# AN INTERMEDIATE ECOLOGICAL RESERVE DETERMINATION STUDY OF THE EAST KLEINEMONDE ESTUARY

**2008**

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# EXECUTIVE SUMMARY

The findings of the East Kleinemonde Intermediate Ecological Reserve Determination Study are presented. The study was undertaken for the Resource Directed Measures Chief Directorate, Department of Water Affairs and Forestry (DWAF) as part of a Water Research Commission project (K5/1581) on temporarily open/closed estuaries in the Eastern and Western Cape Provinces.

The East Kleinemonde Estuary is situated approximately 15 km north east of Port Alfred. The estuary is small, shallow (1-2 m depth), approximately 120 m across at its widest section near the mouth, and has a surface area of approximately 25 ha when closed. During periods of extended mouth closure the water level can rise to about 2.3 m MSL and extensive back flooding occurs as a result of the formation of a sand berm across the mouth. However, after the mouth has opened the estuary is very shallow with a maximum depth of approximately 1 m.

Key findings of the study are summarised in the appendixes to the main report:

| | |
|---|---|
| Appendix A | Availability of data on the East Kleinemonde Estuary |
| Appendix B | Specialist report: Simulated catchment hydrology |
| Appendix C | Specialist report: Physical dynamics |
| Appendix D | Specialist report: Coastal processes and sediment dynamics |
| Appendix E | Specialist report: Water quality |
| Appendix F | Specialist report: Microalgae |
| Appendix G | Specialist report: Macrophytes |
| Appendix H | Specialist report: Macrobenthos |
| Appendix I | Specialist report: Zooplankton and hyperbenthos |
| Appendix J | Specialist report: Fish |
| Appendix K | Specialist report: Birds |
| Appendix L | Proposed changes to RDM methodology for estuaries |

## Project Team

The core specialist team responsible (component leaders indicated in bold typing) for RDM templates and attending the specialist workshop (18-19 April 2007 in Port Elizabeth) is as follows:

| Role/Expertise | Lead specialists | Contact details |
|---|---|---|
| Workshop coordination, Report preparation and Hydrodynamics | **Ms Lara van Niekerk** | CSIR, Stellenbosch, lvnieker@csir.co.za |
| Water quality | **Ms Susan Taljaard*** | CSIR, Stellenbosch, staljaar@csir.co.za |
| Sediment dynamics | **Mr Andre Theron*** | CSIR, Stellenbosch, atheron@csir.co.za |
| Microalgae | **Mr Phumelele Gama** | Nelson Mandela Metropolitan University, phumelele.gama@nmmu.ac.za |
| | Prof Guy Bate | Diatom and Environmental Management, bateg@netfocus.co.za |
| Estuarine vegetation | **Prof Janine Adams** | Nelson Mandela Metropolitan University, janine.adams@nmmu.ac.za |
| Invertebrates | **Prof Tris Wooldridge** | Nelson Mandela Metropolitan University, tris.wooldridge@nmmu.ac.za |
| | **Prof William Froneman*** | Rhodes University, W.Froneman@ru.ac.za |
| Fish | **Dr Paul Cowley** | South African Institute of Aquatic Biodiversity, P.Cowley@ru.ac.za |
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| Birds | **Dr Jane Turpie** | Anchor Environmental Consultants, jane.turpie@botzoo.uct.ac.za |

** Did not attend RDM specialists workshop*

The following persons formed part of the project team to support capacity building in the application of Ecological Reserve determinations on estuaries:

| Person | Role/ expertise | Contact details |
|---|---|---|
| Mr Gavin Snow | Microalgae | Nelson Mandela Metropolitan University,<br>gavin.snow@nmmu.ac.za |
| Ms Taryn Riddin | Estuarine vegetation | Nelson Mandela Metropolitan University,<br>triddin@isat.co.za |
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| Mr Lukhanyiso Vumazonke | Invertebrates | South African Institute of Aquatic Biodiversity,<br>l.vumazonke@ru.ac.za |
| Dr Nadine Strydom | Ichthyoplankton | South African Institute of Aquatic Biodiversity,<br>N.Strydom@ru.ac.za |
| Ms Nicola James | Fish | SAEON Elwandle Node,<br>nikkij@saeon.ac.za |
| Ms Anja Terörde | Birds | University of Cape Town,<br>Anjater@yahoo.de |

Other parties present at the Estuarine Specialist Workshop, held in Port Elizabeth on 18 and 19 April 2007:

| Person | Affiliation/role | Contact details |
|---|---|---|
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| Ms Nicolette Demetriades | Marine and Estuarine Research | nicolette@mer.co.za |

## Overview of the Process on the Determination of the Ecological Reserve for Estuaries

The preliminary determination of the Ecological Reserve can be conducted on different levels, namely:

- Comprehensive
- Intermediate
- Rapid.

The procedures are discussed in detail in *Resource Directed Measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004). A summary of the procedures used for the Intermediate Ecological Reserve Determination for estuaries are illustrated in Figures 1.1 and 1.2 of this report. Based on the available information and expertise, the study on the East Kleinemonde Estuary was conducted at the Intermediate level.

## Assumptions and Limitations

The following assumptions and limitations must be taken into account when assessing the outcomes of this study:

- The hydrological data were provided to the estuarine team by Prof D A Hughes of the Institute for Water Research. Confidence in these data sets was low because runoff data were not available for the calibration of the simulated runoff scenarios.

- The accuracy of predicted Abiotic States for the East Kleinemonde Estuary and the occurrence of these states under Reference Conditions, Present State and Future Scenarios depends largely on the accuracy of the simulated runoff data and the number of observed breaching and closing events recorded during the study.

Criteria for the confidence limits attached to statements in this study are as follows:

| Limit | Degree of confidence |
|---|---|
| Low | If no data were available for the estuary or similar estuaries (i.e. < 40%) |
| Medium | If limited data were available for the estuary or other similar estuaries (i.e. 40% – 80%) |
| High | If sufficient data were available for the estuary (i.e. > 80%) |

## Geographical boundaries

For the purposes of the Ecological Reserve determination for the East Kleinemonde Estuary the geographical boundaries are defined as follows (WGS84):

- **Downstream boundary:** Estuary mouth (33° 32’ 23.76” S, 27 03’ 00.32” E)

- **Upstream boundary:** Approximately 4 km upstream of the mouth (33° 31’ 21.38” S, 27° 01’ 27.53” E).

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

Map of the East Kleinemonde Estuary (Source: Google Earth).

### 3.2.1 Present Ecological Status (PES)

The Estuarine Health Index (EHI) scores allocated to the East Kleinemonde Estuary (Present State) were:

| Variable | Weight % | Score | Weighted score |
|---|---|---|---|
| Hydrology | 25 | 95 | 24 |
| Hydrodynamics and mouth condition | 25 | 90 | 23 |
| Water quality | 25 | 78 | 20 |
| Physical habitat alteration | 25 | 85 | 21 |
| **Habitat health score** | | | **87** |
| Microalgae | 20 | 80 | 16 |
| Macrophytes | 20 | 85 | 17 |
| Invertebrates | 20 | 90 | 18 |
| Fish | 20 | 90 | 18 |
| Birds | 20 | 85 | 17 |
| **Biotic Health Score** | | | **86** |
| **Estuarine Health score** | | | **87** |

The Estuarine Health Index score for the East Kleinemonde Estuary, based on its Present State, is 87, translating into a **Present Ecological Status** of a **B+** as indicated below:

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

Although the Present Ecological Status of the East Kleinemonde Estuary is a high B, the system is on a **trajectory of change downwards**. At the specialist workshop it was noted that an increase in fishing pressure, nutrient input from the catchment and septic tanks, riparian developments, noise disturbance and loss of aquatic habitat due to boating are influencing the system negatively.

The Estuarine Importance scores allocated to the East Kleinmonde Estuary Turpie (2002, 2004), were as follows:

| Criterion | Weight | Score | Weighted score |
|---|---|---|---|
| Estuary Size | 15 | 70 | 11 |
| Zonal Rarity Type | 10 | 10 | 1 |
| Habitat Diversity | 25 | 90 | 23 |
| Biodiversity Importance | 25 | 84 | 21 |
| Functional Importance | 25 | 60 | 15 |
| **Estuarine Importance Score** | | | **70** |

The Functional Importance of the East Kleinemonde on a regional scale is estimated to be 60, since significant amounts of organic material generated in the estuary during the closed phase are exported to the nearshore during the open phase. The overall **Estuarine Importance Score**, based on its Present State is **70**, thus indicating that the estuary is important, as indicated below:

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

### Recommended ecological category for East Kleinemonde Estuary

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

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

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

The minimum Ecological Reserve Category is determined by the Present Ecological Status. The degree to which the Ecological Category needs to be elevated above the Present Ecological Status depends on the level of **importance** and the level of **protection** or **desired protection** of a particular estuary (see below).

| Current/desired protection status and estuary importance | Recommended Ecological Reserve Category | Policy basis |
|---|---|---|
| Protected area | A or BAS* | Protected and desired protected areas should be restored to and maintained in the best possible state of health |
| Desired Protected Area | | |
| Highly important | PES + 1, min B | Highly important estuaries should be in an A or B class |
| Important | PES + 1, min C | Important estuaries should be in an A, B or C class |
| Of low to average importance | PES, min D | The remaining estuaries can be allowed to remain in a D class. |

* BAS = Best Attainable State

The East Kleinemonde Estuary is been targeted as a Desired Protected Area by the C.A.P.E. Estuaries Conservation Plan for the temperate areas of South Africa (Turpie and Clarke 2007). According to the guidelines for assigning a recommended Ecological Reserve Category, the estuary should be classified as a Category A or the Best Attainable State (BAS).

At the specialist workshop it was concluded that the changes currently contributing to the Present State of the estuary are related to flow reduction, fishing pressures, human disturbance around the estuary and nutrient loading from the catchment.

The East Kleinemonde Estuary is very vulnerable to non-flow related activities such as fishing, power boating and nutrient loading. The present level of urban development around the estuary acts as a constraint and prevents the system from being rehabilitated to a Category A. Thus, the workshop concluded that the recommended ERC for the East Kleinemonde Estuary be a **Category B,** i.e. at least maintain the Present Ecological Status.

### Quantification of Ecological Reserve Scenarios

A summary of the suite of future runoff scenarios, evaluated as part of this project, as well as the Reference and Present flow scenarios (provided by Prof D A Hughes, Institute for Water Research, Rhodes University), is presented below.

| **Name** | **Description** | **MAR (million $m^3$/annum)** | **Percentage Retained** |
|---|---|---|---|
| **Reference** | Reference | 2.856 | 100.0 |
| **Present** | Present Flows | 2.748 | 96.2 |
| **Future Scenario 1** | Dam Development (excluding an increase in non-flow related anthropogenic activities) | 2.409 | 84.3 |
| **Future Scenario 2** | Off-channel intermittent abstraction (excluding an increase in non-flow related anthropogenic activities) | 2.575 | 90.1 |
| **Future Scenario 3** | Similar to Scenario 2, factoring in other non-flow related anthropogenic activities. | 2.575 | 90.1 |
| **Future Scenario 4** | Similar to Scenario 2, factoring in other non-flow related anthropogenic activities, but mitigating for the increase in waste water and stormwater runoff | 2.575 | 90.1 |

The Present State of development represents a situation that has 300 residential plots that are supplied with water from the Wellington Dam (capacity: 0.206 x $10^6$ $m^3$) supplemented by borehole water. The Wellington Dam is situated on a tributary of the East Kleinemonde River that draws from approximately 9% of the total catchment area of the East Kleinemonde system.

Details on the four simulated Future Scenarios are as follows:

- Future Scenario 1: This comprises 1010 developed residential plots with the water supply originating from a new dam to be constructed on the main river. The assumption is that the sub-catchment feeding the dam represents about 67% of the total catchment area with the capacity of the dam being determined appropriately, given the patterns of inflow and the demand. Based on this future housing development scenario, the maximum recommended percentage of the MAR impounded increases from approximately 4% (Present) to almost 16%.

- Future Scenario 2: Development plans envisage 1010 developed residential plots with the water supply originating from an off-channel reservoir fed by intermittent pumping from the main river on demand from a suitable weir the size and construction of which is to be determined. The assumption is that pumping will remove most of the water from the river during low flow periods but will have little impact on the short-duration higher flows that have most influence on estuary function. Evaporative loss from a dam will be eliminated in this scenario.

- Future Scenario 3: Similar to Scenario 2, but also including all other non-flow related anthropogenic activities associated with the new developments (e.g. increased fishing pressures, power boating, human disturbance, seepage from septic tanks, storm water runoff).

- Future Scenario 4: Similar to Scenario 3, but mitigating for the increase in municipal waste water and storm water runoff from the new developments.

The individual Estuarine Health Index (EHI) scores, as well as the corresponding Ecological Reserve Category for the various scenarios, were calculated according to EHI methodology and are shown in the following table:

| Variable | Weight | Present | Future Runoff Scenario | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| Hydrology | 25 | 95 | 93 | 93 | 93 | 93 |
| Hydrodynamics/mouth condition | 25 | 90 | 80 | 85 | 85 | 85 |
| Water quality | 25 | 78 | 80 | 79 | 64 | 79 |
| Physical habitat alteration | 25 | 85 | 85 | 85 | 76 | 76 |
| **Habitat Health Score** | **50** | **87** | 85 | 86 | 68 | 71 |
| Microalgae | 20 | 80 | 80 | 80 | 65 | 80 |
| Macrophytes | 20 | 85 | 81 | 83 | 60 | 70 |
| Invertebrates | 20 | 90 | 85 | 80 | 60 | 70 |
| Fish | 20 | 90 | 80 | 85 | 60 | 62 |
| Birds | 20 | 85 | 82 | 85 | 55 | 57 |
| **Biotic Health Score** | **50** | **86** | **82** | **83** | **49** | **56** |
| **Estuarine Health Index Score** | | **87** | **83** | **84** | **58** | **64** |
| **Ecological Reserve Category (ERC)** | | **B** | **B** | **B** | **D** | **C** |

### Recommended ecological flow requirement for East Kleinemonde Estuary

The evaluation of the simulated runoff scenarios was used to derive the recommended Ecological Flow Requirement. The recommended Ecological Flow Requirement is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended ERC.

In evaluating Future Scenarios 1 and 2, the assumption was made that only river in-flow from the catchments will be reduced and that all additional non-flow related anthropogenic activities (e.g. increased fishing and bait collection, power boating, human disturbance, seepage from septic tanks, stormwater runoff) will not be considered. Future Scenario 3 represents the expected impact of flow reduction and additional non-flow related anthropogenic activities on the estuary if 1010 residential plots are developed in the estuarine environs. Scenario 4 represents the expected impact of flow reduction and additional non-flow related anthropogenic activities, but mitigating for the impact of nutrient loading as a result of seepage from septic tanks and pollutants from storm water runoff.

Both Scenario 1 and Scenario 2 will maintain the East Kleinemonde in the recommended ERC, as there is very little reduction in runoff and impact on the estuarine ecosystem. **Scenario 2** was selected as the recommended Ecological Flow Requirement because Scenario 1 (which includes an in-channel dam development) represents a serious risk to migratory species (e.g. eels) that use the river as a conduit to the upper catchment. Dams act as permanent barriers to fish migration and negatively influence river ecosystems by changing the downstream flow regime.

**East Kleinemonde: Summary of flow distribution (mean monthly flows in $m^3\ s^{-1}$) under Future Scenario 2**

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.765 | 1.183 | 0.665 | 0.245 | 0.803 | 1.524 | 1.023 | 2.702 | 1.127 | 0.931 | 0.958 | 1.513 |
| 90%ile | 0.240 | 0.236 | 0.162 | 0.074 | 0.052 | 0.184 | 0.205 | 0.152 | 0.200 | 0.113 | 0.103 | 0.230 |
| 80%ile | 0.117 | 0.074 | 0.065 | 0.012 | 0.019 | 0.081 | 0.064 | 0.051 | 0.039 | 0.025 | 0.037 | 0.065 |
| 70%ile | 0.064 | 0.047 | 0.023 | 0.004 | 0.006 | 0.027 | 0.043 | 0.019 | 0.010 | 0.009 | 0.017 | 0.029 |
| 60%ile | 0.024 | 0.027 | 0.008 | 0.001 | 0.002 | 0.010 | 0.025 | 0.007 | 0.004 | 0.003 | 0.008 | 0.010 |
| 50%ile | 0.010 | 0.016 | 0.003 | 0.000 | 0.000 | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 |
| 40%ile | 0.003 | 0.005 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 30%ile | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

When implementing the recommended ERC (Scenario 2) in future, the following should be noted:

The selection of Scenario 2 means that although the East Kleinemonde is a small temporarily open/closed estuary, it can accommodate the reduction in fluvial flow necessary to meet the requirements of future housing development in the area. However, it will not be able to support the additional non-flow related human disturbance pressures that will be associated with the planned residential developments. Therefore the approval of any future residential developments should be conditional on the following mitigation measures being implemented:

- No consumptive use (e.g. fishing or bait collection) should be allowed in the East Kleinemonde Estuary;
- No power boating on the East and West Kleinemonde estuaries (only canoes and electric motors to be allowed);
- All new urban developments will have to be connected to a Waste Water Treatment Works to eliminate the risk of seepage from septic tanks entering the estuary;
- Storm water run-off from newly developed areas will have to be captured and diverted from the system to prevent hydrocarbons and other pollutants from entering the system.

In order to maintain the estuary in its present state, consumptive use (exploitation) of marine living resources needs to be managed. Because the system is relatively small, there is no optimum zonation scheme that can accommodate this requirement, e.g. white steenbras occur predominantly below the road bridge in the sandy areas while other species occur above the bridge. Zoning to protect one fish species will make others more vulnerable, since it will lead to increased fishing pressure in other parts of the estuary. Serious concern was also raised over habitat destruction caused by bait collection since the areas where bait species occur are limited. Thus, the only effective mitigation measure in response to increased development in the environs of the East Kleinmonde is to close it for all consumptive uses.

Power boating in small estuaries causes habitat destruction (mainly as a result of bank erosion from boat wakes), pollution (antifouling paints and oils), disturbs the feeding and breeding of birds, and significantly disturbs fish (especially small fish in shallow areas). It is, therefore, recommended that power boating be banned from both the East and West Kleinemonde as they are similar in size and closure of one is likely to double the boating pressures on the adjacent system. Larger, permanently open estuaries such as the nearby Kowie and Kariega are much more resilient with respect to the impacts of power boating and are safer systems to use by virtue of their size.

At present, septic tanks are used for the treatment of domestic wastewater (sewage) at Kleinemonde. Although the use of French drains and septic tanks, and absence of sewage treatment plants may be acceptable options for smaller communities, these options are usually not acceptable for larger human settlements. The risk of impact on water resources, associated with spillages and seepage, increases markedly with the increase in the number and density of housing developments. Adverse impacts associated with sewage spillages and seepage include eutrophication (e.g. excessive reed growth along the banks of the estuary) and human health risks (e.g. associated with contract recreation activities). South Africa does not have clear guidelines on this matter, but internationally it has become common practice to provide a collecting system to communities (including coastal communities) with a service population greater than about 2 000 (RSA DWAF, 2004). It is therefore strongly recommended that any new residential development in the East Kleinemonde Estuary consider wastewater collection systems connected to either a conventional existing WWTW or an alternative treatment facility (e.g. artificial wetland).

Increased development (and an increase in hard surfaces) will also increase stormwater runoff into the estuary with likely increases of hydrocarbons, nutrients, turbidity and other pollutant loads. It is proposed that for any new development, the developer be made responsible for managing storm water run-off whereby, for example, the storm water run-off from a new development is contained and treated at central points before discharge into the environment (e.g. Thesen Island Development, Knysna).

The West Kleinemonde Estuary is similar in size to the East Kleinemonde and would therefore also be very vulnerable to increased urban development. This matter needs to be investigated before new developments in the area are approved. In future, RDM determinations should incorporate a regional assessment component to address the impact of development on adjacent systems.

# TABLE OF CONTENTS

# LIST OF APPENDICES

# LIST OF FIGURES

# LIST OF TABLES

# TERMINOLOGY AND ACRONYMS

| | |
|---|---|
| BAS | Best Attainable State |
| DEAT | Department of Environmental Affairs and Tourism |
| DIN | Dissolved Inorganic Nitrogen |
| DIP | Dissolved Inorganic Phosphate |
| DM | Dry Mass |
| DO | Dissolved Oxygen |
| DRS | Dissolved Reactive Silicate |
| DWAF | Department of Water Affairs and Forestry |
| EHI | Estuarine Health Index |
| ERC | Ecological Reserve Category |
| ICE | Intermittently Closed Estuary |
| IOE | Intermittently Open Estuary |
| MAR | Mean Annual Runoff |
| MCM | Marine and Coastal Management |
| MPB | Microphytobenthos |
| MSL | Mean Sea Level |
| NMMU | Nelson Mandela Metropolitan University |
| PES | Present Ecological Status |
| POM | Particulate Organic Matter |
| PS | Present State |
| RC | Reference Condition |
| RDM | Resource Directed Measures |
| REI | River Estuary Interface |
| RQO | Resource Quality Objectives |
| RU | Rhodes University |
| SAIAB | South African Institute for Aquatic Biodiversity |
| TOCE | Temporarily Open/Closed Estuary |

# 1 Introduction

## 1.1 Background

The findings of the East Kleinemonde Intermediate Ecological Reserve Determination Study are presented in this report. The study was undertaken for the Resource Directed Measures Chief Directorate, Department of Water Affairs and Forestry (DWAF) as part of a Water Research Commission project on Intermittently Open Estuaries (K5/1581).

## 1.2 Project Team

The core specialist team responsible (component leaders indicated in bold typing) for RDM templates and attending the specialist workshop (18-19 April 2007 in Port Elizabeth) is as follows:

| Role/Expertise | Lead specialists | Contact details |
|---|---|---|
| Workshop coordination, Report preparation and Hydrodynamics | **Ms Lara van Niekerk** | CSIR, Stellenbosch, lvnieker@csir.co.za |
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** Did not attend RDM specialists workshop*

The following persons formed part of the project team to support capacity building in the application of Ecological Reserve determinations on estuaries:

| Person | Role/ expertise | Contact details |
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| Mr Gavin Snow | Microalgae | Nelson Mandela Metropolitan University, gavin.snow@nmmu.ac.za |
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| Mr Lukhanyiso Vumazonke | Invertebrates | South African Institute of Aquatic Biodiversity, l.vumazonke@ru.ac.za |
| Dr Nadine Strydom | Ichthyoplankton | South African Institute of Aquatic Biodiversity, N.Strydom@ru.ac.za |
| Ms Nicola James | Fish | SAEON Elwandle Node, nikkij@saeon.ac.za |
| Ms Anja Terörde | Birds | University of Cape Town, Anjater@yahoo.de |

## 1.3 Overview of Determination of Ecological Reserve for Estuaries: Process

The preliminary determination of the Ecological Reserve can be conducted on different levels, namely:

- Comprehensive
- Intermediate
- Rapid.

The procedures are discussed in detail in *Resource Directed Measures for Protection of Water Resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004). A summary of the procedures used for the Intermediate Preliminary Ecological Reserve Determination for estuaries are illustrated in the Figures 1.1 and 1.2 below:

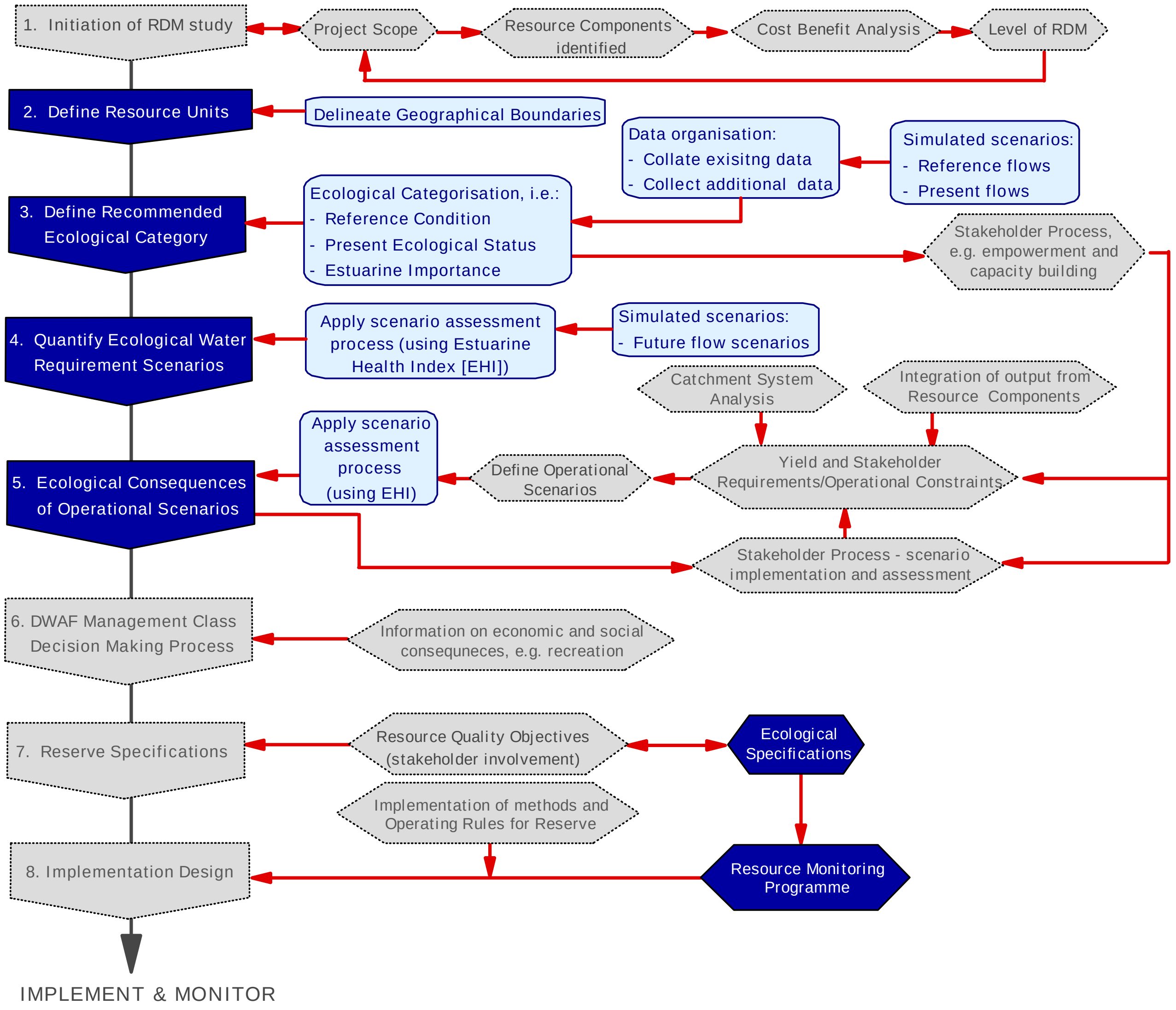


**Figure 1.1. Procedures for an Intermediate Ecological Reserve determination on estuaries, in context of the broader RDM process (components not addressed as part of the Ecological Reserve determination process are indicated by hatched line boxes) (DWAF, 2004)**

A summary of the human resources required to conduct an Intermediate Reserve level determination of the preliminary Ecological Reserve for estuaries are illustrated in Figure 1.2.

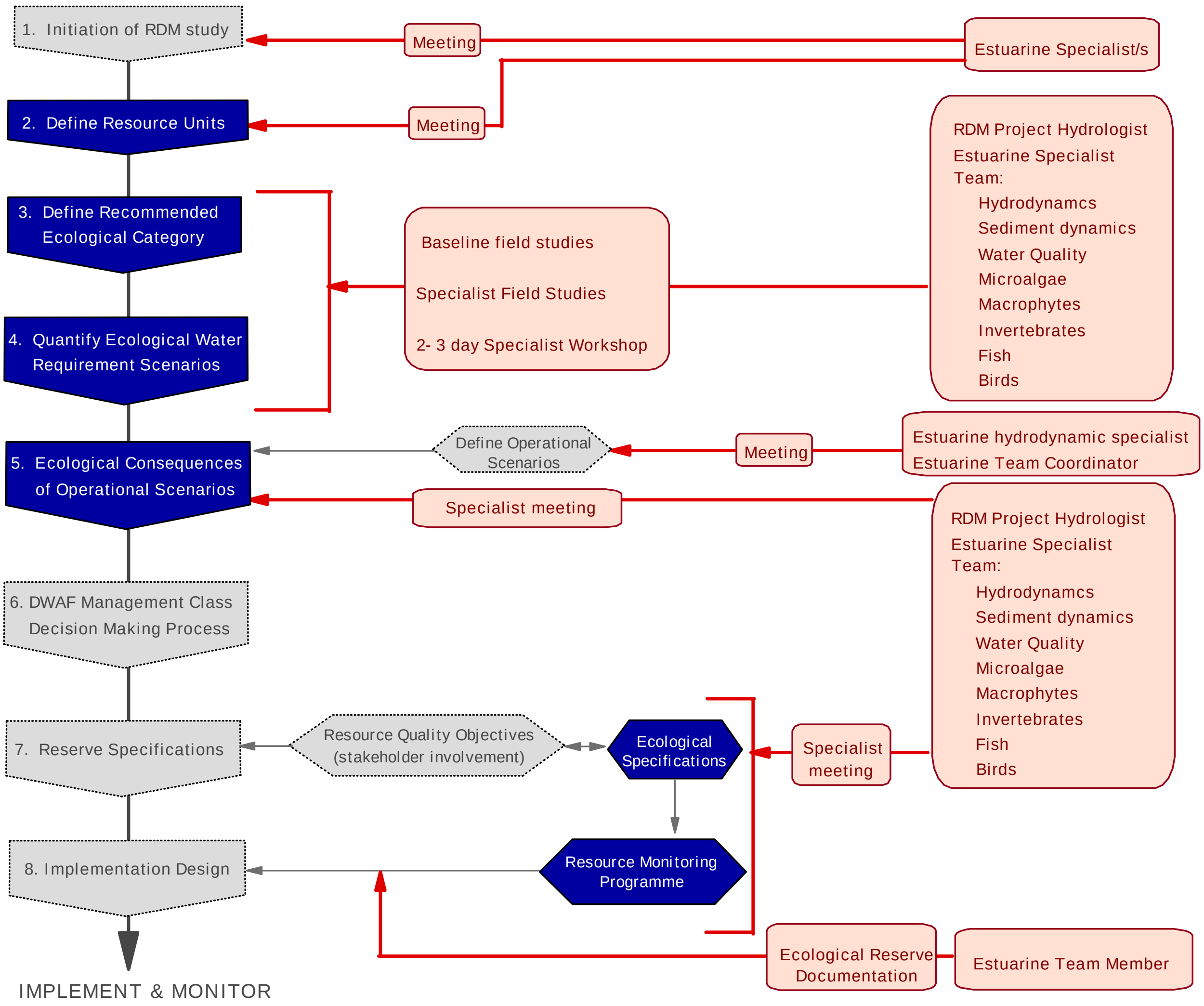


**Figure 1.2 Indication of human resource requirements for an intermediate Ecological Reserve determination on estuaries (DWAF, 2004).**

## 1.4 Assumptions and limitations for this study

The following assumptions and limitations must be taken into account:

- The hydrological data were provided to the estuarine team by Prof D A Hughes of the Institute for Water Research. Confidence in these data sets was low since runoff data were not available for the calibration of the simulated runoff scenarios.
- The accuracy of predicted Abiotic States for the East Kleinemonde Estuary and the occurrence of these states under Reference Conditions, Present State and Future Scenarios depend~~s~~ largely on the accuracy of the simulated runoff data and the number of observed breaching and closing events recorded during the study.

### 1.5 Confidence limits

Criteria for the confidence limits attached to statements in this study are as follows:

| Limit | Degree of confidence |
|---|---|
| Low | If no data were available for the estuary or similar estuaries (i.e. < 40%) |
| Medium | If limited data were available for the estuary or other similar estuaries (i.e. 40% – 80%) |
| High | If sufficient data were available for the estuary (i.e. > 80%) |

## 2 Description of the Resource Unit

The East Kleinemonde Estuary is situated approximately 15 km north east of Port Alfred. The estuary is small with a surface area of approximately 25 ha when closed. The system is navigable to small craft for approximately 3 km and is approximately 120 m across at its widest section near the mouth. It is shallow with the water depth varying between 1 and 2 m in the deeper sections. During periods of extended mouth closure the water level can rise to about 2.3 m MSL and extensive back-flooding occurs as a result of the formation of a sand berm across the mouth. However, after the mouth has opened the estuary is very shallow with a maximum depth of approximately 1m.

For the purposes of this Ecological Reserve determination for the East Kleinemonde Estuary the geographical boundaries are defined as follows (Figure 2.1) (WGS84):

- **Downstream boundary:** Estuary mouth (33° 32’ 23.76” S, 27 03’ 00.32” E)
- **Upstream boundary:** Approximately 4 km upstream of the mouth (33° 31’ 21.38” S, 27° 01’ 27.53” E).
- **Lateral boundaries:** 5 m contour above MSL along the banks, a delineation that can be readily referenced from an ortho-photograph of the area.

Figure 2.1. Map of the East Kleinemonde Estuary (Source: Google Earth).

# 3 Ecological Reserve Categorisation

## 3.1 Typical Abiotic States

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

| | |
|---|---|
| State 1: Intermittently open/closed driven by high flow events | Flow Volume > 0.3 x $10^6$ $m^3$ |
| State 2: Intermittently open/closed driven by persistent low flow periods | Flow Volume < 0.3 x $10^6$ $m^3$ and cumulative inflows > 0.3 x $10^6$ $m^3$ |
| State 3: Closed Mouth | Flow Volume < 0.3 x $10^6$ $m^3$ and cumulative inflows < 0.3 x $10^6$ $m^3$ |

The transitions between the different states will not be instantaneous, but will take place gradually. Breaching can occur due to a slow increase in water level or due to a freshet (> 0.3 x $10^6$ $m^3$) filling up the estuary and triggering a breaching event.

A simple basin model was therefore developed in which river inflows into the estuary were accumulated to estimate the volume in the system. The volume, in turn was used to evaluate probable mouth conditions and the salinity regime of the system.

Assumptions and limitation of the water balance model:

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

- The water balance model was validated against Dr P Cowley's mouth observations for the period 1993 to 2002. Based on the data set, breachings occurred in 2 to 3 months of the year on average.

- The East Kleinemonde Estuary's breaching levels varied between 1.5 m MSL and 2.2 m MSL for the period 2005 to 2006. There was a relationship between the height of the berm and periods between breachings, i.e. the longer the system was closed the higher the berm.

- The water balance model assumes that the East Kleinemonde will breach naturally at approximately 1.8 m MSL to accommodate the observed frequency of breachings.

- At a breaching level of 1.8 m MSL there is about 450 000 $m^3$ of water in the estuary.

- Mouth closure occurred between 0.5 m MSL and 1.0 m MSL. Tidal action can still contribute to the volume of water behind the berm at levels up to 1.3 m MSL. For the purpose of the water balance model mouth closure was taken to occur at a water level of ~0.9 m MSL which relates to a volume of about 150 000 $m^3$.

- Seepage is estimated to be ~ 0.02 $m^3$ $s^{-1}$ to 0.01 $m^3$ $s^{-1}$, depending on the water level in the estuary behind the berm. It was assumed that losses due to seepage were cancelled out by the fact that sea water overwash was not included in the model, that breaching levels vary by more than 0.7 m and that there is a low confidence in the river inflow scenarios.

- The overwash state was not included in the water balance model as overwash events remain a constant, i.e. sea conditions do not change. As the system remains closed for somewhat longer periods under the Future Scenarios, overwash may be slightly reduced under Scenario 1 and 2.

***Abiotic State 1: Intermittently open/closed (high flow)***

***Typical flow patterns***: Average monthly inflow volume greater than 0.3 x $10^6$ $m^3$.

*Confidence: Medium*

***State of the mouth:*** The mouth is intermittently open varying from 1-28 days at a time depending on the inflow volume.

*Confidence: Medium*

***Flood plain inundation patterns:*** This state does not result in inundation of the flood plain, except under flood conditions for short periods at a time (during the peak flood event).

*Confidence: Medium*

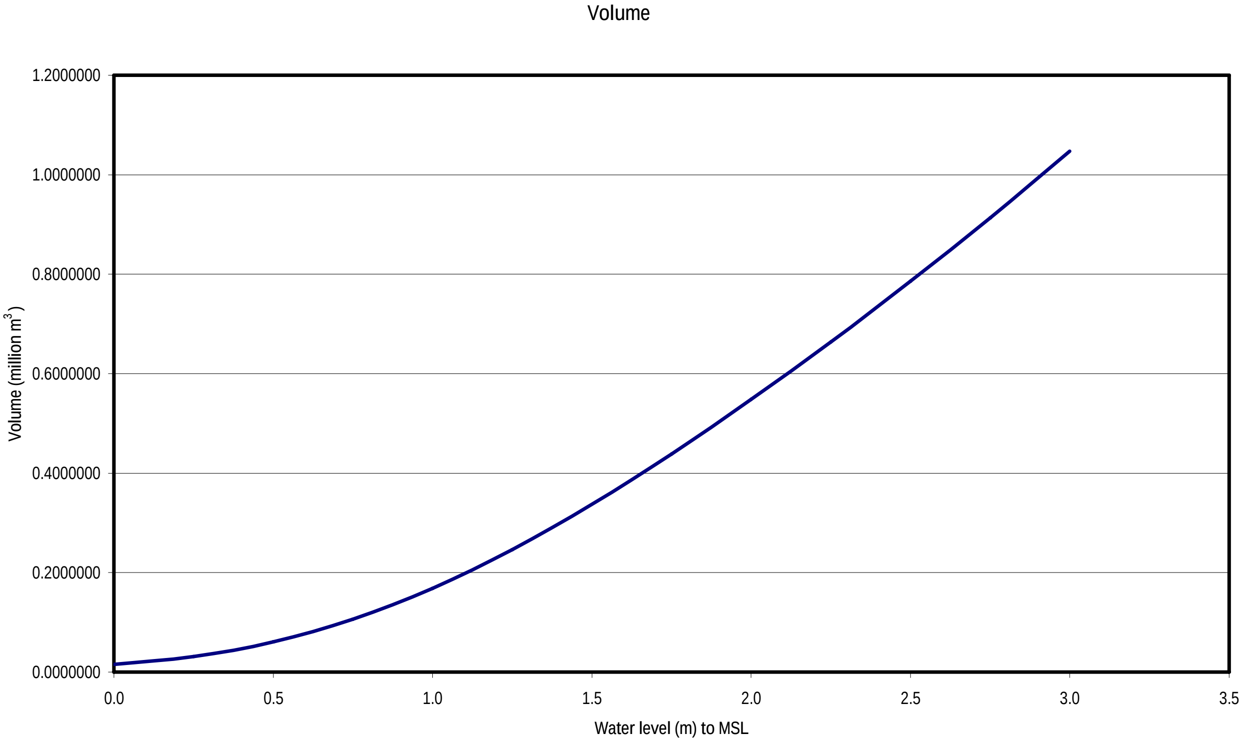
***Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide):*** Tidal variation will only occur during the intermittently open days (1-28 days at a time). When open, a tidal variation range of between 0.1 and 1.0 m has been recorded for the East Kleinemonde (DWAF water level recorder).

*Confidence: Medium*

***Retention times of water masses:*** During the open phase retention time is probably of very short duration (less than one day). Retention times during the intermittently closed state depend on duration of closure.

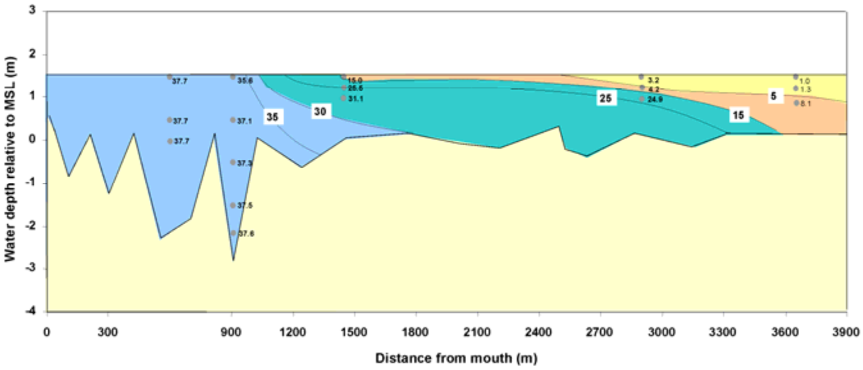
*Confidence: Medium*

***Total volume:*** Between 0.031 x $10^6$ $m^3$ (at 0 m to MSL) and 0.25 x $10^6$ $m^3$ (at 1.25 m to MSL)



*Confidence: Medium*

***Salinity distributions in the estuary:*** This state is driven by a high flow event and the system will initially be flushed, reverting to a strong marine influence within a day, but leaving a significant plug of freshwater in the upper reaches. The resultant salinity distribution during this state is therefore considered to be as follows:



*Confidence: Medium*

---

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

Temperature: Mainly seasonally driven with summer temperature usually between 20 and 25°C and winter temperature typically between 13 and 20 °C.

pH: Range between 7.7 and 8.3

Dissolved oxygen: The system is expected to remain well oxygenated with DO levels not dropping below 4 mg $\ell^{-1}$ (during this state the estuary is not likely to be closed for extended periods).

Turbidity: Turbidity in the system is variable with a median concentration of 36 NTU during intermittently open periods. On occasions, turbidity levels have spiked to values greater than 100 NTU during intermittently open periods. This is attributed to the stronger riverine influence (generally higher turbidity) during the open state, as well as stronger water turbulence (strong tidal exchange) that may resuspend bottom sediments within the estuary.

*Confidence: Medium*

---

***Nutrients:*** Dissolved inorganic nitrogen (DIN, mainly present as $NO_3$-N) concentrations in river inflow during high flow events are exceptionally high under the Present State (> 2500 µg $\ell^{-1}$ - based on data collected during September 2006), associated with anthropogenic inputs (e.g. agricultural fertilizers). These concentrations were probably much lower under the Reference Condition (100-200 µg $\ell^{-1}$). DIN concentrations of seawater entering the system are about 160µg $\ell^{-1}$.

Under the Reference Condition, DIN concentrations in the system were re-set to around 100-200 µg $\ell^{-1}$ every time the mouth opened (because DIN concentrations in the river and sea source waters were similar), with water column primary production reducing DIN stocks during the intermittently closed periods. However, under the Present State, DIN concentrations in the upper reaches (low salinity areas) are probably re-set to around 1500–2500 µg $\ell^{-1}$ (because DIN concentrations in river inflows are an order of magnitude higher than under the Reference Condition) every time the system opens, with re-setting concentration in the lower reaches remaining similar to that of the Reference Condition (100-200 µg $\ell^{-1}$) (seawater concentrations have probably not been modified).

Dissolved inorganic phosphate (DIP) concentrations in both river inflow and seawater entering the system are relatively low, being with the range 20–30 µg $\ell^{-1}$. During this state, DIP concentrations in the system are re-set to 20-30 µg $\ell^{-1}$ every time the mouth opens, with DIP stocks being reduced by water column primary production during the intermittently closed periods.

Dissolved reactive silicate (DRS) concentrations in river inflow and seawater entering the system are about 7000 and 500 µg ℓ$^{-1}$, respectively. During this state, DRS concentrations in the upper reaches (low salinity areas) are probably re-set to around 5000–7000 µg ℓ$^{-1}$ (because DIN concentrations in river inflows are high) every time the system opens, with re-setting concentrations in the lower reaches of around 500 µg ℓ$^{-1}$ DRS stocks may also be reduced during the closed period, e.g. due to diatom productivity.

*Confidence: Low/Medium*

### *State 2: Intermittently open/closed (low flows)*

***Typical flow patterns***: Average monthly inflow volume less than 0.3 x 10$^{6}$ m$^{3}$ but cumulative inflows greater than 0.3 x 10$^{6}$ m$^{3}$

*Confidence: Medium*

***State of the mouth:*** The mouth is intermittently open varying from 1-3 days at a time.

*Confidence: Medium*

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

*Confidence: Medium*

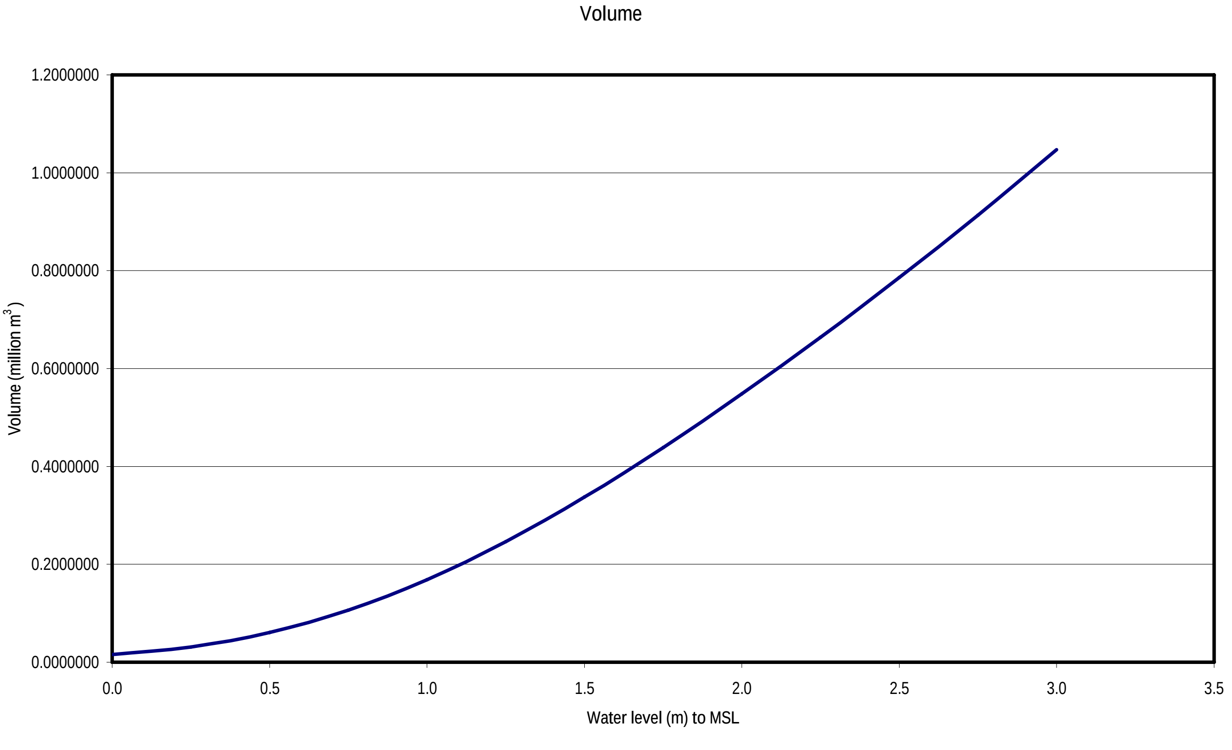
***Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide):*** Tidal variation will only occur during the intermittently open days (1-3 days at a time). When open, a tidal variation of between 0.1 and 0.7 m has been recorded for the East Kleinemonde.

*Confidence: Medium*

***Retention times of water masses:*** During the open days, retention time is probably very short (less than one day). Retention times during the intermittently closed state depend on duration of closure.

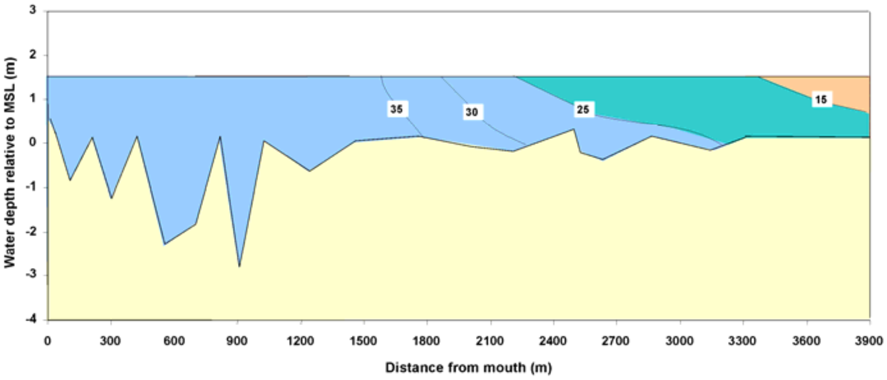
*Confidence: Medium*

***Total volume:*** Between 0.031 x 10$^{6}$ m$^{3}$ (at 0 m to MSL) and 0.25 x 10$^{6}$ m$^{3}$ (at 1.25 m to MSL)



*Confidence: Medium*

***Salinity distributions in the estuary:*** Breaching during this state is driven by periods of extended low river inflow. When it breaches the system is therefore still estuarine (~15 psu), but just after breaching seawater intrudes far upstream. The resultant salinity distribution during this state is therefore considered to be as follows:



*Confidence: Low*

---

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

Temperature: Mainly seasonally driven with summer temperatures typically between 20 and 25$^{o}$C and winter temperatures typically between 13 and 20 $^{o}$C.

pH: Range between 7.7 and 8.3

Dissolved oxygen: The system will tend to remain well oxygenated, with DO levels not dropping below 4 mg l$^{-1}$ (during this state the estuary is not likely to be closed for extended periods).

Turbidity: Turbidity in the system is variable with a median concentration of 36 NTU during intermittently open periods. On occasions, turbidity levels have spiked to values greater than 100 NTU during intermittently open periods. This can probably be largely attributed to stronger water turbulence (strong tidal exchange) that may resuspend bottom sediments (flow is not considered to be of a magnitude to have a significant influence on turbidity level).

*Confidence: Medium*

---

***Nutrients:*** River inflow is not expected to have a marked influence on water column nutrient concentration, except maybe in the very upper reaches. During this state, the water column is primarily flushed with fresh seawater every time the mouth opens, in the absence of strong river inflow. DIN, DIP and DRS concentrations in seawater entering this system are about 160, 20 and 500 µg $\ell^{-1}$, respectively.

During this state, therefore, DIN, DIP and DRS concentrations in the system are re-set to around 160, 20 and 500 µg $\ell^{-1}$, respectively, every time the mouth opens, with water column primary production (and possibly other biogeochemical processes) reducing stocks during the intermittently closed periods.

Note that DIN concentrations in river inflow during low flow periods are probably higher under the Present State (~500 µg $\ell^{-1}$ - extrapolating from data collected during March 2006) due to associated anthropogenic inputs (i.e. fertilizers) than under the Reference Condition (100-200 µg $\ell^{-1}$). Therefore, under the Present State, elevated DIN concentrations (~300-500 µg $\ell^{-1}$) can be present in the very upper reaches of the system even during low inflow periods (concentrations in river water are high, therefore even a small volume can result in a measurable increase).

*Confidence: Low/Medium*

### *Abiotic State 3: Closed Mouth*

***Typical flow patterns***: Average monthly inflow volume less than 0.3 x $10^6$ $m^3$ and cumulative inflows also less than 0.3 x $10^6$ $m^3$.

*Confidence: Medium*

***State of the mouth:*** The mouth is closed.

*Confidence: Medium*

***Flood plain inundation patterns:*** This state does not result in extended inundation of the flood plain. Some limited inundation of saltmarsh may occur at water levels above 1.8 m MSL.

*Confidence: Medium*

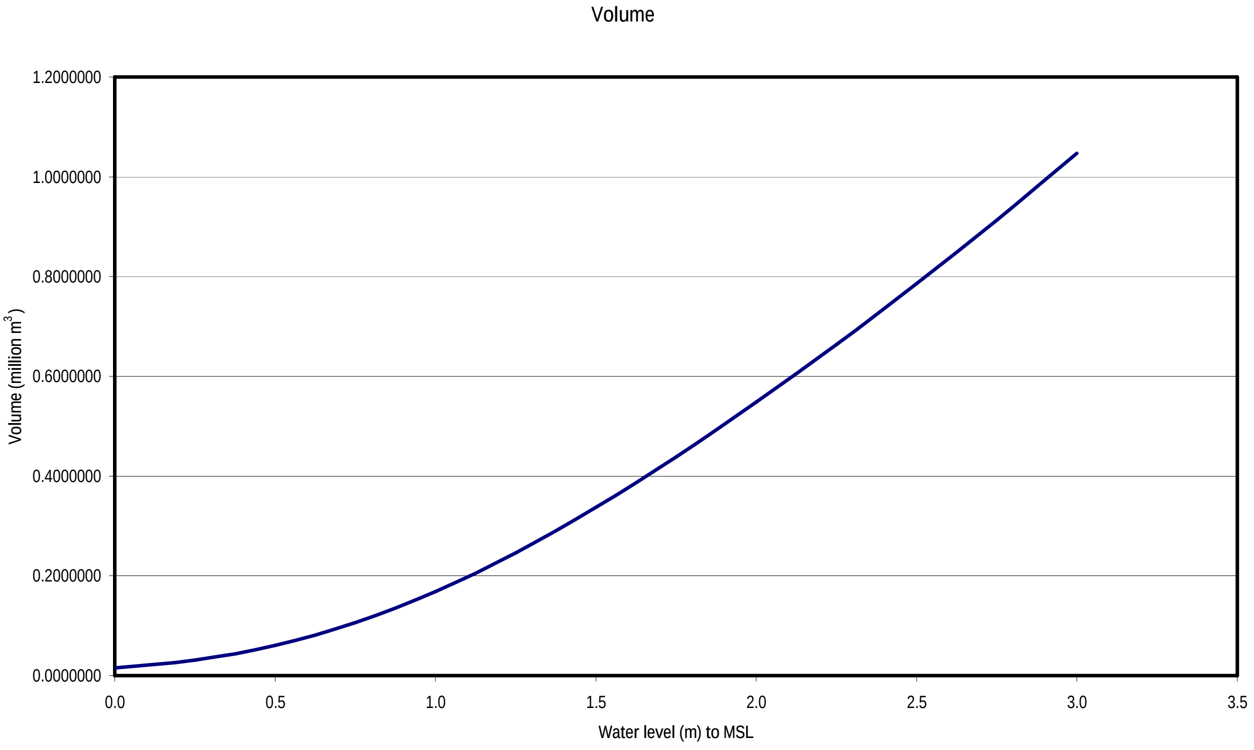
***Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide):*** No tidal variation occurs during this state. Variations in flow result in variations in water levels related to the balance between river inflow, water levels and seepage through the berm.

*Confidence: Medium*

***Retention time of water mass:*** The retention time will last as long as the mouth stays close.

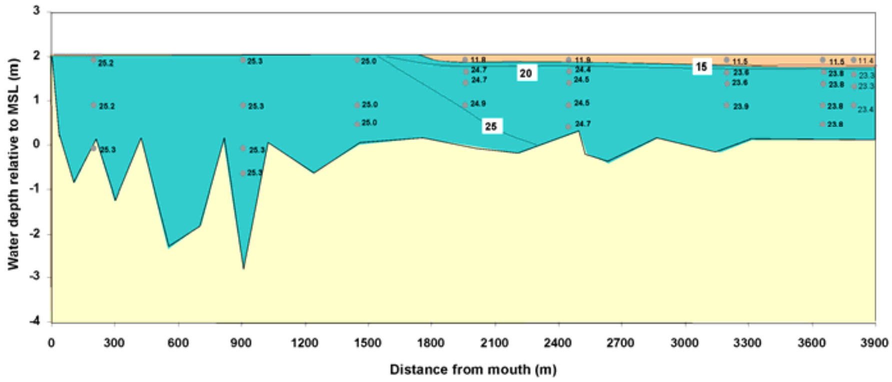
*Confidence: Medium*

***Total volume:*** Between 0.06 x $10^6$ $m^3$ (at 0.5 m to MSL) and 0.66 x $10^6$ $m^3$ (at 2.25 m to MSL)



*Confidence: Medium*

***Salinity distribution in the estuary:*** When the estuary closes it is usually saline (values > 25 psu). During periods of extended mouth closure, when river inflow is low, the system becomes relatively homogenous with salinities ranging between 25 to 15 psu. Small surface freshwater plugs can occur at times as illustrated below:



*Confidence: Medium*

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

Temperature: Mainly seasonally driven with summer temperatures typically between 20 and 25°C and winter temperatures typically between 13 and 20°C)

pH: Range between 7.7 and 8.3

Dissolved oxygen: The system is expected to be generally well oxygenated, with DO levels not dropping below 4 mg $\ell^{-1}$. However, during extended periods of closure, bottom waters (< 1m) may on occasions drop below 2 mg $\ell^{-1}$ (although this is rather the exception than the rule).

Turbidity: Turbidity in the system is variable during this state. Median concentration recorded during the closed state was 12 NTU.

*Confidence: Medium*

***Nutrients:*** During this state DIN and DIP concentrations in the system are essentially depleted, with sporadic (although limited) replenishment associated with over wash (lower reaches near the mouth) and low flows (upper surface reaches). Although a similar scenario follows for DRS, stocks are not completely depleted during this state.

*Confidence: Low/Medium*

## 3.2 Description of Present State

### 3.2.1 Abiotic Components

#### a) Seasonal variability in river inflow

Monthly simulated runoff data for the Present State is provided in Table 3.1. A summary of the flow distribution pattern (mean monthly flows in $m^3$ $s^{-1}$) for the Present State of the East Kleinemonde Estuary, derived from the 83-year simulated data set, is provided below:

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.795 | 1.191 | 0.742 | 0.313 | 0.830 | 1.531 | 1.070 | 2.753 | 1.250 | 0.961 | 0.960 | 1.538 |
| 90%ile | 0.234 | 0.232 | 0.168 | 0.093 | 0.053 | 0.173 | 0.197 | 0.157 | 0.206 | 0.117 | 0.125 | 0.225 |
| 80%ile | 0.122 | 0.079 | 0.070 | 0.024 | 0.025 | 0.082 | 0.064 | 0.055 | 0.045 | 0.041 | 0.043 | 0.079 |
| 70%ile | 0.081 | 0.052 | 0.034 | 0.009 | 0.016 | 0.027 | 0.045 | 0.021 | 0.014 | 0.018 | 0.025 | 0.033 |
| 60%ile | 0.043 | 0.034 | 0.018 | 0.004 | 0.007 | 0.014 | 0.026 | 0.010 | 0.010 | 0.007 | 0.012 | 0.019 |
| 50%ile | 0.019 | 0.020 | 0.008 | 0.002 | 0.003 | 0.008 | 0.010 | 0.005 | 0.004 | 0.004 | 0.006 | 0.010 |
| 40%ile | 0.007 | 0.016 | 0.004 | 0.001 | 0.002 | 0.003 | 0.004 | 0.002 | 0.002 | 0.001 | 0.001 | 0.005 |
| 30%ile | 0.003 | 0.006 | 0.002 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 20%ile | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

#### b) Present flood regime

The flood regime is judged to be very similar to that under reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than 0.12 $m^3$ $s^{-1}$. The 99%ile indicates that there is only a 1.8% decrease in the floods to the estuary from natural to present day flows.

*Confidence: Medium*

#### c) Present sediment processes

The hydrological data indicate that the magnitude and occurrence of major floods has hardly been reduced. This also means that the flushing of sediments during such floods has hardly been reduced. It is therefore likely that the sedimentation in the estuary is not much different from what it was under natural conditions. There may be a slight increase in erosion in the catchment due to changes in land-use.

*Confidence: Low*

**Table 3.1** Simulated monthly volumes (million m$^3$) in the East Kleinemonde Estuary for the Present State.

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breach | High Flow Breach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.15 | 0.15 | 0.20 | 0.22 | 0.23 | 0.33 | 0.15 | 0.36 | 0.39 | 0.41 | 0.43 | 0.44 | 1 | 1 |
| 1921 | 0.45 | 0.15 | 0.25 | 0.26 | 0.27 | 0.27 | 0.36 | 0.42 | 0.15 | 0.15 | 0.15 | 0.36 | 4 | 3 |
| 1922 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.19 | 0.21 | 0.23 | 0.25 | 0.32 | 0.36 | 0.37 | 5 | 4 |
| 1923 | 0.39 | 0.43 | 0.15 | 0.17 | 0.17 | 0.17 | 0.17 | 0.20 | 0.21 | 0.21 | 0.22 | 0.23 | 1 | 0 |
| 1924 | 0.23 | 0.23 | 0.33 | 0.36 | 0.36 | 0.15 | 0.33 | 0.36 | 0.38 | 0.39 | 0.39 | 0.15 | 2 | 1 |
| 1925 | 0.20 | 0.20 | 0.22 | 0.23 | 0.28 | 0.31 | 0.32 | 0.32 | 0.33 | 0.33 | 0.33 | 0.34 | 0 | 0 |
| 1926 | 0.15 | 0.25 | 0.25 | 0.25 | 0.26 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 1 | 1 |
| 1927 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.22 | 0.15 | 4 | 2 |
| 1928 | 0.15 | 0.37 | 0.45 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.28 | 0.15 | 5 | 4 |
| 1929 | 0.15 | 0.29 | 0.30 | 0.30 | 0.31 | 0.15 | 0.21 | 0.21 | 0.24 | 0.25 | 0.28 | 0.35 | 2 | 1 |
| 1930 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.38 | 0.15 | 0.18 | 0.18 | 0.41 | 0.15 | 0.19 | 3 | 1 |
| 1931 | 0.15 | 0.15 | 0.15 | 0.44 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.18 | 0.15 | 5 | 4 |
| 1932 | 0.15 | 0.15 | 0.24 | 0.25 | 0.27 | 0.27 | 0.43 | 0.15 | 0.15 | 0.15 | 0.38 | 0.15 | 4 | 2 |
| 1933 | 0.15 | 0.19 | 0.20 | 0.21 | 0.22 | 0.15 | 0.29 | 0.30 | 0.30 | 0.15 | 0.15 | 0.19 | 4 | 3 |
| 1934 | 0.21 | 0.35 | 0.40 | 0.40 | 0.40 | 0.40 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.40 | 5 | 5 |
| 1935 | 0.15 | 0.30 | 0.38 | 0.45 | 0.15 | 0.20 | 0.23 | 0.28 | 0.30 | 0.32 | 0.33 | 0.33 | 2 | 0 |
| 1936 | 0.15 | 0.15 | 0.36 | 0.36 | 0.36 | 0.15 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 3 | 3 |
| 1937 | 0.32 | 0.34 | 0.15 | 0.15 | 0.15 | 0.25 | 0.36 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 2 | 2 |
| 1938 | 0.39 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 0.25 | 5 | 5 |
| 1939 | 0.41 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 5 | 4 |
| 1940 | 0.40 | 0.15 | 0.22 | 0.22 | 0.23 | 0.24 | 0.15 | 0.15 | 0.19 | 0.20 | 0.20 | 0.20 | 3 | 2 |
| 1941 | 0.20 | 0.25 | 0.15 | 0.32 | 0.34 | 0.35 | 0.36 | 0.44 | 0.15 | 0.15 | 0.16 | 0.16 | 2 | 0 |
| 1942 | 0.41 | 0.15 | 0.16 | 0.33 | 0.38 | 0.38 | 0.15 | 0.21 | 0.22 | 0.22 | 0.27 | 0.29 | 2 | 0 |
| 1943 | 0.29 | 0.15 | 0.31 | 0.31 | 0.33 | 0.15 | 0.24 | 0.31 | 0.34 | 0.34 | 0.34 | 0.15 | 3 | 2 |
| 1944 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 | 0.42 | 0.43 | 0.43 | 0.43 | 0 | 0 |
| 1945 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 1 | 0 |
| 1946 | 0.23 | 0.24 | 0.25 | 0.25 | 0.25 | 0.15 | 0.32 | 0.35 | 0.41 | 0.15 | 0.22 | 0.23 | 2 | 1 |
| 1947 | 0.23 | 0.26 | 0.26 | 0.26 | 0.27 | 0.27 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 2 | 2 |
| 1948 | 0.15 | 0.28 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.32 | 1 | 1 |
| 1949 | 0.32 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.18 | 0.19 | 4 | 4 |
| 1950 | 0.15 | 0.15 | 0.15 | 0.15 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.15 | 5 | 5 |
| 1951 | 0.15 | 0.15 | 0.15 | 0.16 | 0.27 | 0.30 | 0.31 | 0.15 | 0.20 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1952 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.17 | 0.42 | 0.15 | 2 | 2 |
| 1953 | 0.15 | 0.15 | 0.42 | 0.43 | 0.44 | 0.15 | 0.26 | 0.15 | 0.33 | 0.39 | 0.15 | 0.35 | 5 | 4 |
| 1954 | 0.45 | 0.15 | 0.25 | 0.31 | 0.40 | 0.43 | 0.45 | 0.15 | 0.16 | 0.16 | 0.16 | 0.23 | 2 | 0 |
| 1955 | 0.26 | 0.33 | 0.35 | 0.35 | 0.15 | 0.20 | 0.21 | 0.24 | 0.25 | 0.25 | 0.25 | 0.15 | 2 | 0 |
| 1956 | 0.22 | 0.27 | 0.40 | 0.43 | 0.15 | 0.23 | 0.24 | 0.24 | 0.25 | 0.25 | 0.25 | 0.15 | 2 | 1 |
| 1957 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.41 | 0.15 | 0.15 | 0.18 | 0.19 | 0.19 | 2 | 2 |
| 1958 | 0.20 | 0.20 | 0.38 | 0.15 | 0.16 | 0.22 | 0.31 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 1 | 0 |
| 1959 | 0.37 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.40 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 1 | 0 |
| 1960 | 0.43 | 0.15 | 0.15 | 0.17 | 0.21 | 0.22 | 0.23 | 0.31 | 0.34 | 0.35 | 0.35 | 0.35 | 1 | 0 |
| 1961 | 0.35 | 0.39 | 0.41 | 0.42 | 0.42 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 1 | 1 |
| 1962 | 0.15 | 0.33 | 0.33 | 0.15 | 0.19 | 0.15 | 0.15 | 0.15 | 0.17 | 0.25 | 0.31 | 0.33 | 5 | 4 |
| 1963 | 0.33 | 0.34 | 0.34 | 0.34 | 0.15 | 0.40 | 0.40 | 0.40 | 0.15 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1964 | 0.40 | 0.44 | 0.44 | 0.44 | 0.15 | 0.15 | 0.15 | 0.29 | 0.43 | 0.15 | 0.18 | 0.19 | 2 | 0 |
| 1965 | 0.30 | 0.15 | 0.35 | 0.35 | 0.36 | 0.36 | 0.37 | 0.43 | 0.15 | 0.15 | 0.18 | 0.22 | 2 | 1 |
| 1966 | 0.23 | 0.24 | 0.25 | 0.25 | 0.29 | 0.31 | 0.35 | 0.15 | 0.15 | 0.40 | 0.15 | 0.22 | 3 | 2 |

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breach | High Flow Breach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1967 | 0.27 | 0.30 | 0.32 | 0.33 | 0.33 | 0.35 | 0.42 | 0.44 | 0.15 | 0.15 | 0.20 | 0.28 | 2 | 2 |
| 1968 | 0.32 | 0.34 | 0.35 | 0.35 | 0.37 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 1 | 0 |
| 1969 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.24 | 0.24 | 0.15 | 0.15 | 2 | 2 |
| 1970 | 0.15 | 0.27 | 0.15 | 0.15 | 0.23 | 0.26 | 0.15 | 0.32 | 0.34 | 0.37 | 0.44 | 0.15 | 5 | 4 |
| 1971 | 0.21 | 0.23 | 0.28 | 0.30 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.24 | 0.25 | 0.26 | 1 | 0 |
| 1972 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.27 | 0.28 | 0.29 | 0.29 | 0.29 | 0.36 | 0.39 | 0 | 0 |
| 1973 | 0.39 | 0.15 | 0.19 | 0.28 | 0.41 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 8 | 7 |
| 1974 | 0.29 | 0.38 | 0.44 | 0.15 | 0.22 | 0.25 | 0.27 | 0.29 | 0.30 | 0.31 | 0.33 | 0.15 | 2 | 1 |
| 1975 | 0.15 | 0.17 | 0.19 | 0.19 | 0.19 | 0.33 | 0.37 | 0.37 | 0.37 | 0.15 | 0.15 | 0.21 | 3 | 3 |
| 1976 | 0.37 | 0.15 | 0.18 | 0.19 | 0.15 | 0.37 | 0.40 | 0.15 | 0.29 | 0.34 | 0.38 | 0.41 | 3 | 1 |
| 1977 | 0.43 | 0.15 | 0.15 | 0.25 | 0.25 | 0.32 | 0.15 | 0.15 | 0.15 | 0.31 | 0.42 | 0.15 | 6 | 4 |
| 1978 | 0.45 | 0.15 | 0.26 | 0.31 | 0.34 | 0.35 | 0.37 | 0.39 | 0.40 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 1979 | 0.28 | 0.37 | 0.42 | 0.15 | 0.19 | 0.21 | 0.24 | 0.25 | 0.28 | 0.29 | 0.29 | 0.32 | 1 | 0 |
| 1980 | 0.33 | 0.40 | 0.42 | 0.15 | 0.27 | 0.15 | 0.15 | 0.41 | 0.15 | 0.24 | 0.15 | 0.32 | 5 | 4 |
| 1981 | 0.43 | 0.15 | 0.19 | 0.20 | 0.21 | 0.22 | 0.38 | 0.44 | 0.15 | 0.17 | 0.17 | 0.17 | 2 | 0 |
| 1982 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.26 | 0.26 | 1 | 1 |
| 1983 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.15 | 0.37 | 0.40 | 0.42 | 1 | 1 |
| 1984 | 0.43 | 0.43 | 0.43 | 0.44 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 1 | 0 |
| 1985 | 0.37 | 0.15 | 0.15 | 0.21 | 0.23 | 0.29 | 0.31 | 0.31 | 0.31 | 0.31 | 0.44 | 0.15 | 3 | 2 |
| 1986 | 0.20 | 0.24 | 0.25 | 0.25 | 0.25 | 0.26 | 0.27 | 0.27 | 0.36 | 0.39 | 0.41 | 0.44 | 0 | 0 |
| 1987 | 0.44 | 0.44 | 0.44 | 0.44 | 0.15 | 0.22 | 0.23 | 0.24 | 0.24 | 0.25 | 0.25 | 0.26 | 1 | 0 |
| 1988 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.41 | 0.45 | 0.45 | 0.15 | 0.15 | 0.15 | 1 | 0 |
| 1989 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.29 | 0.32 | 0.32 | 0.42 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 1990 | 0.20 | 0.21 | 0.21 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.31 | 0.34 | 0 | 0 |
| 1991 | 0.15 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.15 | 0.15 | 3 | 2 |
| 1992 | 0.15 | 0.36 | 0.37 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.44 | 0.15 | 0.18 | 0.36 | 2 | 1 |
| 1993 | 0.41 | 0.41 | 0.15 | 0.26 | 0.31 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.15 | 0.24 | 2 | 0 |
| 1994 | 0.24 | 0.24 | 0.15 | 0.15 | 0.17 | 0.18 | 0.30 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 2 | 2 |
| 1995 | 0.34 | 0.39 | 0.40 | 0.40 | 0.40 | 0.41 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0 | 0 |
| 1996 | 0.42 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.39 | 0.15 | 0.15 | 0.25 | 0.25 | 0.25 | 4 | 3 |
| 1997 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.15 | 0.29 | 0.29 | 0.29 | 0.30 | 0.34 | 0.36 | 1 | 1 |
| 1998 | 0.37 | 0.37 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.15 | 0.19 | 0.21 | 1 | 0 |
| 1999 | 0.15 | 0.25 | 0.25 | 0.15 | 0.27 | 0.15 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.45 | 3 | 3 |
| 2000 | 0.15 | 0.37 | 0.44 | 0.15 | 0.16 | 0.19 | 0.22 | 0.23 | 0.23 | 0.37 | 0.44 | 0.15 | 3 | 0 |
| 2001 | 0.19 | 0.32 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.15 | 0.15 | 0.15 | 3 | 3 |
| 2002 | 0.15 | 0.20 | 0.23 | 0.23 | 0.23 | 0.23 | 0.26 | 0.15 | 0.15 | 0.20 | 0.23 | 0.24 | 3 | 3 |
| | | | | | | | | | | | | Ave | 2.52 | 1.69 |

🟪 High Flow Breaching

🟦 Low flow breaching

**d) Other Anthropogenic influences**

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

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***Structures (e.g. weirs, bridges, mouth stabilization):***

Historical aerial photographs (1938 to 2004) indicate that the main direct anthropogenic impact on the estuarine morphology upstream of the mouth has resulted from the road-bridge and embankments constructed in the early 1960s. The bridge permanently fixed the deep channel against the west bank. However, it seems that in this area the channel was always deeper towards the western side (being on the outside of the bend). After construction of the bridge, the sand bank on the eastern side downstream of the bridge, seems to have become slightly wider compared to the pre-bridge configuration but this area is very small in proportion to the entire estuary. The foregoing observations indicate that the bridge does not appear to have had a major impact on the physical dynamics of the estuary.

*Confidence: High*

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

Although there are residential developments along the banks of the estuary, measurements did not show any measurable influence of these on the water quality in the estuary (e.g. nutrient enrichment). Water quality in the estuary is mainly affected by agricultural activities in the catchment (e.g. DIN enrichment, organic loading and pesticides). However, increased fringing reed growth along the lower banks suggests some influence of freshwater/nutrient enrichment, e.g. associated with septic tank seepage

*Confidence: Medium*

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***Human exploitation (consumptive or non-consumptive):***

With growing residential and holiday populations in the area, fish and bait resources in the estuary are under increasing pressure. Exploitation is generally confined to certain targeted species of invertebrates (e.g. sand prawns) and fishes (e.g. spotted grunter, leervis and white steenbras). Although most fishing and bait collecting activities are confined to the lower reaches, increasing use is being made of the middle and upper reaches by boat based anglers.

*Confidence: High*

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***Artificial mouth breaching:***

N/A

### 3.2.2 Biotic Components

## MICROALGAE

***Phytoplankton***

Present chlorophyll *a* concentrations are generally low reflective of the low levels of nutrients. The nutrients, however, do spike up during peak floods although they may not be available for uptake by phytoplankton. Open-mouth conditions initially reduce chlorophyll *a* levels, but subsequently these will increase when more stable conditions develop. Development on both banks of the estuary at present appears to have minimal influence on water column chlorophyll *a* concentrations although future impacts need to be examined. Closed-mouth conditions lengthen phytoplankton residence times although available nutrients become depleted resulting in low chlorophyll *a* levels. Species composition is presently characterised by the predominance of flagellates under open-mouth conditions. An increase in planktonic diatoms occurs under closed-mouth conditions but these are washed out to sea when the mouth opens. Impacts of development on phytoplankton species composition require further study.

***Benthic microalgae***

Present microphytobenthic (MPB) chlorophyll *a* concentrations are normally low, although significant increases are exhibited several days following breaching of the mouth when water with fresh supplies of nutrients flow through.. Sustained frequencies of mouth breaching keeps chlorophyll *a* concentrations low until the mouth closes then chlorophyll *a* concentrations recover to previous levels. High levels of turbidity reduce light reaching the sediment during flood and post flood events until stable and clear-water transparency conditions are re-established. Seepage areas are sources of additional nutrient input for MPBs and are likely to influence benthic primary production. Development on the banks of the East Kleinemonde is probably impacting on MPB production, however its overall effects are currently considered as minimal. Present benthic microalgal community composition includes diatoms, greens and cyanobacteria. Future Increased development might increase allochthonous nutrient input from seepage sites including underground sources possibly shifting MPB community structure towards one composed more of a cyanobacterial assemblage.

Confidence: Medium

## MACROPHYTES

***Biomass distribution***

The macrophytes of the East Kleinemonde Estuary cover a total area of 36.21 ha. Supratidal salt marsh (6.36 ha) occurs at 1.8 m above MSL with species such as *Sarcocornia pillansii, Sporobolus virginicus, Paspalum vaginatum, Juncus kraussii* and *Limonium scabrum.* These areas do not become flooded for extended periods. Intertidal salt marsh covers 4.04 ha. The dominant species is *Sarcocornia perennis* with the annual *Salicornia meyeriana* and *Sporobolus virginicus* occurring at lower elevation (< 1.3 m above MSL). Salt marsh occurs above the R72 bridge and represents 14% of the total estuarine vegetation. In the middle reaches the banks become steep and intertidal areas narrow so that salt marsh is limited to isolated locations.

*Phragmites australis* (1.01 ha) occurs in isolated stands along the length of the estuary immediately below and above the R72 bridge. Those stands became established after the construction of the bridge.

Submerged macrophytes in the East Kleinemonde are represented by *Chara* spp., *Ruppia* spp., *Halophila ovalis* and *Potamogeton pectinatus*. At water levels > 1.5 m above MSL this habitat becomes established after inundation for one to two months to cover an area of 0.5 ha. Given stable, clear water levels they have the potential to occupy 14.5 ha. Water column salinity determines species composition; *Ruppia* spp. Occur at 0-45 psu, Charophytes at 0-20 psu and *Potamogeton pectinatus* at <15 psu.

***Species diversity, richness and rarity***

Seven of the nine possible plant community types occur here; only mangroves and swamp forest are absent. The large submerged macrophyte beds (40 % of estuarine areas) are important as they have diverse faunal communities associated with them, including rare fish species. Salt marsh and submerged macrophytes have low species richness because of the stressful environment.

***Seasonal and inter-annual variability, including flood situations and drought conditions***

Past rainfall records show that in 1939, 1974, 2005 and 2006, rainfall figures of 862.4 mm, 1254.7 mm, 1286 mm and 836.5 mm respectively were recorded, thus indicating the occurrence of cyclical 1:30 year floods. The hypothesis is that these floods remove large quantities of sediment, reducing the base level of the estuary and increase the frequency and duration of mouth opening. The reduction in the closed mouth state results in lower cover of submerged macrophytes. Regular breaching (>2.6 times a year) and short periods (< 6 months) of closed mouth conditions with water level below 1.5 m MSL prevent the germination and expansion of submerged macrophytes. Although the East Kleinemonde was closed for 6 months in 2006, average biomass of *Ruppia cirrhosa* only reached 706 g DM $m^{-2}$. *Chara* was 599.48 g DM $m^{-2}$ and *Halophila ovalis* 101 g DM $m^{-2}$.

Regrowth of submerged macrophytes following river flooding depends on seeds and is therefore slow. During drought conditions the mouth remains closed for long periods thus allowing an increase in growth and expansion of submerged macrophytes.

Confidence: High

## INVERTEBRATES

### Zooplankton

***Biomass***

The zooplankton biomass in the estuary is within the range reported for other temporarily open/closed estuaries in the same region. Due to the lack of any distinct horizontal pattern in salinity and temperature, there were no apparent spatial patterns in the total zooplankton biomass and species composition during the closed phase. The total zooplankton biomass will decrease during periods of breaching.

***Species diversity and richness***

The zooplankton diversity within the estuary is similar to that found in temporarily open/closed estuaries in the region, but lower than that recorded in the larger permanently open systems. The community is typically comprised of typical estuarine species, mainly copepods.

***Seasonal and interannual variability***

Changes in the zooplankton community are strongly linked to mouth phase (open versus closed) and the establishment of a link to the marine environment during overtopping events. During prolonged mouth closure (months), maximum zooplankton biomass will be achieved although diversity is likely to be reduced as a result of poor representation of marine breeding species within the system. The overtopping events contribute to an increase in the zooplankton diversity within the system as marine breeding invertebrates recruit into the estuary.

Confidence: High

### Hyperbenthos (*Palaemon peringueyi*)

***Biomass***

The total biomass of *P.peringueyi* within the estuary is in the range reported for other temporarily open/closed estuaries in the region. On the other hand, the estimates are lower than those recorded in the larger permanently open counterparts. The reduced values recorded in temporarily open systems can be linked to reduced recruitment opportunities and habitat availability (extensive beds of submerged macrophytes). Maximum biomass is typically attained in those regions characterised by extensive cover of submerged macrophytes (mainly middle reaches).

***Seasonal and interannual variability***

The recruitment of *P.peringueyi* into temporarily open/closed estuaries is strongly linked to mouth phase. During prolonged mouth closure, total biomass of *P.peringueyi* is likely to decline due to limited recruitment opportunities. Breaching events are associated with a decline in the biomass of the shrimp in the estuary when biomass rich estuarine waters are exported to the marine environment.

Confidence: High

### Macrobenthos

***Biomass***

The biomass of the benthic community can be divided into two distinct groups – a sand community found from the road bridge and extending towards the sea. Above the road bridge a distinct mud community is found. In comparison to adjacent estuaries, invertebrate biomass is considered to be high. Zonation within each of these communities will only develop if a strong salinity gradient develops along the estuary and the mouth remains open for periods > 1 month. A strong salinity gradient along the estuary will only influence the upper and lower reaches (freshwater and marine associated communities). Because high rainfall and relatively strong flow occurs infrequently (1939, 1974, 2005/6) to create these conditions, community biomass will remain relatively high and homogeneous within sandy or muddy areas for extended periods.

***Species diversity, richness and rarity***

The number of macrobenthic species recorded in the East Kleinemonde is about 30, a level about 80-100% lower when compared to permanently open, marine dominated systems and 40-50% higher when compared to freshwater dominated estuaries in the same biogeographical region. Within the temporarily open estuaries group, the East Kleinemonde supports a relatively rich community in the upper quartile of the average for the estuary type. The community is also composed of typical estuarine species, a group well adapted to environmental fluctuations.

***Seasonal and interannual variability***

Changes in water level and the concomitant changes in submerged macrophyte distribution are the main drivers that influence macrobenthic community structure. No strong seasonal variability is apparent. Macrobenthic community variability therefore responds to changes in the submerged macropytes that in turn, respond to flood cycles and mouth condition. During periods of extended mouth closure (months), the microphytobenthos, epiphytes and submerged macrophytes increase in biomass and this will in turn increase biomass of primary food sources, particularly POM. There is evidence to suggest that microphytobentos is more important in sandy areas (Station 1), while submerged macrophytes become more important upstream at muddy sites.

Confidence: High

## FISH

***Distribution and biomass***

Although many species of fish occur throughout the estuary, a number of taxa show preferences for particular regions, e.g. the white steenbras *Lithognathus lithognathus* is most frequently recorded in the sandy lower reaches. Other species may change their distribution patterns according to mouth phase, e.g. the estuarine round-herring *Gilchristella aestuaria* is more abundant in the middle and upper reaches during the closed mouth phase but most of the population retreats into the lower reaches during the open mouth phase.

Fish biomass within the estuary is highest during the closed mouth phase when the volume and surface area of the estuary is at a maximum. Breeding of the dominant estuarine and freshwater fish species also occurs during the closed phase when physico-chemical conditions are most stable. Recruitment by the larvae and 0+ juveniles of most marine migrant fish species occurs when the mouth is open but some of these taxa are also able to enter the estuary during marine overwash events. Emigration of sub-adult and adult marine fishes to the sea occurs almost exclusively during the open mouth phase. Fish biomass in the East Kleinemonde Estuary is variable with a total of 28 g $m^{-2}$ recorded during 1995 closed phase.

***Species diversity, richness and rarity***

The East Kleinemonde fish community can be divided into two broad groups, estuarine residents and marine migrants. Small temporarily open/closed estuaries (TOCEs) such as the East Kleinemonde tend to have fewer fish species than larger TOCEs or permanently open estuaries (POEs). TOCEs also tend to have a higher proportion of estuarine resident taxa when compared to POEs. The lack of marine stragglers in TOCEs tends to reduce the species richness of these systems when compared to POEs. Although the majority of fish species occurring in IOEs tend to be taxa that are tolerant of a range of estuarine conditions and are abundant, there is one fish in the East Kleinemonde that is extremely rare and endangered, viz. the estuarine pipefish *Syngnathus watermeyeri*.

***Seasonal and interannual variability***

Seasonal and interannual variability in the East Kleinemonde fish assemblage is driven primarily by opening and closing of the estuary mouth. The optimum recruitment period for the widest variety of marine fish species is during spring and early summer. Indeed, if the estuary remains closed over this period the fish assemblage will tend to differ markedly from that recorded when the mouth does open fully during this season.

Confidence: High

## BIRDS

***Distribution***

The area between the bridge and the first sharp bend, encompassing the saltmarsh and floodplain, is the most frequented area of the estuary with 53% of birds occurring there in summer and 49% in winter. Twenty percent of birds occur in the middle reaches during summer and 16% in winter. Thirteen percent of birds are found in the upper reaches of the estuary during summer (winter: 11%)

Spatial variation in community composition along the estuary is linked to habitat differences. Wading piscivores and invertebrate feeding waders utilise areas of shallow water in the floodplain and saltmarsh throughout the year. Pursuit swimming piscivores (cormorants, grebes, darters) feed in water depths > 0.3 m. Overall, aerial divers occur relatively evenly along the length of the estuary, but kingfishers and African Fish Eagles prefer the upper reaches of the estuary, while terns and gulls are most common in the lower regions.

While most species feed in the estuary, some of the more abundant species do not use the estuary as their main feeding area. Many wading piscivores use the bushveld vegetation on the steep banks as roosting and nesting sites, but frequently fly to the adjacent West Kleinemonde estuary to feed.

***Species diversity, richness and rarity***

Forth-eight non-passerine waterbird species have been recorded on the estuary with 17 families in 6 orders. Charadriiformes make up the majority (47%) of species, 29% of species belong to the Order Ciconiiformes, 10% to Anseriiformes and 8% to Coraciiformes. Only one record exists for the uncommon to rare African Finfoot, which is currently classified as a vulnerable species. Piscivorous birds dominate the avifauna of the East Kleinemonde estuary, making up 70% of individuals. Invertebrate feeding waders form the second most numerous component (24%). Waterfowl are particularly scarce in the estuary, making up only about 6% of birds.

***Seasonal variability***

The average number of waterbird species recorded in a single count is 34 in summer and 32 in winter. A total of 16 species are long-distance migrants and occur only during the summer months. In summer, the piscivorous component is dominated by wading piscivores (herons, egrets, spoonbills, ibises). The percentage of pursuit swimming piscivores (cormorants, grebes and darters) rises considerably in winter from 16% to 27%. Aerial diver numbers remain relatively constant throughout the year. Non-migrating waders increase in winter, while migratory waders are virtually absent from the estuary during this time. Waterfowl are only present in small numbers, but their numbers do increase in the winter months. An average of 62 and 65 individuals were recorded per count in summer and winter respectively.

Confidence: High

### a) Effect of abiotic characteristics on estuarine biota

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

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| *Mouth condition (provide temporal implications where applicable)* | **Microalgae:**<br>**Phytoplankton**<br>Under the present state (PS) extended periods of mouth closure (>2 months) increase estuarine water volume, hence increasing colonisable habitat by phytoplankton. Improved residence period may support higher chlorophyll *a* biomass depending on residual macronutrient pool. Open-mouth state initially decreases chlorophyll *a* concentrations as a result of loss of estuarine water from flushing followed by a gradual increase in chlorophyll *a* in response to improved nutrient supply (i.e. 4-5 weeks post breaching event). Closed-mouth state (>2 months) supports diatom assemblage while an open mouth state favours a flagellated community (i.e. dinoflagellates & cryptophytes).<br>**Microphytobenthos**<br>Extended periods of mouth closure (>2 months) increase colonisable subtidal estuarine sediment habitat. Improved water-column transparencies supports increased chlorophyll *a* biomass. Strong flows under an open-mouth state scour sediment substrate, completely removing established MPB habitat, thus reducing available habitat & MPB biomass. Mouth breaching from low flows reduce MPB habitat, but may temporarily stimulate residual MPB populations & biomass by increasing the photic depth as estuarine water level is reduced.<br>Confidence: Medium |
| | **Macrophytes:**<br>Under closed mouth conditions with low water levels (< 1.3 m above MSL) intertidal salt marsh is unaffected. Open mouth conditions for periods are important for salt marsh seed germination. The best time of the year for germination is probably spring/summer. Seedling emergence in the intertidal areas commences three days after mouth breaching and seeds germinate intermittently thereafter for 3 months, providing the mouth remains open.<br>Frequent mouth opening and draining events (more than twice a year) prevent submerged macrophyte establishment. Submerged macrophytes develop when the mouth is closed and water levels are >1.5 m above MSL. Because of the increase in open mouth conditions during 2006, submerged macrophyte cover was 4.5% of optimal cover.<br>Confidence: High |
| | **Invertebrates:**<br>**Macrobenthos**<br>The structure and biomass of the macrozoobenthos is strongly linked to submerged macrophyte dynamics. Opening of the estuary mouth followed by draining of the water body lead to a decrease in macrophyte biomass and this in turn will lead to changes in the macrobenthic community. Spatial variability in community structure will increase, while overall biomass of the macrozoobenthos will decline.<br>Confidence: Medium |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| | **Zooplankton**<br>The zooplankton community structure and biomass is strongly linked to mouth phase. The breaching of the estuary coincides with a decrease in the total zooplankton biomass and an increase in the zooplankton diversity. Spatial variability in the zooplankton biomass will not be affected by mouth phase.<br>Confidence: High<br>**Hyperbenthos**<br>The recruitment of *P.peringueyi* into temporarily open closed estuaries is strongly linked to mouth phase. Maximum recruitment of the shrimp larvae into the estuary coincides with breaching events. Similarly, the breaching events are associated with a decline in the biomass of the shrimp in the estuary.<br>Confidence: High |
| | **Fish:**<br>Closed mouth conditions are associated with maximum vegetation cover and optimum availability of food resources for marine, estuarine and freshwater fish species. The dominant freshwater Mozambique tilapia *Oreochromis mossambicus* can only construct breeding nests under closed mouth conditions and its reproductive success is directly linked to the predominant mouth state during spring and summer. Reduced plant, invertebrate and fish stocks during the open mouth conditions have a major impact on the numbers and biomass of fishes in the estuary during this phase. Loss of aquatic macrophytes due to frequent mouth breaching can lead to the loss of certain plant associated fish species, e.g. estuarine pipefish *Syngnathus watermeyeri*.<br>Confidence: High |
| | **Birds:**<br>Piscivorous and invertebrate feeding bird numbers rise immediately after a breaching event. Birds then feed on fish stranded or trapped in puddles and on invertebrates in newly exposed sandbanks.<br>The inundation of the saltmarsh during closed mouth conditions initially creates habitat for wading piscivores (herons, egrets, spoonbills, ibises) and waterfowl. If the water level rises further this habitat becomes unavailable again.<br>Higher water levels associated with closed mouth conditions increase feeding habitat for piscivorous species that hunt by pursuit swimming (cormorants, darters, grebes).<br>Low water levels during open mouth conditions lower available habitat for pursuit swimming piscivores and piscivirous wading birds (non-inundated saltmarsh) but create habitat (exposed sandbanks) for invertebrate feeding waders.<br>Species feeding on submerged macrophytes (coots) are negatively affected by frequent breaching events that lead to loss of submerged macrophytes.<br>Confidence: High |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| *Exposure of inter-tidal areas during low tide* | **Microalgae:**<br>**Phytoplankton**<br>N/A<br>**Microphytobenthos**<br>True intertidal areas in intermittently open estuaries do not exist, since organisms that would inhabit this zone do not establish properly. Instead this area persists for only a very short period of time depending on riverine and tidal flow conditions. Therefore, under an open-mouth state this habitat is lost until the mouth closes and the estuary refills. Loss of habitat would mean a reduction in MPB chlorophyll *a* biomass, however this habitat would be regained when the estuary refills.<br>Confidence: High |
| | **Macrophytes:**<br>Intertidal areas become inundated at water levels > 1.3 m above MSL and if water levels remain < 1.5 m above MSL, they are able to withstand inundation for 3 months. At water levels > 1.5 m above MSL intertidal salt marsh dies back after 3 months inundation. Extended periods of mouth opening increase intertidal vegetation cover.<br>Rapid tidal movement of water prevents submerged macrophytes from establishing during this phase although they may grow in the quiet backwater areas.<br>Reeds (*Phragmites australis)* are not influenced by water level fluctuations because of its high position up the bank and any changes that occur are due to seasonal influences.<br>Confidence: High |
| | **Invertebrates:**<br>**Macrobenthos**<br>The diversity of the macrozoobenthos will decline in intertidal areas since only burrowing forms are likely to survive. Smaller species (e.g. amphipods) that live at the surface or utilize attached plants as habitat will decline because of greater environmental stress (e.g. increased heat and desiccation effects).<br>Confidence: High<br>**Zooplankton**<br>The zooplankton community is unlikely to be affected.<br>Confidence: High<br>**Hyperbenthos**<br>The strong link between the distribution of *P.peringueyi* and macrophyte distribution suggests that the exposure of the inter-tidal regions will be associated with a decline in the biomass of the shrimp.<br>Confidence: High |
| | **Fish:**<br>Exposure of inter-tidal areas will force small fishes into the channel area where they will be more vulnerable to piscivorous fish predators. The lack of aquatic macrophytes in the channel will increase the vulnerability of small fishes that rely on submerged plant beds for food and shelter.<br>Confidence: High |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| | **Birds:**<br>Invertebrate feeding waders feed in inter-tidal areas during low tide.<br>Confidence: High |
| *Sediment processes and characteristics* | **Microalgae:**<br>**Phytoplankton**<br>Under the open mouth state floods generate high levels of turbidity that reduce water-column light transparency, however since sediment processes have changed little from natural conditions there probably has been very little change in the effects of turbidity on the phytoplankton, although increased human activity in the catchment has probably increased suspended sediment load.<br>**Microphytobenthos**<br>There probably has been very little change from natural conditions in the effects of sediment processes on benthic microalgae under the PS. Therefore, sediment loss and accrual remains similar to natural conditions, although activities in the catchment may have slightly increased sediment transport and deposition in the estuary.<br>Confidence: Low/Medium: |
| | **Macrophytes:**<br>Localised sediment input can result in an increase in *Phragmites* (common read) cover. The nature of the substrate can also influence water turbidity and submerged macrophyte growth.<br>Confidence:  High |
| | **Invertebrates:**<br>**Macrobenthos**<br>The structure and composition of the macrozoobenthic community is strongly linked to sediment dynamics.  Changes in the sediment type or scouring of existing sediments will therefore influence the macrozoobenthos<br>Confidence: High<br>**Zooplankton**<br>N/A<br>**Hyperbenthos**<br>N/A |
| | **Fish:**<br>Certain fish species are strongly linked to sediment type and any change in the balance between sandy and muddy substrata will influence the relative abundance of these taxa within the system.<br>Confidence: High |
| | **Birds:**<br>Some bird species associated with reed beds will increase with *Phragmites* expansion. Higher turbidity lowers visibility for pursuit swimming species that hunt by sight. Piscivorous and invertebrate feeding birds will be affected by the abundance of their prey items which are linked to sediment type.<br>Confidence: Medium |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| *Retention time of water masses* | **Microalgae:**<br>**Phytoplankton**<br>Mean monthly inflow conditions under the PS indicate little variation from those under the RC, hence water-mass retention times and phytoplankton dynamics would not have changed markedly from RC. Increased retention would improve regeneration times and colonisable habitat for phytoplankton<br>**Microphytobenthos**<br>Mean monthly inflow patterns under the PS indicate little variation from those under the RC, thus MPB dynamics would remain comparable to that under RC. Back flooding would improve colonisable benthic habitat thus increasing benthic microalgal biomass.<br>Confidence: Medium |
| | **Macrophytes:**<br>Increased retention of the water body (> 6 months) and decreased flow encourages growth of submerged aquatic macrophytes and macroalgae.<br>Confidence: High |
| | **Invertebrates:**<br>**Macrobenthos**<br>Submerged macrophytes increase in biomass following greater retention times of the water body and this will lead to greater biomass of the macrozoobenthic community. Species richness is also likely to decline as non-estuarine species disappear, while at the same time, the euryhaline fauna extends further upstream and downstream.<br>Confidence: High<br>**Zooplankton**<br>Maximum zooplankton biomass will be attained during periods of extended mouth closure. Species richness is likely to decline as non-estuarine species (marine breeding species) disappear.<br>Confidence: High<br>**Hyperbenthos**<br>N/A |
| | **Fish:**<br>Increased aquatic macrophyte and macroalgae will benefit those fish species feeding directly on plants (e.g. Cape stumpnose *Rhabdosargus holubi*) and/or invertebrates associated with these plant beds (e.g. Cape moony *Monodactylus falciformis*). Those fish species that are dependent on submerged plant beds as a habitat (e.g. estuarine pipefish *Syngnathus watermeyeri*) will reach maximum abundance when aquatic plants are most extensive during prolonged water retention periods.<br>Confidence: High |
| | **Birds:**<br>An increase in submerged macrophytes leads to higher abundance of species feeding on these.<br>Confidence: Medium |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| *Flow velocity* | **Microalgae:**<br>**Phytoplankton**<br>Mean monthly inflow conditions under the PS indicate little variation from those under the RC, hence flow velocity and phytoplankton dynamics would not have changed markedly from those under the RC. Phytoplankton chlorophyll *a* would remain largely unchanged under low flows but will be reduced under high flows until high flow subsides to low values.<br>**Microphytobenthos**<br>Mean monthly inflow patterns under the PS indicate little variation from those under the RC, thus MPB dynamics would remain comparable to that under RC. Low flow conditions would largely not affect MPB chlorophyll *a* biomass. However high flows would reduce MPB chlorophyll *a* biomass due to scouring of the sediment<br>Confidence: Medium |
| | **Macrophytes:**<br>Reduced flow can increase submerged macrophyte and macroalgal growth due to decreased turbidity. Flow velocities > 1 m $s^{-1}$ inhibit submerged macrophyte growth, whereas currents of 0.5 m $s^{-1}$ only result in mechanical damage (Adams et al. 1999).<br>Confidence: High |
| | **Invertebrates:**<br>**Macrozoobenthos**<br>Increased flow velocity will lead to a decline in macrozoobenthic biomass. The re-sorting of sediments will also reduce the microphytobenthic food source, while POM could be redistributed away from consumers.<br>Confidence: High<br>**Zooplankton**<br>Increased flow velocities are likely to be associated with a decline in the total zooplankton biomass most likely due to decrease in food availability, mainly microphytobenthic algae.<br>Confidence: Medium<br>**Macrocustaceans**<br>N/A |
| | **Fish:**<br>Reduction in microphytobenthos, zoobenthos and zooplankton food resources during elevated flow velocity will result in a reduction in fish stocks within the estuary.<br>Confidence: High |
| | **Birds:**<br>Piscivorous and invertebrate feeding bird numbers will decline with a reduction in fish stock and macrozoobenthos. Higher turbidity through increased flow lowers visibility for species hunting by pursuit swimming.<br>Confidence: Medium |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| *Volume of water in estuary* | **Microalgae:**<br>**Phytoplankton**<br>River inflow conditions under the PS indicate little variation from those under the RC, hence estuarine water-volume and its impact on phytoplankton dynamics would also not have changed markedly. Increased water volume would improve colonisable habitat for phytoplankton<br>**Microphytobenthos**<br>River inflow patterns under the PS show little variation from those under the RC, thus estuarine water-volume and its related influence on MPB dynamics would remain similar to that under RC. Back flooding would improve colonisable benthic habitat thus increasing benthic microalgal biomass.<br>Confidence: Medium |
| | **Macrophytes:**<br>Submerged macrophytes will only develop substantially once the water level is > 1.5 m above MSL. The pioneer *Halophila ovalis* can occur in monospecific stands in shallower water but once the water level rises it is easily out competed by species that are physically more robust, e.g. *Ruppia* and *Potamogeton*.<br>Confidence: High |
| | **Invertebrates:**<br>**Macrobenthos**<br>Volume of water in the estuary determines habitat distribution and availability. A greater volume of water in the estuary will favour the submerged community at the expense of intertidal organisms.<br>Confidence: High<br>**Zooplankton**<br>Volume of water in the estuary is unlikely be associated with a change in the zooplankton biomass or community structure.<br>Confidence: High<br>**Hyperbenthos**<br>N/A |
| | **Fish:**<br>An increased estuary water volume will support a wider size structure of fishes since both deep and shallow water will be available. The surface area and productivity of the estuary is also likely to increase with increasing water volume and this will support a greater abundance and biomass of fishes within the system.<br>Confidence: High |
| | **Birds:**<br>A greater water volume increases available habitat for most species, excluding small waders, and increases food availability for piscivirous birds and larger invertebrate feeding waders.<br>Confidence: High |

| ABIOTIC COMPONENT OR PROCESS | BIOLOGICAL RESPONSE |
|---|---|
| *Salinity* | **Microalgae:**<br>**Phytoplankton**<br>River inflow conditions under the PS indicate little variation from those under the RC, hence horizontal and vertical salinity patterns and their associated effects on phytoplankton would not have changed much.<br>**Microphytobenthos**<br>River inflow patterns under the PS indicate little variation from those under the RC, thus horizontal and vertical salinity patterns and their related effects on MPB dynamics would remain similar to that under the RC.<br>Confidence: Medium |
| | **Macrophytes:**<br>Under closed mouth conditions salinity in the estuary is 15 to 23 PSU. The submerged macrophyte *Halophila ovalis* can tolerate 20 to 35 PSU, *Ruppia cirrhosa* 0 to 45 PSU and *Potamogeton pectinatus* 0 to 15 PSU. Under open conditions salinity ranges from 0.7 to 35.5 PSU. Intertidal salt marsh can tolerate fluctuating salinity (Adams and Bate 1994). Low salinity (< 20 psu) is important for seed germination and re-establishment of both submerged and salt marsh plants.<br>Confidence: High |
| | **Invertebrates:**<br>**Macrobenthos**<br>Generally, salinity values remained near or slightly above 20 PSU during the period of study. Fluctuations about this level (even down to <10 or >30) will not seriously impact on the macrozoobenthos generally, except for the sandprawn *Callianassa kraussi*. Any decrease below about 17-20 will influence breeding success, as this species requires salinity values >17-20 for successful development of developing young.<br>Confidence: High<br>**Zooplankton**<br>Small fluctuations in the salinity value will not impact on the zooplankton community structure or biomass.<br>Confidence: High<br>**Hyperbenthos**<br>Small fluctuations in the salinity value will not impact on the biomass of *P.peringueyi*<br>Confidence: Medium |
| | **Fish:**<br>The salinity values recorded in the East Kleinemonde do not pose any threat to the marine, estuarine or freshwater fish species recorded within the system. Salinities of 15-20 PSU are optimum for most species since they are isosmotic in relation to the external environment within this salinity range.<br>Confidence: High |
| | **Birds:**<br>Birds are not directly affected by changes in salinity ocurring in this system.<br>Confidence: Medium |

| **ABIOTIC COMPONENT OR PROCESS** | **BIOLOGICAL RESPONSE** |
|---|---|
| *Other water quality variables* | **<u>Microalgae</u>:**<br>**Phytoplankton**<br>River inflow patterns under the PS indicate little variation from those under the RC, hence other water quality conditions (e.g. dissolved oxygen, pH, & conductivity) and their influence on phytoplankton dynamics would also not have noticeably changed.<br>**Microphytobenthos**<br>River inflow patterns under the PS indicate little variation from those under the RC, thus other water quality conditions (e.g. dissolved oxygen, pH, & conductivity) would remain similar to that under the RC.<br>Confidence: Low |
| | **<u>Macrophytes</u>:**<br>Increased nutrient input has a negative effect on submerged macrophytes through a reduction in light availability due to increased epiphytic growth, macroalgal and phytoplankton blooms (Twilley 1985, Bickerton 1982).<br>Confidence: High |
| | **<u>Invertebrates</u>:**<br>**Macrobenthos**<br>Light reduction will have negative impact on the macrozoobenthic community through its primary influence on macrophytic growth. Reduced biomass of the macrophytes will reduce habitat availability and available food through a reducing supply of POM.<br>Confidence: High<br>**Zooplankton**<br>There are unlikely to be any changes in the zooplankton biomass as the primary food sources (phytoplankton and microphytobenthic algae) will be unaffected (see above).<br>Confidence: Medium<br>**Hyperbenthos**<br>Reduced macrophyte biomass as a result of changes in the light environment is likely to be associated with a decline in the biomass of *P.peringueyi* within the estuary<br>Confidence: Medium |
| | **<u>Fish</u>:**<br>The use of cattle dips in the catchment has the potential to influence the health of fishes if these chemicals enter the estuary. However, the available evidence using the Cape stumpnose *Rhabdosargus holubi* as an indicator species suggests that this is not happening.<br>Confidence: High |
| | **<u>Birds</u>:**<br>Piscivorous birds accumulate poisons and chemicals from their prey and this can potentially result in lower reproductive success and other health problems.<br>Confidence: High |

### b) Other Anthropogenic influences

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

| *ANTHROPOGENIC INFLUENCES* | *BIOLOGICAL RESPONSE* |
|---|---|
| *Structures (e.g. weirs, bridges, jetties, causeway)* | **Microalgae:**<br>**Phytoplankton**<br>Direct effects of physical structures on phytoplankton under the PS would be the creation of quiescent backwater areas that form pools for phytoplankton to use as a seed source and function to colonize other habitats. This and related structures would not have been present under the RC.<br>**Microphytobenthos**<br>Direct effects of physical structures on MPBs under the PS would be the influence on sediment loss and accretion processes, especially downstream of the bridge. Increases in sediment deposition would effectively improve colonisable MPB habitat area. These structures would not have been present under the RC.<br>Confidence: Medium |
| | **Macrophytes:**<br>The bridge has increased sedimentation, which has resulted in reed growth on the east bank adjacent to the bridge. Housing developments have increased freshwater run-off and nutrient input to the estuary. Although this is not measured as a change in water quality, increased abundance of reeds and macroalgae may occur as a result. Reed beds on the east bank upstream of the bridge only became established after 1995. Before this the submerged macrophyte *Ruppia cirrhosa* occurred up to depths of 1 m. These changes can be attributed to disturbance of the banks due to residential development and fertiliser and freshwater runoff from the adjacent lawns.<br>Confidence: High |

| ***ANTHROPOGENIC INFLUENCES*** | ***BIOLOGICAL RESPONSE*** |
|---|---|
| | **Invertebrates:**<br>**Macrobenthos**<br>In addition to influencing additional reed growth and hence more potential POM to the lower estuary, the bridge has led to a sharper boundary between sandy and muddy substrata. This in turn leads to a rapid change in community structure across the longitudinal gradient. Housing development on the northern bank near the mouth has probably lead to greater organic loading in the lower estuary, leading to localized nodes of primary food sources that are utilized by some species.<br>Confidence: Medium<br>**Zooplankton**<br>Hard structures are unlikely to influence the zooplankton community structure within the estuary. Housing development near the mouth has probably lead to greater organic loading in the lower estuary, leading to localised nodes of primary food sources that are utilised by some species that occur in the lower estuary.<br>Confidence: Medium<br>**Hyperbenthos**<br>The construction of buildings is unlikely to influence the biomass of *P.peringueyi* in the estuary<br>Confidence: Medium |
| | **Fish:**<br>Expansion of reed beds associated with road and housing developments in the lower reaches has reduced the habitat available to specialised aquatic macrophyte associated species such as the estuarine pipefish *Syngnathus watermeyeri*. The road bridge itself has increased habitat diversity within the estuary by providing a deep scour hole that is present under both open and closed mouth phases. Large fishes will find refuge in this scour hole when water levels in the estuary are low.<br>Confidence: Medium |
| | **Birds:**<br>Housing developments have decreased available undisturbed roosting areas for birds, especially below the bridge. The causeway does not disturb some birds as a heronry was established adjacent to the bridge in 2004. The expanded reed beds provide shelter for some species. Jetties above the bridge are used as perching and roosting sites by some species.<br>Confidence: Medium |
| *Human exploitation (consumptive and non-consumptive)* | **Microalgae:**<br>**Phytoplankton**<br>N/A<br>**Microphytobenthos**<br>N/A<br>Confidence: High |
| | **Macrophytes:**<br>No utilisation takes place.<br>Confidence: High |

| *ANTHROPOGENIC INFLUENCES* | *BIOLOGICAL RESPONSE* |
|---|---|
| | **Invertebrates:**<br>**Macrobenthos**<br>Bait collecting is probably widespread, but the main target species (*Callianassa kraussi*) has a high biomass and removal of prawns does not currently have any major impact on the population.<br>Confidence: High<br>**Zooplankton**<br>N/A<br>**Hyperbenthos**<br>N/A |
| | **Fish:**<br>Increasing human populations in the region are placing increased fishing pressures, particularly by recreational anglers, on the predatory fishes within this system.<br>Confidence: Medium |
| | **Birds:**<br>No direct exploitation takes place, but birds on the estuary have been seen injured and killed by ingesting fishing hooks or being trapped in fishing line. Piscivorous birds will decrease with decreasing fish populations.<br>Confidence: High |

## 3.3 Reference Conditions

### 3.2.3 Abiotic Components

#### a) Seasonal variability in river inflow:

Monthly simulated runoff data for the East Kleinemonde Estuary Reference (or natural) Condition is provided in Table 3.2. A summary of flow distribution (mean monthly flows in $m^3\ s^{-1}$) for the Reference Condition, derived from the 83-year simulated data set, is provided below:

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.803 | 1.228 | 0.759 | 0.320 | 0.841 | 1.576 | 1.085 | 2.791 | 1.249 | 0.975 | 0.998 | 1.561 |
| 90%ile | 0.251 | 0.252 | 0.183 | 0.097 | 0.058 | 0.190 | 0.216 | 0.167 | 0.217 | 0.128 | 0.128 | 0.241 |
| 80%ile | 0.130 | 0.085 | 0.076 | 0.026 | 0.028 | 0.088 | 0.071 | 0.060 | 0.049 | 0.045 | 0.046 | 0.084 |
| 70%ile | 0.088 | 0.056 | 0.036 | 0.010 | 0.018 | 0.029 | 0.049 | 0.023 | 0.015 | 0.020 | 0.028 | 0.036 |
| 60%ile | 0.046 | 0.038 | 0.020 | 0.005 | 0.007 | 0.015 | 0.029 | 0.011 | 0.011 | 0.007 | 0.013 | 0.021 |
| 50%ile | 0.021 | 0.022 | 0.010 | 0.003 | 0.003 | 0.009 | 0.011 | 0.006 | 0.004 | 0.004 | 0.007 | 0.011 |
| 40%ile | 0.008 | 0.017 | 0.004 | 0.001 | 0.002 | 0.004 | 0.004 | 0.002 | 0.002 | 0.001 | 0.002 | 0.006 |
| 30%ile | 0.003 | 0.006 | 0.002 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 |
| 20%ile | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

#### b) Present flood regime

The flood regime is judged to be very similar to that of the Present State based on the fact that the simulated monthly runoff data indicate very little change for months with a flow higher than 0.11 $m^3\ s^{-1}$ (see shaded area in above table).

*Confidence: Medium*

#### c) Present sediment processes

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

*Confidence: Low*

**Table 3.2** Simulated monthly volumes (million $m^3$) in the East Kleinemonde Estuary for Reference Conditions.

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breaches | High Flow Breaches |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.15 | 0.15 | 0.21 | 0.23 | 0.23 | 0.35 | 0.15 | 0.38 | 0.42 | 0.44 | 0.15 | 0.17 | 2 | 1 |
| 1921 | 0.18 | 0.38 | 0.15 | 0.17 | 0.17 | 0.17 | 0.27 | 0.34 | 0.15 | 0.15 | 0.15 | 0.36 | 4 | 3 |
| 1922 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.19 | 0.22 | 0.24 | 0.26 | 0.34 | 0.38 | 0.39 | 5 | 4 |
| 1923 | 0.41 | 0.15 | 0.19 | 0.21 | 0.21 | 0.22 | 0.22 | 0.25 | 0.26 | 0.26 | 0.26 | 0.27 | 1 | 0 |
| 1924 | 0.27 | 0.28 | 0.38 | 0.41 | 0.41 | 0.15 | 0.35 | 0.38 | 0.40 | 0.41 | 0.41 | 0.15 | 2 | 1 |
| 1925 | 0.21 | 0.21 | 0.23 | 0.24 | 0.29 | 0.33 | 0.34 | 0.34 | 0.35 | 0.35 | 0.35 | 0.36 | 0 | 0 |
| 1926 | 0.15 | 0.26 | 0.26 | 0.26 | 0.27 | 0.30 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 1 | 1 |
| 1927 | 0.31 | 0.31 | 0.31 | 0.31 | 0.32 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.23 | 0.15 | 4 | 2 |
| 1928 | 0.15 | 0.37 | 0.15 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.15 | 0.15 | 0.29 | 0.15 | 5 | 4 |
| 1929 | 0.15 | 0.30 | 0.31 | 0.31 | 0.32 | 0.15 | 0.22 | 0.22 | 0.25 | 0.26 | 0.30 | 0.37 | 2 | 1 |
| 1930 | 0.15 | 0.32 | 0.32 | 0.32 | 0.32 | 0.40 | 0.15 | 0.18 | 0.18 | 0.44 | 0.15 | 0.19 | 3 | 1 |
| 1931 | 0.15 | 0.15 | 0.15 | 0.44 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 0.18 | 0.18 | 0.15 | 5 | 4 |
| 1932 | 0.15 | 0.15 | 0.25 | 0.26 | 0.27 | 0.28 | 0.15 | 0.21 | 0.21 | 0.21 | 0.15 | 0.24 | 4 | 2 |
| 1933 | 0.24 | 0.28 | 0.30 | 0.31 | 0.32 | 0.15 | 0.31 | 0.31 | 0.31 | 0.15 | 0.15 | 0.20 | 3 | 3 |
| 1934 | 0.22 | 0.37 | 0.42 | 0.42 | 0.42 | 0.43 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.41 | 5 | 5 |
| 1935 | 0.15 | 0.31 | 0.40 | 0.15 | 0.21 | 0.27 | 0.30 | 0.35 | 0.38 | 0.40 | 0.41 | 0.41 | 2 | 0 |
| 1936 | 0.15 | 0.15 | 0.37 | 0.37 | 0.37 | 0.15 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 3 | 3 |
| 1937 | 0.34 | 0.35 | 0.15 | 0.15 | 0.16 | 0.26 | 0.38 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 2 | 2 |
| 1938 | 0.41 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 0.26 | 5 | 5 |
| 1939 | 0.43 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 5 | 4 |
| 1940 | 0.40 | 0.15 | 0.22 | 0.22 | 0.24 | 0.24 | 0.15 | 0.15 | 0.19 | 0.21 | 0.21 | 0.21 | 3 | 2 |
| 1941 | 0.21 | 0.26 | 0.15 | 0.33 | 0.36 | 0.37 | 0.38 | 0.15 | 0.18 | 0.18 | 0.19 | 0.19 | 2 | 1 |
| 1942 | 0.15 | 0.24 | 0.26 | 0.44 | 0.15 | 0.15 | 0.36 | 0.43 | 0.43 | 0.43 | 0.15 | 0.17 | 3 | 0 |
| 1943 | 0.17 | 0.15 | 0.32 | 0.33 | 0.35 | 0.15 | 0.25 | 0.33 | 0.36 | 0.36 | 0.36 | 0.15 | 3 | 2 |
| 1944 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.40 | 0.44 | 0.15 | 0.15 | 0.15 | 1 | 0 |
| 1945 | 0.39 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2 | 0 |
| 1946 | 0.16 | 0.17 | 0.18 | 0.18 | 0.18 | 0.15 | 0.34 | 0.36 | 0.44 | 0.15 | 0.23 | 0.24 | 2 | 1 |
| 1947 | 0.24 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 2 | 2 |
| 1948 | 0.15 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.33 | 0.33 | 1 | 1 |
| 1949 | 0.34 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.18 | 0.19 | 4 | 4 |
| 1950 | 0.15 | 0.15 | 0.15 | 0.15 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.15 | 5 | 5 |
| 1951 | 0.15 | 0.15 | 0.15 | 0.16 | 0.28 | 0.32 | 0.33 | 0.15 | 0.21 | 0.21 | 0.21 | 0.15 | 3 | 2 |
| 1952 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.44 | 0.15 | 2 | 2 |
| 1953 | 0.15 | 0.15 | 0.43 | 0.44 | 0.45 | 0.15 | 0.27 | 0.15 | 0.34 | 0.40 | 0.15 | 0.35 | 5 | 4 |
| 1954 | 0.15 | 0.39 | 0.15 | 0.22 | 0.32 | 0.36 | 0.37 | 0.38 | 0.39 | 0.39 | 0.39 | 0.15 | 3 | 0 |
| 1955 | 0.18 | 0.26 | 0.28 | 0.28 | 0.41 | 0.15 | 0.16 | 0.19 | 0.20 | 0.20 | 0.20 | 0.42 | 1 | 0 |
| 1956 | 0.15 | 0.21 | 0.35 | 0.39 | 0.15 | 0.24 | 0.25 | 0.25 | 0.26 | 0.27 | 0.27 | 0.15 | 3 | 1 |
| 1957 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.31 | 0.44 | 0.15 | 0.15 | 0.18 | 0.20 | 0.20 | 2 | 2 |
| 1958 | 0.20 | 0.20 | 0.40 | 0.15 | 0.16 | 0.23 | 0.33 | 0.38 | 0.38 | 0.38 | 0.38 | 0.39 | 1 | 0 |
| 1959 | 0.40 | 0.40 | 0.40 | 0.41 | 0.42 | 0.42 | 0.42 | 0.15 | 0.22 | 0.22 | 0.22 | 0.28 | 1 | 0 |
| 1960 | 0.15 | 0.22 | 0.22 | 0.23 | 0.28 | 0.30 | 0.30 | 0.40 | 0.43 | 0.43 | 0.44 | 0.44 | 1 | 0 |
| 1961 | 0.44 | 0.15 | 0.17 | 0.17 | 0.18 | 0.15 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 2 | 1 |
| 1962 | 0.15 | 0.35 | 0.35 | 0.15 | 0.20 | 0.15 | 0.15 | 0.15 | 0.17 | 0.26 | 0.32 | 0.35 | 5 | 4 |
| 1963 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.42 | 0.42 | 0.42 | 0.15 | 0.21 | 0.21 | 0.15 | 3 | 2 |
| 1964 | 0.41 | 0.15 | 0.16 | 0.16 | 0.17 | 0.17 | 0.17 | 0.32 | 0.15 | 0.22 | 0.25 | 0.27 | 2 | 0 |

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breaches | High Flow Breaches |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 0.38 | 0.15 | 0.37 | 0.37 | 0.38 | 0.38 | 0.39 | 0.15 | 0.18 | 0.18 | 0.20 | 0.25 | 2 | 1 |
| 1966 | 0.26 | 0.28 | 0.28 | 0.28 | 0.33 | 0.35 | 0.40 | 0.15 | 0.15 | 0.40 | 0.15 | 0.23 | 3 | 2 |
| 1967 | 0.28 | 0.31 | 0.33 | 0.34 | 0.35 | 0.37 | 0.15 | 0.17 | 0.15 | 0.15 | 0.21 | 0.29 | 3 | 2 |
| 1968 | 0.34 | 0.36 | 0.36 | 0.36 | 0.40 | 0.15 | 0.23 | 0.23 | 0.23 | 0.24 | 0.24 | 0.24 | 1 | 0 |
| 1969 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 | 0.15 | 0.15 | 2 | 2 |
| 1970 | 0.15 | 0.27 | 0.15 | 0.15 | 0.24 | 0.27 | 0.15 | 0.33 | 0.36 | 0.39 | 0.15 | 0.20 | 5 | 4 |
| 1971 | 0.26 | 0.28 | 0.34 | 0.36 | 0.15 | 0.23 | 0.23 | 0.23 | 0.23 | 0.25 | 0.26 | 0.27 | 1 | 0 |
| 1972 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.30 | 0.30 | 0.30 | 0.30 | 0.38 | 0.41 | 0 | 0 |
| 1973 | 0.42 | 0.15 | 0.20 | 0.30 | 0.44 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 8 | 7 |
| 1974 | 0.30 | 0.40 | 0.15 | 0.20 | 0.28 | 0.32 | 0.34 | 0.35 | 0.37 | 0.38 | 0.40 | 0.15 | 2 | 1 |
| 1975 | 0.15 | 0.17 | 0.19 | 0.19 | 0.20 | 0.34 | 0.39 | 0.39 | 0.39 | 0.15 | 0.15 | 0.21 | 3 | 3 |
| 1976 | 0.38 | 0.15 | 0.19 | 0.19 | 0.15 | 0.39 | 0.42 | 0.15 | 0.30 | 0.36 | 0.39 | 0.43 | 3 | 1 |
| 1977 | 0.45 | 0.15 | 0.15 | 0.25 | 0.25 | 0.33 | 0.15 | 0.15 | 0.15 | 0.32 | 0.43 | 0.15 | 6 | 4 |
| 1978 | 0.15 | 0.29 | 0.41 | 0.15 | 0.18 | 0.20 | 0.21 | 0.23 | 0.25 | 0.15 | 0.15 | 0.15 | 5 | 4 |
| 1979 | 0.29 | 0.38 | 0.44 | 0.15 | 0.19 | 0.22 | 0.24 | 0.26 | 0.30 | 0.31 | 0.31 | 0.33 | 1 | 0 |
| 1980 | 0.34 | 0.42 | 0.45 | 0.15 | 0.28 | 0.15 | 0.15 | 0.42 | 0.15 | 0.24 | 0.15 | 0.32 | 5 | 4 |
| 1981 | 0.44 | 0.15 | 0.19 | 0.21 | 0.21 | 0.22 | 0.40 | 0.15 | 0.18 | 0.20 | 0.21 | 0.21 | 2 | 0 |
| 1982 | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.15 | 0.27 | 0.27 | 1 | 1 |
| 1983 | 0.30 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.15 | 0.39 | 0.43 | 0.45 | 1 | 1 |
| 1984 | 0.15 | 0.15 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 1 | 0 |
| 1985 | 0.42 | 0.15 | 0.15 | 0.21 | 0.23 | 0.30 | 0.33 | 0.33 | 0.33 | 0.33 | 0.15 | 0.21 | 3 | 2 |
| 1986 | 0.26 | 0.30 | 0.31 | 0.31 | 0.32 | 0.33 | 0.34 | 0.34 | 0.43 | 0.15 | 0.18 | 0.20 | 1 | 0 |
| 1987 | 0.21 | 0.21 | 0.21 | 0.21 | 0.34 | 0.41 | 0.42 | 0.44 | 0.44 | 0.45 | 0.45 | 0.15 | 1 | 0 |
| 1988 | 0.17 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.32 | 0.36 | 0.36 | 0.37 | 0.37 | 0.37 | 0 | 0 |
| 1989 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.31 | 0.34 | 0.34 | 0.45 | 0.15 | 0.15 | 0.16 | 4 | 3 |
| 1990 | 0.20 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.33 | 0.36 | 0 | 0 |
| 1991 | 0.15 | 0.20 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.15 | 0.15 | 3 | 2 |
| 1992 | 0.15 | 0.38 | 0.39 | 0.39 | 0.40 | 0.40 | 0.41 | 0.41 | 0.15 | 0.17 | 0.20 | 0.39 | 2 | 1 |
| 1993 | 0.45 | 0.45 | 0.15 | 0.27 | 0.32 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.15 | 0.25 | 2 | 0 |
| 1994 | 0.25 | 0.25 | 0.15 | 0.15 | 0.17 | 0.19 | 0.31 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 2 | 2 |
| 1995 | 0.36 | 0.41 | 0.43 | 0.43 | 0.43 | 0.44 | 0.44 | 0.44 | 0.44 | 0.45 | 0.15 | 0.15 | 1 | 0 |
| 1996 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.42 | 0.15 | 0.15 | 0.26 | 0.26 | 0.26 | 4 | 3 |
| 1997 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.15 | 0.30 | 0.30 | 0.30 | 0.32 | 0.36 | 0.38 | 1 | 1 |
| 1998 | 0.39 | 0.40 | 0.40 | 0.41 | 0.41 | 0.42 | 0.42 | 0.42 | 0.42 | 0.15 | 0.19 | 0.22 | 1 | 0 |
| 1999 | 0.15 | 0.26 | 0.26 | 0.15 | 0.28 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 4 | 4 |
| 2000 | 0.25 | 0.15 | 0.22 | 0.27 | 0.28 | 0.31 | 0.35 | 0.36 | 0.36 | 0.15 | 0.23 | 0.38 | 2 | 0 |
| 2001 | 0.43 | 0.15 | 0.20 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.21 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 2002 | 0.15 | 0.21 | 0.23 | 0.24 | 0.24 | 0.24 | 0.27 | 0.15 | 0.15 | 0.20 | 0.24 | 0.25 | 3 | 3 |
|  |  |  |  |  |  |  |  |  |  |  |  | Ave | 2.63 | 1.72 |

🟪 High flow breaching

🟦 Low flow breaching

### 3.2.4 Biotic Components

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

**MICROALGAE**

***Phytoplankton***

The slight decrease in the frequency of floods in the PS poses no significant changes and thus suggests that there is little change in the phytoplankton and microphytobenthic (MPB) chlorophyll *a* levels from the natural state or reference condition (RC). The annual distribution pattern of river inflow under the present state indicate little variation from the RC and thus would be likely that microalgal patterns would have changed little from the RC. Under the PS, chlorophyll *a* concentrations are generally low, reflecting the low levels of nutrients in the system. This may be indicative of a relatively low impact some of the land-use practises have had on the estuary, although during peak floods, nutrients spike up. These increased nutrients, however, may not be readily available for uptake by phytoplankton as they are flushed out of the system by the same flood that brought them in.

Features governing open-mouth events have possibly not changed markedly from those under the RC. It is therefore likely that chlorophyll *a* biomass responses will include an initial reduction followed by a subsequent increase when stable water-column conditions develop after mouth closure. These conditions improve residence times for phytoplankton to develop, although available nutrients will become depleted, thus resulting in low chlorophyll *a* levels.

Species composition under open-mouth conditions in the PS is characterised by the predominance of flagellates including dinoflagellates. High diatom abundances occurred under closed-mouth conditions and were replaced by a flagellated community following a 4-5 week period after mouth breaching. The slight decrease in the flood regime and monthly river inflow patterns in the PS means that these phytoplankton characteristics are probably close to RC.

***Benthic microalgae***

Features governing open-mouth events have possibly not changed markedly from RC, therefore MPB chlorophyll *a* biomass responses will include an initial reduction followed by a subsequent increase in biomass when stable estuarine conditions develop. Under the PS, MPB chlorophyll *a* concentrations are normally low although significant increases are exhibited several days following breaching of the mouth.

Microphytobenthic habitat loss during floods and open mouth conditions, and its subsequent accretion following extended closure of the mouth under the PS, is probably not very different from the RC. Sustained frequencies of mouth breaching reduce chlorophyll *a* levels to low values. Turbidity reduces light reaching the sediment during flood and post flood periods. Under the PS, overwash events may not differ markedly from the RC. Therefore, under a closed-mouth state, overwash events might induce resuspension of fine particulate matter although the imported clear marine water may negate that effect by improving greater photic depth, particularly in the lower reaches of the estuary.

Under the PS, seepage areas (e.g. septic tank seepage) are considered as sources of additional nutrient input for MPBs and are likely to influence benthic primary production. These seepage points would probably not have been present under the RC. Present development is possibly impacting on MPB production, however the overall effects are currently considered minimal. Future Increases in housing development might increase allochthonous nutrient inputs from seepage sites, including additional underground sources possibly affecting MPB community structure by shifting it towards one composed more of a cyanobacterial assemblage.

Confidence: Medium

**MACROPHYTES**

***Biomass distribution***

A small decrease in floods and an increase in the frequency of mouth closure would result in an increase in submerged macrophyte and macroalgal abundance. Agricultural activities in the catchment and nutrient input has probably increased macrophyte growth particularly that of reeds, sedges, macroalgae and submerged macrophytes. Anthropogenic influences such as the construction of the R72 road bridge has caused sedimentation and reeds have established on the east bank below and above the bridge.

An analysis of past aerial photographs showed that salt marsh areas have remained stable. Long periods of closed mouth conditions in the early 1990s to late 1990s resulted in large stands of submerged macrophytes developing. In 2005-2006, submerged macrophyte cover was low because of the increase in open mouth conditions.

***Species diversity, richness and rarity***

There may have been a small loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity.

***Seasonal variability and community composition***

The nutrient changes, decrease in flooding and increased frequency of mouth closure has increased reed, submerged macrophyte and macroalgal cover reducing open water surface area and sand and mudflats.

Confidence: Medium

## INVERTEBRATES (including Macrobenthos, Zooplankton and Hyperbenthos)

### Macrobenthos

***Biomass distribution***

Sediment characteristics are key drivers in influencing macrozoobenthic distribution. Flood patterns have only changed marginally so that the reference condition is likely to have been very similar to present. However, prior to construction of the R72 bridge, the community change between sandy and muddy substrata is likely to have been more gradual.

***Species diversity, richness and rarity***

Any shift is likely to have been very marginal and well within the range of natural variability.

***Seasonal variability and community composition***

As above.

Confidence: Medium

### Zooplankton

***Biomass distribution***

Flood patterns have only changed marginally so that the reference condition is likely to have been very similar to present.

***Species diversity, richness and rarity***

Any shift is likely to have been very marginal and well within the range of natural variability.

***Seasonal variability and community composition***

As above.

Confidence: Medium

### Hyperbenthos

***Biomass distribution***

Flood patterns have only changed marginally so that the reference condition is likely to have been very similar to present

***Seasonal variability and community composition***

As above

Confidence: Medium

## FISH

***Biomass distribution***

Because there has been little change in open mouth conditions between the RC and the PS, it is highly likely that the current fish biomass is very similar to that found in the natural state.

***Species diversity, richness and rarity:***

Similarly, the species diversity, richness and rarity have probably deviated very little from that occurring under the RC.

***Seasonal variability and community composition:***

Once again, it is highly unlikely that seasonal variability and community composition of fishes in the East Kleienmonde are different from the natural state.

Confidence: Medium

## BIRDS

***Distribution***

Bird distribution is determined primarily by habitat and food availability. Food availabilty has remained similar between the Reference Condition (RC) and the Present State (PS). Housing developments have resulted in a loss of roosting and undisturbed feeding habitat below the bridge so that in the PS less birds probably occur in the area between the mouth and the bridge than in the RC. Overall abundance is likely to be slightly lower due to the habitat loss described above.

***Species diversity, richness and rarity***

Due to housing developments and increased human disturbance on the estuary a loss of certain species may have occurred, especially shy and secretive species. In the PS only one species is associated with *Phragmites* reed beds (Purple Heron), showing that the increase in reeds did not increase diversity significantly.

***Seasonal variability and community composition:***

Seasonal variability and community composition has probably not changed considerably from the RC.

Confidence: Medium

## 3.4 Present Ecological Status of the East Kleinemonde Estuary

### 3.4.1 Abiotic Components

### Hydrology

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition | 95 | For the East Kleinemonde Estuary low river flows are defined as less than 0.12 $m^3 s^{-1}$.<br>Months with median low flows of less than 0.12 $m^3 s^{-1}$ occurred under the Reference Condition (RC) for 86.4 of the year. Under the Present State (PS) low flows occur for 86.0 % of the year. | L |
| b. % similarity in mean annual frequency of floods | 95 | The reduction in high flows is deemed to be very small based on the very limited reduction in simulated monthly flows. The 99%ile indicates that there is only a 1.8% decrease in the floods to the estuary | L |
| **Hydrology score** | **95** | | L |

### Hydrodynamics and mouth condition

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Change in mean duration of closure, e.g. over a 5 or 10 year period | 90 | Under the RC the East Kleinemonde Estuary mouth breaching (State 1 and 2) could potentially have occurred in 2.6 months of the year over the 83-year period. Of these 1.7 was related to high flow events that breached the system instantaneously.<br>Under the PS mouth occurrence of breaching events (State 1 and 2) have been reduced to 2.5 months of the year over the 83-year period (95.9% similar to the Reference Condition). Of these 1.7 (State 1) was related to high flow events that breached the system instantaneously. | L |
| **Hydrodynamics and mouth conditions score** | **90** | | L |

### Water quality

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification | 90 | As the river inflow to the East Kleinemonde Estuary and the frequency of breaching events is very similar to the RC, it is assumed that the salinity concentrations will also be very similar. | L |
| 2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary | 70 | River DIN concentrations increased from RC to PS (>10 times during high flow events and ~ 3 times during low flow periods), associated with agricultural activities in the catchment. Although the influence of river inflow in this system (as indicated by salinity) is generally limited to the upper reaches and despite an overall reduction in river inflow from RC to PS, these marked increases in river DIN would nevertheless have resulted in a significant increase in DIN loads to the system compared to the RC. Allow a 30% modification from RC. | L |

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 2b. Suspended solids (turbidity) in the estuary | 95 | Turbidity in the system are influenced by high river inflow (higher turbidity concentration) and turbulence associated with tidal exchange (during intermittently open/closed states)<br>Although there has not been a marked change in the occurrence of intermittently open/closed states (States 1 and 2) compared with the RC, there has been a 5% reduction in river inflow compared to RC. The system should therefore be less turbid compared with RC. Allow a modification of 5% | L |
| 2c. Dissolved oxygen in the estuary | 85 | There are no marked differences between intermittently open/closed states (States 1 and 2) and closed state (State 3) compared with the RC. As DO concentrations are only expected to decrease with a marked increase in the frequency and duration of the closed state, there should be no significant change from the RC.<br>However an increase in nutrient (and possibly organic) loading from the catchment (associated with agricultural activity) probably increased oxygen demand under the PS. Allow a 15% modification from RC | L |
| 2d. Levels of toxins | 80 | There are no major industrial activities in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. Allow a 20% modification from RC. | L |
| **Water Quality score** | **78** | | L |

## Physical habitat alteration

| VARIABLE | | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|---|
| 1. Resemblance of intertidal sediment structure and distribution to reference condition | | | | |
| 1a | % similarity in intertidal area exposed | 85 | Allow for a 5% change in the intertidal area due to changes in river inflow. An additional 5 % is allowed for the stabilisation of the lower estuary and 5 % for infilling of the intertidal area. | M |
| 1b | % similarity in sand fraction relative to total sand and mud | 75 | The bridge acts as barrier that prevents the development of a gradient from marine sediment below the bridge to muddier sediment further upstream. In addition, the system may have become slightly muddier due to land-use changes in the catchment. | M |
| | | | | |
| 2 | Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology | 90 | Allow 5% change in the subtidal area due to changes in river inflow. In addition, 5 % is allocated for lower estuary stabilisation. | M |
| **Anthropogenic influence:** | | | | |
| | Percentage of overall change in intertidal and Supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary | 80 | Sedimentation may have occurred due to change in land-use in the catchment and the bridge. | M |
| | Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, jetties, marinas) rather than modifications to water flow into estuary | 80 | Sedimentation may have occurred due to change in land-use in the catchment, e.g. agriculture and the bridge. | M |
| **Physical habitat score** | | **85** | | M |

### 3.4.2 Biotic Component

## Microalgae

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Phytoplankton | | | |
| 1. Species richness | 90 | There is minimal difference between river inflow patterns under the RC (i.e. low flow occurrence 98.2) and the present state (i.e. low flow occurrence 96.4), corresponding to possibly a 2-5% change , which is equivalent to a score of 90, therefore phytoplankton species richness has probably not changed markedly. | M |
| 2a. Abundance | 95 | There is minimal difference between RC (i.e. low flow occurrence 98.2) and the present state (i.e. low flow occurrence 96.4), corresponding to possibly a 2-5% change, therefore phytoplankton abundances have probably not changed markedly. | M |
| 2b. Community composition | 95 | Since there is minimal difference between RC (i.e. low flow occurrence 98.2) and the present state (i.e. low flow occurrence 96.4), corresponding to possibly a 2-5% change, therefore phytoplankton species composition has probably not changed markedly. | M |
| Benthic microalgae | | | |
| 1. Species richness | 80 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under the present state suggest a slight increase in sediment load altering MPB habitat. Species richness would likely have had a deviation of approximately 10% from natural conditions, which is equivalent to a score of 80. | M |
| 2a. Abundance | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under the present state suggest a slight increase in sediment load altering MPB habitat. Microphytobenthic abundances would likely have had a deviation of approximately 10% from natural conditions. | M |
| 2b. Community composition | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under the present state suggest a slight increase in sediment load altering MPB habitat. Community composition would likely have had a deviation of approximately 10% from natural conditions. | M |
| **Microalgae score** | **80** | | M |

## Macrophytes

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 97 | There may have been a small loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity. (1% change). | M |
| 2a. Abundance/Biomass | 85 | A small decrease in floods and increase in the frequency of mouth closure would result in an increase in submerged macrophyte and macroalgal abundance. Agricultural activities in the catchment and nutrient input has increased macrophyte growth particularly that of reeds, sedges, macroalgae and submerged macrophytes (overall 10% change).<br>Reeds have established on the east bank below and above the R72 bridge (5 % change). These reeds represent 50 % of the total reed area of the estuary. | M |
| 2b. Community composition | 95 | The nutrient changes, decrease in flooding and frequency of mouth closure has increased reed, submerged macrophyte and macroalgal cover reducing open water surface area and bare sand and mudflats.<br>Reed beds have encroached on submerged macrophyte habitat on the East bank. | M |
| **Macrophytes score** | **85** | | M |

## Invertebrates

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Zooplankton | | | |
| 1. Species richness | 90 | Because of the very small reduction in the frequency of larger floods (<2%) and slight reduction in base flow (<2%), species richness is not considered to have been different compared to the PS | M |
| 2a. Abundance | 95 | As above | M |
| 2b. Community composition | 95 | As above | M |
| **Invertebrates score** | **90** | | M |
| Macrobenthos | | | |
| 1. Species richness | 90 | Because of the very small reduction in the frequency of larger floods (<2%) and slight reduction base flow (<2%) species richness is not considered to have been different compared to present | M |
| 2a. Abundance | 95 | As above | M |
| 2b. Community composition | 95 | As above | M |
| **Invertebrates score** | **90** | | M |
| Hyperbenthos | | | |
| 1. Species richness | 90 | Because of the very small reduction in the frequency of larger floods (<2%) and slight reduction base flow (<2%) species richness is not considered to have been different compared to PS | M |
| 2a. Abundance | 95 | As above | M |
| 2b. Community composition | 95 | As above | M |
| **Invertebrates score** | **90** | | M |

## Fish

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 100 | No difference in species richness is likely to have occurred between Reference Conditions and the Present State. | H |
| 2a. Abundance | 90 | A slight reduction in abundance of macrophytes associated fish species is likely, primarily due to encroachment by reeds in the lower reaches. Allow 5% due for changes in macrophytes and 5% for fishing effects. | M |
| 2b. Community composition | 90 | As above | H |
| **Fish score** | **90** | | H |

## Birds

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | Human disturbance and loss of roosting sites is likely to have caused a slight loss of species (a loss of 2 species corresponds to 4 % of species change from RC). More *Phragmites* stands increased diversity probably only by one species. | M |
| 2a. Abundance | 85 | Lower abundance due to increased disturbance and less roosting sites. | M |
| 2b. Community composition | 95 | As above | M |
| **Bird score** | **85** | | M |

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

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

| COMPONENT | % CHANGE CAUSED BY NON-FLOW RELATED ACTIVITIES | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Microalgae | Phytoplankton<br>5<br>Microphytobenthos<br>10 | *Phytoplankton*<br>Direct effects of physical structures (e.g. bridges) on phytoplankton under the PS would be the creation of quiescent backwater areas that form pools for phytoplankton to use as a seed sources and function to colonize other habitats.<br>*Microphytobenthos*<br>Direct effects of physical structures on MPBs under the PS would be the influence on sediment loss and accretion processes, especially downstream of the bridge. Increases in sediment deposition would effectively improve colonisable MPB habitat area. | L |
| Macrophytes | 5 | Bridge and run-off from residential developments have increased reed abundance. | H |
| Invertebrates | 90 | Small localized effects on the scale of metres to tens of metres due to changes in land-use and the bridge. | H |
| Fish | 50 | Some change would be expected in fish assemblages associated with the bridge and fishing activities would certainly have caused increased mortalities for certain species. | M |
| Birds | 90 | Loss of roosting and undisturbed feeding habitat would have decreased abundance and diversity | M |

### 3.4.3 Determining the Present Ecological Status (PES)

The Estuarine Health Index (EHI) scores allocated to the East Kleinemonde Estuary (Present State) were:

| Variable | Weight | Score | Weighted score |
|---|---|---|---|
| Hydrology | 25 | 95 | 24 |
| Hydrodynamics and mouth condition | 25 | 90 | 23 |
| Water quality | 25 | 78 | 20 |
| Physical habitat alteration | 25 | 85 | 21 |
| **Habitat health score** | | | **87** |
| Microalgae | 20 | 80 | 16 |
| Macrophytes | 20 | 85 | 17 |
| Invertebrates | 20 | 90 | 18 |
| Fish | 20 | 90 | 18 |
| Birds | 20 | 85 | 17 |
| **Biotic Health Score** | | | **86** |
| **Estuarine Health score** | | | **87** |

The Estuarine Health Index score for the East Kleinemonde Estuary, based on its Present State, is 87, translating into a **Present Ecological Status** of a **B+** as indicated below:

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

Although the Present Ecological Status of the East Kleinemonde Estuary is a high B, the system is on a **trajectory of change downwards**. At the specialist workshop it was noted that an increase in fishing pressures, nutrient input from the catchment and septic tanks (as reflected in increased reed growth along the eastern shore below the bridge), riparian developments, noise disturbance and loss of aquatic habitat due to boating are influencing the system negatively.

The Estuarine Importance scores allocated to the East Kleinemonde Estuary, guided by Turpie (2002, 2004), were as follows:

| Criterion | Weight | Score | Weighted score |
|---|---|---|---|
| Estuary Size | 15 | 70 | 11 |
| Zonal Rarity Type | 10 | 10 | 1 |
| Habitat Diversity | 25 | 90 | 23 |
| Biodiversity Importance | 25 | 84 | 21 |
| Functional Importance | 25 | 60 | 15 |
| **Estuarine Importance Score** | | | **70** |

The Functional Importance of the East Kleinemonde on a regional scale is estimated to be 60, since significant amounts of organic material generated in the estuary during the closed phase are exported to the nearshore during the open phase. The overall **Estuarine Importance Score**, based on its Present State is **70**, thus indicating that the estuary is important, as indicated below:

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

### Recommended ecological category for East Kleinemonde Estuary

The recommended Ecological Reserve Category (ERC) represents the level of protection that should be assigned to an estuary. In turn, this is used to determine the Ecological Reserve. For estuaries, the first step is to determine the 'minimum' Ecological Reserve Category of an estuary, based on its Present Ecological Status (PES). The relationship between Estuarine Health Index Score, Present Ecological Status and Ecological Reserve Category is set out below:

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

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

The minimum Ecological Reserve Category is determined by the Present Ecological Status. The degree to which the Ecological Category needs to be elevated above the Present Ecological Status depends on the level of **importance** and the level of **protection** or **desired protection** of a particular estuary (see below).

| Current/desired protection status and estuary importance | Recommended Ecological Reserve Category | Policy basis |
|---|---|---|
| Protected area | A or BAS* | Protected and desired protected areas should be restored to and maintained in the best possible state of health |
| Desired Protected Area | | |
| Highly important | PES + 1, min B | Highly important estuaries should be in an A or B class |
| Important | PES + 1, min C | Important estuaries should be in an A, B or C class |
| Of low to average importance | PES, min D | The remaining estuaries can be allowed to remain in a D class. |

* BAS = Best Attainable State

The East Kleinemonde Estuary is been targeted as a Desired Protected Area by the C.A.P.E. Estuaries Conservation Plan for the temperate areas of South Africa (Turpie and Clarke 2007). According to the guidelines for assigning a recommended Ecological Reserve Category, the estuary should be classified as a Category A or the Best Attainable State (BAS).

At the specialist workshop it was concluded that the changes currently contributing to the Present State of the estuary are related to flow reduction, fishing pressures, human disturbance around the estuary and nutrient loading from the catchment.

The East Kleinemonde Estuary is very vulnerable to non-flow related activities such as fishing, power boating and nutrient loading. The present level of urban development around the estuary acts as a constraint and prevents the system from being rehabilitated to a Category A. Thus, the workshop concluded that the recommended ERC for the East Kleinemonde Estuary be a **Category B,** i.e. at least maintain the Present Ecological Status.

# 4 Quantification of Ecological Reserve Scenarios

A summary of the suite of future runoff scenarios, evaluated as part of this project, as well as the Reference and Present flow scenarios, (provided by Prof D A Hughes, Institute for Water Research, Rhodes University) is presented below.

| Name | Description | MAR (million $m^3$/annum) | Percentage Retained |
|---|---|---|---|
| **Reference** | Reference | 2.856 | 100.0 |
| **Present** | Present Flows | 2.748 | 96.2 |
| **Future Scenario 1** | Dam Development (excluding an increase in non-flow related anthropogenic activities) | 2.409 | 84.3 |
| **Future Scenario 2** | Off-channel intermittent abstraction (excluding an increase in non-flow related anthropogenic activities) | 2.575 | 90.1 |
| **Future Scenario 3** | Similar to Scenario 2, including other non-flow related anthropogenic activities. | 2.575 | 90.1 |
| **Future Scenario 4** | Similar to Scenario 2, including other non-flow related anthropogenic activities, but mitigating for the increase in waste water and stormwater runoff | 2.575 | 90.1 |

The Present State represents a situation comprising 300 developed residential plots that are supplied with water from the Wellington Dam (capacity: 0.206 X $10^6$ $m^3$) supplemented by borehole water. The Wellington Dam is situated on a tributary of the East Kleinemonde River that represents approximately 9% of the total catchment area of the East Kleinemonde system.

Details on the four simulated Future Scenarios are as follows:

- Future Scenario 1: This comprises 1010 developed residential plots with the water supply originating from a new dam constructed on the main river. The assumption is that the sub-catchment feeding the dam represents about 67% of the total catchment area with the capacity of the dam being determined appropriately, given the patterns of inflow and the demand. The maximum recommended percentage of the MAR impounded is 15%.

- Future Scenario 2: Comprises 1010 developed residential plots with the water supply originating from an off-channel reservoir fed by intermittent pumping (as required by demand) from the main river (using a weir of appropriate design). The assumption is that pumping will remove most of the water from the river during low flow periods but will have little impact on short-duration higher flows.

- Future Scenario 3: Similar to Scenario 2, but including additional all the other non-flow related anthropogenic activities associated with the proposed new developments (e.g. increased fishing pressures, power boating, human disturbance, seepage from septic tanks, storm water runoff).

- Future Scenario 4: Similar to Scenario 3, but mitigating for the increased pressures including other non-flow related anthropogenic activities in the Estuarine Health Index. This scenario includes mitigating for the increase in municipal waste water and storm water runoff from the proposed new developments.

## 4.1 Future Scenario 1: Dam Development

### 4.1.1 Abiotic Components

**a) Seasonal variability in river inflow:**

Monthly simulated runoff data for the Future Scenario 1 is provided in Table 3. A summary of flow distributions (mean monthly flows in $m^3$ $s^{-1}$) for the Future Scenario 1, derived from the 83-year simulated data set, is provided below:

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.789 | 1.105 | 0.694 | 0.295 | 0.804 | 1.527 | 1.069 | 2.739 | 1.253 | 0.956 | 0.956 | 1.494 |
| 90%ile | 0.223 | 0.221 | 0.154 | 0.045 | 0.020 | 0.073 | 0.125 | 0.145 | 0.133 | 0.078 | 0.119 | 0.207 |
| 80%ile | 0.091 | 0.047 | 0.051 | 0.009 | 0.009 | 0.034 | 0.026 | 0.020 | 0.016 | 0.023 | 0.025 | 0.072 |
| 70%ile | 0.042 | 0.029 | 0.015 | 0.004 | 0.006 | 0.010 | 0.017 | 0.008 | 0.006 | 0.008 | 0.009 | 0.017 |
| 60%ile | 0.025 | 0.014 | 0.007 | 0.001 | 0.002 | 0.005 | 0.009 | 0.004 | 0.003 | 0.003 | 0.004 | 0.008 |
| 50%ile | 0.007 | 0.008 | 0.003 | 0.001 | 0.001 | 0.003 | 0.004 | 0.002 | 0.001 | 0.001 | 0.002 | 0.003 |
| 40%ile | 0.003 | 0.006 | 0.002 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 |
| 30%ile | 0.001 | 0.002 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 20%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**b) Present flood regime**

The flood regime is judged to be very similar to that under reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months with flow higher than 0.12 $m^3$ $s^{-1.}$ The 99%ile indicates that there is only a 3.5 % decrease in floods to the estuary.

*Confidence: Medium*

**c) Present sediment processes**

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

*Confidence: Low*

**Table 4.1** Simulated monthly volumes (million m$^3$) in the East Kleinemonde Estuary for Future Scenario 1.

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total breach | High Flow Breach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.15 | 0.15 | 0.17 | 0.17 | 0.18 | 0.21 | 0.42 | 0.15 | 0.16 | 0.17 | 0.18 | 0.18 | 2 | 0 |
| 1921 | 0.18 | 0.26 | 0.30 | 0.30 | 0.30 | 0.31 | 0.34 | 0.36 | 0.15 | 0.15 | 0.15 | 0.34 | 3 | 3 |
| 1922 | 0.44 | 0.15 | 0.15 | 0.15 | 0.43 | 0.44 | 0.15 | 0.16 | 0.16 | 0.19 | 0.20 | 0.21 | 4 | 3 |
| 1923 | 0.21 | 0.23 | 0.24 | 0.25 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.27 | 0 | 0 |
| 1924 | 0.27 | 0.27 | 0.30 | 0.31 | 0.31 | 0.42 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.23 | 1 | 0 |
| 1925 | 0.24 | 0.24 | 0.25 | 0.25 | 0.27 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0 | 0 |
| 1926 | 0.41 | 0.44 | 0.44 | 0.44 | 0.44 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 1 | 0 |
| 1927 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.18 | 0.38 | 3 | 2 |
| 1928 | 0.15 | 0.35 | 0.40 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.15 | 0.15 | 0.28 | 0.15 | 4 | 3 |
| 1929 | 0.15 | 0.27 | 0.28 | 0.28 | 0.28 | 0.35 | 0.37 | 0.37 | 0.38 | 0.38 | 0.39 | 0.42 | 1 | 1 |
| 1930 | 0.15 | 0.27 | 0.27 | 0.27 | 0.27 | 0.29 | 0.33 | 0.34 | 0.34 | 0.43 | 0.15 | 0.16 | 2 | 1 |
| 1931 | 0.15 | 0.15 | 0.15 | 0.41 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.44 | 0.15 | 4 | 4 |
| 1932 | 0.15 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.29 | 0.31 | 0.31 | 0.31 | 0.42 | 0.15 | 3 | 2 |
| 1933 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.36 | 0.43 | 0.44 | 0.44 | 0.15 | 0.15 | 0.17 | 3 | 2 |
| 1934 | 0.18 | 0.27 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.40 | 5 | 5 |
| 1935 | 0.15 | 0.27 | 0.31 | 0.33 | 0.35 | 0.37 | 0.38 | 0.40 | 0.41 | 0.41 | 0.42 | 0.42 | 1 | 0 |
| 1936 | 0.15 | 0.15 | 0.35 | 0.35 | 0.35 | 0.15 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 3 | 3 |
| 1937 | 0.27 | 0.28 | 0.15 | 0.15 | 0.15 | 0.19 | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 2 | 2 |
| 1938 | 0.24 | 0.15 | 0.43 | 0.43 | 0.15 | 0.15 | 0.45 | 0.15 | 0.15 | 0.15 | 0.15 | 0.18 | 4 | 3 |
| 1939 | 0.28 | 0.31 | 0.15 | 0.15 | 0.15 | 0.15 | 0.37 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 4 | 4 |
| 1940 | 0.38 | 0.15 | 0.17 | 0.17 | 0.18 | 0.18 | 0.15 | 0.15 | 0.17 | 0.17 | 0.17 | 0.17 | 3 | 2 |
| 1941 | 0.17 | 0.19 | 0.34 | 0.43 | 0.45 | 0.45 | 0.45 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 1 | 0 |
| 1942 | 0.26 | 0.29 | 0.30 | 0.36 | 0.38 | 0.38 | 0.15 | 0.18 | 0.18 | 0.18 | 0.20 | 0.21 | 1 | 0 |
| 1943 | 0.21 | 0.15 | 0.27 | 0.28 | 0.28 | 0.41 | 0.15 | 0.19 | 0.21 | 0.21 | 0.21 | 0.15 | 3 | 2 |
| 1944 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.39 | 0.39 | 0.39 | 0.39 | 0 | 0 |
| 1945 | 0.15 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 1 | 0 |
| 1946 | 0.18 | 0.18 | 0.19 | 0.19 | 0.19 | 0.37 | 0.43 | 0.44 | 0.15 | 0.22 | 0.25 | 0.25 | 1 | 0 |
| 1947 | 0.25 | 0.26 | 0.27 | 0.27 | 0.27 | 0.27 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2 | 2 |
| 1948 | 0.15 | 0.26 | 0.26 | 0.26 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 1 | 1 |
| 1949 | 0.27 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 4 | 4 |
| 1950 | 0.15 | 0.15 | 0.15 | 0.15 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.35 | 0.15 | 5 | 5 |
| 1951 | 0.15 | 0.15 | 0.15 | 0.15 | 0.19 | 0.21 | 0.21 | 0.27 | 0.29 | 0.29 | 0.29 | 0.15 | 2 | 2 |
| 1952 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.25 | 0.15 | 2 | 2 |
| 1953 | 0.15 | 0.15 | 0.40 | 0.41 | 0.41 | 0.15 | 0.21 | 0.15 | 0.33 | 0.36 | 0.15 | 0.34 | 5 | 3 |
| 1954 | 0.42 | 0.15 | 0.21 | 0.23 | 0.27 | 0.28 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 | 0.31 | 1 | 0 |
| 1955 | 0.33 | 0.35 | 0.36 | 0.36 | 0.40 | 0.42 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 | 0.15 | 1 | 0 |
| 1956 | 0.18 | 0.20 | 0.24 | 0.25 | 0.32 | 0.34 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.15 | 1 | 0 |
| 1957 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.27 | 0.15 | 0.15 | 0.16 | 0.17 | 0.17 | 2 | 2 |
| 1958 | 0.17 | 0.17 | 0.23 | 0.26 | 0.26 | 0.29 | 0.32 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0 | 0 |
| 1959 | 0.34 | 0.34 | 0.34 | 0.35 | 0.35 | 0.35 | 0.35 | 0.41 | 0.44 | 0.44 | 0.44 | 0.15 | 1 | 0 |
| 1960 | 0.21 | 0.23 | 0.23 | 0.24 | 0.25 | 0.26 | 0.26 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0 | 0 |
| 1961 | 0.30 | 0.32 | 0.33 | 0.33 | 0.33 | 0.15 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 1 | 0 |
| 1962 | 0.38 | 0.44 | 0.44 | 0.15 | 0.17 | 0.15 | 0.15 | 0.15 | 0.16 | 0.21 | 0.27 | 0.27 | 4 | 3 |
| 1963 | 0.27 | 0.27 | 0.28 | 0.28 | 0.15 | 0.34 | 0.34 | 0.34 | 0.41 | 0.43 | 0.43 | 0.15 | 2 | 2 |
| 1964 | 0.39 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.15 | 0.20 | 0.22 | 0.23 | 0.24 | 1 | 0 |
| 1965 | 0.27 | 0.15 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.37 | 0.38 | 0.38 | 0.38 | 0.40 | 1 | 1 |
| 1966 | 0.40 | 0.41 | 0.41 | 0.41 | 0.43 | 0.43 | 0.45 | 0.15 | 0.15 | 0.38 | 0.15 | 0.20 | 3 | 2 |

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total breach | High Flow Breach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1967 | 0.21 | 0.22 | 0.23 | 0.24 | 0.24 | 0.25 | 0.27 | 0.28 | 0.15 | 0.15 | 0.17 | 0.24 | 2 | 2 |
| 1968 | 0.26 | 0.26 | 0.26 | 0.26 | 0.27 | 0.35 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0 | 0 |
| 1969 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.15 | 0.15 | 2 | 2 |
| 1970 | 0.15 | 0.26 | 0.15 | 0.15 | 0.18 | 0.19 | 0.15 | 0.29 | 0.31 | 0.32 | 0.37 | 0.39 | 4 | 4 |
| 1971 | 0.42 | 0.43 | 0.44 | 0.15 | 0.25 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.30 | 1 | 0 |
| 1972 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.31 | 0.34 | 0.35 | 0 | 0 |
| 1973 | 0.35 | 0.40 | 0.41 | 0.44 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 8 | 7 |
| 1974 | 0.27 | 0.32 | 0.34 | 0.36 | 0.38 | 0.40 | 0.40 | 0.41 | 0.41 | 0.42 | 0.43 | 0.15 | 1 | 1 |
| 1975 | 0.15 | 0.16 | 0.16 | 0.16 | 0.17 | 0.21 | 0.23 | 0.23 | 0.23 | 0.15 | 0.15 | 0.18 | 3 | 3 |
| 1976 | 0.33 | 0.43 | 0.45 | 0.45 | 0.15 | 0.33 | 0.34 | 0.15 | 0.28 | 0.32 | 0.33 | 0.34 | 2 | 1 |
| 1977 | 0.35 | 0.42 | 0.15 | 0.24 | 0.24 | 0.27 | 0.15 | 0.15 | 0.15 | 0.30 | 0.39 | 0.15 | 5 | 4 |
| 1978 | 0.43 | 0.15 | 0.23 | 0.25 | 0.26 | 0.26 | 0.27 | 0.28 | 0.28 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 1979 | 0.27 | 0.31 | 0.33 | 0.34 | 0.36 | 0.37 | 0.37 | 0.38 | 0.39 | 0.40 | 0.40 | 0.40 | 0 | 0 |
| 1980 | 0.41 | 0.43 | 0.44 | 0.15 | 0.19 | 0.15 | 0.15 | 0.38 | 0.15 | 0.23 | 0.15 | 0.31 | 5 | 3 |
| 1981 | 0.40 | 0.42 | 0.43 | 0.44 | 0.44 | 0.44 | 0.15 | 0.17 | 0.18 | 0.19 | 0.19 | 0.19 | 1 | 0 |
| 1982 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.31 | 0.35 | 0.35 | 0 | 0 |
| 1983 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.15 | 0.23 | 0.24 | 0.25 | 1 | 0 |
| 1984 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0 | 0 |
| 1985 | 0.34 | 0.15 | 0.15 | 0.17 | 0.18 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.25 | 0.27 | 2 | 2 |
| 1986 | 0.29 | 0.30 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.35 | 0.36 | 0.37 | 0.37 | 0 | 0 |
| 1987 | 0.38 | 0.38 | 0.38 | 0.38 | 0.42 | 0.44 | 0.45 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 1 | 0 |
| 1988 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.21 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0 | 0 |
| 1989 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.20 | 0.21 | 0.21 | 0.25 | 0.26 | 0.26 | 0.26 | 4 | 2 |
| 1990 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.32 | 0.33 | 0 | 0 |
| 1991 | 0.38 | 0.39 | 0.39 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.15 | 0.42 | 1 | 1 |
| 1992 | 0.15 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.38 | 0.39 | 0.40 | 0.15 | 2 | 1 |
| 1993 | 0.17 | 0.17 | 0.23 | 0.27 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.38 | 0.42 | 0 | 0 |
| 1994 | 0.42 | 0.42 | 0.15 | 0.15 | 0.16 | 0.16 | 0.20 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 2 | 2 |
| 1995 | 0.22 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0 | 0 |
| 1996 | 0.25 | 0.15 | 0.35 | 0.36 | 0.36 | 0.36 | 0.44 | 0.15 | 0.15 | 0.25 | 0.25 | 0.25 | 3 | 2 |
| 1997 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.40 | 0.45 | 0.45 | 0.45 | 0.15 | 0.16 | 0.17 | 1 | 0 |
| 1998 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.23 | 0.24 | 0.25 | 0 | 0 |
| 1999 | 0.36 | 0.40 | 0.40 | 0.15 | 0.20 | 0.15 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 2 | 1 |
| 2000 | 0.15 | 0.25 | 0.29 | 0.30 | 0.31 | 0.31 | 0.33 | 0.33 | 0.33 | 0.38 | 0.41 | 0.15 | 2 | 0 |
| 2001 | 0.17 | 0.24 | 0.26 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.38 | 0.15 | 0.15 | 2 | 2 |
| 2002 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.19 | 0.15 | 0.15 | 0.18 | 0.19 | 0.19 | 3 | 3 |
|  |  |  |  |  |  |  |  |  |  |  |  | Ave | 1.96 | 1.41 |

🟪 High flow breaching

🟦 Low flow breaching

### d) EHI for the Future Scenario 1

### Hydrology

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| a. % similarity in the periods of low flows OR Present MAR as a % of MAR in the reference condition. | 95 | For the East Kleinemonde River low flows are defined as less than 0.12 $m^3 s^{-1}$. Months with flows of less than 0.12 $m^3 s^{-1}$ occurred under the RC for 86.0% of the year. Under the Scenario 1 low flows occur for 88.6 % of the year. | L |
| b. % similarity in mean annual frequency of floods. | 90 | The reduction in high flows is deemed to be very small based on the very limited reduction in monthly high flows. The 99%ile indicates that there is only a 3.5% decrease in the floods to the estuary under Scenario 1. | L |
| **Hydrology score** | **93** | | L |

### Hydrodynamics and mouth condition

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| *Change in mean duration of closure, e.g. over a 5 or 10 year period. | 80 | Under the RC the East Kleinemonde Estuary mouth breaching could potentially have occurred in 2.6 months of the year over the 83 year period. Of these 1.7 was related to high flow events that breached the system instantaneously.<br>Under Scenario 1 mouth breaching (State 1 and 2) has reduced to 2.0 months of the year over the 83 year period (74.7% similar to RC). Of these 1.4 was related to high flow events that breached (State 1) the system instantaneously. | L |
| **Hydrodynamics and mouth conditions score** | **80** | | L |

### Water quality

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification. | 80 | Because the river inflow to the East Kleinemonde Estuary and the frequency of breaching events is very similar to the RC, it is assumed that the salinity will also be very similar. | L |
| 2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary. | 80 | River DIN concentrations increased from RC to PS (>10 times during high flow events and ~ 3 times during low flow periods), associated with agricultural activities in the catchment. Although the influence of river inflow (as indicated by salinity) in this system is generally limited to the upper reaches and despite an overall reduction in river inflow, these marked increases in river DIN would nevertheless have resulted in a significant increase in DIN loads to the system compared with the RC.<br>However, because river inflow in Scenario 1 is 10% less than under the PS, modification to DIN loads should be less. There is a possibility that the dam might trap some nutrients, however, it is not considered to have a significant influence on loads reaching the estuary Therefore allow a 20% modification from RC (i.e. 10% less than for PS). | L |

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 2b. Suspended solids (turbidity) in the estuary. | 80 | Turbidity in the system is influenced by river inflow (higher turbidity concentration) and turbulence associated with tidal exchange (during mouth open state).<br>There is a slight decrease in the probable occurrence of intermittently open states (States 1 and 2) compared with the RC (1 month less) This will result in a decrease in turbidity within the estuary. Allow for 5% modification from RC.<br>Furthermore, there is a 15% reduction in river inflow compared to RC, further decreasing turbidity. Allow a further 15% modification from RC. | L |
| 2c. Dissolved oxygen in the estuary. | 80 | There is a slight increase in the occurrence of the closed state (State 3) versus intermittently open/closed states (States 1 and 2) in Scenario 1 compared with RC. DO concentrations are expected to decrease with an increase in the frequency and duration of the closed state, therefore allow for a 5% modification from RC.<br>However an increase in nutrient (and possibly organic) loading from the catchment (associated with agricultural activity) could have increased oxygen demand under the Scenario 1. Because river inflow in Scenario 1 is 10% less than under the PS, modification to DO should be less. Therefore allow a further 5% modification from RC (i.e. 10% less than for PS).<br>More mouth closure will cause increased macrophytes and filamentous algae growth and decomposition, causing lower DO (allow for further 10% modification). | L |
| 2d. Levels of toxins. | 90 | There are no major industrial activities in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system.<br>However, because river inflow in Scenario 1 is 10% less than under the PS, modification in terms of toxins should be less. Therefore allow a further 10% modification from RC (i.e. 10% less than for PS). | L |
| **Water Quality score** | **80** | | L |

## Physical habitat alteration

| VARIABLE | | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|---|
| 1. Resemblance of <u>intertidal sediment</u> structure and distribution to reference condition | | | | |
| 1a | % similarity in intertidal area exposed. | 85 | Allow 5% change in the intertidal area due to changes in river inflow. In addition, 5 % is allocated for the stabilisation of the lower estuary and 5 % infilling of the intertidal area. | L |
| 1b | % similarity in sand fraction relative to total sand and mud. | 75 | The bridge acts as barrier that prevents the development of a gradient from marine sediment below the bridge to muddier sediment further upstream.<br>The system may have become slightly muddier due to land-use changes in the catchment. | L |
| 2 | Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology. | 90 | Allow 5% change in the subtidal area due to changes in river inflow. In addition, 5% is allocated for the stabilisation of the lower estuary. | L |

| | | | | |
|---|---|---|---|---|
| **Anthropogenic influence:** | | | | |
| | Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary. | 95 | Sedimentation may have occurred due to change in land-use in the catchment and the bridge. | L |
| | Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, jetties, marinas) rather than modifications to water flow into estuary. | 95 | Sedimentation may have occurred due to change in land-use in the catchment, e.g. agricultural and the bridge. | L |
| **Physical habitat score** | | **85** | | L |

### 4.1.2 Biotic Components

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

**MICROALGAE**

**Phytoplankton**

Under Scenario 1 the decrease in the frequency of floods is represented by a change of about 3.5% from RC. This suggests that there would be little change in the phytoplankton and microphytobenthic (MPB) chlorophyll *a* levels from the natural condition. The annual distribution patterns of low river inflows under this scenario indicates fewer periods of low flow conditions, thus indicating little variation from RC.

**Benthic microalgae**

Microphytobenthic habitat loss during floods and open mouth conditions and accretion following mouth closure under Scenario 1 is probably not very different from the RC. Turbidity conditions would also possibly remain similar. Seepage areas act as sources of additional nutrient input for MPBs and would influence benthic primary production.

Confidence: Low

**MACROPHYTES**

This scenario represents a dam that would capture the MAR from 67% of the estuary catchment. There is an increase in mouth closure compared to the present state and a decrease in high flow breaching events from 2.6 to 2 months of the year. These conditions would result in an increase in submerged macrophyte and macroalgal abundance. Agricultural activities in the catchment and nutrient input would also increase the growth of reeds, sedges, macroalgae and submerged macrophytes. However nutrient input is slightly less than present because of the reduction in river flow. The higher salinity could inhibit the seed germination of macrophytes. There may have also been a small loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity. The anthropogenic influence of the R72 bridge remains the same as at present.

Confidence: Medium

**INVERTEBRATES (including Macrobenthos, Zooplankton and Hyperbenthos)**

**Macrobenthos**

Because of a slight increase in mouth closure, the probability of the zoobenthos moving towards distinct substructures (a marine associated group at the mouth and a riverine associated subgroup at the head) will be reduced. Instead, the community will maintain two basic substructures based on substrate type (a sand and muddy community) for longer periods. Data suggest that in order to develop substructures based on salinity, the mouth should remain open for >1month and this will be complimented by a stronger base flow to maintain mouth opening. If seed germination of the macrophyte community is negatively affected by increases in salinity, this will have a negative ripple effect on the macrozoobenthos.

Confidence: Medium

**Zooplankton**

The increase in the duration of mouth closure will likely be associated with an increase in the total zooplankton biomass. The zooplankton diversity within the system is likely to be reduced due to the decline in the recruitment of marine breeding species into the system.

Confidence: Medium

**Hyperbenthos:**

Increase in the duration of mouth closure will be associated with a decline in the biomass of *P.peringueyi* in the estuary as a result of reduced recruitment opportunities.

Confidence: Medium.

**FISH**

Even a slight increase in mouth closure could affect the recruitment of larval marine fishes into the estuary, especially if that closure were to occur during the optimum spring period. There is also a potential knock-on effect in terms of fish food resources if the aquatic macrophyte and zoobenthic invertebrate community are negatively affected by the induced changes.

Confidence: Medium

**BIRDS**

A decrease in fish would result in a lower abundance of piscivorous species. Increased submerged macrophyte growth could attract certain species (coots), and an expansion of the reed beds could increase the diversity of the species group associated with reeds and sedges (Rallidae).

Confidence: Medium

## b) EHI for the future Scenario 1:

### Microalgae

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Phytoplankton | | | |
| 1. Species richness | 90 | There is minimal difference between river inflow patterns under the RC (i.e. low flow occurrence 86.0) and Scenario 1 (i.e. low flow occurrence 88.6), corresponding to possibly a 5% change, which is equivalent to a score of 90, therefore phytoplankton species richness has probably not changed markedly. | M |
| 2a. Abundance | 95 | There is minimal difference between RC (i.e. low flow occurrence 86.0) and Scenario 1 (i.e. low flow occurrence 88.6), corresponding to possibly a 5% change, therefore phytoplankton abundances have probably not changed markedly.<br>The proposed dam may remove some nutrients from the system as it will catch some nutrients before they reach the estuary. This scenario may take the estuary closer to the reference conditions | L |
| 2b. Community composition | 95 | Because there is minimal difference between RC (i.e. low flow occurrence 86.1) and Scenario 1 (i.e. low flow occurrence 88.6), corresponding to possibly a 5% change, therefore phytoplankton species composition will probably not change markedly. | M |
| Benthic microalgae | | | |
| 1. Species richness | 80 | Sediment processes have probably changed little from the RC, therefore catchment activities (e.g. agricultural practises) under Scenario 1 suggest a slight increase in sediment load altering MPB habitat. Species richness would likely have had a deviation of approximately 20% from natural conditions, which is equivalent to a score of 80. | M |
| 2a. Abundance | 90 | Sediment processes have changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 1 suggest a slight increase in sediment load altering MPB habitat. Microphytobenthic abundances would likely have had a deviation of approximately 10% from natural conditions. | M |
| 2b. Community composition | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (e.g. agricultural practises) under Scenario 1 suggest a slight increase in sediment load altering MPB habitat. Community composition would likely have had a deviation of approximately 10% from natural conditions. | M |
| **Microalgae score** | **85** | | M |

## Macrophytes

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | There may be a small loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity (3% change). | H |
| 2a. Abundance | 81 | There is an increase in mouth closure compared to the present state and a decrease in high flow breaching events. These conditions would result in an increase in submerged macrophyte (6%) and macroalgal abundance (6%). Sedimentation would also occur in the intertidal zone as a result of the reduction in flow, which would encourage reed growth (2%).<br>Agricultural activities in the catchment and nutrient input would increase macrophyte growth particularly that of reeds, sedges, macroalgae and submerged macrophytes. However nutrient input would be slightly less than present because of the reduction in river flow. Reeds have established on the east bank below and above the R72 bridge (5% change). | H |
| 2b. Community composition | 95 | The nutrient changes, decrease in flooding and frequency of mouth closure has increased reed, submerged macrophyte and macroalgal cover reducing open water surface area and bare sand and mudflats. The score remains the same as for the present condition as the response to the small decrease in nutrients is counteracted by the decrease in flow and increase in closed mouth conditions. | H |
| **Macrophytes score** | **81** | | H |

## Invertebrates

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| **Zooplankton** | | | |
| 1. Species richness | 90 | Zooplankton diversity within the system is likely to be reduced due to the poor representation of marine breeding species to the total zooplankton community within the system. | M |
| 2a. Abundance | 85 | The total zooplankton biomass is likely to increase. | M |
| 2b. Community composition | 80 | The zooplankton community composition within the estuary will numerically be dominated by estuarine species. | M |
| **Macrobenthos** | | | |
| 1. Species richness | 90 | Because of a slight increase in mouth closure, the probability of the zoobenthos moving towards distinct substructures (a marine associated group at the mouth and a riverine associated subgroup at the head) will be reduced. Instead, the community will maintain two basic substructures based on substrate type (a sand and muddy community) for longer periods. Data suggest that in order to develop substructures based on salinity, the mouth should remain open for >1month and this will be complimented by a stronger base flow to maintain mouth opening. If seed germination of the macrophyte community is negatively affected by increases in salinity, this will have a negative ripple effect on the macrozoobenthos. The probability therefore of a low salinity community becoming briefly established is reduced. Allow a 5 % change. | H |

| | | | |
|---|---|---|---|
| 2a. Abundance | 85 | Because of the increase in submerged macrophyte biomass (including expansion into marginal areas presently experiencing occasional intertidal effects), abundance levels will remain high for extended periods with fewer crashes when the mouth opened (drainage effects). | |
| 2b. Community composition | 95 | Unlikely to change much when compared to the PS. Species are well adapted to natural variability in environmental factors. | H |
| **Hyperbenthos** | | | |
| 1. Species richness | 80 | The slight increase in the duration of mouth closure will likely be associated with a slight decline in species richness resulting from reduced recruitment opportunities of marine breeding species into the estuary. | H |
| 2a. Abundance | 80 | The reduced recruitment opportunities are likely to be associated with a slight decline in the total abundance and biomass of hyperbenthos. | H |
| 2b. Community composition | 80 | The hyperbenthos community is likely to be comprised mainly of estuarine species. | H |
| **Invertebrates score** | **80** | | H |

## Fish

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | Little difference in species richness is likely to have occurred between RC and Scenario 1. Allow for a 5% change. | M |
| 2a. Abundance | 80 | The abundance of macrophyte associated fish species is likely to increase and that of bare substratum associated fish species will decrease.<br>The abundance of anguillid eels moving through the estuary is also likely to decrease due to the dam blocking much of the catchment to colonisation by these fishes.<br>The reduction in open mouth conditions will impact on recruitment into the systems. | M |
| 2b. Community composition | 80 | As above. | M |
| **Fish score** | **80** | | |

## Birds

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | No expected loss of species, possibly a minor gain in species due to increased reeds<br>Allow for a 5% change. | M |
| 2a. Abundance | 82 | A slight decrease in abundance of piscivores species, the most common group.<br>Prolong mouth closure may affect fish availability for larger piscivores bird species. | M |
| 2b. Community composition | 85 | Because of the above, a very slight change in community composition | M |
| **Bird score** | **82** | | M |

## 4.2 Future Scenario 2: Intermittent river abstraction

### 4.2.1 Abiotic Components

**a) Seasonal variability in river inflow:**

Monthly simulated runoff data for the Future Scenario 2 is provided in Table 4.2. A summary of flow distribution (mean monthly flows in $m^3 s^{-1}$) for the Future Scenario 2, derived from the 83-year simulated data set, is provided below:

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.765 | 1.183 | 0.665 | 0.245 | 0.803 | 1.524 | 1.023 | 2.702 | 1.127 | 0.931 | 0.958 | 1.513 |
| 90%ile | 0.240 | 0.236 | 0.162 | 0.074 | 0.052 | 0.184 | 0.205 | 0.152 | 0.200 | 0.113 | 0.103 | 0.230 |
| 80%ile | 0.117 | 0.074 | 0.065 | 0.012 | 0.019 | 0.081 | 0.064 | 0.051 | 0.039 | 0.025 | 0.037 | 0.065 |
| 70%ile | 0.064 | 0.047 | 0.023 | 0.004 | 0.006 | 0.027 | 0.043 | 0.019 | 0.010 | 0.009 | 0.017 | 0.029 |
| 60%ile | 0.024 | 0.027 | 0.008 | 0.001 | 0.002 | 0.010 | 0.025 | 0.007 | 0.004 | 0.003 | 0.008 | 0.010 |
| 50%ile | 0.010 | 0.016 | 0.003 | 0.000 | 0.000 | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 |
| 40%ile | 0.003 | 0.005 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 30%ile | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**b) Present flood regime**

The flood regime is judged to be very similar to that under RC based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than 0.12 $m^3 s^{-1}$. The 99%ile indicates that there is only a 5.3 % decrease in the floods to the estuary.

*Confidence: Medium*

**c) Present sediment processes**

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

*Confidence: Low*

**Table 4.2** Simulated monthly volumes (million $m^3$) in the East Kleinemonde Estuary for Future Scenario 2.

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breach | High Flow Breach Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.15 | 0.15 | 0.21 | 0.22 | 0.23 | 0.34 | 0.15 | 0.35 | 0.37 | 0.37 | 0.37 | 0.38 | 1 | 1 |
| 1921 | 0.38 | 0.15 | 0.25 | 0.25 | 0.25 | 0.25 | 0.35 | 0.41 | 0.15 | 0.15 | 0.15 | 0.26 | 4 | 3 |
| 1922 | 0.27 | 0.15 | 0.15 | 0.15 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.26 | 0.28 | 0.28 | 3 | 3 |
| 1923 | 0.29 | 0.32 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0 | 0 |
| 1924 | 0.41 | 0.41 | 0.15 | 0.18 | 0.18 | 0.15 | 0.34 | 0.35 | 0.37 | 0.37 | 0.37 | 0.15 | 3 | 1 |
| 1925 | 0.20 | 0.20 | 0.22 | 0.23 | 0.28 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.33 | 0 | 0 |
| 1926 | 0.15 | 0.25 | 0.25 | 0.25 | 0.26 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 1 | 1 |
| 1927 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.23 | 0.15 | 4 | 2 |
| 1928 | 0.15 | 0.34 | 0.40 | 0.40 | 0.40 | 0.41 | 0.41 | 0.41 | 0.15 | 0.15 | 0.26 | 0.15 | 4 | 4 |
| 1929 | 0.15 | 0.23 | 0.23 | 0.23 | 0.23 | 0.42 | 0.15 | 0.15 | 0.18 | 0.19 | 0.23 | 0.29 | 2 | 1 |
| 1930 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.38 | 0.15 | 0.18 | 0.18 | 0.42 | 0.15 | 0.18 | 3 | 1 |
| 1931 | 0.15 | 0.15 | 0.15 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.38 | 0.38 | 0.15 | 4 | 4 |
| 1932 | 0.15 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.20 | 0.20 | 0.20 | 0.45 | 0.15 | 3 | 1 |
| 1933 | 0.15 | 0.19 | 0.20 | 0.21 | 0.22 | 0.15 | 0.29 | 0.29 | 0.29 | 0.15 | 0.15 | 0.15 | 5 | 3 |
| 1934 | 0.15 | 0.28 | 0.31 | 0.31 | 0.31 | 0.31 | 0.15 | 0.15 | 0.15 | 0.22 | 0.23 | 0.23 | 4 | 3 |
| 1935 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0 | 0 |
| 1936 | 0.15 | 0.15 | 0.33 | 0.33 | 0.33 | 0.15 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 3 | 3 |
| 1937 | 0.32 | 0.34 | 0.15 | 0.15 | 0.15 | 0.25 | 0.36 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 3 | 2 |
| 1938 | 0.38 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.30 | 5 | 4 |
| 1939 | 0.15 | 0.19 | 0.15 | 0.15 | 0.15 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 5 | 3 |
| 1940 | 0.30 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 3 | 2 |
| 1941 | 0.16 | 0.20 | 0.15 | 0.32 | 0.34 | 0.34 | 0.34 | 0.42 | 0.44 | 0.44 | 0.45 | 0.15 | 2 | 0 |
| 1942 | 0.41 | 0.15 | 0.16 | 0.33 | 0.37 | 0.37 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 0.28 | 2 | 0 |
| 1943 | 0.28 | 0.15 | 0.31 | 0.31 | 0.32 | 0.15 | 0.23 | 0.30 | 0.31 | 0.31 | 0.31 | 0.15 | 3 | 2 |
| 1944 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.41 | 0.43 | 0.43 | 0.43 | 0 | 0 |
| 1945 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 1 | 0 |
| 1946 | 0.23 | 0.24 | 0.25 | 0.25 | 0.25 | 0.15 | 0.32 | 0.33 | 0.39 | 0.15 | 0.21 | 0.21 | 2 | 1 |
| 1947 | 0.21 | 0.23 | 0.24 | 0.24 | 0.24 | 0.25 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 2 | 2 |
| 1948 | 0.15 | 0.28 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.32 | 1 | 1 |
| 1949 | 0.32 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 5 | 4 |
| 1950 | 0.15 | 0.15 | 0.15 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.29 | 0.15 | 5 | 5 |
| 1951 | 0.15 | 0.15 | 0.15 | 0.16 | 0.27 | 0.31 | 0.32 | 0.15 | 0.20 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1952 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.43 | 0.15 | 2 | 2 |
| 1953 | 0.15 | 0.15 | 0.26 | 0.26 | 0.26 | 0.15 | 0.25 | 0.15 | 0.31 | 0.34 | 0.15 | 0.31 | 5 | 4 |
| 1954 | 0.38 | 0.15 | 0.21 | 0.23 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.36 | 1 | 0 |
| 1955 | 0.39 | 0.15 | 0.17 | 0.17 | 0.29 | 0.34 | 0.35 | 0.37 | 0.38 | 0.38 | 0.38 | 0.15 | 2 | 0 |
| 1956 | 0.22 | 0.27 | 0.40 | 0.42 | 0.15 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.15 | 2 | 1 |
| 1957 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.42 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2 | 2 |
| 1958 | 0.15 | 0.15 | 0.34 | 0.42 | 0.42 | 0.15 | 0.24 | 0.27 | 0.27 | 0.27 | 0.27 | 0.28 | 1 | 0 |
| 1959 | 0.28 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 1 | 0 |
| 1960 | 0.44 | 0.15 | 0.15 | 0.16 | 0.20 | 0.21 | 0.21 | 0.30 | 0.32 | 0.33 | 0.33 | 0.33 | 1 | 0 |
| 1961 | 0.33 | 0.37 | 0.39 | 0.39 | 0.39 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 1 | 1 |
| 1962 | 0.15 | 0.33 | 0.33 | 0.15 | 0.19 | 0.15 | 0.15 | 0.44 | 0.44 | 0.15 | 0.20 | 0.20 | 5 | 3 |
| 1963 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.39 | 0.39 | 0.39 | 0.15 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1964 | 0.39 | 0.42 | 0.42 | 0.42 | 0.42 | 0.43 | 0.43 | 0.15 | 0.30 | 0.35 | 0.38 | 0.39 | 1 | 0 |

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breach | High Flow Breach Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 0.15 | 0.15 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.41 | 0.43 | 0.43 | 0.15 | 0.19 | 3 | 1 |
| 1966 | 0.21 | 0.22 | 0.22 | 0.22 | 0.27 | 0.29 | 0.33 | 0.15 | 0.15 | 0.34 | 0.43 | 0.45 | 2 | 2 |
| 1967 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.15 | 0.22 | 0.23 | 0.15 | 0.15 | 0.15 | 0.18 | 4 | 2 |
| 1968 | 0.18 | 0.18 | 0.18 | 0.18 | 0.21 | 0.45 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 1 | 0 |
| 1969 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.15 | 0.15 | 2 | 2 |
| 1970 | 0.15 | 0.22 | 0.15 | 0.40 | 0.41 | 0.41 | 0.15 | 0.28 | 0.28 | 0.28 | 0.33 | 0.34 | 3 | 3 |
| 1971 | 0.38 | 0.38 | 0.41 | 0.41 | 0.15 | 0.20 | 0.20 | 0.20 | 0.20 | 0.22 | 0.23 | 0.24 | 1 | 0 |
| 1972 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 | 0.26 | 0.27 | 0.27 | 0.27 | 0.34 | 0.37 | 0 | 0 |
| 1973 | 0.37 | 0.15 | 0.19 | 0.28 | 0.41 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.38 | 7 | 6 |
| 1974 | 0.38 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.41 | 0.15 | 1 | 1 |
| 1975 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.29 | 0.33 | 0.33 | 0.33 | 0.15 | 0.15 | 0.17 | 3 | 3 |
| 1976 | 0.29 | 0.37 | 0.37 | 0.37 | 0.15 | 0.36 | 0.37 | 0.15 | 0.26 | 0.29 | 0.29 | 0.29 | 2 | 1 |
| 1977 | 0.29 | 0.42 | 0.15 | 0.23 | 0.23 | 0.30 | 0.15 | 0.15 | 0.37 | 0.40 | 0.40 | 0.40 | 3 | 3 |
| 1978 | 0.15 | 0.18 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 1979 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.17 | 0.20 | 0 | 0 |
| 1980 | 0.21 | 0.28 | 0.30 | 0.15 | 0.27 | 0.15 | 0.15 | 0.33 | 0.39 | 0.39 | 0.15 | 0.23 | 4 | 3 |
| 1981 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.42 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 1 | 0 |
| 1982 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.25 | 0.25 | 1 | 1 |
| 1983 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.15 | 0.37 | 0.39 | 0.39 | 1 | 1 |
| 1984 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0 | 0 |
| 1985 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.21 | 0.22 | 0.22 | 0.22 | 0.22 | 0.35 | 0.40 | 3 | 2 |
| 1986 | 0.44 | 0.15 | 0.15 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.27 | 0.30 | 0.32 | 0.34 | 1 | 0 |
| 1987 | 0.34 | 0.34 | 0.34 | 0.34 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.25 | 1 | 0 |
| 1988 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.40 | 0.44 | 0.44 | 0.45 | 0.45 | 0.15 | 1 | 0 |
| 1989 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.30 | 0.32 | 0.32 | 0.43 | 0.15 | 0.15 | 0.15 | 5 | 3 |
| 1990 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.31 | 0.34 | 0 | 0 |
| 1991 | 0.15 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.15 | 3 | 2 |
| 1992 | 0.15 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.33 | 0.33 | 0.38 | 0.39 | 0.43 | 0.15 | 2 | 1 |
| 1993 | 0.20 | 0.20 | 0.38 | 0.15 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.24 | 2 | 0 |
| 1994 | 0.24 | 0.24 | 0.15 | 0.15 | 0.15 | 0.15 | 0.26 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 2 | 2 |
| 1995 | 0.29 | 0.34 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 | 0.38 | 0 | 0 |
| 1996 | 0.38 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.40 | 0.15 | 0.15 | 0.25 | 0.25 | 0.25 | 4 | 3 |
| 1997 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.15 | 0.29 | 0.29 | 0.29 | 0.30 | 0.34 | 0.36 | 1 | 1 |
| 1998 | 0.37 | 0.37 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.15 | 0.19 | 0.21 | 1 | 0 |
| 1999 | 0.15 | 0.25 | 0.25 | 0.15 | 0.27 | 0.15 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.44 | 3 | 3 |
| 2000 | 0.15 | 0.38 | 0.44 | 0.15 | 0.16 | 0.17 | 0.20 | 0.20 | 0.20 | 0.34 | 0.42 | 0.15 | 3 | 0 |
| 2001 | 0.19 | 0.31 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.15 | 0.15 | 3 | 3 |
| 2002 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.18 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3 | 3 |
| | | | | | | | | | | | | | 2.34 | 1.55 |

🟪 High flow breaching 🟦 Low flow breaching

## d) EHI for the Future Scenario 2

### Hydrology

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition. | 95 | For the East Kleinemonde River estuary low flows are defined as less than 0.12 $m^3 s^{-1}$.<br>Months with flows less than 0.116 $m^3/ s^{-1}$ occurred under the RC for 86.0 of the year. Under Scenario 2 low flows occur for 87.5 % of the year. | L |
| b. % similarity in mean annual frequency of floods. | 90 | The reduction in high flows is deemed to be very small based on the very limited reduction in monthly high flows. The 99%ile indicates that there is only a 5.3% decrease in the floods to the estuary under Scenario 2.<br>The slight decrease in high flows is assumed to be an artefact of the manner in which this Scenario was generated and not realistic (See Appendix B) | L |
| **Hydrology score** | **93** | | L |

### Hydrodynamics and mouth condition

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Change in mean duration of closure, e.g. over a 5 or 10 year period. | 85 | Under the RC the East Kleinemonde estuary mouth breaching could potentially have occurred in 2.6 months of the year over the 83-year period. Of these 1.9 was related to high flow events that breached the system instantaneously.<br>Under the Scenario 2 mouth breaching (State 1 and 2) has reduced to 2.3 months of the year over the 83-year period (88.9 similar to the RC). Of these 1.6 was related to high flow events (State 1) that breached the system instantaneously. | L |
| **Hydrodynamics and mouth conditions score** | **85** | | L |

### Water quality

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification. | 85 | As the river inflow to the East Kleinemonde Estuary and the frequency of breaching events is very similar to the RC, it is assumed that the salinity will also be very similar. | L |
| 2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary. | 75 | River DIN concentrations increased from RC to PS (>10 times during high flow events and ~ 3 times during low flow periods), associated with agricultural activities in the catchment. Although the influence of river inflow (as indicated by salinity) in this system is generally limited to the upper reaches and despite an overall reduction in river inflow, these marked increases in river DIN would nevertheless have resulted in a significant increase in DIN loads to the system compared with the RC.<br>However, because river inflow in Scenario 2 is 5% less than under the PS, modification to DIN loads should be less. Therefore allow a 25% modification from RC (i.e. 5% less than for PS). | L |

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 2b. Suspended solids (turbidity) in the estuary. | 85 | Turbidity in the system is influenced by river inflow and turbulence associated with tidal exchange (during intermittently open phase). There is a slight decrease in the probable occurrence of intermittently open phases during States 1 and 2 compared with the RC (1 month less) This will result in a decrease in turbidity. Allow for 5% modification from RC. Furthermore, there is a 10% reduction in river inflow compared to RC, further decreasing turbidity. Allow a further 10% modification from RC. | L |
| 2c. Dissolved oxygen in the estuary. | 75 | There is a slight increase in the occurrence of the closed state (State 3) versus intermittently open phase (States 1 and 2) in Scenario 2 compared with RC. DO concentrations are expected to decrease with an increase in the frequency and duration of the closed state. Therefore allow for a 5% modification from RC.<br>However an increase in nutrient (and possibly organic) loading from the catchment (associated with agricultural activity) could have increased oxygen demand under the Scenario 2. Because river inflow in Scenario 2 is 5% less than under the PS, modification to DO should be less. Therefore allow a further 10% modification from RC (i.e. 5% less than for PS).<br>More mouth closure will cause increased macrophytes and filamentous algae growth and decomposition, causing lower DO. Allow for further 10% modification. | L |
| 2d. Levels of toxins. | 85 | There are no major industrial activities in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. Because river inflow in Scenario 2 is 5% less than under the PS, modification in terms of toxins should be less. Therefore allow a 15% modification from RC (i.e. 5% less than for PS). | L |
| **Water Quality score** | **79** | | L |

## Physical habitat alteration

| VARIABLE | | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|---|
| 1. Resemblance of intertidal sediment structure and distribution to reference condition | | | | |
| 1a | % similarity in intertidal area exposed. | 85 | Allow 5% change in the intertidal area due to changes in river inflow. In addition, 5% is allocated for the stabilisation of the lower estuary and 5% infilling of the intertidal area. | L |
| 1b | % similarity in sand fraction relative to total sand and mud. | 75 | The bridge acts as barrier that prevents the development of a gradient from marine sediment below the bridge to muddier sediment in the upper reaches. The system may also have become slightly muddier due to land-use changes in the catchment. | L |
| 2 | Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology. | 90 | Allow 5% change in the subtidal area due to changes in river inflow. In addition, 5% is allocated for the stabilisation of the lower estuary. | L |
| **Anthropogenic influence:** | | | | |
| | Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to | 95 | Sedimentation may have occurred due to change in land-use in the catchment and the bridge. | L |

| | | | | |
|---|---|---|---|---|
| | water flow into estuary. | | | |
| | Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, jetties, marinas) rather than modifications to water flow into estuary. | 95 | Sedimentation may have occurred due to change in land-use in the catchment, e.g. agricultural and the bridge. | L |
| **Physical habitat score** | | **85** | | |

### 4.2.2 Biotic Components

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

**MICROALGAE**

**Phytoplankton**

Under Scenario 2 the decrease in the frequency of floods is represented by a change of about 5% from RC. This suggests that there would be little change in the phytoplankton and microphytobenthic (MPB) chlorophyll *a* levels from natural condition. The annual distribution patterns of low river inflows under this scenario indicates less periods of low flow conditions, thus indicating little variation from RC and would likely be the case for microalgal biomass and community patterns.

**Benthic microalgae**

Microphytobenthic habitat loss during floods and open mouth conditions, and accretion following mouth closure in Scenario 2, is probably not very different from the RC. Turbidity conditions would also possibly remain similar. Seepage areas act as sources of additional nutrient input for MPBs and would influence benthic primary production.

Confidence: Low

**MACROPHYTES**

The influence of the off-channel storage dam with intermittent pumping results in a removal of low flows but the effect on floods is similar to that of the present state. This scenario has less of an influence on mouth closure and the salinity gradient compared to Scenario 1 but there are higher nitrate and phosphate inputs. Mouth closure, salinity and nutrients have the greatest effect on the macrophytes and therefore this scenario results in slightly higher scores for the macrophytes compared to Scenario 1.

Confidence: Medium

**INVERTEBRATES (including Macrobenthos, Zooplankton and Hyperbenthos)**

**Macrobenthos**

A reduction in low flow conditions will probably lead to higher salinity values throughout the estuary with little variability between the upper and lower estuary. Because of a reduced base flow, the mouth is likely to close sooner than under Reference condition. Salinity gradients will probably not persist for long enough to allow the macrozoobenthic community to develop substructures based on the salinity pattern.

Confidence: Medium

**Zooplankton**

The reduction in flow is likely to be associated with an increase in the total zooplankton biomass within the system. The occasional flood will be associated with a decline in the zooplankton biomass within the system as biomass rich estuarine waters are exported to the marine environment.

Confidence: Medium.

**Hyperbenthos**

The occasional flood will provide opportunities for the recruitment of *P.peringueyi* into the estuary.

Confidence: Medium

**FISH**

Because there is likely to be little change in open mouth conditions between the RC and Scenario 2, it is highly likely that the fish assemblage will be very similar to that found in the natural state. Small changes in fish distribution and abundance are likely due to the slight reductions in high flows and base flows when compared to the RC.

Confidence: Medium

**BIRDS**

The avifauna is unlikely to be affected by slight changes in mouth conditions. An increase in the submerged macrophytes will attract coots and possibly grebes. Small changes in fish populations are unlikely to affect piscivorous bird numbers.

Confidence: Low

### b) EHI for the Future Scenario 2:

### Microalgae

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Phytoplankton | | | |
| 1. Species richness | 90 | There is minimal difference between river inflow patterns under the RC (i.e. low flow occurrence 86.0) and Scenario 2 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton species richness has probably not changed markedly. Allow a 5% change , which is equivalent to a score of 90. | M |
| 2a. Abundance | 95 | There is minimal difference between RC (i.e. low flow occurrence 86.0) and Scenario 2 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton abundance has probably not changed markedly. | M |
| 2b. Community composition | 95 | Since there is minimal difference between RC (i.e. low flow occurrence 98.2) and Scenario 2 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton species composition has probably not changed markedly. | M |
| Benthic microalgae | | | |
| 1. Species richness | 80 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 2 suggest a slight increase in sediment load altering MPB habitat. Species richness would likely have had a deviation of approximately 10% from natural conditions, which is equivalent to a score of 80. | M |
| 2a. Abundance | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 2 suggest a slight increase in sediment load altering MPB habitat. Microphytobenthic abundance would likely have had a deviation of approximately 10% from natural conditions. | M |
| 2b. Community composition | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 2 suggest a slight increase in sediment load altering MPB habitat. Community composition would likely have had a deviation of approximately 10% from natural conditions. | M |
| **Microalgae score** | **80** | | M |

## Macrophytes

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 95 | There may have been a small loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity (2% change). | M |
| 2a. Abundance | 83 | There is a reduction in low flows but the effect on floods is similar to that of the PS. This scenario has less of an influence on mouth closure and the salinity gradient compared to Scenario 1 but there are higher nitrate and phosphate inputs. The influence on the macrophytes is less than for Scenario 1 and therefore the scores lie between that of the PS and Scenario 1<br>Closed mouth conditions and a decrease in high flow breaching events would result in an increase in submerged macrophyte (5%) and macroalgal abundance (5%). Sedimentation would also occur in the intertidal zone as a result of the reduction in flow, which would encourage reed growth (2%).<br>Agricultural activities in the catchment and nutrient input will increase macrophyte growth particularly that of reeds, sedges, macroalgae and submerged macrophytes. However nutrient input will be slightly less than at present because of the reduction in river flow.<br>Reeds will establish on the east bank below and above the R72 bridge (5 % change). | M |
| 2b. Community composition | 95 | The nutrient changes, decrease in flooding and frequency of mouth closure will increase reed, submerged macrophyte and macroalgal cover reducing open water surface area and bare sand and mudflats. The score remains the same as for PC because the response to the small decrease in nutrients is counteracted by the decrease in flow and increase in closed mouth conditions.<br>Reed beds may encroach on submerged macrophyte habitat on the East bank. | M |
| **Macrophytes score** | **83** | | M |

## Invertebrates

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| **Zooplankton** | | | |
| 1. Species richness | 90 | The minimal difference in flow between the various scenarios suggests that there will be little change in the zooplankton species richness within the system. | M |
| 2a. Abundance | 80 | The increase in the duration of mouth closure is likely to be associated with an increase in the total zooplankton biomass within the system. | M |
| 2b. Community composition | 90 | The community composition is unlikely to change | M |
| **Macrobenthos** | | | |
| 1. Species richness | 80 | The probability of a low salinity community becoming briefly established is reduced, probably at a level slightly lower than Scenario 1. Although floods are not affected, a reduction in base flow will lead to salinity values returning to a weaker horizontal gradient faster. This may not allow a freshwater linked community to develop. Allow for a 10% change. | M |

|  |  |  |  |
|---|---|---|---|
| 2a. Abundance | 90 | Because of the increase in submerged macrophyte biomass (including expansion into marginal areas presently experiencing occasional intertidal effects), abundance levels will remain high for extended periods with the frequency of crashes similar to the present condition (drainage effects). | M |
| 2b. Community composition | 95 | Unlikely to change compared to the present condition. Species are well adapted to natural variability in environmental factors | M |
| **Hyperbenthos** |  |  |  |
| 1. Species richness | 90 | The minimal difference in flow between the various scenarios suggests that there will be little change in the hyperbenthos species richness within the system. | M |
| 2a. Abundance | 80 | The extended mouth closure is likely to be associated with a decline in the total biomass of Hyperbenthos due to reduced recruitment opportunities of marine breeding species into the estuary. | M |
| 2b. Community composition | 90 | Unlikely to change compared to the present condition. Species are well adapted to natural variability in environmental factors. |  |
| **Invertebrates score** | **80** |  | M |

## Fish

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | Little difference in species richness is likely to have occurred between the RC and Scenario 2. Allow for a 5% change. | M |
| 2a. Abundance | 87 | The abundance of macrophyte associated fish species is likely to increase and that of bare substratum associated fish species will decrease. | M |
| 2b. Community composition | 85 | As above. | M |
| **Fish score** | **85** |  | M |

## Birds

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | Species richness is unlikely to change compared to RC. Allow for a 5% change. | L |
| 2a. Abundance | 85 | Increase in species associated with submerged macrophytes, negligible change in most piscivorous species. | L |
| 2b. Community composition | 90 | Slight change due to the above. | L |
| **Bird score** | **85** |  | L |

## 4.3 Future Scenario 3: Similar to Scenario 2 but including other non-flow related anthropogenic activities

### 4.3.1 Abiotic Components

**a) Seasonal variability in river inflow:**

Monthly simulated runoff data for the Future Scenario 3 is provided in Table 4.3. A summary of flow distribution (mean monthly flows in $m^3 s^{-1}$) for the Future Scenario 3, derived from the 83-year simulated data set, is provided below:

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.765 | 1.183 | 0.665 | 0.245 | 0.803 | 1.524 | 1.023 | 2.702 | 1.127 | 0.931 | 0.958 | 1.513 |
| 90%ile | 0.240 | 0.236 | 0.162 | 0.074 | 0.052 | 0.184 | 0.205 | 0.152 | 0.200 | 0.113 | 0.103 | 0.230 |
| 80%ile | 0.117 | 0.074 | 0.065 | 0.012 | 0.019 | 0.081 | 0.064 | 0.051 | 0.039 | 0.025 | 0.037 | 0.065 |
| 70%ile | 0.064 | 0.047 | 0.023 | 0.004 | 0.006 | 0.027 | 0.043 | 0.019 | 0.010 | 0.009 | 0.017 | 0.029 |
| 60%ile | 0.024 | 0.027 | 0.008 | 0.001 | 0.002 | 0.010 | 0.025 | 0.007 | 0.004 | 0.003 | 0.008 | 0.010 |
| 50%ile | 0.010 | 0.016 | 0.003 | 0.000 | 0.000 | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 |
| 40%ile | 0.003 | 0.005 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 30%ile | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**b) Present flood regime**

The flood regime is judged to be very similar to that under reference conditions based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than 0.12 $m^3 s^{-1}$. The 99%ile indicates that there is only a 5.3 % decrease in the floods to the estuary.

*Confidence: Medium*

**c) Present sediment processes**

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

*Confidence: Low*

**Table 4.3** Simulated monthly volumes (million $m^3$) in the East Kleinemonde Estuary for Future Scenario 3.

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breach | High Flow Breach Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.15 | 0.15 | 0.21 | 0.22 | 0.23 | 0.34 | 0.15 | 0.35 | 0.37 | 0.37 | 0.37 | 0.38 | 1 | 1 |
| 1921 | 0.38 | 0.15 | 0.25 | 0.25 | 0.25 | 0.25 | 0.35 | 0.41 | 0.15 | 0.15 | 0.15 | 0.26 | 4 | 3 |
| 1922 | 0.27 | 0.15 | 0.15 | 0.15 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.26 | 0.28 | 0.28 | 3 | 3 |
| 1923 | 0.29 | 0.32 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0 | 0 |
| 1924 | 0.41 | 0.41 | 0.15 | 0.18 | 0.18 | 0.15 | 0.34 | 0.35 | 0.37 | 0.37 | 0.37 | 0.15 | 3 | 1 |
| 1925 | 0.20 | 0.20 | 0.22 | 0.23 | 0.28 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.33 | 0 | 0 |
| 1926 | 0.15 | 0.25 | 0.25 | 0.25 | 0.26 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 1 | 1 |
| 1927 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.23 | 0.15 | 4 | 2 |
| 1928 | 0.15 | 0.34 | 0.40 | 0.40 | 0.40 | 0.41 | 0.41 | 0.41 | 0.15 | 0.15 | 0.26 | 0.15 | 4 | 4 |
| 1929 | 0.15 | 0.23 | 0.23 | 0.23 | 0.23 | 0.42 | 0.15 | 0.15 | 0.18 | 0.19 | 0.23 | 0.29 | 2 | 1 |
| 1930 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.38 | 0.15 | 0.18 | 0.18 | 0.42 | 0.15 | 0.18 | 3 | 1 |
| 1931 | 0.15 | 0.15 | 0.15 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.38 | 0.38 | 0.15 | 4 | 4 |
| 1932 | 0.15 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.20 | 0.20 | 0.20 | 0.45 | 0.15 | 3 | 1 |
| 1933 | 0.15 | 0.19 | 0.20 | 0.21 | 0.22 | 0.15 | 0.29 | 0.29 | 0.29 | 0.15 | 0.15 | 0.15 | 5 | 3 |
| 1934 | 0.15 | 0.28 | 0.31 | 0.31 | 0.31 | 0.31 | 0.15 | 0.15 | 0.15 | 0.22 | 0.23 | 0.23 | 4 | 3 |
| 1935 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0 | 0 |
| 1936 | 0.15 | 0.15 | 0.33 | 0.33 | 0.33 | 0.15 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 3 | 3 |
| 1937 | 0.32 | 0.34 | 0.15 | 0.15 | 0.15 | 0.25 | 0.36 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 3 | 2 |
| 1938 | 0.38 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.30 | 5 | 4 |
| 1939 | 0.15 | 0.19 | 0.15 | 0.15 | 0.15 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 5 | 3 |
| 1940 | 0.30 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 3 | 2 |
| 1941 | 0.16 | 0.20 | 0.15 | 0.32 | 0.34 | 0.34 | 0.34 | 0.42 | 0.44 | 0.44 | 0.45 | 0.15 | 2 | 0 |
| 1942 | 0.41 | 0.15 | 0.16 | 0.33 | 0.37 | 0.37 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 0.28 | 2 | 0 |
| 1943 | 0.28 | 0.15 | 0.31 | 0.31 | 0.32 | 0.15 | 0.23 | 0.30 | 0.31 | 0.31 | 0.31 | 0.15 | 3 | 2 |
| 1944 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.41 | 0.43 | 0.43 | 0.43 | 0 | 0 |
| 1945 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 1 | 0 |
| 1946 | 0.23 | 0.24 | 0.25 | 0.25 | 0.25 | 0.15 | 0.32 | 0.33 | 0.39 | 0.15 | 0.21 | 0.21 | 2 | 1 |
| 1947 | 0.21 | 0.23 | 0.24 | 0.24 | 0.24 | 0.25 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 2 | 2 |
| 1948 | 0.15 | 0.28 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.32 | 1 | 1 |
| 1949 | 0.32 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 5 | 4 |
| 1950 | 0.15 | 0.15 | 0.15 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.29 | 0.15 | 5 | 5 |
| 1951 | 0.15 | 0.15 | 0.15 | 0.16 | 0.27 | 0.31 | 0.32 | 0.15 | 0.20 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1952 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.43 | 0.15 | 2 | 2 |
| 1953 | 0.15 | 0.15 | 0.26 | 0.26 | 0.26 | 0.15 | 0.25 | 0.15 | 0.31 | 0.34 | 0.15 | 0.31 | 5 | 4 |
| 1954 | 0.38 | 0.15 | 0.21 | 0.23 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.36 | 1 | 0 |
| 1955 | 0.39 | 0.15 | 0.17 | 0.17 | 0.29 | 0.34 | 0.35 | 0.37 | 0.38 | 0.38 | 0.38 | 0.15 | 2 | 0 |
| 1956 | 0.22 | 0.27 | 0.40 | 0.42 | 0.15 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.15 | 2 | 1 |
| 1957 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.42 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2 | 2 |
| 1958 | 0.15 | 0.15 | 0.34 | 0.42 | 0.42 | 0.15 | 0.24 | 0.27 | 0.27 | 0.27 | 0.27 | 0.28 | 1 | 0 |
| 1959 | 0.28 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 1 | 0 |
| 1960 | 0.44 | 0.15 | 0.15 | 0.16 | 0.20 | 0.21 | 0.21 | 0.30 | 0.32 | 0.33 | 0.33 | 0.33 | 1 | 0 |
| 1961 | 0.33 | 0.37 | 0.39 | 0.39 | 0.39 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 1 | 1 |
| 1962 | 0.15 | 0.33 | 0.33 | 0.15 | 0.19 | 0.15 | 0.15 | 0.44 | 0.44 | 0.15 | 0.20 | 0.20 | 5 | 3 |
| 1963 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.39 | 0.39 | 0.39 | 0.15 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1964 | 0.39 | 0.42 | 0.42 | 0.42 | 0.42 | 0.43 | 0.43 | 0.15 | 0.30 | 0.35 | 0.38 | 0.39 | 1 | 0 |
| 1965 | 0.15 | 0.15 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.41 | 0.43 | 0.43 | 0.15 | 0.19 | 3 | 1 |

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breach | High Flow Breach Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1966 | 0.21 | 0.22 | 0.22 | 0.22 | 0.27 | 0.29 | 0.33 | 0.15 | 0.15 | 0.34 | 0.43 | 0.45 | 2 | 2 |
| 1967 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.15 | 0.22 | 0.23 | 0.15 | 0.15 | 0.15 | 0.18 | 4 | 2 |
| 1968 | 0.18 | 0.18 | 0.18 | 0.18 | 0.21 | 0.45 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 1 | 0 |
| 1969 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.15 | 0.15 | 2 | 2 |
| 1970 | 0.15 | 0.22 | 0.15 | 0.40 | 0.41 | 0.41 | 0.15 | 0.28 | 0.28 | 0.28 | 0.33 | 0.34 | 3 | 3 |
| 1971 | 0.38 | 0.38 | 0.41 | 0.41 | 0.15 | 0.20 | 0.20 | 0.20 | 0.20 | 0.22 | 0.23 | 0.24 | 1 | 0 |
| 1972 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 | 0.26 | 0.27 | 0.27 | 0.27 | 0.34 | 0.37 | 0 | 0 |
| 1973 | 0.37 | 0.15 | 0.19 | 0.28 | 0.41 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.38 | 7 | 6 |
| 1974 | 0.38 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.41 | 0.15 | 1 | 1 |
| 1975 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.29 | 0.33 | 0.33 | 0.33 | 0.15 | 0.15 | 0.17 | 3 | 3 |
| 1976 | 0.29 | 0.37 | 0.37 | 0.37 | 0.15 | 0.36 | 0.37 | 0.15 | 0.26 | 0.29 | 0.29 | 0.29 | 2 | 1 |
| 1977 | 0.29 | 0.42 | 0.15 | 0.23 | 0.23 | 0.30 | 0.15 | 0.15 | 0.37 | 0.40 | 0.40 | 0.40 | 3 | 3 |
| 1978 | 0.15 | 0.18 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 1979 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.17 | 0.20 | 0 | 0 |
| 1980 | 0.21 | 0.28 | 0.30 | 0.15 | 0.27 | 0.15 | 0.15 | 0.33 | 0.39 | 0.39 | 0.15 | 0.23 | 4 | 3 |
| 1981 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.42 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 1 | 0 |
| 1982 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.25 | 0.25 | 1 | 1 |
| 1983 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.15 | 0.37 | 0.39 | 0.39 | 1 | 1 |
| 1984 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0 | 0 |
| 1985 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.21 | 0.22 | 0.22 | 0.22 | 0.22 | 0.35 | 0.40 | 3 | 2 |
| 1986 | 0.44 | 0.15 | 0.15 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.27 | 0.30 | 0.32 | 0.34 | 1 | 0 |
| 1987 | 0.34 | 0.34 | 0.34 | 0.34 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.25 | 1 | 0 |
| 1988 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.40 | 0.44 | 0.44 | 0.45 | 0.45 | 0.15 | 1 | 0 |
| 1989 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.30 | 0.32 | 0.32 | 0.43 | 0.15 | 0.15 | 0.15 | 5 | 3 |
| 1990 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.31 | 0.34 | 0 | 0 |
| 1991 | 0.15 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.15 | 3 | 2 |
| 1992 | 0.15 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.33 | 0.33 | 0.38 | 0.39 | 0.43 | 0.15 | 2 | 1 |
| 1993 | 0.20 | 0.20 | 0.38 | 0.15 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.24 | 2 | 0 |
| 1994 | 0.24 | 0.24 | 0.15 | 0.15 | 0.15 | 0.15 | 0.26 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 2 | 2 |
| 1995 | 0.29 | 0.34 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 | 0.38 | 0 | 0 |
| 1996 | 0.38 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.40 | 0.15 | 0.15 | 0.25 | 0.25 | 0.25 | 4 | 3 |
| 1997 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.15 | 0.29 | 0.29 | 0.29 | 0.30 | 0.34 | 0.36 | 1 | 1 |
| 1998 | 0.37 | 0.37 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.15 | 0.19 | 0.21 | 1 | 0 |
| 1999 | 0.15 | 0.25 | 0.25 | 0.15 | 0.27 | 0.15 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.44 | 3 | 3 |
| 2000 | 0.15 | 0.38 | 0.44 | 0.15 | 0.16 | 0.17 | 0.20 | 0.20 | 0.20 | 0.34 | 0.42 | 0.15 | 3 | 0 |
| 2001 | 0.19 | 0.31 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.15 | 0.15 | 3 | 3 |
| 2002 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.18 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3 | 3 |
|  |  |  |  |  |  |  |  |  |  |  |  |  | 2.34 | 1.55 |

🟪 High flow breaching

🟦 Low flow breaching

## d) EHI for the Future Scenario 3

### Hydrology

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition. | 95 | For the East Kleinemonde River, estuary low flows are defined as less than 0.12 $m^3\ s^{-1}$. Months with flows < 0.12 $m^3\ s^{-1}$ occurred under the RC for 86.0 % of the year. Under the Scenario 3 low flows occur for 87.5% of the year. Assume that the increase housing development and farming of the catchment will not substantially change hydrology. | L |
| b. % similarity in mean annual frequency of floods. | 90 | The reduction in high flows is deemed to be very small based on the very limited reduction in monthly high flows. The 99%ile indicates that there is only a 5.3% decrease in the floods to the estuary under Scenario 3. The slight decrease in high flows is assumed to be an artefact of the manner in which this scenario was generated (See Appendix A) | L |
| **Hydrology score** | **93** | | L |

### Hydrodynamics and mouth condition

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Change in mean duration of closure, e.g. over a 5 or 10 year period. | 85 | Under the RC the East Kleinemonde Estuary mouth breaching could potentially have occurred in 2.6 months of the year over the 83 year period. Of these 1.9 was related to high flow events that breached the system instantaneously. Under Scenario 3 mouth breaching (State 1 and 2) has been reduced to 2.3 months of the year over the 83 year period (88.9 similar to the RC). Of these 1.6 was related to high flow events (State 1) that breached the system instantaneously. | L |
| **Hydrodynamics and mouth conditions score** | **85** | | L |

### Water quality

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification. | 85 | As the river inflow to the East Kleinemonde Estuary and the frequency of breaching events is very similar to the RC, it is assumed that the salinity will also be very similar. | L |
| 2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary. | 50 | River DIN concentrations increased from RC to PS (>10 times during high flow events and ~ 3 times during low flow periods), associated with agricultural activities in the catchment. Although the influence of river inflow (as indicated by salinity) in this system is generally limited to the upper reaches and despite an overall reduction in river inflow, these marked increases in river DIN would nevertheless have resulted in a significant increase in DIN loads to the system compared with the RC.<br>However, because river inflow in Scenario 3 is 5% less than under the PS, modification to DIN loads should be less. Therefore allow a 25% modification from RC (i.e. 5% less than for PS).<br>However there is also expected to be a marked increase in nutrient loading due to increased septic tank seepage and return flow form gardens and hardened surfaces (i.e. increased storm water runoff). Allow for a further 25% modification. | L |

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 2b. Suspended solids (turbidity) in the estuary. | 75 | Turbidity in the system is influenced by river inflow (higher turbidity concentration) and turbulence associated with tidal exchange (during intermittently open/closed states)<br>There is a slight decrease in the probable occurrence of intermittently open phases (States 1 and 2) compared with the RC (1 month less) This will result in a decrease in turbidity. Allow for 5% modification from the RC.<br>Furthermore, there is a 10% reduction in river inflow compared to RC, further decreasing turbidity in the upper reaches. Allow a further 10% modification from RC.<br>Storm water drains and erosion from surrounding areas, due to increased development, may introduce turbidity into the lower reaches of the system (where turbidity from river inflows would not have had an influence), thus allow for an additional 10% modification. | L |
| 2c. Dissolved oxygen in the estuary | 65 | There is a slight increase in the occurrence of the closed state (State 3) versus intermittently open/closed phases (States 1 and 2) in Scenario 2 compared with RC. DO concentrations are expected to decrease with an increase in the frequency and duration of the closed state, therefore allow for a 5% modification from RC.<br>However an increase in nutrient (and possibly organic) loading from the catchment (associated with agricultural activity) could have increased oxygen demand under the Scenario 3. Because river inflow in Scenario 3 (as in Scenario 2) is 5% less than under the PS, modification to DO should be less. Therefore allow a further 10% modification from RC (i.e. 5% less than for PS).<br>More mouth closure will cause increased macrophytes and filamentous algae growth, causing lower DO, allow for further 10% modification.<br>Furthermore, increased organic loading due to increased septic tank seepage and return flow form gardens and hardened surfaces (i.e. increase in storm water runoff) may cause even further reductions in DO. Allow for a further 10% modification. | L |

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 2d. Levels of toxins. | 70 | There are no major urban or industrial activities in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system.<br>However, because river inflow in Scenario 3 (as in Scenario 2) is 5% less than under the PS, modification in terms of toxins should be less. Therefore allow a 15% modification from RC (i.e. 5% less than for PS).<br>The level of toxins in the system is expected to increase under Scenario 3 because there will be increased boating activity (oils, fuels, antifouling agents), increase storm water runoff (e.g. trace metals and hydrocarbons). The system is particularly sensitive as it does not open frequently and toxins can therefore accumulate. Allow a further 15% modification. | L |
| **Water Quality score** | **64** | | L |

## Physical habitat alteration

| VARIABLE | | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|---|
| 1. Resemblance of intertidal sediment structure and distribution to reference condition | | | | |
| 1a | % similarity in intertidal area exposed. | 75 | Allow 5% change in the intertidal area due to changes in river inflow. In addition, 20 % is allocated for stabilisation, construction of jetties and infilling of the intertidal area of the estuary. | L |
| 1b | % similarity in sand fraction relative to total sand and mud. | 70 | The bridge act as a barrier that prevents the development of a gradient from marine sediment below the bridge to muddier sediment in the upper reaches, e.g. invertebrate communities may be distinctly different at the mouth.<br>The system may have become even muddier due to land-use changes in the catchment. | L |
| 2 | Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology. | 80 | Allow 5% change in the subtidal area due to changes in river inflow. In addition, 5 % is allocated for the stabilisation of the lower estuary.<br>Channel modification to provide access for power boats. | L |
| **Anthropogenic influence:** | | | | |
| | Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary. | 95 | Sedimentation may occur due to change in land-use in the catchment and the bridge. | L |
| | Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary. | 95 | Sedimentation may occur due to change in land-use in the catchment, e.g. agricultural and the bridge. | L |
| **Physical habitat score** | | **76** | | L |

### 4.3.2 Biotic Components

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

**MICROALGAE**

**Phytoplankton**

Under Scenario 3 the decrease in the frequencies of floods is represented by a change of about 5.3% from RC. This suggests that there would be little change in the phytoplankton and microphytobenthic (MPB) chlorophyll *a* levels from natural condition. The annual distribution patterns of low river inflows under this scenario indicates less periods of low flow conditions, thus indicating little variation from RC and would likely be the case for microalgal biomass and community patterns. An increase in nutrient input may enhance chlorophyll *a* biomass and alter species composition as a result of increased return flow and increased seepage points.

**Benthic microalgae**

Microphytobenthic habitat loss during floods and open mouth conditions and accretion following mouth closure Scenario 3 is probably not very different from the RC. Turbidity conditions would also possibly remain similar. An increase in seepage areas act as sources of additional nutrient input for MPBs and would likely influence benthic primary production.

Confidence:Medium

**MACROPHYTES**

The influence of the off-channel storage dam with intermittent pumping results in a removal of low flows but the effect on floods is similar to that of the PS. Infilling of the intertidal areas and stabilisation of the lower estuary due to housing developments would facilitate reed encroachment. An increase in nutrients due to increased septic tank input, stormwater run-off and return flow from gardens and hardened surfaces would increase the abundance of macrophytes particularly that of reeds, sedges, macroalgae and submerged macrophytes. In particular macroalgae would increase in abundance potentially displacing other habitats.

Confidence: Medium

**INVERTEBRATES (including Macrobenthos, Zooplankton and Hyperbenthos)**

**Macrobenthos**

A reduction in low flow conditions will probably lead to higher salinity values throughout the estuary with little variability between the upper and lower estuary. Since flooding will be less affected compared to Scenario 1, the occasional flood will open the mouth but because of a reduced base flow, the mouth is likely to close sooner than under RC. Salinity gradients will probably not persist for long enough to allow the macrozoobenthic community to develop substructures based on the salinity pattern (development of a river-associated community).

Confidence: Medium

**Zooplankton**

The zooplankton community composition and biomass under Scenario 3 is unlikely to change from the RC.

Confidence: Medium

**Hyperbenthos**

The low deviation in frequency of floods from the RC to that proposed in Scenario 3, suggests that there will be no/little change in the biomass of *P.peringueyi* in the estuary.

**FISH**

Since there is likely to be little change in open mouth conditions between the Reference Condition and Scenario 2, it is highly likely that the fish assemblage will be very similar to that found in the natural state. Small changes in fish distribution and abundance are likely due to the slight reductions in high flows and base flows when compared to the RC.

Confidence: Medium

**BIRDS**

The avifauna is unlikely to be affected by slight changes in mouth conditions. An increase in macrophytes will attract coots and possibly grebes. Small changes in fish populations are unlikely to affect piscivirous bird numbers. An increase in human disturbance factors of feeding, roosting and nesting habitat (walking, swimming, boating, fishing, housing developments) will impact negatively on bird abundance.

Confidence: Low

### b) EHI for the Future Scenario 3:

### Microalgae

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Phytoplankton | | | |
| 1. Species richness | 65 | There is minimal difference between river inflow patterns under the RC (i.e. low flow occurrence 86.0) and Scenario 3 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton species richness has probably not changed markedly.<br>Increased nutrients bring in opportunistic forms at the expense of rarer form. Allow for a 20% change, which is equivalent to a score of 65. | L |
| 2a. Abundance | 80 | There is minimal difference between RC (i.e. low flow occurrence 86.0) and Scenario 3 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton abundances have probably not changed markedly.<br>An increase in nuisance algal blooms due to an increase in nutrients would affect phytoplankton abundance. | L |
| 2b. Community composition | 80 | Since there is minimal difference between RC (i.e. low flow occurrence 98.2) and Scenario 3 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton species composition has probably not changed markedly.<br>Increase in nuisance algal blooms due to an increase in nutrients would affect phytoplankton species composition. | L |
| Benthic microalgae | | | |
| 1. Species richness | 65 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 3 suggest a slight increase in sediment load altering MPB habitat. Species richness would likely have had a deviation of approximately 20% from natural conditions.<br>Sediment infilling, and an increase in nutrients would decrease species diversity as a result. | L |
| 2a. Abundance | 80 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 3 suggest a slight increase in sediment load altering MPB habitat. Microphytobenthic abundances would likely have had a deviation of approximately 20% from natural conditions.<br>Increases in nutrients would affect abundance as a result. | L |
| 2b. Community composition | 80 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 3 suggest a slight increase in sediment load altering MPB habitat. Community composition would likely have had a deviation of approximately 20% from natural conditions.<br>Increases in nutrients would alter species composition as a result. | L |
| **Microalgae score** | **65** | | L |

## Macrophytes

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | There may have been a loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity (5% change).<br>Some infilling may change substrate characteristics that might cause the loss of rare species. Increased development and proximity of gardens could result in the introduction of exotic plants particularly in the supratidal-terrestrial habitat. | L |
| 2a. Abundance | 60 | There is a reduction in low flows but the effect on floods is similar to that of the PS. Reeds will become established on the east bank below and above the R72 bridge (15% change). Infilling of the intertidal areas and stabilisation of the lower estuary due to housing developments would facilitate reed encroachment.<br>Closed mouth conditions and a decrease in high flow breaching events would result in an increase in submerged macrophytes (5%) and macroalgal abundance (5%). Sedimentation would also occur in the intertidal zone as a result of the reduction in flow, which would encourage reed growth (2%).<br>An increase in nutrients due to increased septic tank input, stormwater run-off and return flow from gardens and hardened surfaces would increase the abundance of macrophytes particularly that of reeds, sedges, macroalgae and submerged macrophytes (13%). | L |
| 2b. Community composition | 70 | The nutrient changes, decrease in flooding and frequency of mouth closure will increase reed, submerged macrophyte and macroalgal cover reducing open water surface area and bare sand and mudflats. Increased nutrients will result in macroalgal blooms which would displace other vegetation. Reed beds may encroach on submerged macrophyte habitat. | L |
| **Macrophytes score** | **60** | | L |

## Invertebrates

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| **Zooplankton** | | | |
| 1. Species richness | 90 | The minimal difference in flow between the various scenarios suggests that there will be little change in the zooplankton species richness within the system. | M |
| 2a. Abundance | 80 | The increase in the duration of mouth closure is likely to be associated with an increase in the total zooplankton biomass within the system. | M |
| 2b. Community composition | 80 | The community composition is unlikely to change to any significant extent. | M |
| **Macrobenthos** | | | |
| 1. Species richness | 80 | The probability of a low salinity community becoming briefly established is reduced, probably at a level slightly lower than Scenario 1. Although floods are not affected, a reduction in base flow will lead to salinity values returning to a weaker horizontal gradient faster. This may not allow a freshwater linked community to develop. Allow for a 10% change. | L |

| | | | |
|---|---|---|---|
| 2a. Abundance | 60 | Because of the increase in submerged macrophyte biomass (including expansion into marginal areas presently experiencing occasional intertidal effects), abundance levels will remain high for extended periods with the frequency of crashes similar to the present condition (drainage effects).<br>Abundance will Increase because of an increase in food availability (phytoplankton and detritus from macrophytes). | L |
| 2b. Community composition | 70 | Change in composition of macrophytes (engorgement) it is going to influence community composition. It is also likely that dominance patterns will change.<br>Bait collection will also influence community composition because of habitat disturbance. | M |
| **Hyperbenthos** | | | |
| 1. Species richness | 90 | The minimal difference in flow between the various scenarios suggests that there will be little change in the hyperbenthic species richness within the system. | M |
| 2a. Abundance | 70 | The extended mouth closure is likely to be associated with a decline in the total biomass of hyperbenthic species due to reduced recruitment opportunities of marine breeding species into the estuary. | M |
| 2b. Community composition | 80 | Unlikely to change compared to the present condition. Species are well adapted to natural variability in environmental factors. | M |
| **Invertebrates score** | **60** | | M |

## Fish

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | Little difference in species richness is likely to have occurred between the RC and Scenario 3. Allow for a 5% change. | M |
| 2a. Abundance | 60 | The abundance of macrophyte associated fish species is likely to increase and that of bare substratum associated fish species will decrease.<br>Mullet abundance will increase due to increase in stormwater and nutrient input. Overall biomass will decrease due to an increase in angling effort (targeting larger fish).<br>Laval fish are more sensitive to eutrophication than adults and this effect will ripple through populations. | L |
| 2b. Community composition | 60 | As above. | M |
| **Fish score** | **60** | | M |

## Birds

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 80 | The 300% increase in development will cause an increase in disturbance (walking, boating, angling) of feeding, roosting and nesting areas. Allow for a 10% change. | L |
| 2a. Abundance | 55 | Increase in species associated with submerged macrophytes, negligible change in most piscivorous species.<br>Abundance will be negatively affected due to an increase in disturbance factors (e.g. walking, boating, angling). | L |
| 2b. Community composition | 80 | Slight change due to the above. | L |
| **Bird score** | **55** | | L |

## 4.4 Future Scenario 4: Similar to Scenario 2, but including non-flow related anthropogenic activities except the increase in waste water and stormwater runoff

### 4.4.1 Abiotic Components

#### a) Seasonal variability in river inflow:

Monthly simulated runoff data for the Future Scenario 4 is provided in Table 4.4. A summary of flow distribution (mean monthly flows in $m^3 s^{-1}$) for the Future Scenario 4, derived from the 83-year simulated data set, is provided below:

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.765 | 1.183 | 0.665 | 0.245 | 0.803 | 1.524 | 1.023 | 2.702 | 1.127 | 0.931 | 0.958 | 1.513 |
| 90%ile | 0.240 | 0.236 | 0.162 | 0.074 | 0.052 | 0.184 | 0.205 | 0.152 | 0.200 | 0.113 | 0.103 | 0.230 |
| 80%ile | 0.117 | 0.074 | 0.065 | 0.012 | 0.019 | 0.081 | 0.064 | 0.051 | 0.039 | 0.025 | 0.037 | 0.065 |
| 70%ile | 0.064 | 0.047 | 0.023 | 0.004 | 0.006 | 0.027 | 0.043 | 0.019 | 0.010 | 0.009 | 0.017 | 0.029 |
| 60%ile | 0.024 | 0.027 | 0.008 | 0.001 | 0.002 | 0.010 | 0.025 | 0.007 | 0.004 | 0.003 | 0.008 | 0.010 |
| 50%ile | 0.010 | 0.016 | 0.003 | 0.000 | 0.000 | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 |
| 40%ile | 0.003 | 0.005 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 30%ile | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

#### b) Present flood regime

The flood regime is judged to be very similar to that under RC based on the fact that the simulated monthly runoff data indicate very little change for months of flow higher than 0.116 $m^3 s^{-1}$ (highlighted in blue). The 99%ile indicates that there is only a 5.3 % decrease in the floods to the estuary.

*Confidence: Medium*

#### c) Present sediment processes

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

*Confidence: Low*

**Table 4.4** Simulated monthly volumes (million m$^3$) in the East Kleinemonde Estuary for Future Scenario 4.

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breaches | High Flow Breaches |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.15 | 0.15 | 0.21 | 0.22 | 0.23 | 0.34 | 0.15 | 0.35 | 0.37 | 0.37 | 0.37 | 0.38 | 1 | 1 |
| 1921 | 0.38 | 0.15 | 0.25 | 0.25 | 0.25 | 0.25 | 0.35 | 0.41 | 0.15 | 0.15 | 0.15 | 0.26 | 4 | 3 |
| 1922 | 0.27 | 0.15 | 0.15 | 0.15 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.26 | 0.28 | 0.28 | 3 | 3 |
| 1923 | 0.29 | 0.32 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0 | 0 |
| 1924 | 0.41 | 0.41 | 0.15 | 0.18 | 0.18 | 0.15 | 0.34 | 0.35 | 0.37 | 0.37 | 0.37 | 0.15 | 3 | 1 |
| 1925 | 0.20 | 0.20 | 0.22 | 0.23 | 0.28 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.33 | 0 | 0 |
| 1926 | 0.15 | 0.25 | 0.25 | 0.25 | 0.26 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 1 | 1 |
| 1927 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.23 | 0.15 | 4 | 2 |
| 1928 | 0.15 | 0.34 | 0.40 | 0.40 | 0.40 | 0.41 | 0.41 | 0.41 | 0.15 | 0.15 | 0.26 | 0.15 | 4 | 4 |
| 1929 | 0.15 | 0.23 | 0.23 | 0.23 | 0.23 | 0.42 | 0.15 | 0.15 | 0.18 | 0.19 | 0.23 | 0.29 | 2 | 1 |
| 1930 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.38 | 0.15 | 0.18 | 0.18 | 0.42 | 0.15 | 0.18 | 3 | 1 |
| 1931 | 0.15 | 0.15 | 0.15 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.38 | 0.38 | 0.15 | 4 | 4 |
| 1932 | 0.15 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.20 | 0.20 | 0.20 | 0.45 | 0.15 | 3 | 1 |
| 1933 | 0.15 | 0.19 | 0.20 | 0.21 | 0.22 | 0.15 | 0.29 | 0.29 | 0.29 | 0.15 | 0.15 | 0.15 | 5 | 3 |
| 1934 | 0.15 | 0.28 | 0.31 | 0.31 | 0.31 | 0.31 | 0.15 | 0.15 | 0.15 | 0.22 | 0.23 | 0.23 | 4 | 3 |
| 1935 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0 | 0 |
| 1936 | 0.15 | 0.15 | 0.33 | 0.33 | 0.33 | 0.15 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 3 | 3 |
| 1937 | 0.32 | 0.34 | 0.15 | 0.15 | 0.15 | 0.25 | 0.36 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 3 | 2 |
| 1938 | 0.38 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.30 | 5 | 4 |
| 1939 | 0.15 | 0.19 | 0.15 | 0.15 | 0.15 | 0.15 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 5 | 3 |
| 1940 | 0.30 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 3 | 2 |
| 1941 | 0.16 | 0.20 | 0.15 | 0.32 | 0.34 | 0.34 | 0.34 | 0.42 | 0.44 | 0.44 | 0.45 | 0.15 | 2 | 0 |
| 1942 | 0.41 | 0.15 | 0.16 | 0.33 | 0.37 | 0.37 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 0.28 | 2 | 0 |
| 1943 | 0.28 | 0.15 | 0.31 | 0.31 | 0.32 | 0.15 | 0.23 | 0.30 | 0.31 | 0.31 | 0.31 | 0.15 | 3 | 2 |
| 1944 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.41 | 0.43 | 0.43 | 0.43 | 0 | 0 |
| 1945 | 0.15 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 1 | 0 |
| 1946 | 0.23 | 0.24 | 0.25 | 0.25 | 0.25 | 0.15 | 0.32 | 0.33 | 0.39 | 0.15 | 0.21 | 0.21 | 2 | 1 |
| 1947 | 0.21 | 0.23 | 0.24 | 0.24 | 0.24 | 0.25 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 2 | 2 |
| 1948 | 0.15 | 0.28 | 0.28 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.32 | 1 | 1 |
| 1949 | 0.32 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 5 | 4 |
| 1950 | 0.15 | 0.15 | 0.15 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.29 | 0.15 | 5 | 5 |
| 1951 | 0.15 | 0.15 | 0.15 | 0.16 | 0.27 | 0.31 | 0.32 | 0.15 | 0.20 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1952 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.43 | 0.15 | 2 | 2 |
| 1953 | 0.15 | 0.15 | 0.26 | 0.26 | 0.26 | 0.15 | 0.25 | 0.15 | 0.31 | 0.34 | 0.15 | 0.31 | 5 | 4 |
| 1954 | 0.38 | 0.15 | 0.21 | 0.23 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.36 | 1 | 0 |
| 1955 | 0.39 | 0.15 | 0.17 | 0.17 | 0.29 | 0.34 | 0.35 | 0.37 | 0.38 | 0.38 | 0.38 | 0.15 | 2 | 0 |
| 1956 | 0.22 | 0.27 | 0.40 | 0.42 | 0.15 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.15 | 2 | 1 |
| 1957 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.42 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 2 | 2 |
| 1958 | 0.15 | 0.15 | 0.34 | 0.42 | 0.42 | 0.15 | 0.24 | 0.27 | 0.27 | 0.27 | 0.27 | 0.28 | 1 | 0 |
| 1959 | 0.28 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.15 | 0.21 | 0.21 | 0.21 | 0.27 | 1 | 0 |
| 1960 | 0.44 | 0.15 | 0.15 | 0.16 | 0.20 | 0.21 | 0.21 | 0.30 | 0.32 | 0.33 | 0.33 | 0.33 | 1 | 0 |
| 1961 | 0.33 | 0.37 | 0.39 | 0.39 | 0.39 | 0.15 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 1 | 1 |
| 1962 | 0.15 | 0.33 | 0.33 | 0.15 | 0.19 | 0.15 | 0.15 | 0.44 | 0.44 | 0.15 | 0.20 | 0.20 | 5 | 3 |
| 1963 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.39 | 0.39 | 0.39 | 0.15 | 0.20 | 0.20 | 0.15 | 3 | 2 |
| 1964 | 0.39 | 0.42 | 0.42 | 0.42 | 0.42 | 0.43 | 0.43 | 0.15 | 0.30 | 0.35 | 0.38 | 0.39 | 1 | 0 |
| 1965 | 0.15 | 0.15 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.41 | 0.43 | 0.43 | 0.15 | 0.19 | 3 | 1 |
| 1966 | 0.21 | 0.22 | 0.22 | 0.22 | 0.27 | 0.29 | 0.33 | 0.15 | 0.15 | 0.34 | 0.43 | 0.45 | 2 | 2 |
| 1967 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.15 | 0.22 | 0.23 | 0.15 | 0.15 | 0.15 | 0.18 | 4 | 2 |

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total Breaches | High Flow Breaches |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 0.18 | 0.18 | 0.18 | 0.18 | 0.21 | 0.45 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 1 | 0 |
| 1969 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.15 | 0.15 | 2 | 2 |
| 1970 | 0.15 | 0.22 | 0.15 | 0.40 | 0.41 | 0.41 | 0.15 | 0.28 | 0.28 | 0.28 | 0.33 | 0.34 | 3 | 3 |
| 1971 | 0.38 | 0.38 | 0.41 | 0.41 | 0.15 | 0.20 | 0.20 | 0.20 | 0.20 | 0.22 | 0.23 | 0.24 | 1 | 0 |
| 1972 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 | 0.26 | 0.27 | 0.27 | 0.27 | 0.34 | 0.37 | 0 | 0 |
| 1973 | 0.37 | 0.15 | 0.19 | 0.28 | 0.41 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.38 | 7 | 6 |
| 1974 | 0.38 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.41 | 0.15 | 1 | 1 |
| 1975 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.29 | 0.33 | 0.33 | 0.33 | 0.15 | 0.15 | 0.17 | 3 | 3 |
| 1976 | 0.29 | 0.37 | 0.37 | 0.37 | 0.15 | 0.36 | 0.37 | 0.15 | 0.26 | 0.29 | 0.29 | 0.29 | 2 | 1 |
| 1977 | 0.29 | 0.42 | 0.15 | 0.23 | 0.23 | 0.30 | 0.15 | 0.15 | 0.37 | 0.40 | 0.40 | 0.40 | 3 | 3 |
| 1978 | 0.15 | 0.18 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.15 | 0.15 | 0.15 | 4 | 3 |
| 1979 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.17 | 0.20 | 0 | 0 |
| 1980 | 0.21 | 0.28 | 0.30 | 0.15 | 0.27 | 0.15 | 0.15 | 0.33 | 0.39 | 0.39 | 0.15 | 0.23 | 4 | 3 |
| 1981 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.42 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 1 | 0 |
| 1982 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.25 | 0.25 | 1 | 1 |
| 1983 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.15 | 0.37 | 0.39 | 0.39 | 1 | 1 |
| 1984 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0 | 0 |
| 1985 | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.21 | 0.22 | 0.22 | 0.22 | 0.22 | 0.35 | 0.40 | 3 | 2 |
| 1986 | 0.44 | 0.15 | 0.15 | 0.15 | 0.16 | 0.17 | 0.17 | 0.17 | 0.27 | 0.30 | 0.32 | 0.34 | 1 | 0 |
| 1987 | 0.34 | 0.34 | 0.34 | 0.34 | 0.15 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.25 | 1 | 0 |
| 1988 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.40 | 0.44 | 0.44 | 0.45 | 0.45 | 0.15 | 1 | 0 |
| 1989 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.30 | 0.32 | 0.32 | 0.43 | 0.15 | 0.15 | 0.15 | 5 | 3 |
| 1990 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.31 | 0.34 | 0 | 0 |
| 1991 | 0.15 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.15 | 3 | 2 |
| 1992 | 0.15 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.33 | 0.33 | 0.38 | 0.39 | 0.43 | 0.15 | 2 | 1 |
| 1993 | 0.20 | 0.20 | 0.38 | 0.15 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.15 | 0.24 | 2 | 0 |
| 1994 | 0.24 | 0.24 | 0.15 | 0.15 | 0.15 | 0.15 | 0.26 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 2 | 2 |
| 1995 | 0.29 | 0.34 | 0.36 | 0.36 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 | 0.38 | 0 | 0 |
| 1996 | 0.38 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.40 | 0.15 | 0.15 | 0.25 | 0.25 | 0.25 | 4 | 3 |
| 1997 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.15 | 0.29 | 0.29 | 0.29 | 0.30 | 0.34 | 0.36 | 1 | 1 |
| 1998 | 0.37 | 0.37 | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.15 | 0.19 | 0.21 | 1 | 0 |
| 1999 | 0.15 | 0.25 | 0.25 | 0.15 | 0.27 | 0.15 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.44 | 3 | 3 |
| 2000 | 0.15 | 0.38 | 0.44 | 0.15 | 0.16 | 0.17 | 0.20 | 0.20 | 0.20 | 0.34 | 0.42 | 0.15 | 3 | 0 |
| 2001 | 0.19 | 0.31 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.15 | 0.15 | 0.15 | 3 | 3 |
| 2002 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.18 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 3 | 3 |
|  |  |  |  |  |  |  |  |  |  |  |  |  | 2.34 | 1.55 |

🟪 High flow breaching

🟦 Low flow breaching

### d) EHI for the Future Scenario 4

## Hydrology

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| a. % similarity in period of low flows OR Present MAR as a % of MAR in the reference condition. | 95 | For the East Kleinemonde River Estuary low flows are defined as less than 0.12 $m^3 s^{-1}$.<br>Months with flows less than 0.12 $m^3 s^{-1}$ occurred under the RC for 86.0 of the year. Under Scenario 4 low flows occur for 87.5 % of the year. | L |
| b. % similarity in mean annual frequency of floods. | 90 | The reduction in high flows is deemed to be very small based on the very limited reduction in monthly high flows. The 99%ile indicates that there is only a 5.3 % decrease in the floods to the estuary under Scenario 4. | L |
| **Hydrology score** | **93** | | L |

## Hydrodynamics and mouth condition

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Change in mean duration of closure, e.g. over a 5 or 10 year period. | 85 | Under the RC the East Kleinemonde Estuary mouth breaching could potentially have occurred in 2.6 months of the year over the 83-year period. Of these 1.9 was related to high flow events that breached the system instantaneously.<br>Under the Scenario 4 mouth breaching (State 1 and 2) has been reduced to 2.3 months of the year over the 83-year period (11% change from the RC). Of these 1.6 was related to high flow events (State 1) that breached the system instantaneously. | L |
| **Hydrodynamics and mouth conditions score** | **85** | | L |

## Water quality

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification. | 85 | As the river inflow to the East Kleinemonde Estuary and the frequency of breaching events is very similar to the RC, it is assumed that the salinities will also be very similar. | L |
| 2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary. | 75 | River DIN concentration increased from RC to PS (>10 times during high flow events and ~ 3 times during low flow periods), associated with agricultural activities in the catchment. Although the influence of river inflow (as indicated by salinity) in this system is generally limited to the upper reaches and despite an overall reduction in river inflow, these marked increases in river DIN would nevertheless have resulted in a significant increase in DIN loads to the system compared with the RC.<br>However, because river inflow in Scenario 4 (as in Scenario 2) is 5% less than under the PS, modification to DIN loads should be less. Therefore allow a 25% modification from RC (i.e. 5% less than for PS). | L |

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 2b. Suspended solids (turbidity) in the estuary. | 85 | Turbidity in the system is influenced by river inflow and turbulence associated with tidal exchange (during intermittently open phase). There is a slight decrease in the probable occurrence of intermittently open/closed states (States 1 and 2) compared with the RC. This will result in a decrease in turbidity. Allow for 5% modification from the RC. Furthermore, there is a 10% reduction in river inflow compared to RC, further decreasing turbidity. | L |
| 2c. Dissolved oxygen in the estuary. | 75 | There is a slight increase in the occurrence of the closed state (State 3) versus intermittently open/closed phases (States 1 and 2) in Scenario 2 compared with RC. DO concentrations are expected to decrease with an increase in the frequency and duration of the closed state. Therefore allow for a 5% modification from RC.<br>However an increase in nutrient loading from the catchment (associated with agricultural activity) could have increased oxygen demand under Scenario 2. Because river inflow in Scenario 4 is 5% less than under the PS, modification to DO should be less. Therefore allow a further 10% modification from RC (i.e. 5% less than for PS).<br>More mouth closure will cause increased macrophytes and filamentous algae growth and decomposition, causing lower DO (allow for further 10% modification). | L |
| 2d. Levels of toxins. | 80 | There are no major industrial activities in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. However, because river inflow in Scenario 4 (as in Scenario 2) is 5% less than under the PS, modification in terms of toxins should be less. Therefore allow a 15% modification from RC (i.e. 5% less than for PS).<br>The level of toxins in the system is nevertheless expected to increase under Scenario 4 as there will still be increased boating activity (oils, fuels, antifouling agents), although toxins from stormwater will no longer be a concern. Allow a further 5% modification. | L |
| **Water Quality score** | **79** | | L |

## Physical habitat alteration

| VARIABLE | | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|---|
| 1. Resemblance of <u>intertidal sediment</u> structure and distribution to reference condition | | | | |
| 1a | % similarity in intertidal area exposed. | 75 | Allow 5% change in the intertidal area due to changes in river inflow. In addition, 20% is allocated for stabilisation, construction of jetties and infilling of intertidal areas. | L |
| 1b | % similarity in sand fraction relative to total sand and mud. | 70 | The bridge acts as barrier that prevents the development of a gradient from marine sediment below the bridge to muddier sediment upstream. The system may become even more muddy due to land-use changes in the catchment. | L |
| 2 | Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology. | 80 | Allow 5% change in the subtidal area due to changes in river inflow. In addition, 5% is allocated for the stabilisation of the lower estuary and channel modification to provide access for power boats. | L |

| | | | | |
|---|---|---|---|---|
| **Anthropogenic influence:** | | | | |
| | Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary. | 95 | Sedimentation may have occurred due to change in land-use in the catchment and the bridge. | L |
| | Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges) rather than modifications to water flow into estuary. | 95 | Sedimentation may have occurred due to changes in land-use in the catchment, e.g. agriculture and the bridge. | L |
| **Physical habitat score** | | **76** | | L |

### 4.4.2 Biotic Components

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

**MICROALGAE**

**Phytoplankton**

Under Scenario 4 the decrease in the frequencies of floods is represented by a change of about 5% from RC. This suggests that there would be little change in the microphytobenthos (MPB) chlorophyll *a* levels from natural condition. The annual distribution patterns of low river inflows under this scenario indicates less periods of low flow conditions, thus indicating little variation from RC.

**Benthic microalgae**

Microphytobenthic habitat loss during floods and open mouth conditions and accretion following mouth closure under Scenario 4 is probably not very different from the RC. Seepage areas act as sources of additional nutrient input for MPBs and would likely influence benthic primary production in a similar fashion.

Confidence: Low

**MACROPHYTES**

This Scenario is similar to Scenario 2 except that infilling of the intertidal areas and stabilisation of the lower estuary due to housing developments could influence the macrophytes. Sediment stabilization would result in reed encroachment and changes in substrate type could cause the loss of rare species. Increased development and proximity of gardens could result in the introduction of exotic plants particularly in the supratidal-terrestrial habitat. Community composition may change as a result of human activities such as the construction of jetties and trampling. Other changes are similar to that described for Scenario 2.

Confidence: Medium

**INVERTEBRATES (including Macrobenthos, Zooplankton and Hyperbenthos)**

**Macrobenthos**

A reduction in low flow conditions will probably lead to higher salinity values throughout the estuary with little variability between the upper and lower estuary. Since flooding will be less affected compared to Scenario 1, the occasional flood will open the mouth but, because of a reduced base flow, the mouth is likely to close sooner than under RC. Salinity gradients will probably not persist for long enough to allow the macrozoobenthic community to develop substructures based on the salinity pattern (development of a river-associated community).

Confidence: Medium

**Zooplankton and Hyperbenthos**

The zooplanktonic and hyperbenthic invertebrate community under reduced flow conditions (Scenario 2) is unlikely to change from the RC.

Confidence: Medium

**FISH**

Since there is likely to be little change in open mouth conditions between the RC and Scenario 2, it is highly likely that the fish assemblage will be very similar to that found in the natural state. Small changes in fish distribution and abundance are likely due to the slight reductions in high flows and base flows when compared to the RC.

Confidence: Medium

**BIRDS**

The avifauna is unlikely to be affected by slight changes in mouth conditions. An increase in macrophytes will attract coots and possibly grebes. Small changes in fish populations are unlikely to affect piscivirous bird numbers.

Confidence: Low

### b) EHI for the Future Scenario 4:

### Microalgae

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| Phytoplankton | | | |
| 1. Species richness | 90 | There is minimal difference between river inflow patterns under the RC (i.e. low flow occurrence 86.0) and Scenario 4 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton species richness has probably not changed markedly. Allow a 5% change, which is equivalent to a score of 90. | M |
| 2a. Abundance | 95 | There is minimal difference between RC (i.e. low flow occurrence 86.0) and Scenario 4 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton abundances have probably not changed markedly. | M |
| 2b. Community composition | 95 | Since there is minimal difference between RC (i.e. low flow occurrence 98.2) and Scenario 4 (i.e. low flow occurrence 87.5), corresponding to possibly a 5% change, therefore phytoplankton species composition has probably not changed markedly. | M |
| Benthic microalgae | | | |
| 1. Species richness | 80 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 4 suggest a slight increase in sediment load altering MPB habitat. Species richness would likely have had a deviation of approximately 10% from natural conditions which is equivalent to a score of 80. | M |
| 2a. Abundance | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 4 suggest a slight increase in sediment load altering MPB habitat. Microphytobenthic abundances would likely have had a deviation of approximately 10% from natural conditions. | M |
| 2b. Community composition | 90 | Sediment processes have probably changed little from the RC, therefore catchment activities (i.e. agricultural practises, land development, and physical structures) under Scenario 4 suggest a slight increase in sediment load altering MPB habitat. Community composition would likely have had a deviation of approximately 10% from natural conditions. | M |
| **Microalgae score** | **80** | | M |

### Macrophytes

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 95 | There may have been a loss in opportunistic brackish species as a result of the reduction in flooding and increase in salinity (2% change).<br>Some infilling may change substrate characteristics that might cause the loss of rare species. Increased development and proximity of gardens could result in the introduction of exotic plants particularly in the supratidal-terrestrial habitat. | M |

| | | | |
|---|---|---|---|
| 2a. Abundance | 70 | Closed mouth conditions and a decrease in high flow breaching events would result in an increase in submerged macrophyte (5%) and macroalgal abundance (5%). Sedimentation would also occur in the intertidal zone as a result of the reduction in flow, which would encourage reed growth (2%).<br>Agricultural activities in the catchment and nutrient input will increase macrophyte growth particularly that of reeds, sedges, macroalgae and submerged macrophytes. However nutrient input will be slightly less than at present because of the reduction in river flow.<br>Reeds have become established on the east bank below and above the R72 bridge (15 % change). Infilling of the intertidal areas and stabilisation of the lower estuary due to housing developments would facilitate reed encroachment (3%). | M |
| 2b. Community composition | 85 | The nutrient changes, decrease in flooding and frequency of mouth closure will increase reed, submerged macrophyte and macroalgal cover reducing open water surface area, bare sand and mudflats. Reed beds will encroach on submerged macrophyte habitat. There may be a change in community composition due to an increase in human activities, e.g. trampling, jetties. | M |
| **Macrophytes score** | **70** | | |

## Invertebrates

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| **Zooplankton** | | | |
| 1. Species richness | 90 | Little difference in species richness is likely to have occurred between the RC and Scenario 4. | M |
| 2a. Abundance | 90 | As above | |
| 2b. Community composition | 90 | As above | |
| **Macrobenthos** | | | |
| 1. Species richness | 80 | The probability of a low salinity community becoming briefly established is reduced, probably at a level slightly lower than scenario 1. Although floods are not affected, a reduction in base flow will lead to salinity values returning to a weaker horizontal gradient faster. This may not allow a freshwater linked community to develop.<br>Allow for a 10% change. | M |
| 2a. Abundance | 70 | Because of the increase in submerged macrophyte biomass (including expansion into marginal areas presently experiencing occasional intertidal effects), abundance levels will remain high for extended periods with the frequency of crashes similar to the present condition (drainage effects).<br>Abundance will be negatively affected due to an increase in human activities (e.g. bait collection) and changes in the macrophyte communities brought about by human disturbances. | M |

| | | | |
|---|---|---|---|
| 2b. Community composition | 85 | Unlikely to change compared to the present condition. Species are well adapted to natural variability in environmental factors<br>Increase human activities (e.g. bait collection). Changes in the macrophyte communities brought about by human disturbances. | M |
| **Hyperbenthos** | | | |
| 1. Species richness | 90 | The minimal difference in flow between the various scenarios suggests that there will be little change in the hyperbenthic species richness within the system. | M |
| 2a. Abundance | 90 | The extended mouth closure is likely to be associated with a decline in the total biomass of hyperbenthos due to reduced recruitment opportunities of marine breeding species into the estuary. | M |
| 2b. Community composition | 90 | Unlikely to change compared to the present condition. Species are well adapted to natural variability in environmental factors. | M |
| **Invertebrates score** | **70** | | M |

## Fish

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 90 | Little difference in species richness is likely to have occurred between the RC and Scenario 4. Allow for a 5% change. | M |
| 2a. Abundance | 62 | The abundance of macrophyte associated fish species is likely to increase and that of bare substratum associated fish species will decrease.<br>In addition, there will be disturbance of fish in the shallows because of boating activities. Mortalities due to prop action. | M |
| 2b. Community composition | 62 | As above. | M |
| **Fish score** | **62** | | |

## Birds

| VARIABLE | SCORE | MOTIVATION | CONFIDENCE |
|---|---|---|---|
| 1. Species richness | 85 | Species richness is unlikely to change compared to RC. Allow for a 7% change. | L |
| 2a. Abundance | 57 | Increase in species associated with submerged macrophytes, but a negligible change in most piscivorouss species.<br>Abundance will be negatively affected due to an increase in disturbance factors (e.g. walking, boating, fishing).<br>Slight increase from Scenario 3. | L |
| 2b. Community composition | 80 | Slight change due to the above. | L |
| **Bird score** | **57** | | **L** |

# 5 Recommended ecological flow requirement for East Kleinemonde Estuary

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

| Variable | Weight | Present | Runoff scenario | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| Hydrology | 25 | 95 | 93 | 93 | 93 | 93 |
| Hydrodynamics/mouth condition | 25 | 90 | 80 | 85 | 85 | 85 |
| Water quality | 25 | 78 | 80 | 79 | 64 | 79 |
| Physical habitat alteration | 25 | 85 | 85 | 85 | 76 | 76 |
| **Habitat Health Score** | **50** | **87** | **85** | **86** | **68** | **71** |
| Microalgae | 20 | 80 | 80 | 80 | 65 | 80 |
| Macrophytes | 20 | 85 | 81 | 83 | 60 | 70 |
| Invertebrates | 20 | 90 | 80 | 80 | 60 | 70 |
| Fish | 20 | 90 | 80 | 85 | 60 | 62 |
| Birds | 20 | 85 | 82 | 85 | 55 | 57 |
| **Biotic Health Score** | **50** | **86** | **81** | **83** | **49** | **56** |
| **Estuarine Health Index Score** | | **87** | **83** | **84** | **58** | **64** |
| **Ecological Reserve Category (ERC)** | | **B** | **B** | **B** | **D** | **C** |

The evaluation of the simulated runoff scenarios was used to derive the recommended Ecological Flow Requirement. The recommended Ecological Flow Requirement is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended ERC.

In evaluating Future Scenarios 1 and 2 the assumption was made that only river in-flow from the catchments will be reduced, and that all additional non-flow related anthropogenic activities (e.g. increased fishing and bait collection, power boating, human disturbance, seepage from septic tanks, stormwater runoff) will not be considered. Future Scenario 3 represents the expected impact of flow reduction and additional non-flow related anthropogenic activities on the estuary if 1010 plots are developed in the estuarine environs. Scenario 4 represents the expected impact of flow reduction and additional non-flow related anthropogenic activities, but mitigating for the impact of nutrient loading as a result of seepage from septic tanks and pollutants from storm water run-off.

Both Scenario 1 and Scenario 2 will maintain the East Kleinemonde in the recommended ERC as they differ very little in reduction of runoff and impact on the estuarine ecosystem. **Scenario 2** was selected as the recommended Ecological Flow Requirement because Scenario 1 (which includes an in-channel dam development) represents a serious risk to migratory species (e.g. eels) that use the river as a conduit to the upper catchment. Dams act as permanent barriers to fish migration and negatively influence river ecosystems by changing the downstream flow regime.

The selection of Scenario 2 means that although the East Kleinemonde is a small temporarily open/closed estuary, it can accommodate the reduction in fluvial flow necessary to meet the requirements of future housing development in the area. However, it will not be able to support the additional non-flow related human disturbance pressures that come with the new residential developments. Therefore the approval of any future residential development should be conditional on the following mitigation measures being implemented:

- No consumptive use (e.g. fishing or bait collection) should be allowed in the East Kleinemonde Estuary;
- No power boating on the East and West Kleinemonde estuaries (only canoes and electrical motors);

- All new urban development will have to be connected to a Waste Water Treatment Works to eliminate the risk of seepage from septic tanks entering the estuaries;
- All stormwater from newly developed areas will have to be captured and diverted from the system to prevent hydrocarbons and other pollutants from entering the system.

**East Kleinemonde: Summary of flow distributions (mean monthly flows in m$^3$ s$^{-1}$) under Future Scenario 2**

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99%ile | 0.765 | 1.183 | 0.665 | 0.245 | 0.803 | 1.524 | 1.023 | 2.702 | 1.127 | 0.931 | 0.958 | 1.513 |
| 90%ile | 0.240 | 0.236 | 0.162 | 0.074 | 0.052 | 0.184 | 0.205 | 0.152 | 0.200 | 0.113 | 0.103 | 0.230 |
| 80%ile | 0.117 | 0.074 | 0.065 | 0.012 | 0.019 | 0.081 | 0.064 | 0.051 | 0.039 | 0.025 | 0.037 | 0.065 |
| 70%ile | 0.064 | 0.047 | 0.023 | 0.004 | 0.006 | 0.027 | 0.043 | 0.019 | 0.010 | 0.009 | 0.017 | 0.029 |
| 60%ile | 0.024 | 0.027 | 0.008 | 0.001 | 0.002 | 0.010 | 0.025 | 0.007 | 0.004 | 0.003 | 0.008 | 0.010 |
| 50%ile | 0.010 | 0.016 | 0.003 | 0.000 | 0.000 | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 |
| 40%ile | 0.003 | 0.005 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| 30%ile | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1%ile | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

In order to maintain the estuary in its present state, consumptive use (exploitation) of marine living resources needs to be managed. Because the system is relatively small, there is no optimum zonation scheme that can accommodate this requirement, e.g. white steenbras occur predominantly below the road bridge in the sandy areas while other species occur above the bridge. Zoning to protect one fish species will make others more vulnerable, since it will lead to increased fishing pressure in other parts of the estuary. Serious concern was also raised over habitat destruction caused by bait collection since the areas where bait species occur are limited. Thus, the only effective mitigation measure in response to increased development in the environs of the East Kleinmonde is to close it for all consumptive uses.

Power boating in small estuaries causes habitat destruction (mainly as a result of bank erosion from boat wakes), pollution (antifouling paints and oils), disturbs the feeding and breeding of birds, and significantly disturbs fish (especially small fish in shallow areas). It is, therefore, recommended that power boating be banned from both the East and West Kleinemonde as they are similar in size and closure of one is likely to double the boating pressures on the adjacent system. Larger, permanently open estuaries such as the nearby Kowie and Kariega are much more resilient with respect to the impacts of power boating and are safer systems to use by virtue of their size.

At present, septic tanks are used for the treatment of domestic wastewater (sewage) at Kleinemonde. Although the use of French drains and septic tanks, and absence of sewage treatment plants may be acceptable options for smaller communities, these options are usually not acceptable for larger human settlements. The risk of impact on water resources, associated with spillages and seepage, increases markedly with the increase in the number and density of housing developments. Adverse impacts associated with sewage spillages and seepage include eutrophication (e.g. excessive reed growth along the banks of the estuary) and human health risks (e.g. associated with contract recreation activities). South Africa does not have clear guidelines on this matter, but internationally it has become common practice to provide a collecting system to communities (including coastal communities) with a service population greater than about 2 000 (RSA DWAF, 2004). It is therefore strongly recommended that any new residential development in the East Kleinemonde Estuary consider wastewater collection systems connected to either a conventional existing WWTW or an alternative treatment facility (e.g. artificial wetland).

Increased development (and an increase in hard surfaces) will also increase stormwater runoff into the estuary with likely increases of hydrocarbons, nutrients, turbidity and other pollutant loads. It is proposed that for any new development, the developer be made responsible for managing storm water run-off whereby, for example, the storm water run-off from a new development is contained and treated at central points before discharge into the environment (e.g. Thesen Island Development, Knysna).

The West Kleinemonde Estuary is similar in size to the East Kleinemonde and would therefore also be very vulnerable to increased urban development. This matter needs to be investigated before new developments in the area are approved. In future, RDM determinations should incorporate a regional assessment component to address the impact of development on adjacent systems.

# 6 References

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