	10.5	16.3	29.6	46.7	40.3	19.0	7.1	3.8	2.5	1.7	2.0
30	3.8	8.2	12.0	22.0	41.6	36.4	12.7	5.8	3.1	1.9	1.5	1.7
20	2.8	5.6	8.2	13.9	32.9	28.8	10.0	4.5	2.2	1.5	1.4	1.5
10	1.6	3.1	3.8	8.1	19.6	21.3	6.6	3.5	1.8	1.3	1.3	1.3
1	1.3	1.6	1.9	3.3	4.5	7.9	5.2	2.0	1.4	1.2	1.2	1.2
0.1	1.3	1.6	1.9	2.9	2.1	6.5	4.7	1.6	1.3	1.2	1.2	1.2

8.2 Resource Quality Objectives

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 Reserve category, which was decided upon by the authorities utilising environmental, social and economic criteria. Thresholds of Potential Concern (TPC) are defined as measurable end points related to specific abiotic or biotic indicators that if reached prompts management action. In essence, thresholds of potential concern should be defined such that they provide early warning signals of potential non-compliance to ecological specifications.

In essence this concept implies that the indicators (or monitoring activities) selected as part of a long term monitoring programme need to include biotic and abiotic components that are particularly sensitive to ecological changes associated with changes in river inflow into the system.

The ecological specifications for the uMkhomazi Estuary, as outlined in Table 8.2 and Table 8.3, are set for the REC of an B.

Table 8.2 Ecological specifications and thresholds of potential concern for abiotic components

Abiotic Component	Ecological Specification	Threshold of Potential Concern	Causes
Hydrology	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ River inflow distribution patterns differ by more than 5% from that of Scenario B (i.e. the recommended flow scenario for the uMkhomazi) ▪ Monthly river inflow < 1.0 m^3/s ▪ Monthly river inflow < 2.0 m^3/s persists for longer than 3 months in a row ▪ Monthly river inflow < 5.0 m^3/s for more than 30% of the time.	Flow reduction
Hydrodynamics	Maintain a mouth conditions to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Mouth closure occurs more than 2 - 3 weeks in a year. ▪ Mouth closure occurs for more than 2 years out of ten ▪ Mouth closure occurs between Sep and Apr ▪ Changes in tidal amplitude at the tidal gauge of more than 20% from Present State (2013)	Flow reduction
Water Quality	Salinity distribution not to cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae (see above)	▪ 0 in the upper reaches (end of Zone C and beginning of Zone D) of the estuary. ▪ Salinity values > 20 in middle reaches (above the N2 bridge) during the low flow season ▪ Freshwater dominated for 70% of the time	Flow reduction
	System variables (pH, DO and turbidity) not to cause exceedence of TPCs for biota (see above)	River inflow: ▪ 7.5 < pH > 8.5 consistently over 2 months ▪ DO <6 mg/l ▪ Turbidity >15 NTU (low flow) ▪ Turbidity high flows naturally turbid Estuary: ▪ Average turbidity >10 NTU (low flow) ▪ Turbidity high flow, naturally turbid ▪ 7.0 < pH > 8.5 in a sampling survey ▪ Average DO <6 mg/l in a sampling survey	▪ Agricultural return flow ▪ Erosion of agricultural land ▪ Municipal wastewater (organic loading)
	Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see above)	River inflow (flows < 5 m^3/s): ▪ NO_x-N >150 µg/l over 2 months ▪ NH_3-N> 20 µg/l over 2 months ▪ PO_4-P > 10 µg/l over 2 months River inflow (flows > 5 m^3/s): ▪ Average DIN > 200 µg/l. ▪ Average DIP > 20 µg/l. Estuary (river flows < 5 m^3/s): ▪ Average NO_x-N > 150 µg/l in a sampling survey ▪ Average NH_3-N > 20 µg/l in a sampling survey ▪ Average PO_4-P > 10 µg/l in a sampling survey	▪ Agricultural return flow (nutrients) ▪ Municipal wastewater (nutrients)

Abiotic Component	Ecological Specification	Threshold of Potential Concern	Causes
		Estuary (river flows > 5 m^3/s): ▪ Average NO_x-N > 300 µg/l in a sampling survey ▪ Average NH_3-N > 20 µg/l in a sampling survey ▪ Average PO_4-P > 20 µg/l in a sampling survey	
	Presence of toxic substances not to cause exceedence of TPCs for biota (see above)	River inflow: ▪ Trace metals (to be determined) ▪ Pesticides/herbicides (to be determined) Estuary: ▪ Total metal concentrations in estuary waters exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Total metal concentration in sediment exceeds target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)	• Agricultural return flow (e.g. pesticides/herbicides) • Municipal wastewater including industrial trade effluent (e.g. metals)
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota (see above)	▪ River inflow distribution patterns (flood components) differ by more than 20% (in terms of magnitude, timing and variability) from that of the Present State (2013) ▪ Suspended sediment concentration from river inflow deviates by more than 20% of the sediment load-discharge relationship to be determined as part of baseline studies (Present State 2013) ▪ Findings from the bathymetric surveys undertaken as part of a monitoring programme indicate changes in the sedimentation and erosion patterns in the estuary have occurred (± 0.5 m). ▪ Intertidal and subtidal habitat in Zone C and D are not available for estuarine species (increase by > 20% from present).	▪ Reduced floods ▪ Sandmining
	Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates (see above).	▪ The median bed sediment diameter deviates by more than a factor of two from levels to be determined as part of baseline studies (Present State 2013). ▪ Sand/mud distribution in middle and upper reaches change by more than 20% from Present State (2013). ▪ Changes in tidal amplitude at the tidal gauge of more than 20% from Present State (2013)	▪ Reduced floods ▪ Sandmining

Table 8.3 Ecological specifications and thresholds of potential concern for biotic components

Component	Ecological Specification	Threshold of Potential Concern	Possible causes
Microalgae	Maintain current microalgae assemblages, specifically >5 diatom species at a frequency >3% of the total population in saline reaches (i.e. Zone A in low flow)	▪ Medium phytoplankton: > 5 µg/l for more than 50% of the stations ▪ MPB: > 30 mg m^2 for more than 50% of the stations in the saline portion of the estuary ▪ Observable bloom in the estuary	Excessive nutrient levels in the water
Macrophytes	▪ Maintain the distribution of macrophyte habitats ▪ Maintain the integrity of the riparian zone particularly in Zone and D where the sandmining no longer occurs ▪ No invasive floating aquatic species present in the estuary e.g. water hyacinth ▪ No sugarcane in the estuarine functional zone	▪ Greater than 10 % change in the area covered by different macrophyte habitats ▪ Invasive plants (e.g. syringa berry, Spanish reed, black wattle, Brazilian pepper tree) largely absent from the riparian zone ▪ Die-back of reeds and sedges in the lower reaches ▪ Unvegetated, cleared areas along the banks ▪ Floating invasive aquatics observed in the upper estuary reaches ▪ Sugarcane is present in the estuarine functional zone	▪ Reduced flow, sedimentation, infilling and spread of reeds, sedges, grasses ▪ Increase in salinity to greater than 20 for 3 months ▪ Disturbance ▪ Increase in nutrients and possible eutrophication.
Invertebrates	▪ Maintain current levels of zoobenthic abundance (including seasonal variation) ▪ Retain an invertebrate community assemblage in the estuary based on species diversity and abundance that includes a variety of indigenous spp. ▪ Species diversity (between 15 species in summer - 40 species in winter) ▪ Polychaetes, amphipods and tanaeids should numerically dominate during all seasons. However, abundance of all taxon groups should be higher during summer high flow periods and lower during winter low flow period	▪ Salinities should be <15 in upper reaches ▪ DO levels should not drop below 4 ppt in >25% of the estuary ▪ Sediment distribution ▪ Greater than 20% change in the intertidal and subtidal habitats ▪ Occurrence of invertebrate alien species (e.g. *Tarebia granifera*) ▪ Decrease in abundance of zooplankton by >20% in terms of numbers per m^2 over entire estuarine area (3 sample sites) over 3 years ▪ Decrease in abundance of benthic macroinvertebrates ▪ No occurrence of *Paratylodiplax blephariskios* in annual sample	▪ Nutrient enrichment ▪ Loss of baseflows ▪ Mouth closure
Fish	▪ Zone C in its entirety acts as a nursery to a diversity of EDC2 species (EDC2a especially) ▪ A good trophic basis exists for predatory estuarine dependant marine species (e.g. *Agyrosomus japonicus, Carynx* spp.) ▪ Estuarine residents species represented by core group (*Glossogobius* spp., *Oligolepis* spp. *Ambassis* spp. and *Gilchistella aestuaria*). Zone D is used by these species as well ▪ *Oreochromis mossambicus* limited to the upper	▪ An abundance (to be defined as an average with prediction limits) of EDC2a species as young juveniles in spring and early summer (*Solea bleekeri, Acanthopagrus vagus, Ponmadasys comerssonnii, Rhabdosargus holubi*) ▪ Mullet occur throughout the system represented by a full array of size classes ▪ Any one of these species does not occur in the estuary in two consecutive years (to include occurrence in Zone D) ▪ *Oreochromis mossambicus* distribution extend into Zone B for more than two consecutive years	▪ Hydrological (flow and mouth condition related) and habitat (sediment dynamics) changes. Sand mining impacts ▪ Water quality changes (toxic impacts, persistent low oxygen levels (< 4 mg/L) or intermittent fish kills ▪ Changes salinity gradients

Component	Ecological Specification	Threshold of Potential Concern	Possible causes
	reaches of Zone C in the low flow period ▪ Species assemblage comprises indigenous species only ▪ Connectivity to a healthy transitional marine-estuary waters is maintained. Connectivity down the full length of the historic estuary and into the marine environment is restored	▪ Alien fish species occur ▪ A decline in nearshore linefsh catches (*Agyrosomus japonicus*) (not related to gear changes or bag limit restrictions). Estuarine species occur in Zone D	resulting from flow and/or mouth condition changes ▪ Water quality impacts, primarily changes in salinity gradient and mouth closure ▪ Translocations (IBT) and poor water quality (often coincident with higher nutrient levels eutrophication) ▪ Loss of trophic bases (prey fish), loss of transitional marine-estuary waters. Loss of connectivity with upper estuary (tidal freshwaters)
Birds	The most characteristic component of the avifaunal waterbird community is the piscivores and it is this group that would be the most valuable for monitoring	▪ Resident pair of African Fish Eagle disappears or fails to breed successfully ▪ Pied Kingfishers, White-breasted Cormorants or Reed Cormorants fail to be recorded on more than three consecutive counts spanning a period of 18 months or more ▪ Numbers of waterbird species drop below 10 for 2 consecutive counts	Decrease in food availability – fish

8.3 Monitoring Requirements

Recommended minimum monitoring requirements to ascertain impacts of changes in freshwater flow to the estuary and any improvement or reductions therein are listed in below.

Table 8.4 Recommended baseline monitoring requirements

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Hydrodynamics	Record water levels	Continuous	At bridge
	Measure freshwater inflow into the estuary	Continuous	Above the estuary
	Aerial photographs of estuary (spring low tide)	Every 3 years	Entire estuary
Sediment dynamics	▪ Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary
	▪ Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	Every 3 years (with invert sampling)	Entire estuary (6 stations)
Water quality	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue (must also include sediment grain size analysis of samples).	Every 3 - 6 years	Focus on sheltered, depositional areas
Microalgae	▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC. ▪ Intertidal and subtidal benthic chlorophyll-a measurements.	Monthly sampling for 2 years (seasonal trends)	Entire estuary (5 stations)
Fish	Record species and abundance of fish, based on seine net and gill net sampling. The data will establish Zone specific baselines and provide a measure of natural variability. They should be based on replicate sampling of stations and wet and dry seasons.	Late spring, summer and two winter survey every year for 3 years	Entire estuary (9 stations) (increase to 12 to include Zone D)
Birds	Undertake counts of all water associated birds, identified to species level.	A series of monthly counts for a yea	Entire estuary (3 sections)

Table 8.5 Recommended long term monitoring requirements

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Hydrodynamics	Record water levels.	Continuous	At bridge
	Measure freshwater inflow into the estuary.	Continuous	Above the estuary
	Aerial photographs of estuary (spring low tide).	Every 3 years	Entire estuary
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary
	Set sediment grab samples (at cross section profiles) for analysis of PSD and origin (i.e. using microscopic observations).	Every 3 years (with invert sampling)	Entire estuary (6 stations)
Water quality	Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary.	Monthly continuous	DWS WQ monitoring station(U1H006)
	Longitudinal salinity and temperature profiles ((and any other in situ measurements possible e.g. pH, DO, turbidity) collected during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion/closed mouth). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Seasonally every year	Entire estuary (9 stations)
	Water quality parameters (i.e. system variables, and inorganic nutrients) taken along the length of the estuary (at least surface and bottom samples).	Coinciding with biotic surveys or when significant change in quality expected	Entire estuary (9 stations)
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue (must also include sediment grain size analysis of samples).	Every 3 - 6 years	Focus on sheltered, depositional areas
Microalgae	▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements,	Summer and winter survey every 3 years	Entire estuary (5 stations)
Macrophytes	▪ Map the area covered by the different macrophyte habitats during a field survey. ▪ Compile a species list and check for expansion of invasive plants, reed, sedge and grass areas.	Summer survey every 3 years	Entire estuary

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Invertebrates	▪ Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; ▪ Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of hole densities; ▪ Measures of sediment characteristics at each station	Winter/low flow survey every year	Entire estuary (6 stations) include extra upper station if weir removed
Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Late spring/ summer and winter survey every year. Repeated within season if any Ecospec is not met	Entire estuary (9 stations) (increase to 12 to include Zone D)
Birds	Undertake counts of all water associated birds, identified to species level.	Winter and summer surveys every year Coordinated Waterbird Counts (CWAC)	Entire estuary

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10 APPENDIX A: REPORT COMMENTS

Page / Section	Report statement	Comments	Changes made	Author comment
Comments from Mmaphefo Twala: 30 January 2015				
Front pages		Include cover page.	Yes	
		The report title could perhaps include EWR and Recommended RQOs?	Yes	
		Report numbering: volume 2b?	Yes	
		The page after the Document Index page: replace Water Affairs with Water and Sanitation.	Yes	
Page i		Remove 'comments received from DWS' below the Acknowledgements.	Yes	
		Duplicated: numbering error.	Yes	
	Study area: …"open and **one** of only…. **The uMkhomazi river** with a catchment **area** of …."	Suggested correction	Yes	
		Acronyms and abbreviations: add DWS to the list	Yes	
	Fix or remove all the reference errors: i.e page xi, 6, 9"**Error! Reference source not found"**	Suggested correction	Yes	
		Page numbers are not visible on the printed report for the rest of the document: format error	Yes	
Sentence above table 1.2	"…classes provide**d** below…"	Suggested correction	Yes	
Page 3, second last paragraph	raph "…estuary cannot be allocated **an** REC…."	Suggested correction	No	Use "a" before REC and "an" before EC.
Page 3, step 4	Remove: "Quantify **of** the…"	Suggested correction	Yes	
Page 4		Remove last bullet.	Yes	
Page 16, 2nd paragraph		Edit 6% by removing the space in between the number and the sign.	Yes	

Page / Section	Report statement	Comments	Changes made	Author comment
Page 16 and 17		Numbering error, 4.1.2, 4.1.3, 4.1.4?	Yes	
Table 4.14		Previously zones were labelled A, B and C but now column 4 refers to Lower, Middle and Upper; maintain one to avoid confusion.	Yes	
Page 32 par 2 refer to (figure 4-2),		This appears on the electronic version but not on the printed one: **Error! Reference source not found**" please ensure that the final report does not print this way.	Yes	
Page 38	"….sloping sand**-** and mud banks" "…the best nursery **are** would…"	Suggested correction	Yes	
Page 38	Sentence above table 4.33 "….changes compared to reference conditions **are** given…"	Suggested correction	Yes	