Western Cape Government
Environmental Affairs and Development Planning

Hartenbos River Estuary Draft Estuarine Management Plan

2021

DOCUMENT DESCRIPTION

Document title and version:

Hartenbos River Estuary Draft Estuarine Management Plan (2021).

Developed by:

This report was developed for Mossel Bay Local Municipality by EOH: Coastal & Environmental Services (2018) and was edited by Western Cape Government Department of Environmental Affairs and Development Planning (2021)

Acknowledgements:

Mossel Bay Municipality
Hartenbos Estuary Advisory Forum
Western Cape Department of Environmental Affairs and Development Planning
Oceans Research

Date:

2021

This document should be referenced as

Western Cape Government (2021). Hartenbos River Estuary Draft Estuarine Management Plan (2021). Western Cape Department of Environmental Affairs and Development Planning.

Disclaimer

The Estuarine Functional Zone depicted in this estuarine management plan will be subject to change based on new data published from time to time.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

BCMM	Buffalo City Metropolitan Municipality
BGCMA	Breede-Gouritz Catchment Management Agency
CSIR	Council for Scientific and Industrial Research
DFFE: Fisheries	Department of Forestry, Fisheries and Environmental: Fisheries Management
DFFE: Oceans and Coasts	Department of Forestry, Fisheries and Environmental: Oceans and Coasts
DEADP	Department of Environmental Affairs and Development Planning
DWS	Department of Water and Sanitation
EAF	Estuary Advisory Forum
EIA	Environmental Impact Assessment
EMP	Estuarine Management Plan
ICMA	Integrated Coastal Management Act (Act No. 24 of 2008)
IDP	Integrated Development Plan
MBLM	Mossel Bay Local Municipality
MLRA	Marine Living Resources Act (Act No. 18 of 1998)
MMP	Mouth Management Plan
MSA	Municipal Systems Act (Act No. 32 of 2000)
NBA	National Biodiversity Assessment 2012
NCC	National Coastal Committee
NCMP	National Coastal Management Plan (2015)
NEM: BA	National Environmental Management: Biodiversity Act (Act No. 10 of 2004)
NEM: PAA	National Environmental Management: Protected Areas Act (Act No. 57 of 2003)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NEMP	National Estuary Management Protocol (2013)
NHRA	National Heritage Resources Agency
PCC	Provincial Coastal Committee
RMA	Relevant Management Authority
SANBI	South African National Biodiversity Institute
SDF	Spatial Development Framework
SEA	Strategic Environmental Assessment
SPLUMA	Spatial Planning and Land Use Management Act (Act No. 16 of 2013)

1 INTRODUCTION

1.1 Background

Estuarine ecosystems are not isolated systems. They form an interface between marine and freshwater aquatic systems and are part of regional, national and global aquatic ecosystems either directly via water flows, or indirectly through the movement of fauna. In addition to the biota that these estuaries support, they provide a range of goods and services (uses) to the inhabitants of the estuarine regions. Disturbances to an estuary can influence a wide variety of habitats and organisms in the associated freshwater or marine ecosystems. Thus, the interaction between the estuarine system and users creates a delicate balance, the sustainability of which needs to be maintained by implementing an appropriate management plan.

The Hartenbos Estuary is one of approximately 289 functional estuaries in South Africa and is one of 21 estuaries within the warm temperate biogeographic region to be classified as a temporarily open/closed (Turpie et al., 2012, Van Niekerk and Turpie, 2012). It is located in the Mossel Bay Local Municipality within the Garden Route District Municipality, Western Cape Province (Figure 1.1). The Hartenbos is a small estuary with a relatively large floodplain and covers a total of approximately 268 ha. The Hartenbos Estuary is ranked 74th of all South African estuaries in terms of its overall conservation importance and can be considered a moderately important for estuarine biodiversity on a national scale (van Niekerk, et. al., 2012). The Hartenbos Estuary is an important recreational area along the Cape south coast with a small resident population. However, during peak seasons there is a large influx of holiday makers into the area.

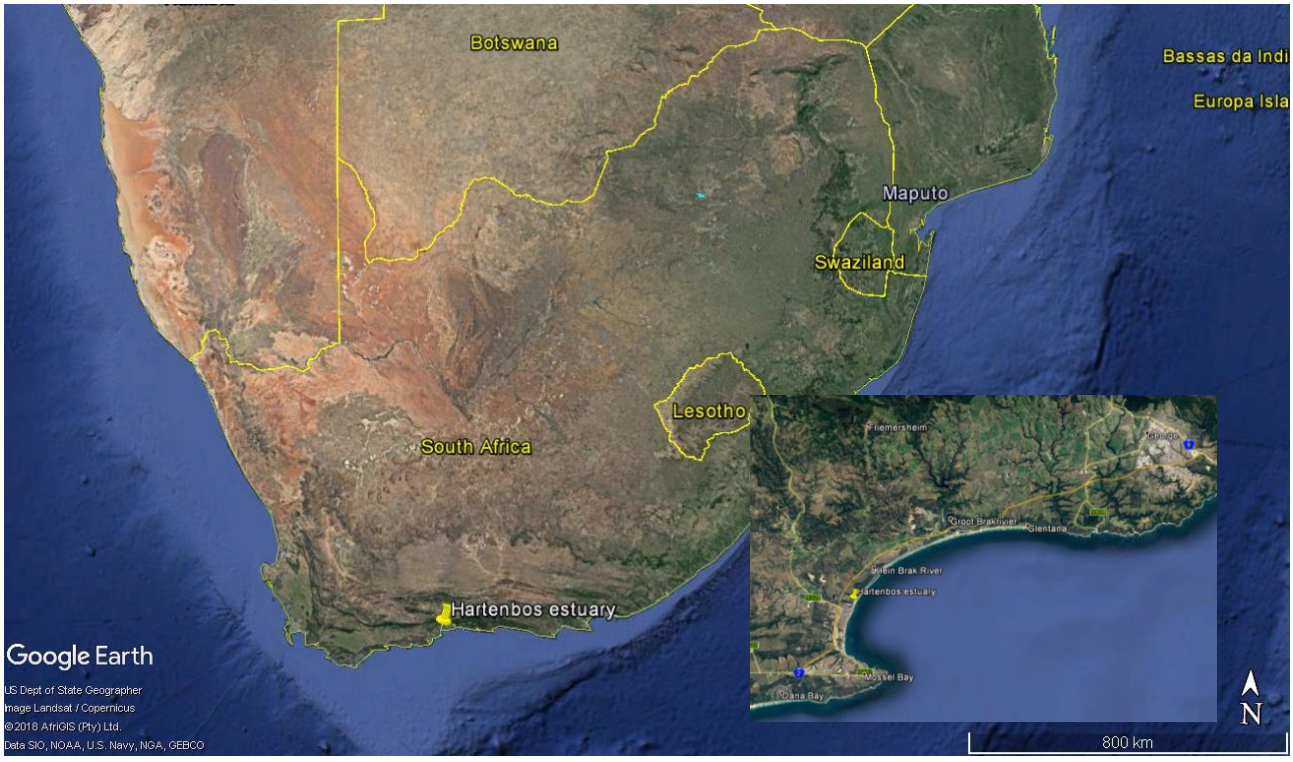


Figure 1.1: Locality of the Hartenbos estuary

The need for Estuary Management Plans (EMPs) in South Africa is addressed in the Integrated Coastal Management Act (Act 24 of 2008; ICMA). Historically, estuaries and the management thereof have not been adequately addressed by marine, freshwater and biodiversity conservation legislation. However, the ICMA recognises the importance of

estuaries and their management and outlines a National Estuarine Management Protocol (NEMP) to support this. The protocol identifies the need and minimum requirements for the development of EMPs, and also delegates responsibility to relevant authorities and agencies in an attempt to help to align and coordinate estuaries management at a local level. The NEMP identifies three phases in the development of an Estuary Management Plan. The phases are:

1. Scoping phase, which includes initial stakeholder engagement and the development of the Situation Assessment report
2. Objectives setting phase where:
    - Vision and objectives for estuary management are identified,
    - Geographical boundaries of the estuary are delineated and graphically represented,
    - Spatial zonation of activities is determined
    - Management objectives and activities are described
    - An integrated monitoring plan is developed, and
    - Institutional capacity and arrangements are discussed.
3. Implementation phase, which is based on:
    - The development of an implementation strategy and project plans,
    - Continuous monitoring and performance evaluation, based on performance indicators, and
    - Review of the EMP every five years

1.2 Purpose of the Second Generation Estuary Management Plan

The Estuarine Management Plan (EMP) was been developed in two phases: 1.) Situation Assessment Phase; and 2.) Estuarine Management Plan and Implementation Plan. The EMP was initially developed through a public consultative process, which included workshops and direct engagement with key stakeholders.

The Situation Assessment report provided the baseline assessment to inform the EMP and aided in the development of the local vision for the Hartenbos Estuary and the identification of management objectives and priorities, and should be read in conjunction with this EMP.

The purpose of the Second Generation EMP is to amend the First Generation EMP with data gathered during the implementation of the EMP in 2016 and 2017 and the information received from the Hartenbos Estuary Advisory Forum. The first generation EMP was compiled in 2016-2017 represented the first year in which the EMP was implemented. The lessons learnt are extremely valuable and is contributes significantly to the review of the first generation EMP.

2 SITUATION ASSESSMENT

This chapter provides an updated Situation Assessment of the Hartenbos estuary that was developed for the First Generation EMP in 2016.

2.1 Introduction

The generally accepted definition of an estuary in South Africa is "a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or when there is little or no fluvial input an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline" (van Niekerk and Turpie, 2012).

Estuaries form a transition zone between river environments and marine environments. They are subject both to marine influences—such as tides, waves, and the influx of saline water—and to riverine influences—such as flows of fresh water and sediment. The inflows of both sea water and fresh water provide high levels of nutrients both in the water column and in sediment, making estuaries among the most productive natural habitats in the world.

Disturbances to an estuary can influence a wide variety of habitats and organisms in the associated freshwater or marine ecosystem. Thus, the interaction between the estuarine systems and users creates a delicate balance, the sustainability of which needs to be maintained by implementing an appropriate management plan

2.2 Catchment Characteristics

2.2.1. Introduction

The Hartenbos River falls within the K10B quaternary catchment of the Breede-Gourtiz Water Management Area WMA 8. The Hartenbos River originates in the foothills of the Outeniqua Mountains and its tributaries drain into a relatively small area of approximately 205 km^2 in south-easterly direction. The Hartenbos River has a total length of approximately 34 km from the source to the mouth and drains into the Indian Ocean 7.5 km east of Mossel Bay.

The Hartebeeskuil Dam is the primary dam along the Hartenbos river. A review of aerial photographs shows that there are up to 8 instream irrigation dams between the north western extent of the estuarine functional zone (EFZ) and the Hartebeeskuil dam. Due to current drought conditions, the water level of the Hartebeeskuil dam is critically low. Figure 2.1 indicates the locality of the dam in relation to the mouth of the Hartenbos estuary.

Figure 2.1: the location if the Hartebeeskuil Dam in relation to the mouth of the Hartenbos estuary

2.2.2. Land use within the catchment

The catchment falls within the Fynbos Biome, but most of the area is transformed and under agriculture (pasture, wheat and vegetables) or forestry. The catchment has also shows high levels of invasive alien vegetation, particularly acacias, including *Acacia cyclops* (rooikrans), especially in the lower reaches of the estuary. Historical aerial photographs suggest that the north western extent of the estuary functional zone has become overgrown with reeds. This is confirmed by the 2016 survey of Alien Invasive Plant species conducted by Credo Environmental.

The geographic trend in economic activity along the catchment is predominately agriculturally based in the middle and upper reaches and tourism related industry near the mouth. One of the larger tourism developments is the Afrikaanse Taal en Kultuur Vereniging (Hartenbos ATKV) Holiday Resort, located at the estuary mouth, which includes permanent holiday cottages, caravan sites and recreational amenities.

Urban areas in the catchment are almost exclusively in the surroundings of the estuary, while the lower reaches of the estuary and remaining catchment are dominated by agricultural land. The average annual growth rate of the MBM population based on the years from 2001-2011 is 2.24% and pressures on the Hartenbos River system and estuary are likely to increase over time

2.2.3. Mean Annual Runoff

The mean annual temperature of the Hartenbos catchment is 17°C and is located within a region of bimodal rainfall, where precipitation peaks in spring and autumn. The average annual rainfall is 446 mm and is contrasted by 1400 mm mean annual evaporation with a mean annual runoff (MAR) for the whole catchment of approximately 5.7 million m^3. The Western Cape is currently in the midst of one of the worst droughts in recorded history. The change in weather patterns observed in the last few years is consistent with the predicted

effects of climate change for the Garden Route District area. Prolonged drier periods will untimely greatly reduce mean average runoff with mean annual evaporation rates increasing.

The first generation EMP suggested that the Hartenbos estuary currently receives some 64% of its natural MAR due to the Hartebeeskuil Dam and water abstractions downstream of the dam. Controlled water release records show that releases from the dam have increased since 1988, peaking in 1998 and 2009. Overall, most water is released for irrigation purposes, followed by downstream river ecology and the lowest allocation is released for the maintenance of ecological functioning of the Hartenbos Estuary.

The release of water from the Hartebeeskuil dam was envisioned to be a mitigation measure in response to the DWS's decision to authorise the discharge of treated effluent into the estuary, which was already prone to eutrophication. Water use for irrigation purposes is seasonal and is most frequently released from the Hartebeeskuil Dam in low flow months at higher average volumes compared to the remainder of the year. Ecological releases are much more constant all year around, but are on average of a much lower volume than releases for irrigation.

Water is seldom released for the estuary, but when releases are made these are usually during the hot summer months, where very large volumes are released in the hope that larger volumes of water will reach the estuary. During November 2016, DWS authorised the release of 150 000 cubic meters of water from the Hartebeeskuil dam, prior to a planned artificial breach to be conducted as per a Section 30A Directive issued by DEA&DP. Water level data from DWS (Figure 2.2) shows that none of this water reached the estuary.

It is therefore important that it is noted in this the second generation EMP, that there may in fact be no natural MAR at all. The cumulative effects of the anthropogenic impacts in the upper catchment and the drought may have led to this.

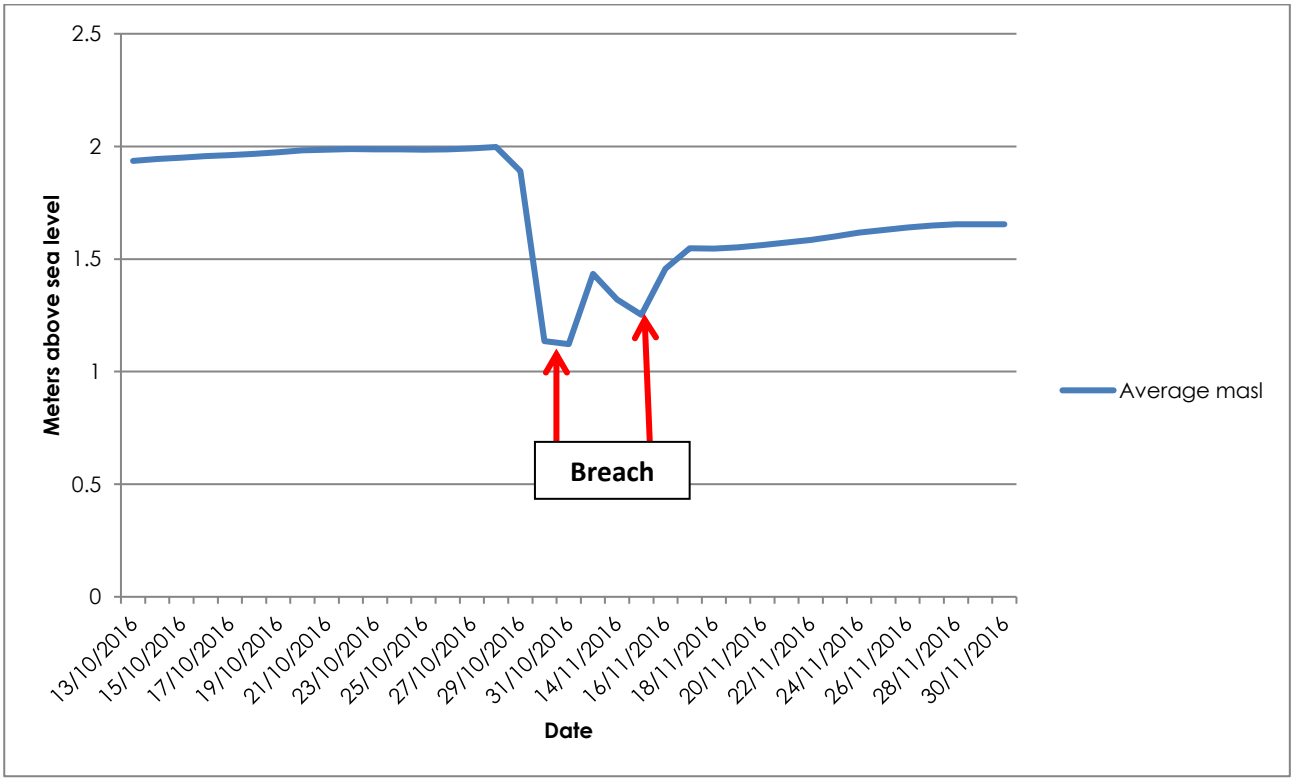


Figure 2.2: Water level data in the Hartenbos estuary before and after the release of 150 000 cubic meters of water from the Hartebeeskuil dam in November

2.2.4. The water quality of the Hartenbos River Catchment

Water quality of the Hartenbos River Catchment is monitored through a number of programmes and implementing agents:

a) The River Eco-Status Monitoring Programme (REMP)

The River Eco-status Monitoring Programme (REMP) evolved from the River Health Programme (RHP). The REMP replaced the RHP in 2016 and is a component of the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP).

The REMP primarily makes use of biological indicators (e.g. fish communities, riparian vegetation, aquatic invertebrate fauna) to assess the condition or health of river systems. The goal of the REMP is to serve as a source of information regarding the ecological state of river ecosystems in South Africa, in order to support the rational management of these natural resources through the following objectives:

- Measure, assess and report on the ecological state of aquatic ecosystems;
- Detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems;
- Identify and report on emerging problems regarding aquatic ecosystems;
- Ensure that all reports provide scientifically and managerially relevant information for national aquatic ecosystem management.

Figure 2.3 below indicates that there are only two RHP sample sites within the K10B catchment. The Rivers Database, the repository for all RHP data, is currently operating with severely reduced functionality. Both sites were sampled in October 2002 and again in October 2012. However, no water quality data was collected at either of the RHP monitoring sites.

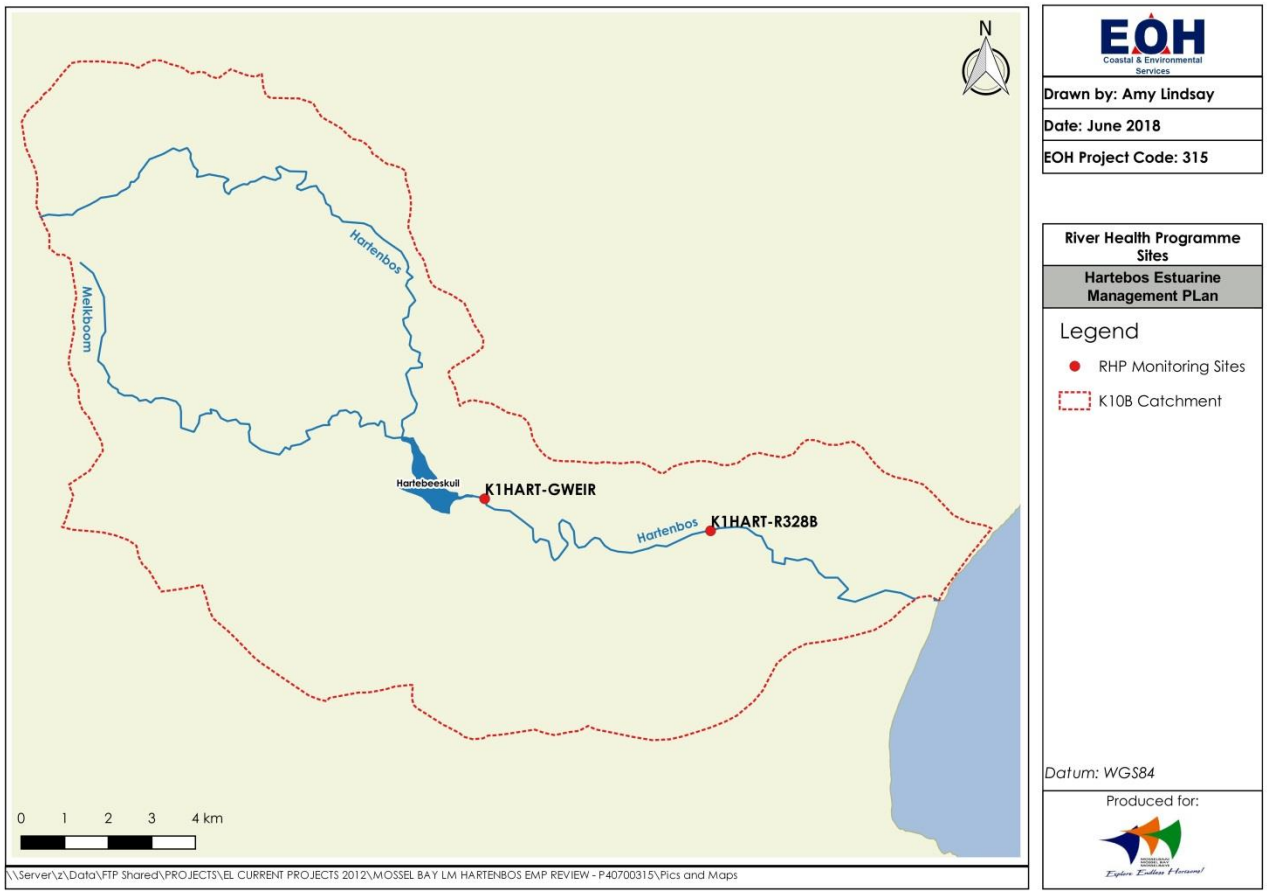


Figure 2.3: River Health Programme Sampling Sites within the R20 catchment.

b) Mossel Bay Local Municipality (MBLM)

The MBLM Technical Services Department monitors the final effluent quality from the wastewater treatment works (WWTW) discharging into the Hartenbos River. Figure 2.4 below indicates the location of the WWTWs in the K10B Catchment. MBLM are responsible for ensuring that the effluent quality is compliant with the water quality requirements specified in the license conditions stipulated by DWS. According the information available through eh DWS Green Drop programme, the level of compliance of the WWTW effluent from April 2017 until May 2018 is indicated below:

MONTH	MONITORING COMPLIANCE (%)	MICROBIOLOGICAL COMPLIANCE (%)	PHYSICAL COMPLIANCE (%)	CHEMICAL COMPLIANCE (%)
April 2017	25%	100%	100%	50%
May 2017	22%	100%	100%	50%
June 2017	22%	100%	100%	25%
July 2017	22%	100%	100%	50%
August 2017	25%	100%	100%	50%
September 2017	25%	100%	100%	50%
October 2017	22%	100%	100%	25%
November 2017	25%	100%	100%	25%
December 2017	25%	100%	100%	50%
January 2018	25%	100%	100%	25%
February 2018	25%	100%	100%	75%
March 2018	25%	100%	100%	25%
April 2017	25%	100%	75%	25%

MONTH	MONITORING COMPLIANCE (%)	MICROBIOLOGICAL COMPLIANCE (%)	PHYSICAL COMPLIANCE (%)	CHEMICAL COMPLIANCE (%)
May 2017	25%	100%	100%	25%

While the above results from the Green Drop programme indicate that the Hartenbos WWTW is 100% compliant in terms of microbial parameters, the data indicated above may be skewed as a result of the poor compliance in terms of monitoring. Actual water quality data has not been supplied by MBLM Technical Services for this EMP.

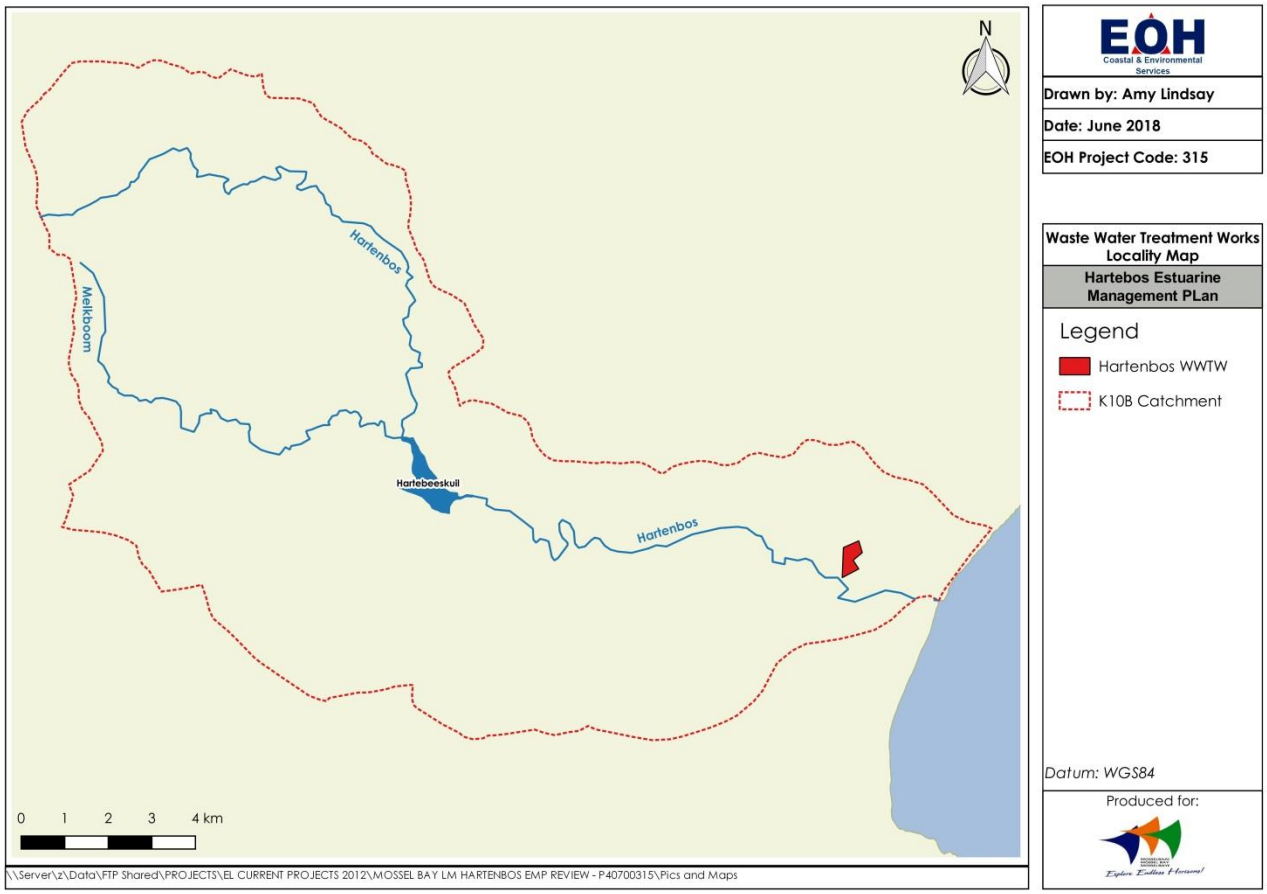


Figure 2.4: The location of the Hartenbos WWTW in the K10B Catchment

c) Department of Water and Sanitation

Resource Quality Information Services (RQS) provides national water resource managers with aquatic resource data, technical information, guidelines and procedures that support the strategic and operational requirements for assessment and protection of water resource quality. The national monitoring programmes mostly monitor "raw" surface water quality in rivers and dams and produce long-term trend reports and visualisations of, for example, chemistry, eutrophication, microbiology and ecosystems. Figure 5 below indicates the RQIS sample sites within the K10B catchment.

The detailed water quality results for each of the monitoring points in Figure 2.5 are provided in Appendix A.

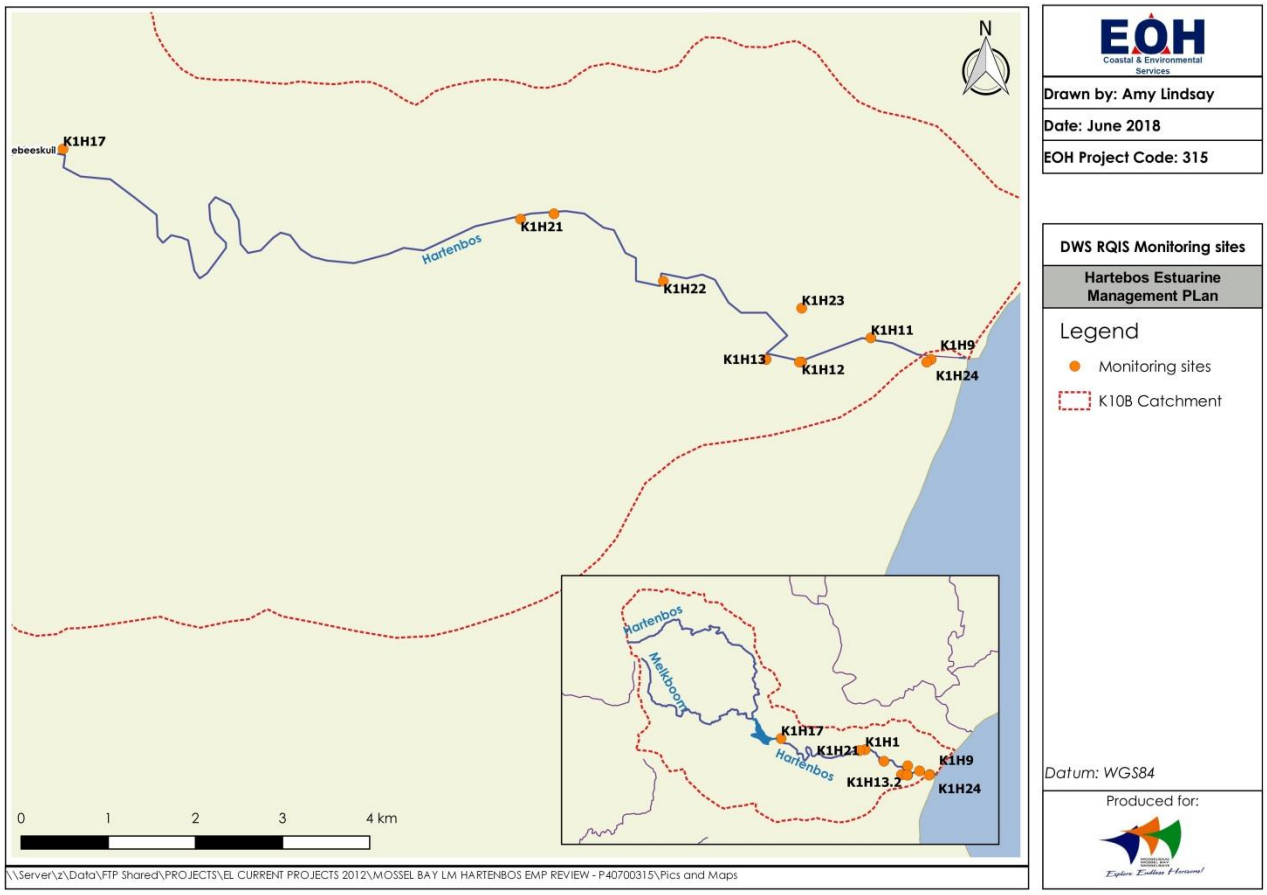


Figure 2.5: RQIS Monitoring points within the K10B catchment

2.2.5. The river health status of the Hartenbos River

The health status of the Hartenbos River has been described by both the National Freshwater Ecosystem Priority Areas (NFEPA) project in 2014 and the desktop Present Ecological State and Ecological Importance and Sensitivity (PESEIS) Assessment in 2014.

According to NFEPA, the Hartenbos river has been classified as a Category C River that has been moderately modified.

According to the PESEIS Assessment, the PES for Hartenbos river in the lower reaches has been classified as E, with a moderate Ecological Importance (EI) and a high Ecological Sensitivity (ES) (Figure 2.6).

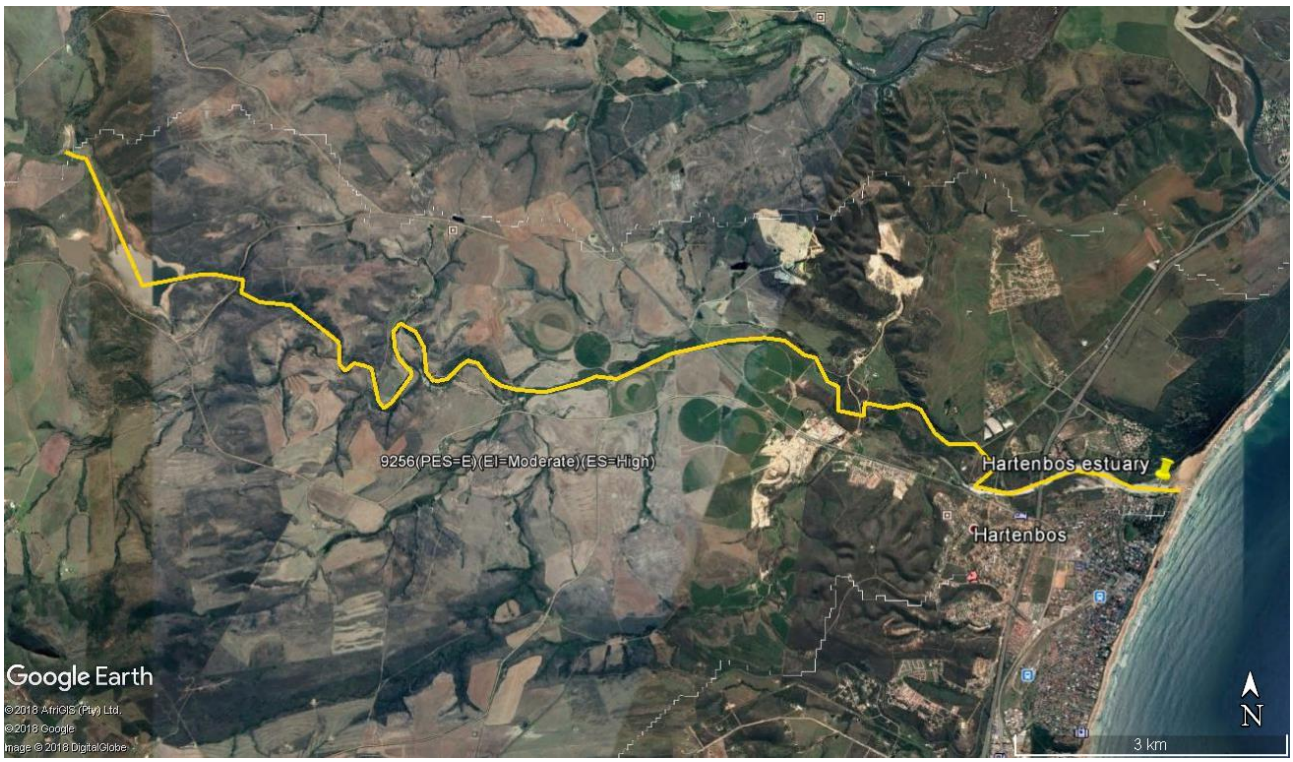


Figure 2.6: Desktop PES, EI and ES for the Hartenbos River.

2.2.6. Infrastructure within the catchment

The upper reaches of the Hartenbos catchment are used mostly for grain and wheat farming, while the lower reaches are used for grazing for cattle, sheep and ostrich farming. Urban development occusr around the Hartenbos estuary. A number of bridges cross over the Hatrenbos River in the catchment and the Hartebeeskuil Dam is the only major impeding structure within the catchment.

2.3 Ecological function and state of the estuary

In this section, the physical description of the Hartenbos River Estuary has been described, which includes the classification of the Hartenbos Estuary, the delineation of the Estuarine Functional Zone (EFZ) and the Estuarine Zone of Influence (EZI).

2.3.1. Estuarine Functional Zone

In defining the "estuarine functional zone" and hence in the preparation of the most recent edition of the "National Estuaries Layer", van Niekerk & Turpie (2012) used the following definition of an estuary:

''…a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or when there is little or no fluvial input an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline".

In each case, the following areas were considered in defining the boundaries of the Hartenbos estuary:

- Estuary mouth was taken as the downstream boundary or, where the mouth was

closed, the middle of the sand berm between the open water and the sea.

- The upstream boundary was determined as the limits of tidal variation or salinity penetration.
- Lateral boundaries of each estuary were defined to include all associated wetlands, intertidal mud and sand flats, beaches and foreshore environments that are affected by riverine or tidal flood events whichever penetrates furthest, and were mostly plotted as the 5 m topographical contour surrounding each estuary.

For the purposes of this management plan, the geographical limits of the Hartenbos Estuary have been defined in accordance with the National Biodiversity Assessment: Estuary Component (van Niekerk & Turpie 2012) and is shown in Figure 2.7. The EFZ correlates with the 5 m topographical contour and includes any open water areas, estuarine habitat (sand and mudflats, rock and plant communities) and floodplain areas.

Figure 2.7: Geographical extent of the estuarine functional zone of the Hartenbos Estuary as defined in the National Biodiversity Assessment: Estuary Component (van Niekerk & Turpie 2012, South African National Biodiversity Institute http://bgis.sanbi.org).

2.3.2. Water quantity and quality

WATER QUANTITY

It is suggested that the natural mean annual runoff (MAR) for the Hartenbos catchment of approximately 5.7 million m3 of the Hartenbos catchment is significantly less than the actual

MAR that the estuary is currently receiving.

The Regional Waste Water Treatment Works (from hereinafter referred to as the Hartenbos WWTW) became operational in 1986 and has been discharging treated effluent into the upper reaches of the estuary. The Bickerton (1981) study advised against the authorisation of the discharge, as the estuary had been so negatively affected by the construction of the Hartebeeskuil dam. Nevertheless the WWTW was approved. The WWTW has since then been upgraded to more than double the original treatment capacity from 7.8 to 18 mega litres per day (Swartz *et al.*, 2000). Full capacity has not been reached to date but approximately 6-10 mega litres of treated effluent is released into the estuary per day. This means that the WWTW is discharging 3.45 Mm^3 of freshwater to the estuary annually.

Consequently, the estuary below the WWTW currently receives approximately 2 Mm^3 of water per year in excess of the MAR that was provided by the flow regime prior to the construction of the Hartebeeskuil Dam. Although the WWTW has more than replaced the MAR impounded by the Hartebeeskuil Dam, the water is of poor quality and has been contributing significantly to the deterioration of estuary health (Lemley *et al*. 2015).

Figure 2.8 provides an indication of the water level in the estuary between 2016 and 2018. The water level data has been obtained from the DWS and the meter is located on the estuary bank of the estuary under the N2 bridge at the following point: Lat:-34.11722222 Long: 22.11638889.

Figure 2.8 shows that the water level in the estuary is breached when it reached approximately 2 meters above sea level (masl). This freshwater input is almost entirely derived from the WWTW. The figure indicate that the water level, once the estuary has been breached, takes approximately 12 weeks to reach the 2 meter level again.

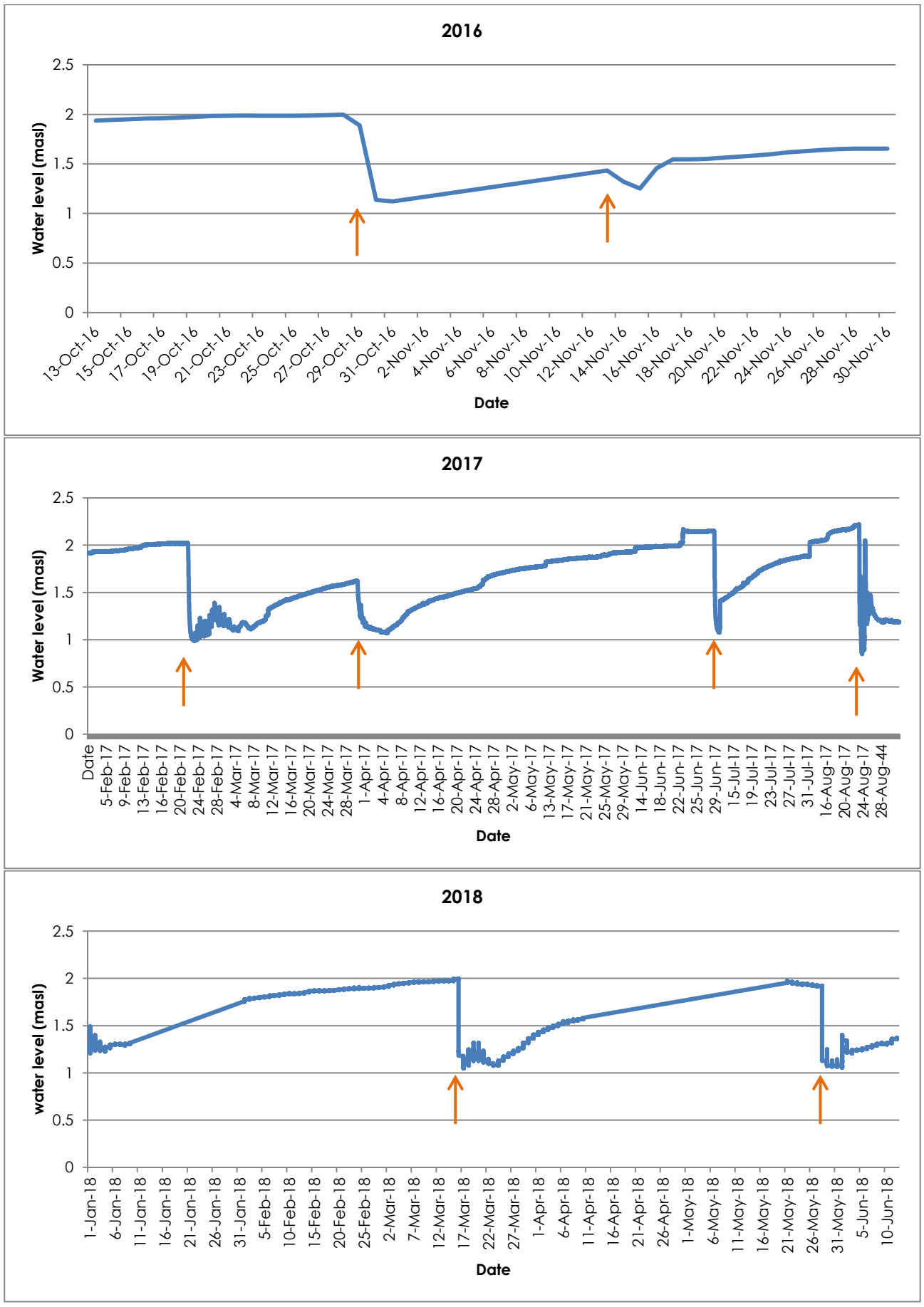


Figure 2.8: Water level data for the Hartenbos estuary from October 2016 until June 2018. The orange arrows indicate when the mouth of the estuary was breached.

WATER QUALITY

The water quality characteristics of the Hartenbos Estuary are influenced by a number of factors, the most important of which are runoff and mouth state. As long as the mouth of the estuary is open or runoff is sufficient to maintain adequate flushing in the system, water quality is generally good and poses no risk to human health or the health of the fauna or flora of the estuary. Following periods of prolonged mouth closure, water quality characteristics can change rapidly and can begin to pose a threat to both human and ecosystem health. For example, prolonged exposure to either very low (hyposaline <5 PSU) or very high (hypersaline, >40 PSU) conditions can cause mass mortality of marine (mostly the former) and estuarine organisms (mostly the latter), while even short term exposure to low levels of dissolved oxygen (< 4 mg/l) can cause mass mortalities of all types of aquatic organisms.

Figure 2.9 below show the dissolved oxygen (DO) levels at two locations within the Hartenbos estuary: the "Oupad Brug" and the estuary mouth. These samples were collected and analysed by Ocean Research, who is affiliated with Rhodes University. The red line in the graphs indicated the 4mg/mL level where mass mortalities of organisms can occur. Breaching events are also indicated on the graphs. The results indicated in the graphs shows that there is some improvement of the DO levels in the estuary after breaching of the mouth occurs.

Large-scale fish kills have become a common phenomenon in estuaries impacted by anthropogenic activities and the Hartenbos Estuary is no exception. The most recent fish kills in the Hartenbos Estuary occurred in January 2015, in March 2016, October 2016 and August 2017. Understanding the causes of fish kills will be fundamental in order to implement preventative measures to reduce their frequency and magnitude in the long-term. The need for a standardised national protocol to deal with such incidences was recognised and a national protocol has been proposed by Grant *et al.* 2014 (Refer to Appendix B).

High nutrient levels (nitrates, ammonia, phosphates) in the estuary can lead to proliferation of macroalgae or blooms of microalgae in the estuary (phytoplankton or benthic microalgae) which are unsightly, can smother natural vegetation (e.g. saltmarsh), clog gills of fish, inhibit feeding by fish and birds, and frequently leads to occurrence of low oxygen events. Bickerton's (1981) study showed that the system was prone to eutrophication prior to the construction of the WWTW and that it was directly related to closed mouth conditions. Under closed mouth conditions Nitrate and Phosphate levels in the estuary were elevated. It follows then that after the construction of the WWTW that

discharges nutrient rich effluent into the estuary, the existing historical trend towards eutrophication under closed mouth conditions would be exacerbated. High levels of indicator bacteria (*E. coli*, faecal coliforms and/or Enterococci) are indicative of the possible presence of pathogens or disease causing organisms in the estuary that can pose a risk to the health of recreational users. Bickerton's (1981) study suggests that closed mouth conditions increase the risk in terms of public safety.

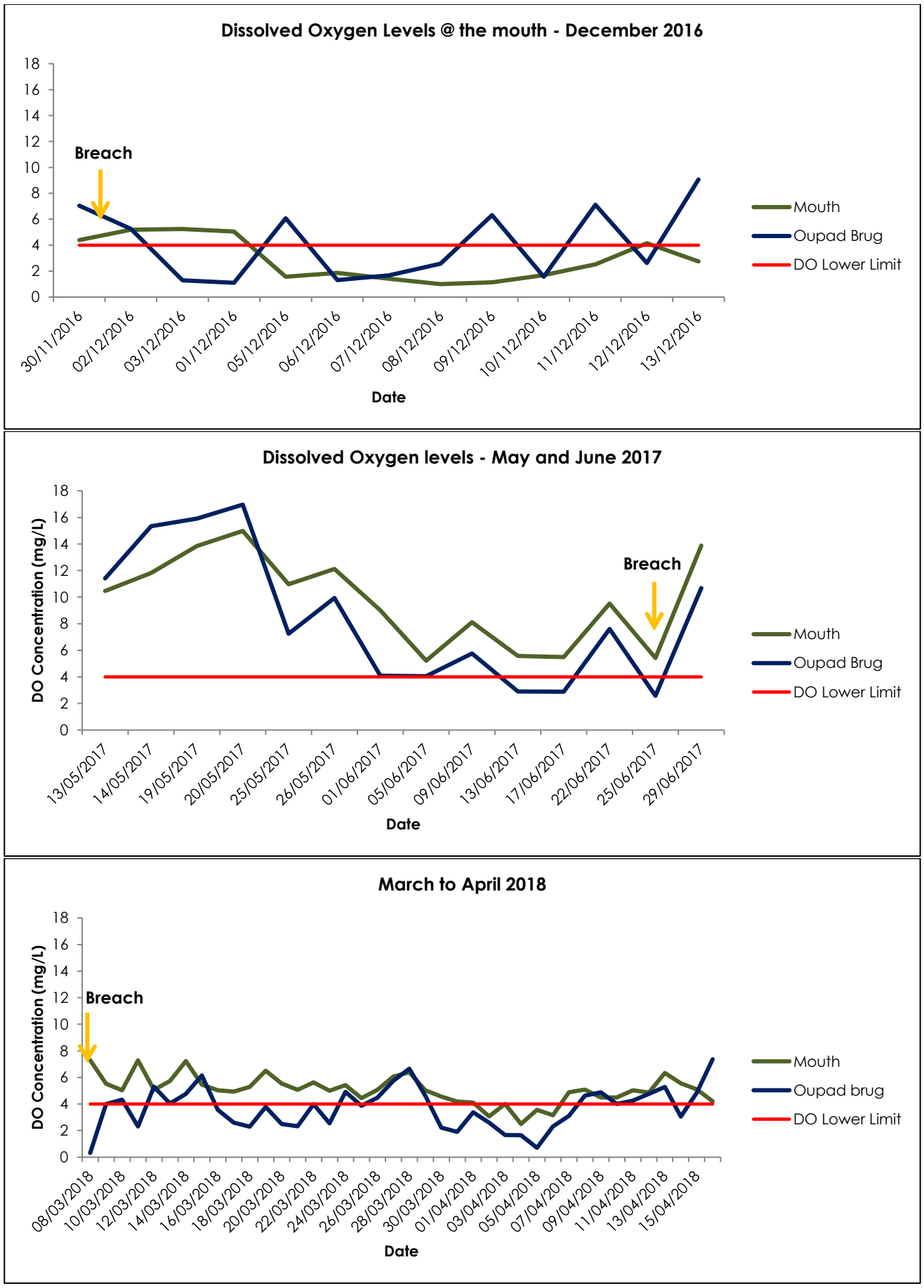


Figure 2.9: The Dissolve Oxygen (DO) concentrations (mg/mL) at two sampling points within the Hartenbos estuary from December 2016 to April 2018.

Macroalgal blooms have been reported in the Hartenbos Estuary during closed mouth conditions and form thick algal mats in the estuary. Bickerton's (1981) study suggests that this began happening after the construction of the Hartebeeskuil dam and that it was occurring prior to the construction of the WWTW. During the night photosynthesis ceases but these algal continue to respire lowering dissolved oxygen concentrations, whilst the decay of these algal mats further reduces available oxygen in the water.

Although the WWTW has more than replaced the MAR impounded by the Hartebeeskuil Dam, the water is of poor quality and has been contributing significantly to the deterioration of estuary health (Lemley *et al*. 2015). This is true in the context that the river as not been actively managed as was required when the Department of Water and Sanitation first authorised the construction of the Hartebeeskuil dam and the WWTW.

Cognisance must be taken that the licence conditions of the WWTW does not require that all nitrates and phosphates be removed. Agricultural return flows containing fertilisers, stormwater outlets, malfunctioning septic tanks, as well as cattle and ostrich farming along

the river banks are other sources of pollutants that influence water quality in the estuary. While the WWTW provides the bulk of nitrogen and phosphate to the estuary, it has been shown that contrary to popular belief, bacterial contamination mostly originates from sources upstream of the WWTW. In addition, the septic tanks on the southern bank of the estuary have always been considered a possible source of bacteriological pollution. Recent investigations have shown that illegal dumping and septic tanks along the northern bank of the estuary may also be a contributing source. A recent storm water monitoring project has also shown that storm water is a potential point source.

It is also important to note that the WWTW will be undergoing significant upgrades during the next few funding cycles. In addition interventions are being implemented to ensure that the discharges from the WWTW are more effectively monitored. Mossel Bay Municipality is also in process of assessing the opportunities for diverting treated effluent away from the estuary. The possibilities in this regard include: treating up to 5 ML of treated effluent to drinking water or process water standards via their Reverse Osmosis Plant, diverting treated effluent for agricultural use and/or for use at composting facilities. These options are currently being explored. If implemented, the discharge of treated effluent to the river will be reduced by up to 50%.

Water quality in the Hartenbos Estuary has been monitored by the MBLM and the DWS at various stations in the Hartenbos Estuary since 1982. Early detection of low oxygen events, eutrophication risks or bacterial contamination and their appropriate management actions (short to long-term interventions) rely on continued monitoring that is aligned with existing water quality sampling locations and methods of the MBLM and the DWS.

2.3.3. Ecological reserve of the estuary

The extent to which an estuary's functioning is catered for is determined by the designated future management "class" (where classes A – F describe state of health), called the Ecological Reserve Category (ERC). In future this will be determined using a recently-developed, holistic classification process. In the interim, however, the amount of freshwater allocated to estuaries is determined through a "Reserve Determination" study.

The preliminary reserve determination process was recently completed for the Hartenbos Estuary (and other systems in the Breede-Gouritz Water Management Area). The estuarine health index score was determined to be 51, giving it a Present Ecological Status (PES) of Category D. The Resource Directed Measures (RDM) study also concluded that the Hartenbos Estuary should be managed as a Recommended Ecological Category (REC) of C (moderately modified) i.e. management should achieve an improvement in ecological status of the estuary. The RDM recommended REC of C suggests that the Hartenbos estuary must be actively managed. It follows then that the main management interventions e.g. mouth management cannot only be re-active. This is a principal that is central to the second generation Hartenbos EMP. The first generation EMP proved an important step in ensuring that its Present Ecological Status does not drop lower than a D. The consensus amongst the Hartenbos EAF is that this has occurred through the efforts during 2017. However, now the emphasis has to be on achieving the Recommended Ecological Category.

2.3.4. Estuarine classification and mouth dynamics

The estuarine classification system of Whitfield (1992) separates estuaries into permanently open estuaries, temporarily open/closed estuaries, estuarine lake systems, estuarine bays and river mouths. The Hartenbos Estuary is classified as a temporarily open/closed estuary.

The channel and mouth dynamics of the Hartenbos Estuary have been strongly influenced by anthropogenic developments in the catchment and have been sporadically managed since the Hartebeeskuil Dam was built. A detailed assessment of the mouth dynamics of the Hartenbos estuary was conducted in 1981(Bickerton, 1981). Figure 2.10 below provides a schematic description of the structure and movement of sand in and around the estuary mouth. The study also showed that the construction of the Hartebeeskuil dam has had a significant effect on the channel and mouth dynamics. Bickerton (1981:31) suggests that:

> *'The primary effect of the Hartebeeskuil Dam on the estuary has been the closure of the mouth for extended periods'*

Bickerton (1981:16) also asserts that:

> *'Since dam construction the estuary has usually been stagnant with high salinities and dense mats of algae, due to eutrophication''*

In the 1970s and 1980s artificial breaching was motivated primarily by the desire of holiday makers to access holiday facilities on the northern bank. Information received from the Hartenbos EAF suggests that the mouth was also frequently artificially breached in response to concerns about water quality and excessive algae growth. In addition artificial breaching of the estuary mouth done by the local authority occurred in response to the risk of flooding. This is confirmed in the Bickerton (1981) study.

Information received from the Hartenbos EAF suggests that the mouth was breached in the past to prevent water level in the estuary rising to levels where it covers storm water outlets. The estuary is also dug open illegally by bait harvesters to reduce water levels and allow easy access to the burrowing sand prawns. While Bickerton's (1981) study confirmed that artificial breaching did occur historically, it also cautioned against ill-timed breaches. Illegal opening of the mouth in January 2015 is thought to have contributed to a large fish kill, as the dramatically reduced water levels resulted in higher water temperatures and decreased dissolved oxygen concentrations. The mouth dynamics are also heavily influenced by coastal processes. Bickerton (1981) provides a detailed description of sediment dynamics as of 1981.

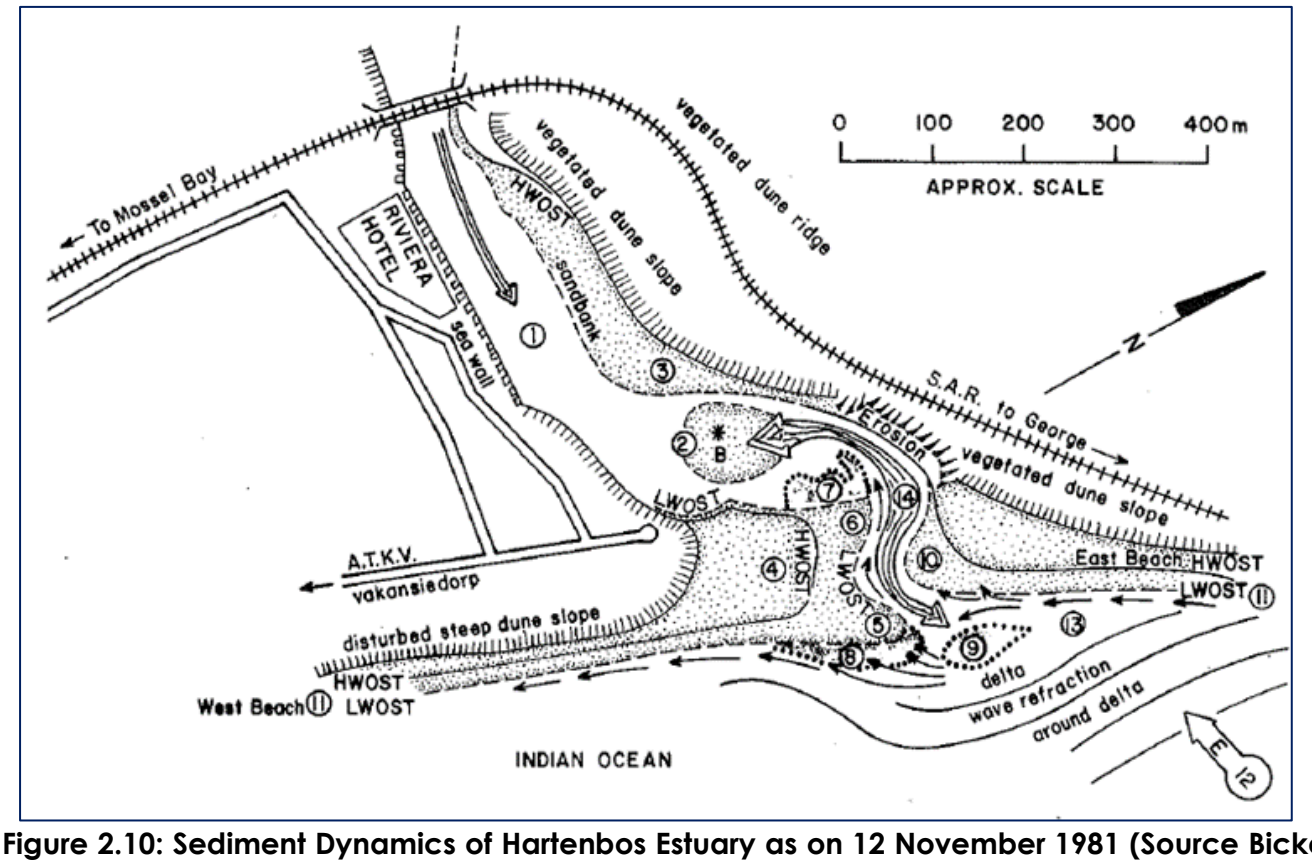


Figure 2.10: Sediment Dynamics of Hartenbos Estuary as on 12 November 1981 (Source Bickerton 1981). Table 2.1 provides the legend to this figure.

Table 2.1: Legend for Figure 2.10.

Number	Description
1	River course.
2	Inner tidal delta, formed by the influx of marine sand during incoming tide.
3	Tidal sandbank in north-eastern bank of estuary.
4	North-easterly sandpit above HWOST.
5	Outer (seaward) tip of south-western sandspit below HWOST.
6	Inner (landwards) tip of south-western sandspit below HWOST.
7	Submerged prograding sandbank at inner tip of south-western sandspit, mainly caused by sand migration along north-easterly face of south-western sandspit, and by wash-over during HW-tides.
8	Submerged prograding sandbank at outer tip of south-western sandspit, receiving material from delta.
9	Delta formation in front of estuary mouth, caused by sand movement in mouth channel during outgoing tide.
10	North-easterly sandspit below HWOST.
11	Beach (between LWOST and backshore).
12	North-easterly swell breaking obliquely against the beach, generating a south-westbound sand movement along the shore.
13	Longshore (littoral) sand transportation moving in a south-westerly direction (under the influence of a north-easterly swell (12)).
14	Deep section of estuary mouth channel, scored by tidal currents, ending seawards at the tidal delta.
LWOST, HWOST	Low and high water ordinary spring tide water edges.
B	Dune bush slumped down from erosion on north-eastern bank and being washed upstream by tidal current.

Recent surveys conducted at the Hartenbos Estuary Mouth suggest that the accretion rate of the sand berm across the mouth is approximately 400 mm per month under closed mouth conditions. The historic breaching described earlier ceased when legislation was introduced which made breaching illegal. It is currently illegal to breach the river mouth without an environmental authorisation or a legally recognised breaching protocol and associated management plan in terms of Government Notice 983 (Activity 19) of the EIA Regulations 2014. Note that since the compilation of the first generation EMP, Mossel Bay Municipality has obtained environmental authorisation (via an MMP agreement) to artificially breach the estuary.

2.3.5. Existing infrastructure located within the EFZ

Freshwater flows reaching the Hartenbos Estuary have been strongly influenced by anthropogenic developments in the catchment, of which the most significant were the construction of the Hartebeeskuil Dam and the Hartenbos Regional Waste Water Treatment Works (WWTW). The Hartebeeskuil Dam was constructed in 1970 and is situated 12 km upstream of the estuary, impounding a large proportion of the MAR from the catchment. Consequently, the estuary currently receives only 64% of its natural MAR and overall variability in the flow regime shows little resemblance to the natural condition, where the frequency and magnitude of floods has decreased significantly. The Bickerton (1981) study makes explicit the effects of the Hartebeeskuil dam. The construction of the dam meant that the system no longer functioned as a natural system. Bickerton (1981) identifies a number of other impoundments or obstructions in his study. As far as is known these have never been properly investigated, although many of the obstructions listed by Bickerton (1981) may have subsequently addressed. Nevertheless Bickerton's (1981) list is included below:

1. Two road causeways which cross the two main causeways of the Hartenbos River approximately 2,5 km upstream of the mouth. The one is a low laying concrete structure.
2. The old national road single span bridge built prior to 1940 which crosses the Hartenbos approximately 2 km upstream of the mouth.
3. The new national road bridge constructed in 1973 which crosses the Hartenbos approximately 1.6 km from the mouth of the estuary.
4. A cause way, which supports the old water pipeline, located approximately 1.2 km from the estuary mouth. Note that this may have since been removed.
5. The railway bridge constructed in 1956 located approximately 800 m from the mouth.

6. The remains of the old railway bridge immediately downstream of the railway bridge. The old bridge was removed in 1950's, but the remains of the pylons were never removed.

Surveys were conducted on selected infrastructure within the EFZ of the estuary. Contour maps for the 7th September 2017 and 8th of September 2017where water level was average of 1.15m and 1.2m respectively.

Figure 2.11 represents a survey conducted inform of the AKTV Hartenbos on the north eastern bank of the estuary. The following important low-lying infrastructure is noted on the map:

- Boat launching ramp between 1.65 meters and 2.15 meters;
- Stormwater outlet at 2.17 meters;
- Retaining wall at 2.5 meters; and
- Public area (Erf 3062) at an average height of 2.20 meters.

Figure 2.12 represents a survey conducted at Villa Riviera on the southern bank of the estuary. The following important low-lying infrastructure is indicated on the map:

- A public walkway along the bank of the estuary with streetlights at an average of 2.6 meters;
- Manhole covers at 2.5 meters;
- Floor level of existing buildings at 2.71 meters; and
- Drainage canal with the outlet at 1.7 meters and one towards the mouth at 2.03 meters.

Other important low-lying infrastructure that has not been indicated on the contour maps is the effluent discharge point and the associated pump station. The effluent discharge point is located approximately 1.9 meters above sea level while the pump station is located approximately 2.4 meters above sea level.

It is important that the water level in the estuary is continuously monitored in order to protect this infrastructure.

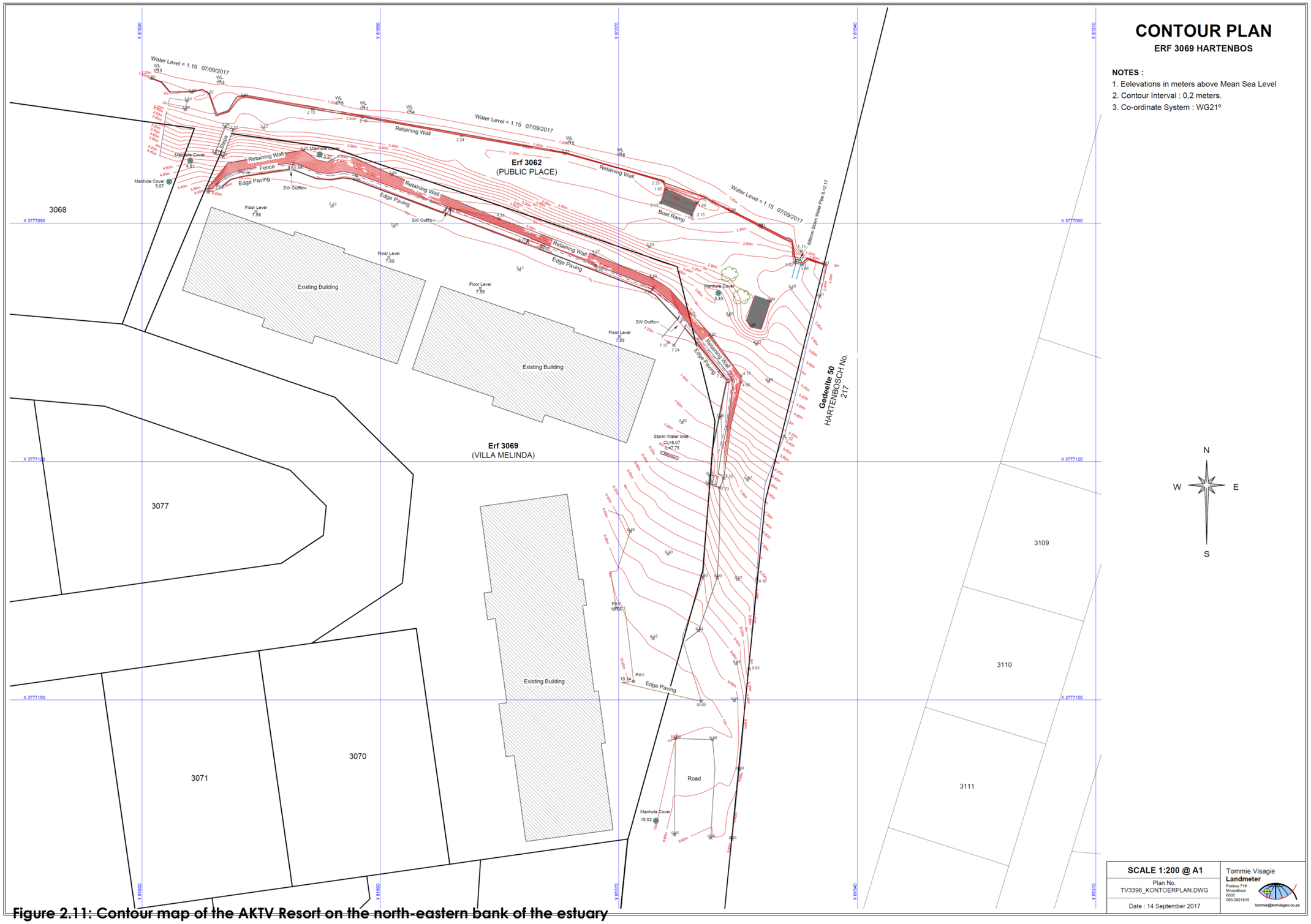


Figure 2.11: Contour map of the AKTV Resort on the north-eastern bank of the estuary

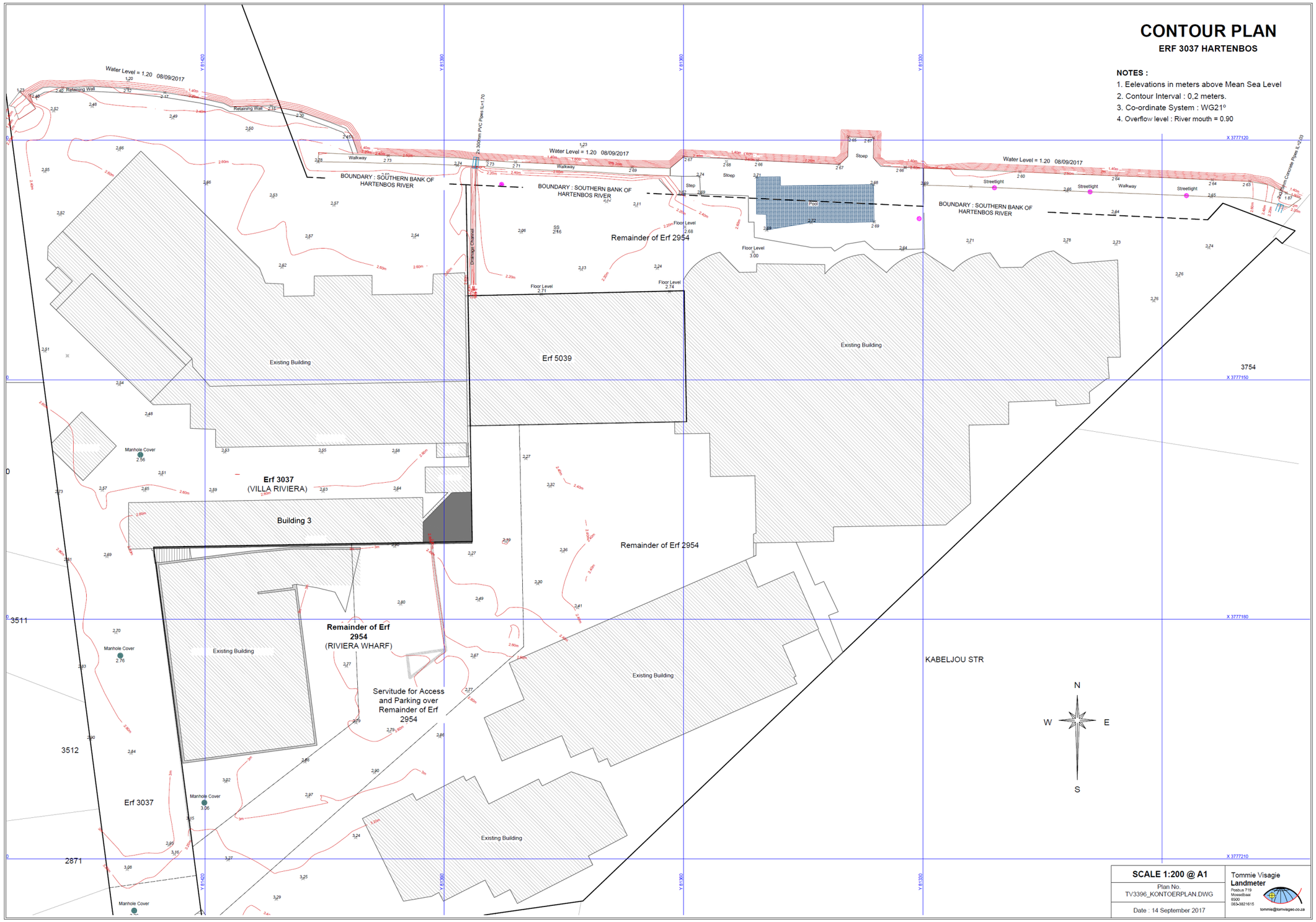


Figure 2.12: Contour map of the southern section of the banks of the Hartenbos estuary where Villa Riviera is located

2.3.6. Climate change

A study was conducted in 2010 by The Umvoto Africa to assess Sea Level Rise and Flood Risk Assessment in the Garden Route District Municipality. The study divided the coastline of Mossel Bay into different coastal management units based on its risk profile. The section of the coast where the Hartenbos estuary drains into the sea is identified as the Hartenbos Coastal management unit which stretches from Bayview to the southern bank of the Klein Brak estuary. In terms of the sea level rise and flood risk assessment done, the Hartenbos Coastal Management Unit has a relatively high risk score. Umvoto Africa (2010c:5) qualifies the findings of the risk assessment by stating the following:

> *The severity of sea level rise induced erosion/inundation and extreme events can be affected by various factors, including mean wave height, the amount of sea level rise, tidal range, geomorphology, coastal slope and rates of accretion/erosion (Thieler and Hammar- Klose, 1999). The mean wave height, rate of sea level rise and tidal range is generally the same along the Garden Route DM coastline, and the rates of accretion/erosion are unknown, therefore geomorphology and coastal slope were the two variables used to assess the severity of both hazards*.

The Provincial MEC, in consultation with the Local Municipalities, is required to define a coastal protection zone of at least 1 km from the coastal and estuarine high tide mark under the Integrated Coastal Management Act (2008 as amended in 2014) for all areas surrounding the Hartenbos Estuary zoned agricultural or undetermined use and that are not part of a lawfully-established township, urban area or other human settlement, and a corresponding zone of 100 m for all other land.

The Integrated Coastal Management Act (2008) also provides for the establishment of a coastal management line, designed to protect the coastal protection zone. Any future development seawards of the coastal management lines is automatically be subject to an assessment and would have to be compatible with the vision and objectives defined within this management plan.

DEA&DP is currently in the process of developing coastal management lines. The final draft coastal management lines have been completed and they have been subjected to a public participation process. The following lines have been determined:

a) An accurate delineation of the high water mark;
b) A line demarcating physical processes or hazards;
c) One or more management lines, or coastal management lines, that can be used to manage development along the coast; and
d) A line demarcating the Coastal Protection Zone (CPZ) as required by ICMA.

DEA&DP must now move towards getting the CML adopted by the Minister. Establishment of coastal management lines around the Hartenbos Estuary will prevent development from encroaching too close to the estuary and hence will ensure an adequate buffer for the estuary. It is recommended that as a starting point for the coastal management line for the Hartenbos Estuary corresponds with the estuarine functional zone for this estuary as defined in the National Biodiversity Assessment: Estuary Component (van Niekerk & Turpie 2012). The Hartenbos Estuary Advisory forum should be involved in determining the final coastal management line position (e.g. exclusion of already developed areas within the 5m contour). The coastal management line will serve to protect ecological functioning and integrity of the estuary, limit disturbance to estuarine flora and fauna, and will assist in successful rehabilitation of disturbed areas in the estuary and enhance its ecotourism

appeal.

In addition to these provisions, the NEMA EIA regulations also list a number of activities which, if undertaken within the estuarine precinct, require an EIA. The National Water Act (1998) also places some restrictions on development adjacent to water courses, which includes estuaries. This Act requires that authorisation (a water use licence) be obtained for any alterations to the bed, banks, course or characteristics of a water course (which includes changes in land use, vegetation cover, topography, soil, etc.) or the adjacent riparian habitat (defined as any flooded area adjacent to the river channel) from the Department of Water and Sanitation (DWS). The riparian habitat is considered to include everything within the 1:100 year flood line of a water course. The 1:50 and 1:100 year flood lines have been delineated for the Hartenbos Estuary.

2.3.7. Sediment quality and processes

Mossel Bay Municipality together with DEA&DP commissioned RHDHV to conduct a Sediment Supply Study. The purpose of this study was to provide information on accretion and erosion rates so that a more accurate risk assessment of Coastal Management Units could be conducted. The sediment supply study indicated that the sand berm forming across the Hartenbos river mouth was inhibiting tidal exchange. Tidal exchange is amongst the criteria used to assess risk. Citing Bicketon (1982 in Umvoto Africa 2010) the afore-mentioned study suggests that the tidal range of the Hartenbos Estuary is approximately 2, 5 km.

The study suggested that accretion is occurring at river mouths along the coast of Mossel Bay, and is occurring despite the fact that the beaches adjacent to them are eroding. This may be related to the fact that the MAR of rivers have been negatively affected by compoundments and extraction taking place within the catchment.

The sedimentation study shows that accretion is the net process at the Hartenbos estuary mouth. In addition there is no indication that this will change particularly as the removal of the Hartebeeskuil dam is not feasible. Surveys conducted indicate that the berm height raises 400 mm per month under closed mouth conditions. This may present an opportunity to manage the risk associated with any efforts to manage berm heights.

2.3.8. Vegetation

There are three main types of vegetation associated with the Hartenbos Estuary: terrestrial vegetation including invasive plants that have encroached into the riparian zone, intertidal and supratidal salt marsh, and macroalgae. The distribution and extent of these vegetation types is determined by water levels in the system and salinity.

2.3.9. Bethic invertebrates

Benthic invertebrates of the Hartenbos Estuary are dominated by the sandprawn *Callichirus kraussi* and the bivalve *Loripes clausus*. Diversity and abundance is considered to be low relative to other temporarily open/closed estuaries in the region. The invasive tube worm *Ficopomatus enigmatica* has also been reported in the estuary in the 1980s, however, the present day extent and abundance of this aggressive species is unknown.

2.3.10. Fish

A total of 17 fish species have been recorded from the Hartenbos Estuary to date, which is considered to be low compared to other temporarily open/closed estuaries in the region.

During a survey conducted in October/November 1997 a total of nine species were recorded of which three taxa were estuarine resident species (Category Ia) and six species were Euryhaline marine species that breed at sea, with juveniles showing varying degrees of dependence on estuaries. The presence of both estuarine-resident and estuarine-dependent species in the Hartenbos Estuary indicate that fishes typical of estuarine habitats are supported by this system. The absence of any more recent data on both fish and benthic invertebrates is unfortunate. This data would greatly assist management efforts.

Fish kills in the Hartenbos estuary were reported in October 2016 and August 2017. The 2016 fish kill was reported to MBLM on the 29th of October were it was described that a number of juvenile had been found dead and that adult fish were seen in a distressed state. Water samples at the mouth and 2km upstream of the mouth and fish samples were collected and analysed. The results of the water quality analysis indicated the following:

- Dissolved oxygen levels were 1.73 mg/L at the mouth and 0.51 mg/L 2km upstream of the mouth.
- Ammonia levels were 2.7mg/L at the mouth and 2.7mg/L 2km upstream of the mouth;
- Nitrate levels were 0.31mg/L at the mouth and 0.29mg/L 2km upstream of the mouth; and
- Phosphate levels were 5.29mg/L at the mouth and 6.52mg/L 2km upstream of the mouth.

The results of the fish necropsy indicated that protozoan organisms were present in the gills of fish and are often seen in fish that are stressed. It was suggested that these protozoan infections could be the cause of death in cases where fish are stressed due to high ammonia levels or changes in salinity levels of water. However, the water quality results do not indicate that the ammonia levels were critically high. It is probable that the cause of the fish kills was related to the critically low DO levels recorded in the estuary.

The 2017 fish kill involved the report of carp and catfish being found dead in tributaries leading into the Hartenbos estuary. These specimens were sent for examination. The results of the necropsy indicated that all the specimens showed the same pathology with the internal organs showing signs of dehydration and severe inflammation. Both species are exclusively fresh water fish and would not survive for long periods in water with a high salinity as it seemed to be the case on that branch of the river were they were found that day. Unfortunately the water quality results from the day and location from which the samples were collected were not available.

2.3.11. Birds

A total of 59 water-associated bird species of nine taxonomic orders, excluding rare vagrant species, have been recorded at the Hartenbos Estuary to date. The most species-rich taxonomic group is the Charadriiformes, which include the waders, gulls and terns. The relative contribution of taxa to the bird numbers on the estuary differs moderately in summer and winter, due to the presence of migratory birds in summer. There are no important populations of red data species on the estuary, although wader numbers, especially resident wader numbers have slowly but steadily increased since 2005. Birds of prey and kingfishers have decreased in abundance, while waterfowl abundance has increased over time.

2.4 Ecosystem Goods, Services and Threats to Ecological Functioning

2.4.1. Estuarine ecosystem goods and services

Estuarine ecosystem goods and services are defined as the benefits that result from the ecological functioning of a healthy estuarine ecosystem. The ecosystem services that are provided are directly linked to the ecosystem goods.

Table 2.2 below identifies the ecosystem goods and services that are provided by the Hartenbos estuary.

Table 2.2: The ecosystem goods and services provided by the Buffalo River estuary.

Ecosystem goods	Ecosystem services
Clean air	Air quality is improved and greenhouse gas emissions are reduced through the photosynthetic processes associated with the vegetation that is found along the banks of the Hartenbos estuary.
Natural resources	Bait collection is practiced in the Hartenbos estuary. Bait collection (prawn pumping) occurs regularly on the northern and southern banks of the estuary mouth. However, the estuary does not support large scale or commercial fishing.
Habitat	The Hartenbos estuary may potentially provide a nursery for fish and invertebrate species that require estuaries as a part of their life cycle. The banks of the estuary provide a habitat for numerous bird species. Those that have been recorded include, but are not limited to, African fish eagle (*Haliaeetus vocifer*), goliath heron (*Ardea goliath*), numerous kingfisher species, sand piper species, turn species and seagull species.
Access to the coastal zone	The Hartenobs estuary provides public access to the coastal zone with a formalised parking area.
Recreation	The Hartenbos EAF asserts that water-contact recreational activities were common in the past and included canoeing or pedal boating, while motorised boat use is minimal. The Hartenbos estuary, particularly the mouth area, was always extensively used for bathing as it provided a safe swimming environment for kids. Hoever, doe to the water quality concerns in the estuary, these recreational activities have become less common. Dog walking is a common activity near the mouth. This information is corroborated by observations during the 2016 and 2017 peak holiday period.
Tourism	Hartenbos area has been a popular holiday and retirement destination for decades. The estuary forms part of the beginning of the Garden Route and is also in close proximity to towns such as George and Mossel Bay, and within easy reach of Cape Town and Port Elizabeth. Peak visitor seasons coincide with the school holiday periods.

Ecosystem goods	Ecosystem services
Research opportunities	Increasing use by visitors, surrounding development, changes in freshwater supply from the catchment, climate and sea-level change could also impact on the health and ecological functioning of the estuary, as well as its value at different spatial scales. These factors all provide potential research opportunities. Examples of these research opportunities include those looking at water quality, estuarine and marine ecology, ichthyology, microbiology, climate change, urban development, invasive species, etc.
Aesthetic/ Scenic value	The Hartenbos estuary mouth is surrounded by beautiful beaches and fynbos-type vegetation that is typical of this section of South Africa's coastline.

Both direct and indirect users rely on the resources provided by the Hartenbos estuary. Direct users utilise resources provided by the Hartenbos estuary for financial or recreational purposes and directly benefit from the utilisation of the resources provided by the estuary.

Examples of direct users associated with the Hartenbos estuary include:

- Nursery areas for fish
- Members of the public utilising natural resources for both subsistence and recreational purposes –
    - Subsistence and recreational fishermen
    - Bait collectors
    - Hotels, bed and breakfasts and other places of accommodation located along the banks of the estuary.

Indirect users are defined as users that indirectly rely on resources the Hartenbos estuary provide. Examples of ways in which the Hartenbos estuary is indirectly utilised include the following:

- Tourism
- Waste disposal/water purification
- Stormwater runoff
    - Domestic
- Tributaries

2.4.2. Threats to ecological functioning

The Hartenbos Estuary is a highly disturbed system, which has been manipulated for at least four decades. The system is currently managed in a state which is quite different from its natural condition, as has been necessitated by the low-lying developments around the estuary. There are a number of factors that threaten the future health of the system and hence its biodiversity and capacity to deliver ecosystem services. The main threats to the system or areas of potential conflict are as follows:

1. **Water quantity and quality**

    a. Reduction in freshwater inflows due to water storage in the catchment (Hartebeeskuil Dam and other instream dams) and insufficient controlled releases to maintain the flood regime of the system;

b. Increased and continuous input of treated freshwater from the WWTW into the upper reaches of the estuary;
c. Nutrient enrichment resulting from effluent discharges by the WWTW;
d. Loss of important habitat area such as salt marsh through eutrophication and stagnation;
e. Reduced tidal exchange which means that there is not the regular change in water level and salinity required to ensure a healthy estuarine functional zone.

2. Land-use and associated disturbance

a. potential for increased residential/resort development around the estuary leading to change in sense of place and existence value, increased human disturbance of biota, and damage or loss of estuarine habitat. Mossel Bay Municipality is currently in the process of compiling a Hartenbos Precinct Plan. This plan will limit land uses within the estuary functional zone and catchment to those which will not negatively impact on the environment.
b. Bail collecting activities that occur along the mud banks in the estuary negatively impact the structural integrity of the banks as well as places pressure on the survival of biota living within the sand banks.

3. Ineffective management of estuary mouth

a. Prolonged closed mouth conditions, particularly during the peak fish recruitment periods, negatively affect the health of the system. The good health of the Hartenbos Estuary is directly related to prolonged periods of either tidal exchange or open mouth conditions.

3 LOCAL VISION AND OBJECTIVES

3.1 Vision

The vision for the Hartenbos estuary should be a reflection of the desired state of the estuary and should provide the starting point for the identification of management objectives for the estuary. The vision for the Hartenbos estuary has been developed through stakeholder input and their expectations for the overall outcome of the effective management of the EAF. From the stakeholder input, the following vision for the Hartenbos estuary has been proposed:

Vision Statement

"The Hartenbos Estuary is a highly disturbed system and must be managed as such. Well managed breaching of the estuary must form an essential component of the management of this highly disturbed estuary. In a system where the flow regime is dominated by a discharge from a WWTW, regular breaching is essential. It facilitates tidal exchange and promotes good water quality that supports a healthy and functioning ecosystem. This contributes towards economic growth and facilitates improved recreational use for the benefit of present and future generations."

3.2 Objectives

In order to achieve the vision for the Hartenbos River Estuary, the following objectives have been identified that describe specific outcomes that aim to achieve the vision:

1. **Improve estuary health**

Use of freshwater resources and land in the Hartenbos River catchment must be effectively managed so as to improve the quality and quantity of freshwater reaching the estuary. Water quality within the estuary must also be managed by restoring MAR and tidal exchange, reducing discharges from WWTW and reducing pollution.

2. **Maximise economic benefits**

Increasing the recreational value of the estuary will directly benefit local and regional economic growth. The estuary must also be managed to maximize the value of ecosystem goods and services delivered in the long term, ensuring an equitable balance among local, regional and national benefits.

3. **Restore aesthetic value**

The aesthetic value of the estuary needs to be restored through improving water quality and quantity in the system. This will reduce water stagnation, excessive algae proliferation as well as odours associated with biological decay. Furthermore, removal of alien vegetation and rehabilitation of degraded riparian areas will play an important role in enhancing the aesthetic value of the estuary.

4. **Increase awareness**

Residents and visitors need to be made aware of the importance and economic value of the estuary, be knowledgeable regarding regulations applicable to the system, and understand the rationale for management measures and interventions.

5. **Harmonious and effective governance**

Institutional roles and responsibilities pertaining to the management of the estuary must be clearly defined, and coordination between responsible institutions improved and maintained.

4 MANAGEMENT OBJECTIVES AND ASSOCIATED ACTIVITIES

The management objectives for the Hartenbos estuary have been developed from the issues identified in the Situation Assessment as well as from the local vision and objectives for the estuary. Eight management objectives have been identified and include:

1. Improve estuary health
2. Improve water quality
3. Effective mouth management
4. Improve recreational value
5. Improve aesthetic value
6. Increase awareness and appreciation of the Hartenbos Estuary
7. Research and monitoring
8. Harmonious and effective governance

The management objectives have been assigned strategies to achieve the management objective and has proposed activities within each strategy and where applicable, a description of the ecological impact or socio-economic consequence, the responsible implementing agent, a cost estimate as well as the expected duration in which the action should be implemented have been provided.

Management Objective 1: Improve estuary health

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
DWS/BGCMA to conduct a water audit of the Hartenbos catchment to establish the location and number of, and volumes abstracted by – water use license holders illegal water abstractions	Loss of freshwater inflow into the Hartenbos estuary.	DWS, BGCMA,
DWS/BGCMA to ensure compliance with water use licenses	Potential impacts on water quality and quantity due to unmonitored discharges and abstraction activities.	DWS, BGCMA
Negotiate highest environmental release volume for the estuary with DWS/BGCMA. The largest proportion of the allocation should be released from 1 December – 31 February.	Sufficient freshwater inflow into the Hartenbos estuary.	EMF, DWS, BGCMA, MBLM
Develop operating rules for the Hartebeeskuil Dam in accordance with the allocated environmental release volume.	Sufficient freshwater inflow into the Hartenbos estuary.	EMF, DWS, BGCMA, MBLM
Assess extent of alien invasive species in the EFZ.	Loss of indigenous vegetation and freshwater availability	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Prioritise areas for the clearing of alien invasive plants in the EFZ.	Loss of indigenous vegetation and freshwater availability	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI
Obtain funds to clear alien invasive plants in the EFZ	Loss of indigenous vegetation and freshwater availability	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI
Clearance of alien invasive vegetation from the Hartenbos EFZ and catchment.	Loss of indigenous vegetation and freshwater availability	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI
Implement second generation EMP and Mouth Management Plan	Improved functioning and health of the Hartenbos estuary	MBLM
Erect signs at public access points highlighting the impact of bait collecting in the estuary and discouraging bait collection practices, particularly after the estuary mouth has been breached and the mud banks have become exposed.	Excessive bait collection alters the sediment and banks of the estuary.	MBLM, EAF

Management Objective 2: Improve water quality

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Conduct a water audit to identify unlicensed discharges and establish the location and number of water use license holders and the amount of effluent that is discharged in the Hartenbos Catchment (as a minimum below the Hartebeeskuil Dam)	Reduced freshwater flow and quality into the Hartenbos estuary	EMF, DWS, BGCMA
WWTW to improve effluent quality in terms of inorganic nutrient concentrations • Thoroughly investigate the possibility of installing floating wetlands or conventional wetlands Investigate how contingency plans for the malfunctioning of the WWTW can be updated to reduce the risk of poorly or	Improved water quality in the estuary	EMF, DWS, BGCMA

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
untreated sewage entering the Hartenbos Estuary		
Lobby farmers to reduce application of inorganic fertilizer and to reduce runoff from livestock holding areas in the Hartenbos catchment	Improved water quality in the estuary	EMF, DWS, BGCMA, MBLM
Ensure that malfunctioning conservancy tanks are replaced/upgraded	Improved water quality in the estuary	EMF, DWS, BGCMA, MBLM
Improved treatment and diversion of waste water outside of the Hartenbos catchment	Improved water quality in the estuary	EMF, DWS, BGCMA, MBLM
Improved compliance by water users regarding discharge limits (volume and pollutants) contained in water use licenses.	Improved water quality in the estuary	EMF, DWS, BGCMA, MBM

Management Objective 3: Effective mouth management

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Submit the Emergency Mouth Management Protocol for the Hartenbos Estuary for stakeholder review and sign-off	Inappropriate breaching activities could significantly negatively affect the functioning of the estuary	EMF, MBM, EDM
Conduct Emergency breaches responsibly and transparently in accordance with the Emergency Mouth Management Protocol	Inappropriate breaching activities could significantly negatively affect the functioning of the estuary	EAF, MBM, GRDM, DWS, DEADP, CapeNature, DEA
Regular review of the Emergency Mouth Management Protocol by specialists	Inappropriate breaching activities could significantly negatively affect the functioning of the estuary	EAF, RMA, MBM, GRDM, DWS CapeNature, DFFE: OCEANS & COASTS, DEADP, consulting specialists

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Develop a law enforcement strategy to prevent illegal breaching	Inappropriate breaching activities could significantly negatively affect the functioning of the estuary	EMF, MBM, GRDM, DEADP, CapeNature
Create public awareness about the ecological consequences of illegally breaching an estuary	Inappropriate breaching activities could significantly negatively affect the functioning of the estuary	EMF, MBM

Management Objective 4: Improve recreational value

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Erect informative and educational signage at key access points that highlights the ecological importance and value of the Hartenbos Estuary.	Creating of a sense of custodianship of the estuary and the will to protect it.	MBLM, EAF
Develop appropriate nature friendly infrastructure for visitors to the estuary (ablutions, parking, bird hides, walking paths, nature trails, mountain bike trails) in collaboration with local communities and independent contractors that does not detract from sense of place of the area or impact on the environment.	Increased number of visitors resulting in increased revenue for local businesses.	MBLM, EAF
Ensure that visitor facilities are maintained in good condition at all times to maximise visitor experiences.	Increased number of visitors resulting in increased revenue for local businesses.	MBLM, EAF

Management Objective 5: Improve aesthetic value.

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Finalise and adopt the zonation plan for the Hartenbos Estuary including the position of the coastal protection zone and coastal management line and overlay zones.	Protection of resources and infrastructure in the EFZ.	EAF, DFFE: OCEANS & COASTSDEA, MBM, GRDM

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Incorporate coastal management lines into the IDP and SDF documents published by the Garden Route District and Mossel Bay Municipalities and the Garden Route District Coastal Management Programme	Protection of resources and infrastructure in the EFZ.	EAF, DFFE: OCEANS & COASTS: O&C, MBM, GRDM
Erect 'Do not litter' signs in popular recreational spots.	Decrease of solid waste impacting on the aesthetics of the estuary	EAF, MBLM
Ensure that enough rubbish bins are available in popular recreational spots.	Decrease of solid waste impacting on the aesthetics of the estuary	EAF, MBLM
Conduct strategic and regular collection of rubbish in key areas within estuarine functional zone.	Decrease of solid waste impacting on the aesthetics of the estuary	EAF, MBLM

Management Objective 6: Increase awareness and appreciation for the Hartenbos Estuary.

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Develop an effective communication strategy.	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM, GRDM
Maintain stakeholder database.	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM, GRDM
Explore alternative communications mechanisms (workshops, signage, radio etc.).	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM, GRDM
Establish a visitor centre at the estuary which will act as a focal point where visitors can go to learn more about the estuary, the ecology of the system, and the need for rationale behind existing management interventions.	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM
Source and/ or commission educational and informative material including signage, posters, pamphlets, and relevant literature that will be housed in appropriate localities that will enhance visitor experiences.	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Encourage field excursions to the estuary by local schools, community groups, and other stakeholder groupings.	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM

Management Objective 7: Research and monitoring.

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Identify information gaps and develop research programme(s) aimed at gathering/ consolidating ecological data.	Improve understanding of the ecological functioning of the estuary to enhance effective management of resources	EAF, RMA, DWS, GRDM, DFFE: OCEANS & COASTS
Engage local research institutes and universities to collaborate on priority research projects.	Improve understanding of the ecological functioning of the estuary to enhance effective management of resources	EAF, RMA, DWS, GRDM, DFFE: OCEANS & COASTS: O+C
Obtain research funding support.	Improve understanding of the ecological functioning of the estuary to enhance effective management of resources	EAF, RMA, DWS, GRDM, DFFE: OCEANS & COASTS
Implement a monitoring programme in as outlined in Chapter 7. a. Clearly define responsible agencies for each monitoring component (i.e. municipality, conservancies, service providers, CapeNature etc). b. Ensure that each monitoring component has a clearly defined methodology.	Monitor the effectiveness of the implementation off the EMP and MMP	EAF, RMA, DWS, BGCMA, GRDM, DFFE: OCEANS & COASTS
Assess results in terms of thresholds of potential concern (Appendix 3).	Monitor the effectiveness of the implementation off the EMP and MMP	EAF, RMA, BGCMA, DWS, GRDM, DFFE: OCEANS & COASTS
Implement monitoring programme as outlined in Chapter 7.	Monitor the effectiveness of the implementation of the EMP and MMP	EAF, RMA, DWS, GRDM, DFFE: OCEANS & COASTS

Management Objective 8: Harmonious and effective governance.

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
Invite representative members of stakeholders and government to be members of the Hartenbos Estuary Advisory Forum (EAF)	Lack of coordinated management and monitoring of the health of the Hartenbos estuary and compromise the ecological functioning of the estuary.	EAF, RMA, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM
Estuary Advisory Forum to obtain agreement from participating agencies in respect of their roles and responsibilities	Lack of coordinated management and monitoring of the health of the Hartenbos estuary and compromise the ecological functioning of the estuary.	EAF, RMA, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM
Individual government agencies to make provision for the necessary resources in the short, medium and long-term expenditure frameworks to create and fill posts, and acquire necessary infrastructure and resources for effective management of the Hartenbos Estuary	Lack of coordinated management and monitoring of the health of the Hartenbos estuary and compromise the ecological functioning of the estuary.	EAF, DFFE: OCEANS & COASTS, DWS, BGCMA, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM
Develop a long-term financing plan	Lack of coordinated management and monitoring of the health of the Hartenbos estuary and compromise the ecological functioning of the estuary.	EAF, RMA, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM
Individual agencies to acquire access to necessary equipment (office equipment, water quality meter, boat, vehicle) for effective	Lack of adequate resources inhibits the effective management of the estuary.	EAF, RMA, DFFE: OCEANS & COASTS, DWS, BGCMA, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM

PROPOSED ACTIVITY	ECOLOGICAL IMPACTS/SOCIO-ECONOMIC CONSEQUENCES	PROPOSED IMPLEMENTING AGENTS
management of the Hartenbos Estuary		
Individual agencies to identify and address training needs among staff involved in estuary management	Lack of adequate resources inhibits the effective management of the estuary.	EAF, RMA, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM
Evaluate performance of staff, contractors and volunteers	Lack of adequate resources inhibits the effective management of the estuary.	EAF, RMA, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM
Create and administer a website for the Hartenbos Estuary Forum (upload minutes, photos, data, monitoring reports. Possibly include a blog to facilitate discussions)	Creating of a sense of custodianship of the estuary and the will to protect it.	EAF, MBLM

5 PROPOSED ZONATION OF ACTIVITIES

The development of zonation plans, particularly within aquatic environments, is becoming an important component of any integrated management plan. Spatial planning tools aim to assist in finding cohesion between the demand for growth and development of infrastructure and the need for biodiversity conservation. With regards to estuarine management, the process of zonation is defined as "a process of analysing and allocating the spatial and temporal distribution of human activities and conservation areas in an estuary to achieve the vision and objectives". Zonation and spatial planning typically allows for:

- Partitioning of activities within the estuary and its catchments thus permitting their existence without one activity precluding or conflicting with another.
- Identifying sensitive and small habitat fragments for protection.
- Focussing management activities in specific areas.
- Guiding future land/water uses and development activities in the area.

The zonation plan for the Hartenbos estuary was developed in accordance with the Integrated Coastal Management Act (2008) taking consideration discussions with and submissions received from stakeholders engaged in the development of the Hartenbos Estuary Situation Assessment Report (Mossel Bay Municipality 2015) and the Draft EMP.

The proposed management zones shown in Figure 5.1 are intended to satisfy conflicting requirements of the different user groups and stakeholders who wish to enjoy the benefits provided by the Hartenbos Estuary. Zonation will allow for partitioning of activities within the estuary thus permitting their co-existence without one activity precluding or conflicting with another. Details of the extent, intention and supported/not supported uses of the estuary are provided in Table 5.1.

The proposed zonation plan focuses rehabilitation efforts in ecologically important areas and restricts the area where bait can be collected. Bait collection is defined as prawn and/or blood worm pumping. Except for the limitations placed on bait collection, no restrictions pertaining to other recreational activities or harvesting of marine and estuarine living resource are recommended in the Hartenbos Estuary (note that cast netting for harders is not restricted in the estuary). Notwithstanding, legal requirements such as maximum speed of motorised vehicles, bag limits for harvesting, types of species and implements for harvesting etc. will still apply.

Note: This section will be reviewed in conjunction with the Hartenbos Precinct Plan which is currently being compiled. The precinct plan attempts to describe which land uses would be most appropriate for land adjacent to and within the estuary functional zone. The idea is that these land uses would assist is rehabilitating the estuary. The Hartenbos Precinct plan is currently in draft form. It will be added to the EMP upon completion of the study.

Table 5.1: Details, purpose, goals and management guidelines for recommended spatial planning categories for the Hartenbos Estuary.

Spatial Management Zones	Description and Location	Purpose	Goals	Management Guidelines
Rehabilitation Focus Area	Riparian Buffer Strip (30 m inland from the bank), Riparian Vegetation and Salt Marsh areas within the Estuarine Functional Zone.	To contribute towards improving: • ecosystem health • aesthetic value • recreational value • economic value	a) Reduce sediment load surface run-off and leaching of pollutants into the estuary. b) Control of invasive alien vegetation. c) Flood attenuation and minimisation of flood damage. d) Mitigate visual impact of development. e) Formalise access to the estuary.	• No bait collection. • No cultivation except where rehabilitation is underway. • No clearing of indigenous vegetation on public land except for facilities in line with MAP for improving recreational value (e.g. boardwalks, bird hides, access points for fishing). Encourage private land owners to assist the rehabilitation process. • Invasive alien vegetation management programme in place. • No fertilisers or pesticides to be used. • No new edge-hardening of the Riparian Buffer. • No new development or infrastructure below the 1:50 year floodline. • No septic tank, soakaway, solid or liquid waste disposal within 50 m of the river bank. • No establishment of new informal paths, formalise selected existing paths. • Erect signage and information boards to inform the public about rehabilitation efforts.
Bait collection area	Area designated for bait collection.	Restricting bait harvesting to this area will allow rehabilitation of the remaining estuary.	a) Promote easy compliance with MLRA regulations.	• Bait collection restricted to this zone. • Bait collection restricted to daylight hours using legal implements. • Bait collection subject to periodic review of MLRA regulations. • No bait collection permitted during emergency mouth breaching events.

Resort/Tourism Areas	Existing tourism nodes.	Enhance contribution towards economic growth of the area.	a) Promote eco-tourism and associated visitor facilities.	• Promote eco-tourism developments: guest houses, resorts, camping in accordance with Municipal SDF. • Ensure that these areas have formalised access to the estuary. Plant indigenous gardens. • Maintain existing indigenous vegetation. • Rehabilitate transformed areas where possible.

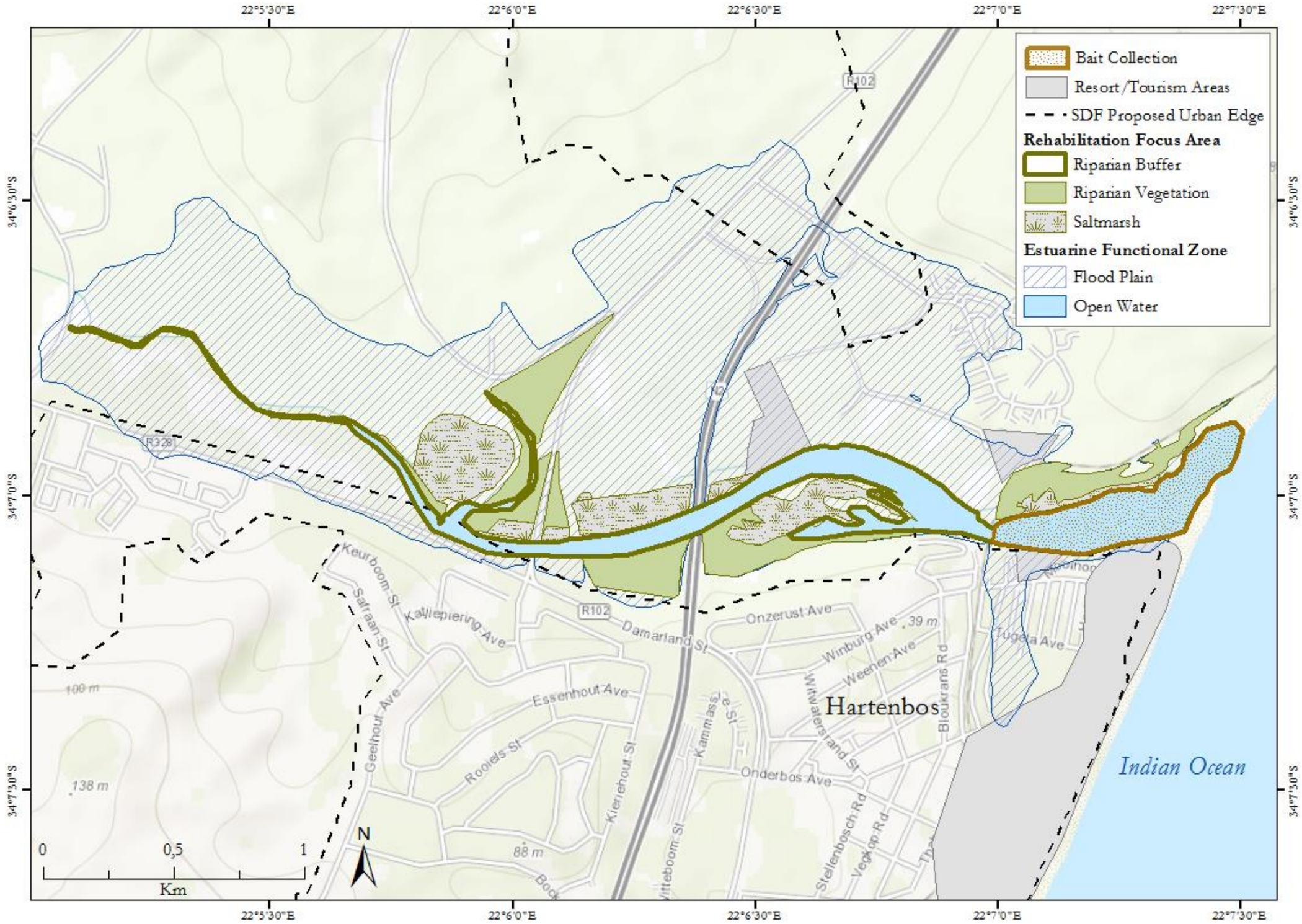


Figure 5.1: The zonation plan for the Hartenbos estuary

6 RECOMMENDED MANAGEMENT PRIORITIES

Management Objective 1: Improve estuary health

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1.1 Improve or re-establish flow regimes in the Hartenbos estuary				
DWS/BGCMA to conduct a water audit of the Hartenbos catchment to establish the location and number of, and volumes abstracted by – water use license holders and illegal water abstractions.	National Water Act	DWS, BGCMA,	• A database of all license holders detailing abstraction volumes is available. • Illegal water abstractions have been located and abstraction volumes have been determined. • An estimate of the total water volume that is abstracted from the Hartenbos catchment per annum has been calculated.	H
DWS/BGCMA to ensure compliance with water use licenses.	National Water Act	DWS, BGCMA	• Compliance monitoring records are available.	H
Negotiate highest environmental release volume for the estuary with DWS/BGCMA. The largest proportion of the allocation should be released from 1 December – 31 February.	National Water Act	EMF, DWS, BGCMA, MBLM	• Environmental release records are available.	H
Develop operating rules for the Hartebeeskuil Dam in accordance with the allocated environmental release volume.	National Water Act	EMF, DWS, BGCMA, MBLM	• Operating rules for the Hartebeeskuil Dam are in place.	M
2. Eradication/management of alien invasive species from the estuary and catchment				

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
Assess extent of alien invasive species in the EFZ.	NEM: Biodiversity Act	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI	• A plan of action for the clearing of alien invasive plants that prioritises certain species and areas within the rehabilitation focus area (Chapter 5).	L
Prioritise areas for the clearing of alien invasive plants in the EFZ.	NEM: Biodiversity Act	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI		L
Obtain funds to clear alien invasive plants in the EFZ.	NEM: Biodiversity Act	EAF, RMA, MBLM, DFFE: OCEANS & COASTS, SANBI, Landowners	• Records from alien clearing programmes (ha cleared of alien vegetation).	L
Clearance of alien invasive vegetation from the Hartenbos EFZ and catchment.	NEM: Biodiversity Act	EMF, MBLM, DFFE: OCEANS & COASTS, SANBI		L
3. Improve tidal exchange				
Implement second generation Mouth Management Plan.	NEM: Integrated Coastal Management Act	MBLM	• Obtain approval for the second generation Mouth Management Plan.	H
4. Reduce bait collection				
Erect signs at public access points highlighting the impact of bait collecting in the estuary and discouraging bait collection practices, particularly after the estuary mouth has been breached and the mud banks have become exposed.	Marine Living Resources Act	MBLM, EAF, RMA	• Reduced number of areas affected by bait collectors.	M

Management Objective 2: Improve water quality.

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Identify pollution sources				
Conduct a water audit to identify unlicensed discharges and establish the location and number of water use license holders and the amount of effluent that is discharged in the Hartenbos Catchment (as a minimum below the Hartebeeskuil Dam).	National Water Act	EAF, RMA, DWS, BGCMA	• Water audit has been completed and a licence database is available. • Unlicensed discharges have been licensed.	H
2. Reduce pollutants into the Hartenbos estuary				
WWTW to improve effluent quality in terms of inorganic nutrient concentrations • Thoroughly investigate the possibility of installing floating wetlands or conventional wetlands Investigate how contingency plans for the malfunctioning of the WWTW can be updated to reduce the risk of poorly or untreated sewage entering the Hartenbos Estuary.	National Water Act	EMF, DWS, BGCMA	• Improved water quality in the estuary as evidenced by water quality monitoring data. • *E. coli* and Enterococci counts comply with the ranges for good or excellent water quality in terms of the receiving water quality guidelines for recreational use (RSA DEA 2012). • Thresholds of potential concern for the Recommended Ecological Category C have been exceeded. • Ecological Specifications for a Recommended Ecological Category C are met.	H
Lobby farmers to reduce application of inorganic fertilizer and to reduce runoff from livestock holding areas in the Hartenbos catchment.	National Water Act	EMF, DWS, BGCMA, MBLM		M
Ensure that malfunctioning conservancy tanks are replaced/upgraded.		EMF, DWS, BGCMA, MBLM		M
Improved treatment and diversion of waste water outside of the Hartenbos catchment.	National Water Act	EMF, DWS, BGCMA, MBLM		M
3. Improve compliance				

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
Improved compliance by water users regarding discharge limits (volume and pollutants) contained in water use licenses.	National Water Act	EMF, DWS, BGCMA, MBM	• Compliance monitoring records are available.	H

Management Objective 3: Effective mouth management

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Implement and improve the Emergency Mouth Management Protocol for the Hartenbos Estuary [National Environmental Management Act 1998, National Environmental Management Act: Integrated Coastal Management Act 2008].				
Submit the Emergency Mouth Management Protocol for the Hartenbos Estuary for stakeholder review and sign-off.	NEM: Integrated Coastal Management Act	EAF, MBM, GRDM	• Mouth Management Protocol accepted and approved.	H
Conduct Emergency breaches responsibly and transparently in accordance with the Emergency Mouth Management Protocol.	NEM: Integrated Coastal Management Act	EAF, MBM, GRDM, DWS, DEADP, CapeNature, DFFE: OCEANS & COASTS	• Post breaching reports are compiled timeously and the public has access to these reports. • Registered stakeholders are notified and kept up to date leading up to, during and after a breaching event.	H
Regular review of the Emergency Mouth Management Protocol by specialists.	NEM: Integrated Coastal Management Act	EAF, MBM, GRDM, DWS CapeNature, DFFE: OCEANS & COASTS, DEADP, consulting specialists	• Review report is available and the Mouth Management Protocol has been amended accordingly.	H
2.Prevent illegal breaching, defined as breaching done at incorrect times i.e. not as specified in Mouth Management Protocol				

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
Develop a law enforcement strategy to prevent illegal breaching.	NEM: Integrated Coastal Management Act	EAF, RMA, MBM, GRDM, DEADP, CapeNature	• Reduced occurrence of illegal breaching.	M
Create public awareness about the ecological consequences of illegally breaching an estuary.		EAF, MBM, RMA	• This aspect has been integrated into pamphlets, information boards etc.	M

Management Objective 4: Improve recreational value

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Establish and manage visitors facilities				
Erect informative and educational signage at key access points that highlights the ecological importance and value of the Hartenbos Estuary.		MBLM, EAF	• Visitors are sensitive to and aware of activities affecting health and functioning of the estuary, and management regulations governing use of the estuary.	M
Develop appropriate nature friendly infrastructure for visitors to the estuary (ablutions, parking, bird hides, walking paths, nature trails, mountain bike trails) in collaboration with local communities and independent contractors that does not detract from sense of place of the area or impact on the environment.		MBLM, EAF	• Visitor infrastructure and facilities have been erected.	M

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
Ensure that visitor facilities are maintained in good condition at all times to maximise visitor experiences.		MBLM, EAF	• Facilities receive good reviews.	M

Management Objective 5: Improve aesthetic value.

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Prevent further encroachment by development into the estuarine functional zone of the Hartenbos Estuary [National Environmental Management: Integrated Coastal Management Act 2008, Municipal Systems Act 2000]				
Finalise and adopt the zonation plan for the Hartenbos Estuary including the position of the coastal protection zone and coastal management line and overlay zones.	NEM: Integrated Coastal Management Act Spatial Planning and Land Use Management Act (SPLUMA)	RMA, EAF, DFFE: OCEANS & COASTS, MBM, GRDM	• Final Zonation plan ratified and adopted by all stakeholders.	H
Incorporate coastal management lines into the IDP and SDF documents published by the Garden Route District and Mossel Bay Municipalities and the Garden Route District Coastal Management Programme.	NEM: Integrated Coastal Management Act Municipal Systems Act SPLUMA	EAF, RMA, DFFE: OCEANS & COASTS: O&C, MBM, GRDM	• Coastal management lines contained in the Hartenbos EMP Zonation Plan and incorporated into Municipal IDP and SDF documents.	H
2. Manage solid waste pollution in the Hartenbos Estuarine Functional Zone				
Erect 'Do not litter' signs in popular recreational spots.		EAF, MBLM	• No solid waste in the EF of the Hartenbos estuary.	M
Ensure that enough rubbish bins are available in popular recreational spots.		EAF, MBLM		H
Conduct strategic and regular collection of rubbish in key areas within estuarine functional zone.		EAF, MBLM		H

Management Objective 6: Increase awareness and appreciation for the Hartenbos Estuary activities.

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Create effective mechanisms for on-going communication with stakeholders				
Develop an effective communication strategy.		RMA, EAF, MBLM, GRDM	• Communication strategy developed.	M
Maintain stakeholder database.		RMA, EAF, MBLM, GRDM	• Stakeholder database developed and maintained.	M
Explore alternative communications mechanisms (workshops, signage, radio etc.).		RMA, EAF, MBLM, GRDM	• Record of communications kept.	M
2. Develop an effective education and awareness programme for the Hartenbos Estuary that enhances visitor experiences				
Establish a visitor centre at the estuary which will act as a focal point where visitors can go to learn more about the estuary, the ecology of the system, and the need for rationale behind existing management interventions.		RMA, EAF, MBLM	• Visitors centre open to the public.	M
Source and/ or commission educational and informative material including signage, posters, pamphlets, and relevant literature that will be housed in appropriate localities that will enhance visitor experiences.		RMA, EAF, MBLM	• Posters, pamphlets, signage, literature developed and distributed/displayed.	M
Encourage field excursions to the estuary by local schools, community groups, and other stakeholder groupings.		RMA, EAF, MBLM	• Field excursions undertaken.	M

Management Objective 7: Research and monitoring.

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Promote scientific research.				
Identify information gaps and develop research programme(s) aimed at gathering/ consolidating ecological data.		RMA, EAF, DWS, GRDM, DFFE: OCEANS & COASTS	• Research projects. • Scientific reports, paper and publications.	M
Engage local research institutes and universities to collaborate on priority research projects.		RMA, EAF, DWS, GRDM, DFFE: OCEANS & COASTS		M
Obtain research funding support.		RMA, EAF, DWS, GRDM, DFFE: OCEANS & COASTS		M
2. Implement monitoring programme for biological, physical and chemical indicators of estuary health (Chapter 7) [National Water Act 1998].				
Implement a monitoring programme in as outlined in Chapter 7. a. Clearly define responsible agencies for each monitoring component (i.e. municipality, conservancies, service providers, CapeNature etc). b. Ensure that each monitoring component has a clearly defined methodology.	National Water Act	RMA, EAF, DWS, GRDM, DFFE: OCEANS & COASTS	• Monitoring data and reports are available on a real time basis. • Monitoring data and reports inform short-term and long-term management interventions (e.g. dealing with fish kills, mouth management, alien clearing).	H
Assess results in terms of thresholds of potential concern (Appendix 3).	National Water Act	RMA, EAF, DWS, GRDM, DFFE: OCEANS & COASTS		H
3. Monitor human use of the estuary [National Water Act 1998].				

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
Implement monitoring programme as outlined in Chapter 7.	National Water Act	RMA, EAF, DWS, BGCMA, MBLM, GRDM, DFFE: OCEANS & COASTS	• Monitoring data and reports are available on a real time basis. • Monitoring data and reports inform short-term and long-term management interventions (e.g. dealing with fish kills, mouth management and alien clearing).	H

Management Objective 8: Harmonious and effective governance.

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
1. Constitute the Hartenbos Estuary Advisory Forum (EAF) [National Environmental Management Integrated Coastal Management Act 2008]				
Invite representative members of stakeholders and government to be members of the Hartenbos Estuary Advisory Forum (EAF).	NEM: Integrated Coastal Management Act	RMA, EAF, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM	• Circulation of attendance registers to all stakeholders.	L
2. Define co-operative governance arrangements for management of the Hartenbos Estuary [National Environmental Management: Integrated Coastal Management Act 2008; Protected Areas Act 2003]				
Estuary Advisory Forum to obtain agreement from participating agencies in respect of their roles and responsibilities.	NEM: Integrated Coastal Management Act	RMA, EAF, DFFE: OCEANS & COASTS, DWS,	• Formal agreements in place.	H

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
	NEM: Protected Areas Act	DPW, DFFE: FISHERIES, DEADP, BGCMA, CapeNature, GRDM, MBLM		
3. Secure financing				
Individual government agencies to make provision for the necessary resources in the short, medium and long-term expenditure frameworks to create and fill posts, and acquire necessary infrastructure and resources for effective management of the Hartenbos Estuary.		RMA, EAF, DFFE: OCEANS & COASTS, BGCMA, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM	• Memorandum of Understanding between MBLM and relevant government agencies in place.	H
Develop a long-term financing plan.		RMA, EAF, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM	• Long term financial plan developed and adopted.	H
4. Develop adequate resources and capacity				
Individual agencies to acquire access to necessary equipment (office equipment, water quality meter, boat, vehicle) for effective management of the Hartenbos Estuary.		EAF, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP,	• Necessary equipment acquired.	H

ACTION	RELEVANT LEGISLATION	RESPONSIBLE AUTHORITIES	PERFORMANCE INDICATOR	PRIORITY ALLOCATED (H/M/L)
		CapeNature, GRDM, MBLM		
Individual agencies to identify and address training needs among staff involved in estuary management		EAF, RMA. DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM	• Training programme developed and implemented.	H
Evaluate performance of staff, contractors and volunteers		EAF, RMA, DFFE: OCEANS & COASTS, DWS, DPW, DFFE: FISHERIES, DEADP, CapeNature, GRDM, MBLM	• Annual performance reviews conducted.	H
5. Ensure that all stakeholders are informed regarding management progress and challenges faced				
Create and administer a website for the Hartenbos Estuary Forum (upload minutes, photos, data, monitoring reports. Possibly include a blog to facilitate discussions)		RMA, EAF, MBLM	• Website live and maintained.	M

7 INTEGRATED MONITORING PLAN

The integrated monitoring plan for the Hartenbos estuary includes a list of recommended abiotic and biotic parameters to be monitored (Table 7.2), which are linked to the Ecological Specifications and Thresholds of Potential Concern (Table 7.3). These generic recommendations were sourced from DWS (2015b) and were adapted where necessary to reflect the specific needs of the Hartenbos Estuary and to align future monitoring with existing monitoring wherever possible.

Water quality in the Hartenbos Estuary has been monitored by the Mossel Bay Municipality and the Department of Water and Sanitation (DWS) at various stations in the Hartenbos Estuary since 1982. Early detection of low oxygen events, eutrophication risks or bacterial contamination and their appropriate management actions (short to long-term interventions) rely on continued monitoring that is aligned with existing water quality sampling locations and methods of the Mossel Bay Municipality and the DWS. Figure 7.1 and Table 7.1 indicates the locations of the recommended water quality monitoring stations. In line with the recommendations by DWS (2015b), the monitoring programme includes a baseline survey and ongoing monitoring thereafter to assess changes in health of the system over time.

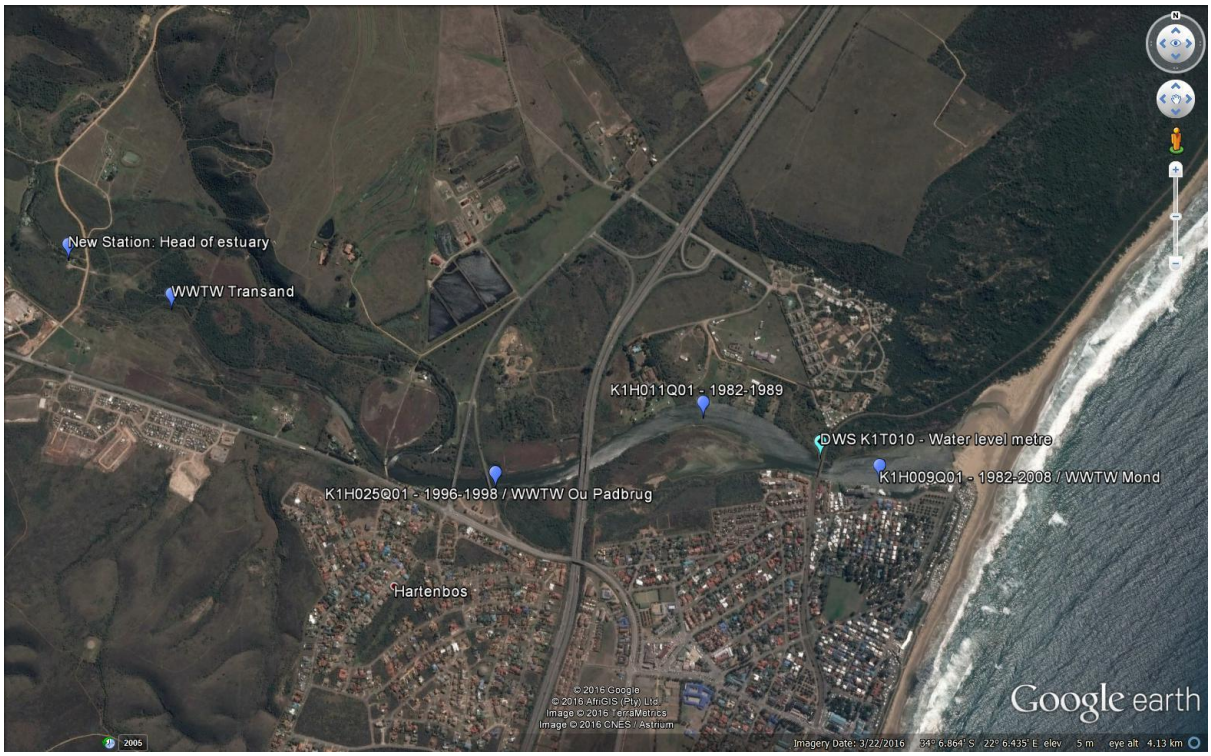


Figure 7.1: Recommended water quality monitoring stations and location of the water level metre (DWS K1T010) in the Hartenbos Estuary.

Table 7.1: GPS location and status of water quality stations and water level metre in the Hartenbos Estuary.

Monitoring station	Existing/ New	GPS coordinates
Head of estuary	New	34°6.610'S, 22°5.037'E
Transand	Existing – Hartenbos Regional Waste Water Treatment Works	34°6.718'S 22° 5.296'E

Monitoring station	Existing/ New	GPS coordinates
K1H025Q01/Ou Padbrug	Existing – DWS & Hartenbos Regional Waste Water Treatment Works	34°7.098'S, 22°6.150'E
K1H011Q01	Existing – DWS	34°6.949'S, 22°6.683'E
K1H009Q01/Mond	Existing - DWS & Hartenbos Regional Waste Water Treatment Works	34°7.083'S, 22°7.133'E
K1T010	Existing water level meter - DWS	34°7.033'S, 22°6.983'E

Recommendations for monitoring of visitor numbers, profiles and opinions, and angler catch and effort required in terms of the management plan are also included here. The responsibility of the monitoring outlined below falls with the Department of Water Services who are responsible for the National Estuarine Management Project. As per the conditions of the Water Use Licence for the WWTW, MBM will continue doing water quality monitoring for a limited set of parameters. Garden Route District Municipality will also assist with Water Quality Monitoring. It is however critically important that all tiers of the National estuarine monitoring project is rolled out.

Table 7.2: Recommended baseline and long-term monitoring protocols for the Hartenbos Estuary. Monitoring parameters include biotic and abiotic components and are linked to the Ecological Specifications and Thresholds of Potential Concern (Modified from the generic monitoring protocol in DWS, 2015b).

Ecological Component	Monitoring Action	Temporal Scale (frequency and when)	Spatial Scale (No. Stations)
Hydrology	Record river inflow at the head of the estuary	Continuous	Install recorder near the upstream boundary of the estuary
	Obtain effluent volumes released into the estuary from the WWTW	Monthly	WWTW outfall point
	Obtain environmental release volumes from the Hartebeeskuil Dam	Monthly	Outlet pipe of Hartebeeskuil Dam
Hydrodynamics	Record water level in metres above mean sea level	Hourly	Existing recorder at the old railway bridge DWS K1T010 (operational since 1993).
	Aerial photography (or using high resolution satellite imagery i.e. 5x5 m pixel size, e.g. Google Pro or BirdEye).	Once-off (baseline), thereafter every three years.	Entire estuary
	Mouth State: • Take at least one photo from the same angle each time. • Note whether the estuary is open, closed or overflowing. • Note whether there evidence of illegal artificial breaching.	Weekly.	Mouth
Sediment dynamics	Monitor berm height using appropriate technologies.	Quarterly	Mouth

Ecological Component	Monitoring Action	Temporal Scale (frequency and when)	Spatial Scale (No. Stations)
	Bathymetric surveys: Series of cross section profiles and a longitudinal profile	Once-off (baseline), thereafter every three years and after large re-setting event.	Entire estuary. Collected at fixed 500 m intervals but in more detail at the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.
	Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations).	Once-off (baseline), thereafter every three years	Entire estuary
Water quality	Electrical conductivity	Monthly	New monitoring station at the head of the estuary
	Salinity and temperature profiles	Quarterly	At all stations except at the head of the estuary.
	Dissolved oxygen and surface water temperature.	Monthly from 1 April - 1 November, daily from 1 December – 31 March. Take daily measurements for 30 days if insufficiently treated sewage has been released into the estuary. Dissolved oxygen must be measured before sunrise (DO minimum is expected at night)	At all stations
	pH, nitrate, nitrite, ammonia, phosphate, total suspended solids.	Monthly	At all stations.

Ecological Component	Monitoring Action	Temporal Scale (frequency and when)	Spatial Scale (No. Stations)
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007).	Once-off (baseline), thereafter every three to six years if baseline results show contamination.	At all stations and depositional areas (i.e. muddy areas, to be determined)
	E. coli and *Enterococci*	Monthly. Weekly for one month after insufficiently treated sewage has been released into the estuary from WWTW.	At all stations
Microalgae	• Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. • Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe. • Intertidal and subtidal benthic chlorophyll-a measurements (4 replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferably for two years. Thereafter every three years	Along length of estuary, minimum five stations
Macrophytes	• Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophytes habitats, identification and total number of macrophytes species, number of rare or endangered species, or	Once-off in summer (baseline). Thereafter every three years in summer.	Entire estuary (mapping) Where there is salt marsh (minimum three transect sites)

Ecological Component	Monitoring Action	Temporal Scale (frequency and when)	Spatial Scale (No. Stations)
	those with limited populations. Assess extent of invasive species in EFZ. • For salt marsh areas greater than 1 ha, measure percentage plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field, measure depth to water table and ground water salinity.		
Invertebrates	• Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary. • Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um). • Collect grab samples (5 replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um). • Intertidal invertebrate hole counts using 0.25 m^2 grid (5 replicates per site). • Establish the species concerned (*Callichirus kraussi* or *Upogebia Africana*) using a prawn pump. • Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (preferably link with sediment dynamics)	Quarterly, preferably for two years (baseline). Thereafter every two years in mid-summer	Minimum of three sites along length of entire estuary For hole counts –three sites in each of muddy or sandy areas,

Ecological Component	Monitoring Action	Temporal Scale (frequency and when)	Spatial Scale (No. Stations)
Fish	**Ongoing:** • Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. • Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh 5 m either side and including the cod-end. • Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm • Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). • Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end **Fish kills:** Identify species, count, measure, and weigh dead fish.	**Ongoing:** Once-off in spring/ summer and autumn/ winter (baseline). Thereafter bi-annually spring/summer and autumn/winter. **Fish kills**: Daily for at least one month after the need for an emergency breach has been identified.	**Ongoing:** 3-5 stations (mouth, mid, top) **Fish kills**: Entire estuary
Birds	**Ongoing:** Undertake counts of all water-associated birds. All birds should be identified to species level and total number of each counted. **Avian botulism:** Identify species and count dead birds.	**Ongoing:** Baseline data exists (CWAC data). Continue CWAC counts bi-annually. **Avian botulism:** Daily for at least one month after the need for an emergency breach has been identified.	**Ongoing:** Entire estuary, continue as per CWAC methodology. **Avian botulism:** Entire estuary

Ecological Component	Monitoring Action	Temporal Scale (frequency and when)	Spatial Scale (No. Stations)
Human use	Collect statistics on the profile (origin, sex, age, income category) and activities of visitors to the Hartenbos Estuary using self-fill in questionnaires	Continuous	Visitor entry points and key sites of interest
	Survey visitor and local opinions on impacts of key management interventions.	Every two years	Entire estuary
	Creel surveys of Catch, Effort and C.P.U.E. for shore-based anglers.	Conduct a survey on five randomly selected days per week (include weekends and public holidays) over a two month period during peak holidays (December & January). Repeat every 5 years.	Entire estuary

Table 7.3 provides "Ecological Specifications/Resource Quality Objectives" and "Thresholds of Potential Concern" (TPC) for the Hartenbos Estuary. "Ecological Specifications/Resource Quality Objectives" are defined as being clear and measurable specifications of ecological attributes (in the case of estuaries - hydrodynamics, sediment dynamics, water quality and different biotic components) that define a specific ecological reserve category, while "Thresholds of Potential Concern" are defined as measurable end points related to specific abiotic or biotic indicators that if reached (or when modelling predicts that such points will be reached) should prompt management action. Note that thresholds of potential concern endpoints are generally defined such that they provide early warning signals of potential non-compliance to ecological specification (i.e. not the point of 'no return'). Therefore, indicators (or monitoring activities) included here incorporate biotic and abiotic components that are considered particularly sensitive to ecological changes associated with changes in river inflow and should be interpreted as such.

Table 7.3: Ecological Specifications and Thresholds of Potential Concern for the Hartenbos Estuary (Category C) (Source DWS 2015).

Ecological Component	Ecological Specifications	Threshold of Potential Concern
Hydrology	• Maintain at least present day base flows	• MAR does not vary by more than 10% • Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. • Base flows do not incresae by more than 50% from present
Hydrodynamics	• Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	• Closed mouth state do not decrease by 10% from present • Average water level in system >10% from present • Tidal amplitude (when open) <20%
Water Quality	• Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae • Turbidity and Dissolved oxygen not to cause exceedance of TPCs for biota • DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae • Toxic substances not to cause exceedance of TPCs for biota	• Average salinity along estuary decrease by 5 below baseline average (to be determined) • DO <5 mg/l in estuary • Turbidity >20 NTU in low flow • Secchi in fresher part: <0.5 m • DIN >200 µg/l average (to be confirmed through future monitoring) • DIP > 50 µg/l average (to be confirmed through future monitoring) • Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) • Concentrations in sediment exceed target values as per W10 Region guidelines (UNEP/Nairobi Convention

Ecological Component	Ecological Specifications	Threshold of Potential Concern
		Secretariat and and CSIR, 2009)
Sediment dynamics	• Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota • Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates • Changes in average sediment composition and characteristics • Change in average bathymetry	• Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) • Average depth along main channel change from 30% of baseline (to be determined) (system expected to significantly fluctuate in bathymetry between flood and extended closed periods)
Microalgae	• Maintain median phytoplankton/benthic microalgae biomass • Prevent formation of phytoplankton blooms	• Phytoplankton >8 µg/l (median) • Benthic microalgae >42 mg/m^2 (median) • Phytoplankton >20 µg/l and/or cell density >10 000 cell/ml (once off) • Dinoflagellates, chlorophytes and/or cyanobacteria >10% of relative abundance
Macrophytes	• Maintain distribution of macrophyte habitats • Prevent the spread of reeds into open water • Prevent and increase in nutrients and macroalgae blooms • Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone. • Maintain integrity of salt marsh	• 20% change in macrophyte area (reeds currently cover 9 ha, saltmarsh 47 ha) • Macroalgal blooms cover > 50% of the open water area • Presence of invasive aquatic macrophytes (e.g. Azolia, water hyacinth) • Invasive plants cover > 10% of flood plain • Increase in bare areas in salt marsh because of decrease in moisture and increase in salinity > 30% of salt marsh
Invertebrates	• Establish presence absence of sand prawn *Callichirus kraussi* on sand banks in lower estuary • Establish abundance of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	• If present populations deviate from average baselines (as determined in first three visits) by more than 30%

Ecological Component	Ecological Specifications	Threshold of Potential Concern
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: • Ia estuarine residents (20-60%) • Ib marine and estuarine breeders (10-30%) • IIa obligate estuarine-dependent (20-40%) • IIb estuarine associated species (5-20%) • IIc marine opportunists (20-80%) • IV indigenous fish (1-5%) • V catadromous species (1-5%) Cateogory Ia species should contain viable populations of at least two species (e.g. *G aestuaria, Hyporamphus capensis, Omobranchus woodii*) Category IIa obligate dependents should be well represented by large exploited species (i.e. *A. japonicus, L. lithognathus, P. commersonnii, Lichia amia*) REI species dominated by both *Myxus capensis* and *G. aestuaria.*	• Ia estuarine residents <20% • Ib marine and estuarine breeders <10% • IIa obligate estuarine-dependent <20% • IIb estuarine associated species <5% • IIc marine opportunists <20% • IV indigenous fish <1% • V catadromous species 1% • Ia represented only by G. aestuaria • IIa exploited species in very low numbers of absent • REI species represented only by G. aestuaria, Myxys capensis absent.
Birds	• Maintain populations of original groups of birds present on the estuary	• Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

8 INSTITUTIONAL CAPACITY AND ARRANGEMENTS

Due to estuaries forming the interface between freshwater, terrestrial and marine environments, management of estuaries requires cooperation from a large number of separate national, provincial and local government agencies, each acting under a different legislative mandate.

The 2021 NEMP identifies the **Department of Environmental Affairs & Development Planning (DEA&DP)** (**provincial environmental department)**, or its assigned representative, as the RMA responsible for the co-ordination of the implementation of the Hartenbos River Estuary EMP. I**t is noted that the NEMP allocates such responsibilities to the DEA&DP (provincial environmental department) unless agreement / or until agreement is reached with the respective body to undertake the coordination of the implementation process. Ultimately, the role of the RMA must be designated through formal signed agreement.**

As a minimum the following national government agencies have a mandate with regards to the management of the Hartenbos Estuary:

- Department of Forestry, Fisheries and Environmental (DFFE: Oceans & Coasts);
- Department of Water and Sanitation (DWS);
- Department of Public Works (DPW);
- Breede-Gouritz Catchment Management Agency (BGCMA); and
- Department of Forestry, Fisheries and Environment (DFFE: Fisheries).

Provincial and local government agencies implicated in management of the estuary include:

- Department of Environmental Affairs & Development Planning (DEADP);
- Cape Nature;
- Garden Route District Municipality (GRDM); and
- Mossel Bay Local Municipality (MBLM).

Co-management and effective governance is the keystone for achieving the vision set by the stakeholders for the Hartenbos estuary, and therefore attainment of the overall objective of conserving the system's ecological functioning and biodiversity. Without well-structured and efficient institutional and management arrangements, integrated environmental management of the estuary may be no more than a series of uncoordinated reactions to immediate problems.

Ensuring effective governance is therefore one of the most important objectives to be achieved. To this end, DEADP is in the process of developing the Western Cape Estuaries Framework and Implementation Strategy (EMFIS) to assist with conformance with respect to establishing institutional and management structures for estuarine management within the province.

As per Chapter 5 of the ICM Act the main 'institutions' will be in effect regarding the management of activities in and around or relating to the Hartenbos estuary. These are

- the Responsible Management Authority;
- the Mossel Bay Local Municipality;
- Hartenbos Estuary Advisory Forum (EAF);
- Municipal coastal committee, the Provincial Coastal Committee (PCC) and the National Coastal Committee (NCC); and
- Various of stakeholders with vested interest in the Hartenbos estuary.

These institutions will represent the mechanisms through which the implementation of the EMP can be coordinated and monitored.

The **Hartenbos EAF** is an import factor with regards to effective governance, provided it is administered proficiently and remains functional. The EAF lead the process of integration of the EMP into the Integrated Development Plans and Spatial Development Frameworks of the local and district municipalities.

The **Provincial Coastal Committee** must in turn lead the process of integration of the EMP into the Provincial Coastal management Programme, the Provincial Spatial Development Framework as well as the strategic planning and budget plans of DEA&DP, Cape Nature, regional / provincial office of DWS, BGCMA and regional / provincial office of DFFE: FISHERIES.

The provincial and national coastal committee should also serve as one of the mechanisms for securing funding from Provincial and National Treasury for estuarine management.

In addition, co-operative governance is required for identifying, lobbying, and promulgation of additional by-laws or amendments to existing by-laws. The importance of the National and Provincial Coastal committees become evident when considering the responsibility of these committees as specified in the following sections of the ICM Act:

"6.8.2 The National Coastal Committees

The National Coastal Committee, led by DFFE: OCEANS & COASTS, must promote integrated coastal management in the Republic and effective co-operative governance by co-ordinating the effective implementation of this Act and of the National coastal management programme, and in particular must -

(a) promote integrated coastal management -
(i) within each sphere of government;
(ii) between different spheres of government; and
(iii) between organs of state and other parties concerned with coastal management;
(b) promote the integration of coastal management concerns and objectives into -
(i) those environmental implementation plans and environmental management plans
referred to in Chapter 3 of the National Environmental Management Act to which they are relevant;
(ii) national, provincial and municipal development policies, plans and strategies;
(iii) other plans, programmes and policies of organs of state whose activities may create
adverse effects on the coastal environment; and
(c) perform any function delegated to it.

6.8.3 The Provincial Coastal, led by DEA&DP Committee Provincial Coastal Committee must

(a) promote integrated coastal management in the province and the co-ordinated and effective implementation of this Act and the provincial coastal management programme;
(b) advise the MEC, the provincial lead agency and the National Coastal Committee on matters concerning coastal management in the province;

(c) advise the MEC on developing, finalising, reviewing and amending the provincial coastal management programme;
(d) promote a co-ordinated, inclusive and integrated approach to coastal management within the province by providing a forum for, and promoting, dialogue, co-operation and co-ordination between the key organs of state and other persons involved in coastal management in the province;
(e) promote the integration of coastal management concerns and objectives into the plans, programmes and policies of other organs of state whose activities may have caused or may cause adverse effects on the coastal environment;"

The NCC and PCC will need to ensure that funding is allocated by the relevant departments for building sufficient capacity to implement various actions within this EMP, as per the mandate and responsibilities of each department and state owned entity.

The RMA will, where possible, ensure that funding is made available for activities it is directly responsible for. Funding will also be required to perform activities such as:

- provision of interpretative and compliance signage; and
- Educational material.

While funding may be solicited from the relevant national departments for specific actions, such as:

- rehabilitation of degraded areas; and
- assistance with research and monitoring of biophysical indicators and human use.

In addition, the RMA may need to drive the promulgation and review of municipal by-laws in order to provide the necessary legal support for the execution of their functions and ultimately give effect to the EMP management objectives, particularly in terms of compliance management. This will however be limited to those functions which are directly assigned to the RMA's as per the Constitution.

A summary of the activities specific to the implementation of the Hartenbos Estuarine Management Plan and the responsible authority required to implement them has been provided below:

ACTIVITY	RESPONSIBLE AUTHORITIES	LEGISLATION
Management of the Hartenbos estuary	RMA, DFFE: OCEANS & COASTS, MBLM, EAF	NEM: Integrated Coastal Management Act
Water quality monitoring within the catchment	DFFE, DWS, MBLM and BGCMA	National Water Act NEMA
Water quality monitoring within the Estuary	DFFE: OCEANS & COASTS, MBLM, DWS	NEM: Integrated Coastal Management Act
Protected Areas	DFFE, DEADP, CapeNature	NEM: Protected Areas Act National Forestry Act
Development of infrastructure in the coastal zone	DFFE: OCEANS & COASTS, DEADP	National Environmental Management Act EIA regulations 2014 NEM: Integrated Coastal Management Act National Water Act
Solid waste management	DFFE, MBLM	NEM: Waste Act

ACTIVITY	RESPONSIBLE AUTHORITIES	LEGISLATION
		Municipal Services Act
Hazardous waste management	DFFE, MBLM	NEM: Waste Act NEM: Air Quality Act NEMA EIA Regulations 2014
Subsistence/recreational fishing, bait collection	DFFE: OCEANS & COASTS, DFFE: FISHERIES	Marine Living Resources Act
Promotion of tourism	DFFE: OCEANS & COASTS, RMA, MBLM	N/A
Spatial planning	DFFE, MBLM, DEA&DP	Spatial Planning and Land Use Management Act

9 REFERENCES

AEC. 2015. Biodiversity and ecosystem services of the Mossel Bay Municipality: impacts of compact growth versus urban sprawl. In *Mossel Bay Growth Options Study*, Palmer Development Group (ed). Report prepared by Anchor Environmental Consultants (Pty) Ltd. for the Western Cape Department of Environmental Affairs and Development Planning, in partnership with Mossel Bay Municipality.

Bickerton IB. 1982. Report No. 11 Hartenbos (CMS1). In *Estuaries of the Cape Part II: Synopsis of available information on individual systems*, Heydorn AEF, Grindley JR (eds). CSIR Research Report 425. Stellenbosch.

Department of Water and Sanitation (DWS), 2015. *Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area:* Estuaries RDM Report – Desktop Assessment, Volume 1. Prepared by the Council for Scientific and Industrial Research (CSIR) for Scherman Colloty and Associates cc. Report no. RDM/WMA16/04/CON/0613, Volume 1.

Department of Water and Sanitation (DWS), 2015b. *Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area*: Monitoring Report. Prepared by Koekemoer Aquatic Services and Scherman Colloty & Associates cc.. Report no. RDM/WMA16/00/CON/1213.

Lemley DA, Taljaard S, Adams JB, Strydom N. 2014. Nutrient characterisation of river inflow into the estuaries of the Gouritz Water Management Area, South Africa. *Water SA* 40: 687–698.

Morant P. and Quinn N. 1999. Influence of Man and management of South African Estuaries. In *Estuaries of South Africa,* Allanson BR and Baird D (eds). Pp 289-320.
Mossel Bay Municipality 2015. Hartenbos Estuary Situation Assessment Report. Prepared for the Mossel Bay Municipality by Anchor Environmental Consultants (Pty) Ltd.

Newman, B.K. and Watling, J. 2007. Definition of baseline metal concentrations for assessing metal enrichment of sediment from the south-eastern Cape coastline of South Africa. Water SA, vol 33, no. 5, pp. 675-692.

RSA DEA. 2012. South African Water Quality Guidelines (second edition) Volume 2. Guidelines for Recreational Use. Republic of South Africa Department of Environmental Affairs (RSA DEA): Cape Town, South Africa.

Swartz CD, Knott M, Malan W, Eden JD van. 2000. *Biological Phosphate Removal to Meet Strict Quality Requirements for Discharge into Ecosensitive Hartenbos Estuary*. Presented at the WISA 2000 Biennial Conference, Sun City, South Africa, 28 May - 1 June 2000.

Turpie JK, Wilson G, Van Niekerk L. 2012. *National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa*. Anchor Environmental Consultants (Pty) Ltd. Report No AEC2012/01, Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

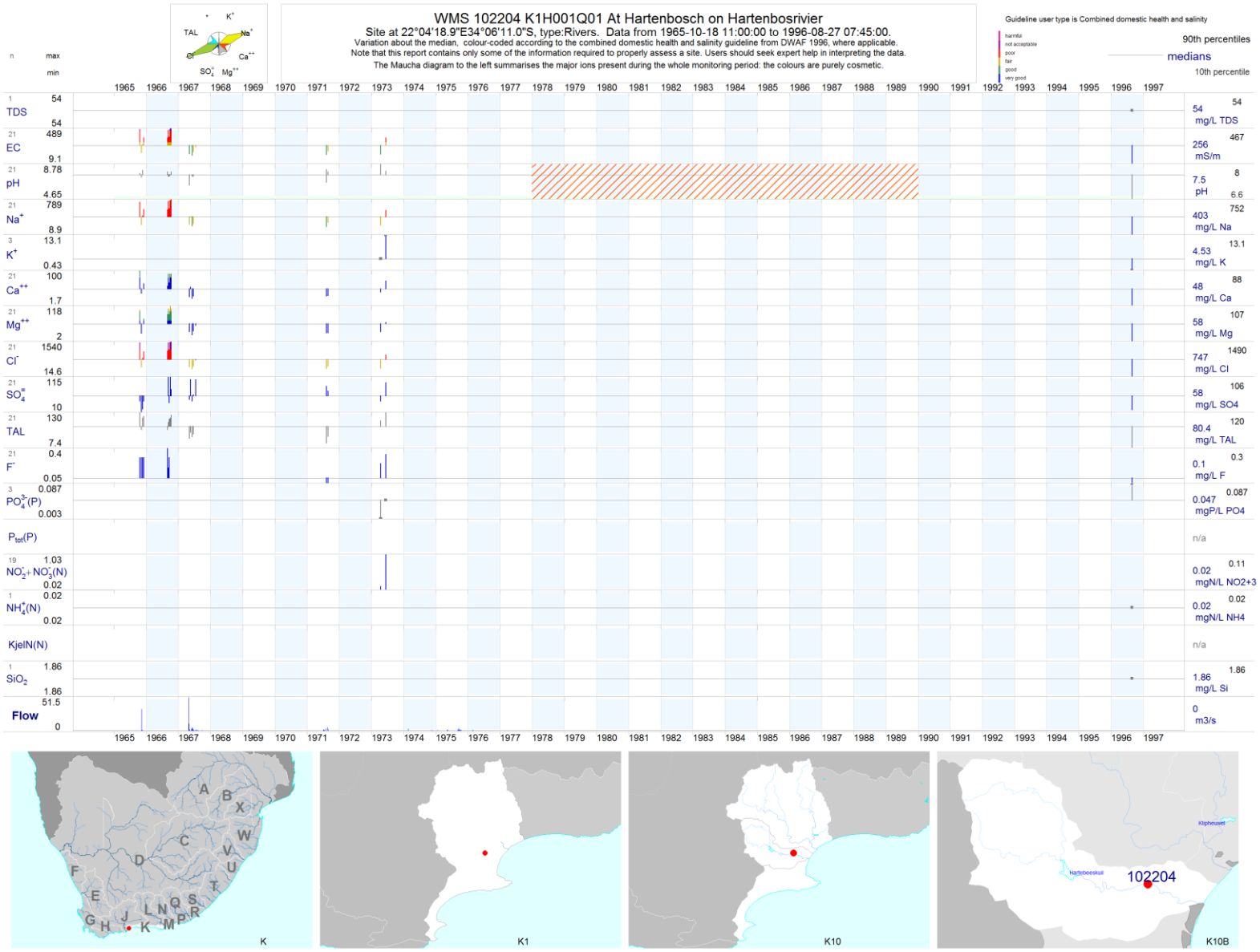
Turpie JK, Clark BM. 2007. *The health status, conservation importance, and economic value of temperate South African estuaries and development of a regional conservation plan*. Anchor Environmental Consultants (Pty) Ltd., Report to CapeNature.

Umvoto Africa 2010. Sea Level Rise and Flood Risk Assessment for a Select Disaster Prone Area Along the Western Cape Coast. Phase 3 Report: Eden District Municipality Sea Level Rise and Flood Hazard Risk Assessment. Prepared by Umvoto Africa (Pty) Ltd for the Provincial Government of the Western Cape Department of Environmental Affairs and Development Planning: Strategic Environmental Management (May 2010).

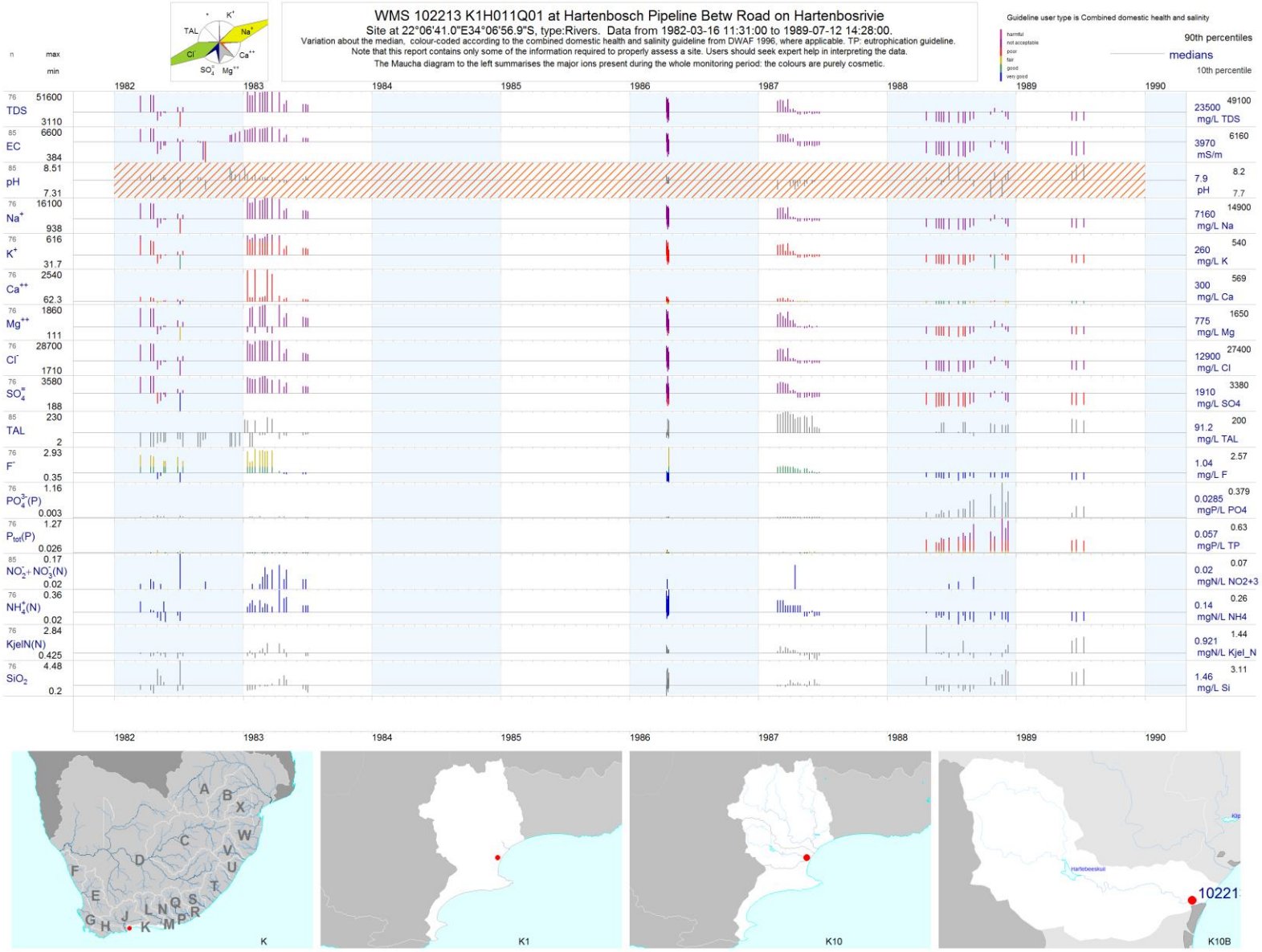
Van Niekerk L, Turpie JK. 2012. *South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component*. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch.

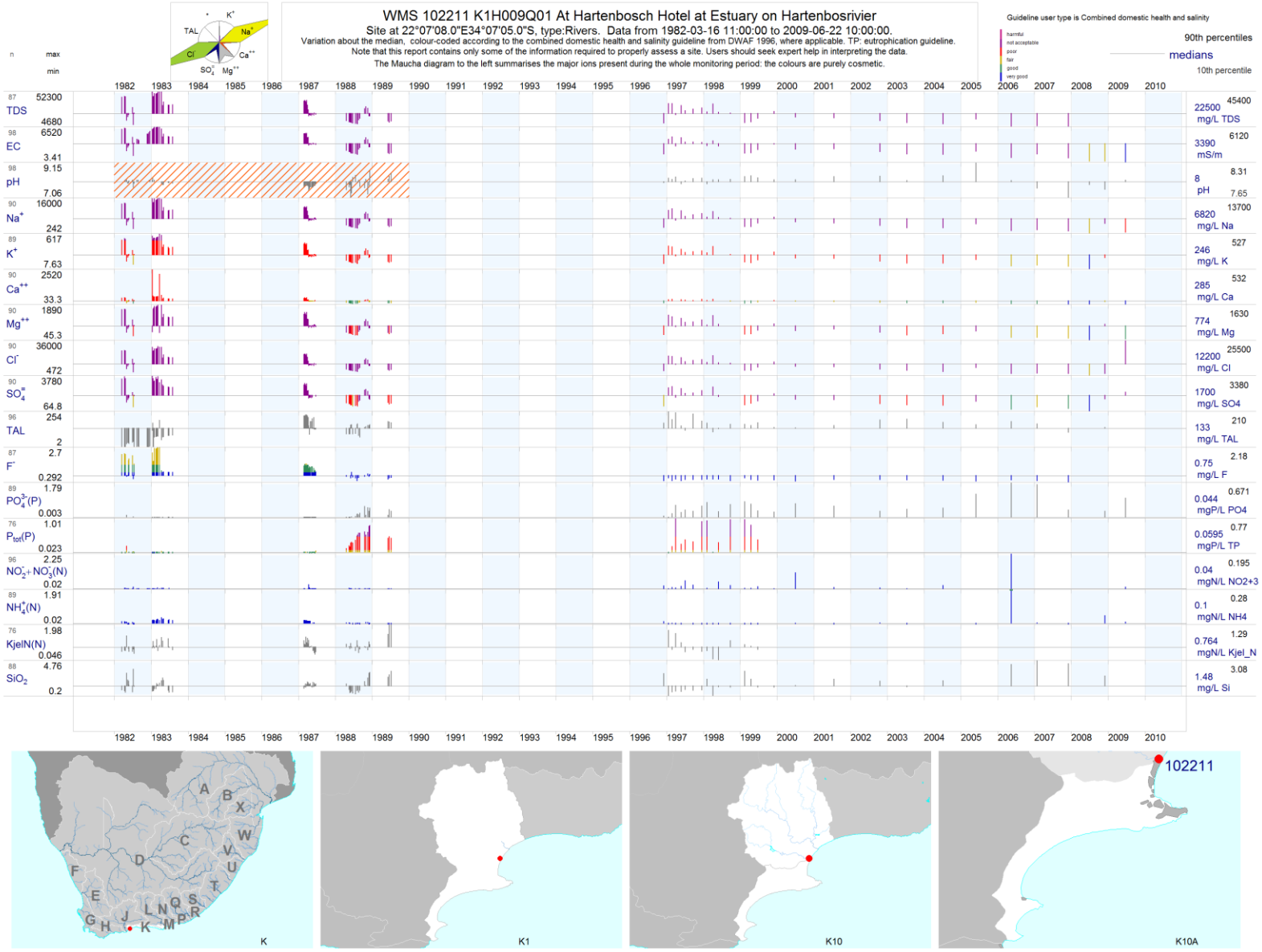
APPENDIX A: DETAILED WATER QUALITY RESULTS

This section provides the detailed water quality results for the RQIS Monitoring points within the K10B catchment. This data is publically available from the DWS website for each of the monitoring points.

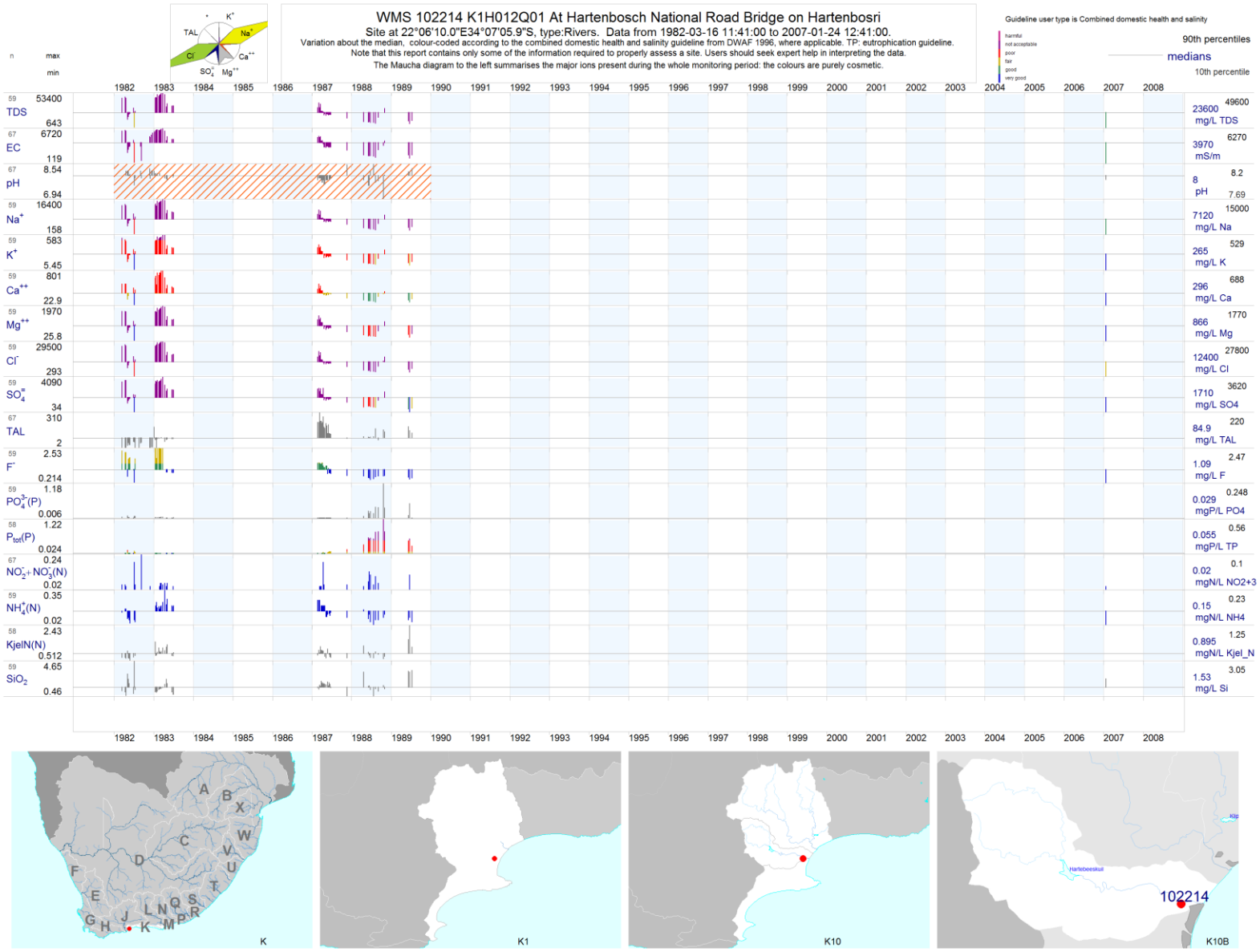


Data for 102204 from the Department of Water and Sanitation databases. Labs: DWS-RQIS. Plotted at Resource Quality Information Services on 2018-03-18 20:55:43 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs

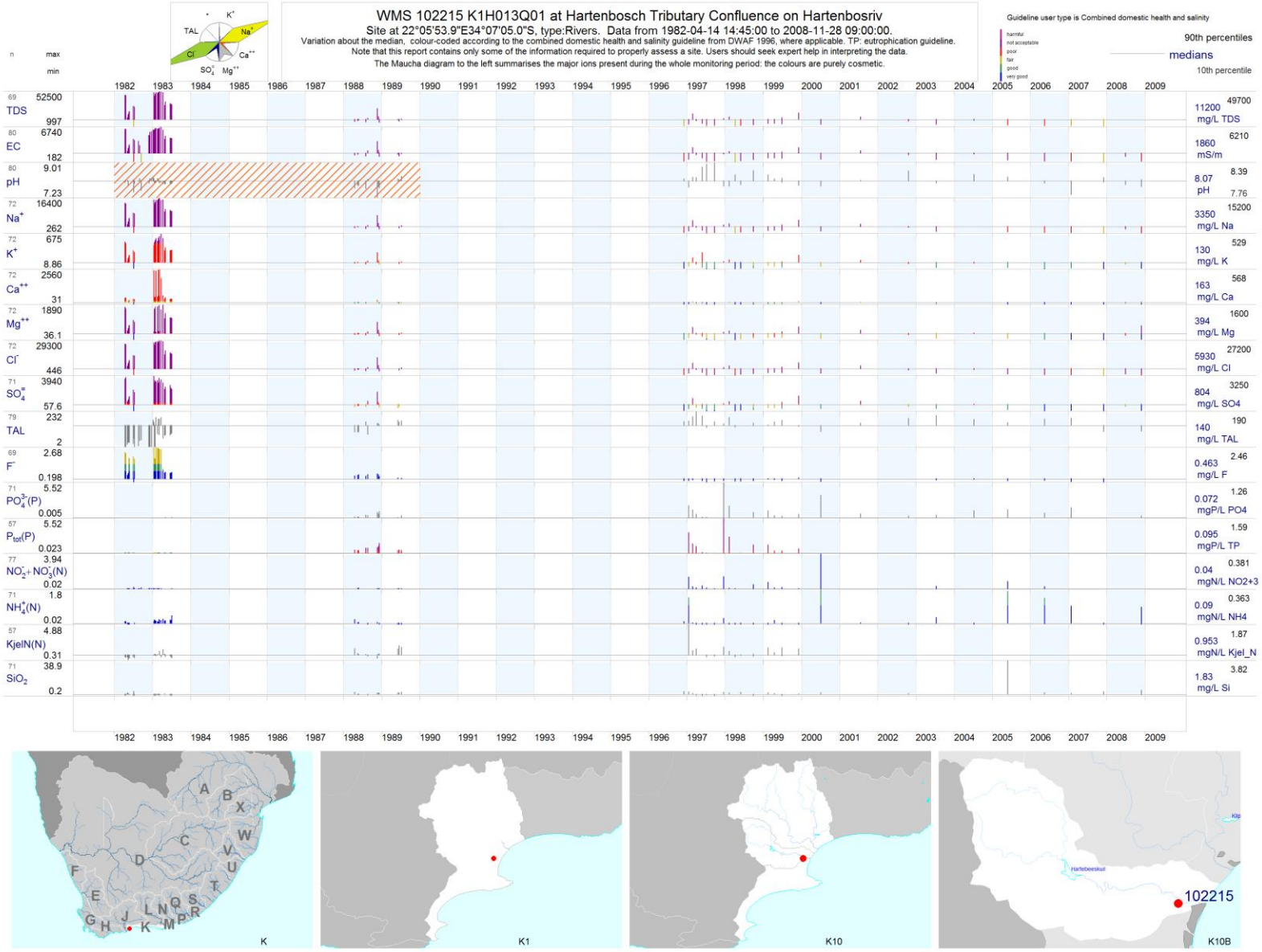

WMS 102213 K1H011Q01 at Hartenbosch Pipeline Betw Road on Hartenbosrivie
Site at 22°06'41.0"E34°06'56.9"S, type:Rivers. Data from 1982-03-16 11:31:00 to 1989-07-12 14:28:00.
Variation about the median, colour-coded according to the combined domestic health and salinity guideline from DWAF 1996, where applicable. TP: eutrophication guideline.
Note that this report contains only some of the information required to properly assess a site. Users should seek expert help in interpreting the data.
The Maucha diagram to the left summarises the major ions present during the whole monitoring period: the colours are purely cosmetic.
Guideline user type is Combined domestic health and salinity
harmful
not acceptable
poor
fair
good
very good
90th percentiles
medians
10th percentile
n max min
1982 1983 1984 1985 1986 1987 1988 1989 1990
TDS 76 51600 3110 23500 49100 mg/L TDS
EC 85 6600 384 3970 6160 mS/m
pH 85 8.51 7.31 7.9 8.2 pH 7.7
Na+ 76 16100 938 7160 14900 mg/L Na
K+ 76 616 31.7 260 540 mg/L K
Ca++ 76 2540 62.3 300 569 mg/L Ca
Mg++ 76 1860 111 775 1650 mg/L Mg
Cl- 76 28700 1710 12900 27400 mg/L Cl
SO4 76 3580 188 1910 3380 mg/L SO4
TAL 85 230 2 91.2 200 mg/L TAL
F- 76 2.93 0.35 1.04 2.57 mg/L F
PO4(P) 76 1.16 0.003 0.0285 0.379 mgP/L PO4
Ptot(P) 76 1.27 0.026 0.057 0.63 mgP/L TP
NO2+NO3(N) 85 0.17 0.02 0.02 0.07 mgN/L NO2+3
NH4(N) 76 0.36 0.02 0.14 0.26 mgN/L NH4
KjelN(N) 76 2.84 0.425 0.921 1.44 mgN/L Kjel_N
SiO2 76 4.48 0.2 1.46 3.11 mg/L Si
1982 1983 1984 1985 1986 1987 1988 1989 1990
K
K1
K10
K10B
10221
Harfiebeeskuil
Data for 102213 from the Department of Water and Sanitation databases. Labs: DWS-RQIS. Plotted at Resource Quality Information Services on 2018-03-18 20:55:55 using barcode R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs



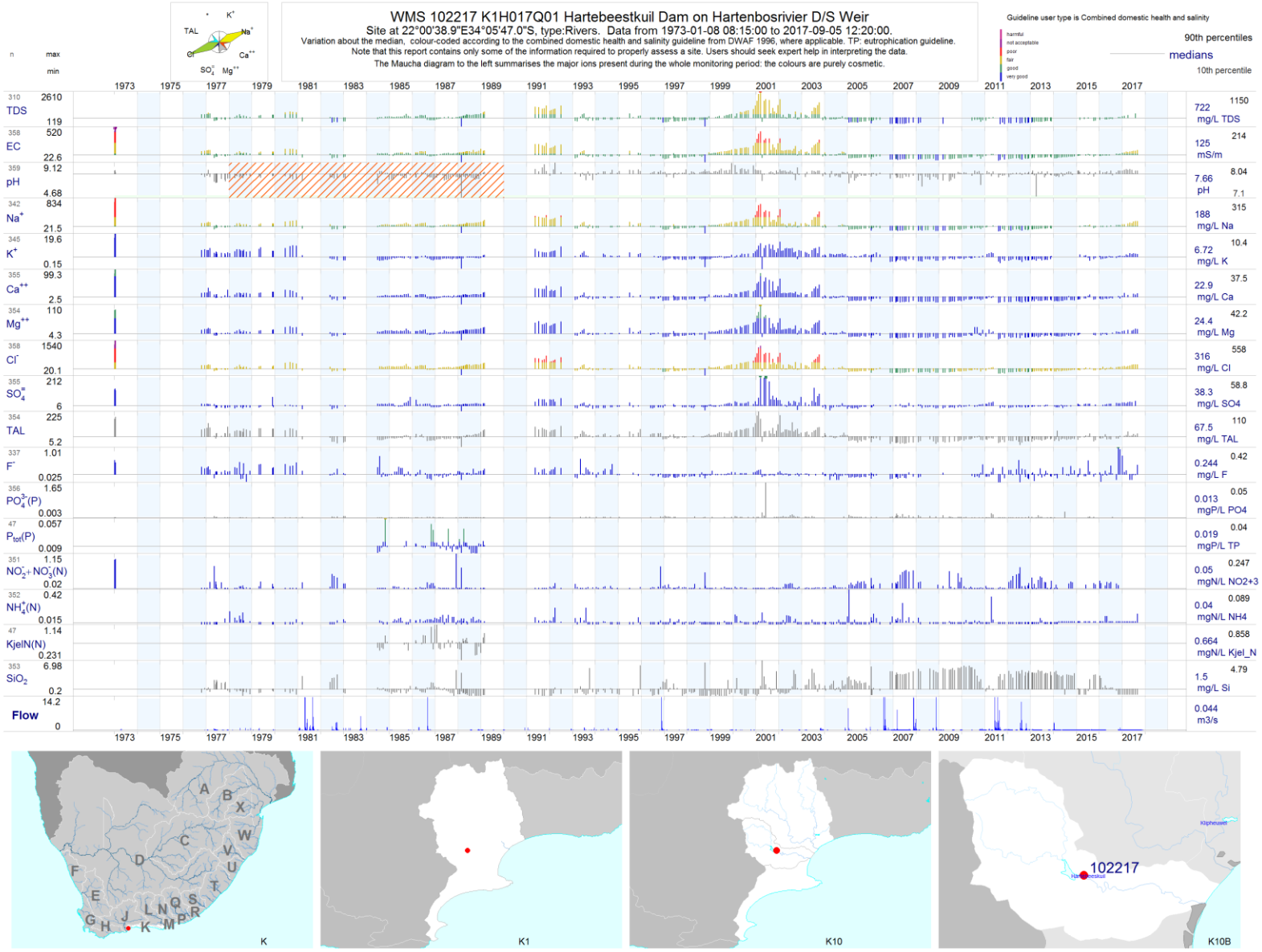
Data for 102211 from the Department of Water and Sanitation databases. Labs: DWS-RQIS, WC-TCS (SABS). Plotted at Resource Quality Information Services on 2018-03-18 20:53:28 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs



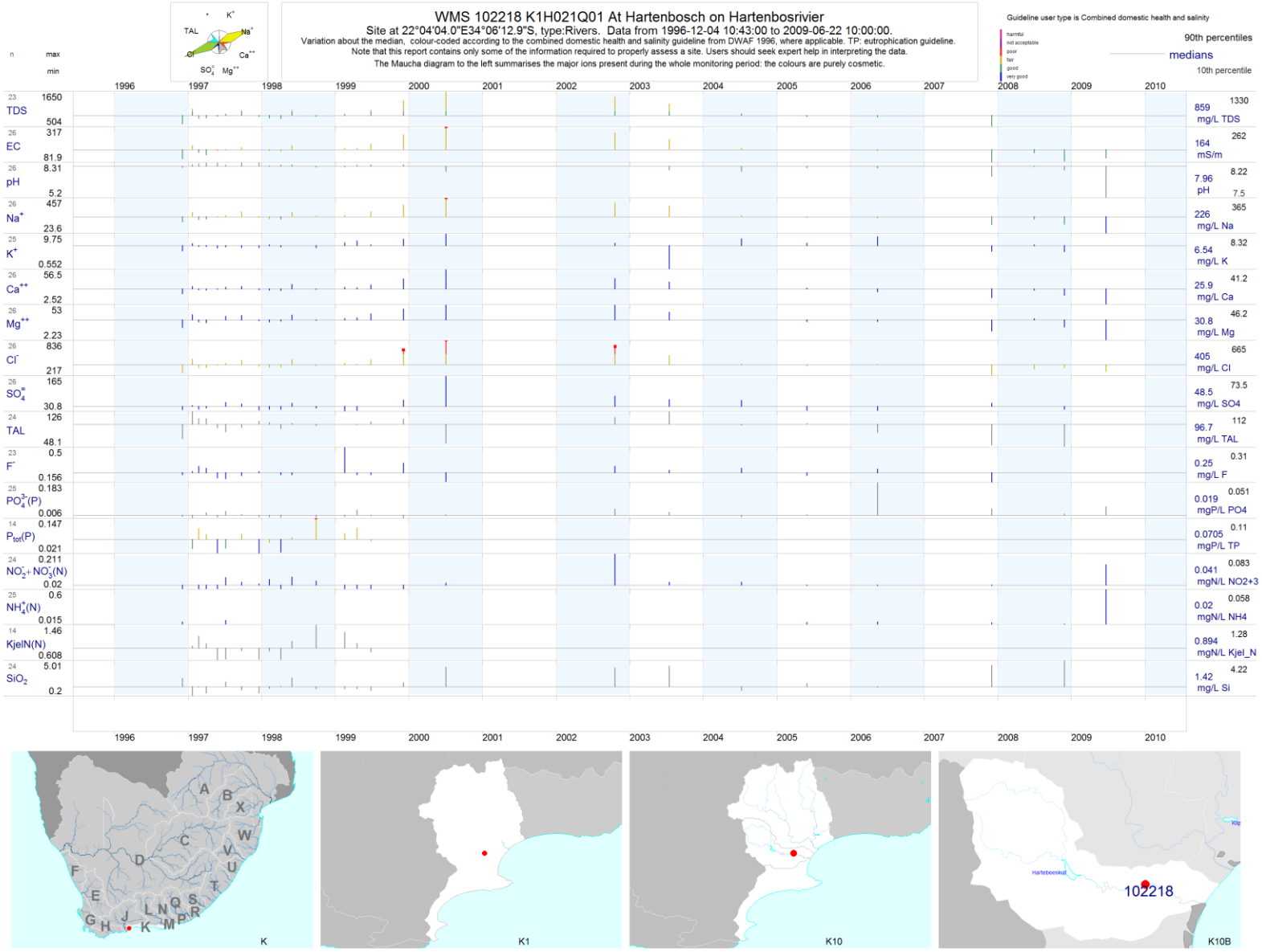
Data for 102214 from the Department of Water and Sanitation databases. Labs: DWS-RQIS. Plotted at Resource Quality Information Services on 2018-03-18 20:56:06 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs



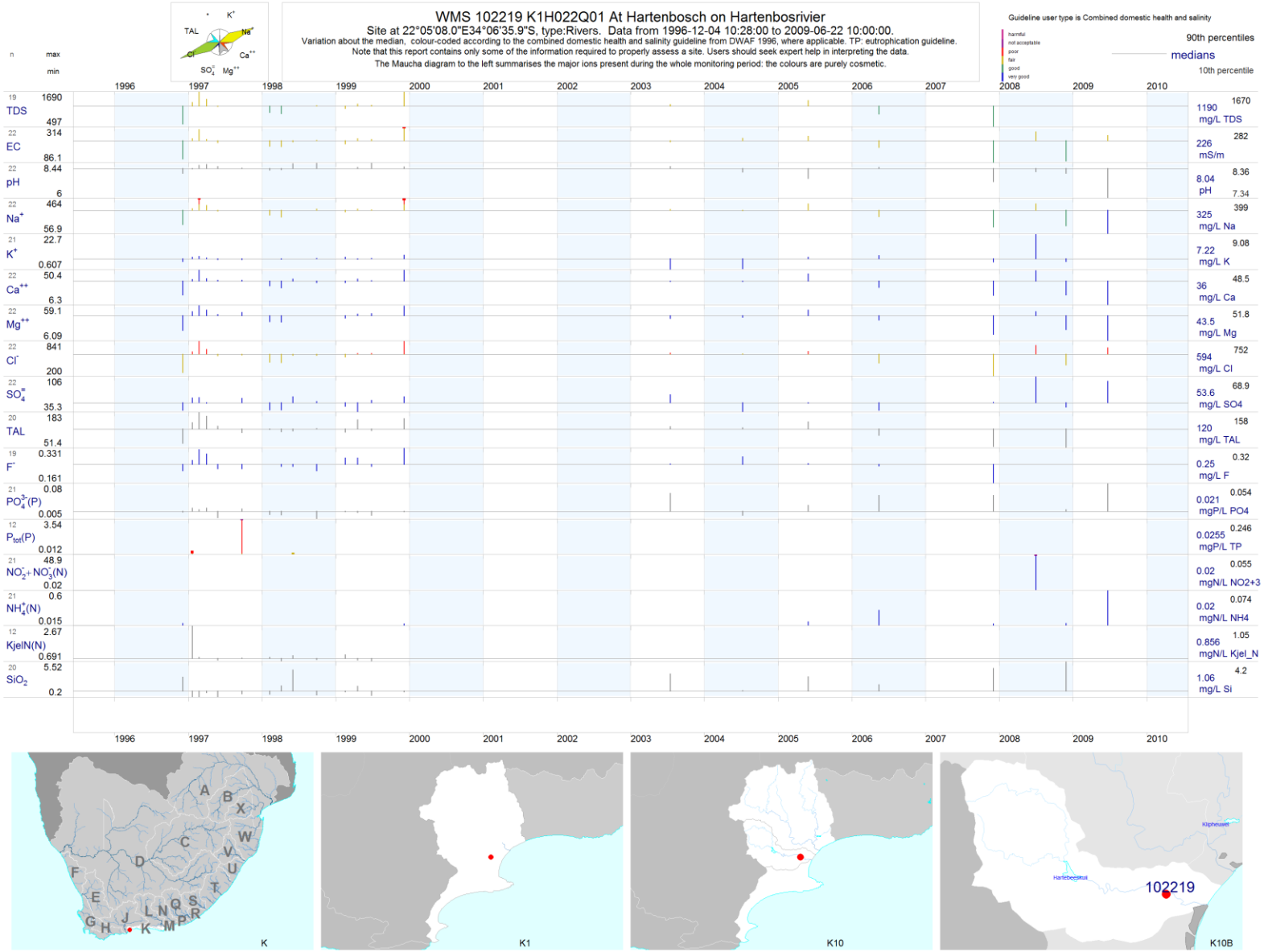
Data for 102215 from the Department of Water and Sanitation databases. Labs: DWS-RQIS. Plotted at Resource Quality Information Services on 2018-03-18 20:56:18 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/rwqs

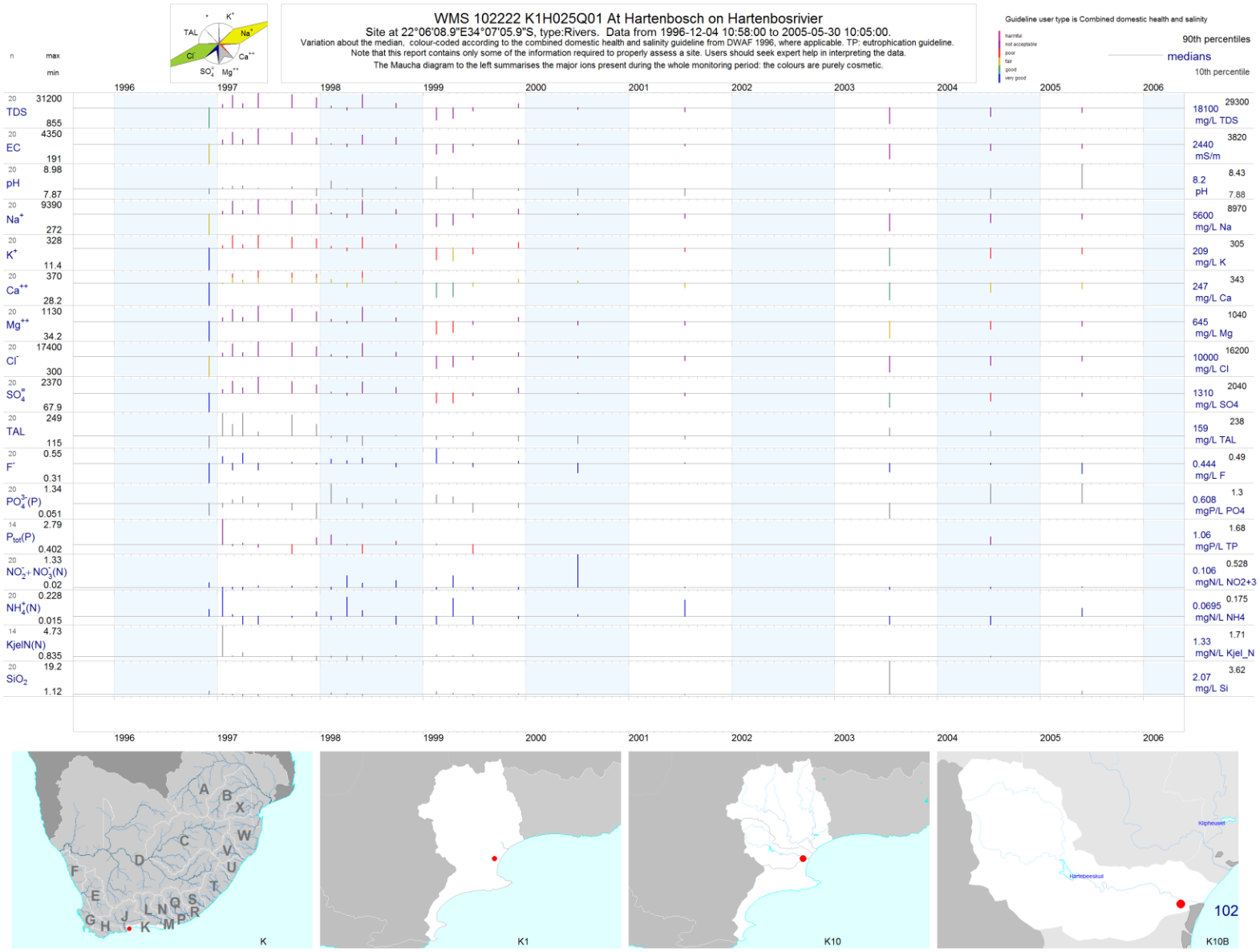


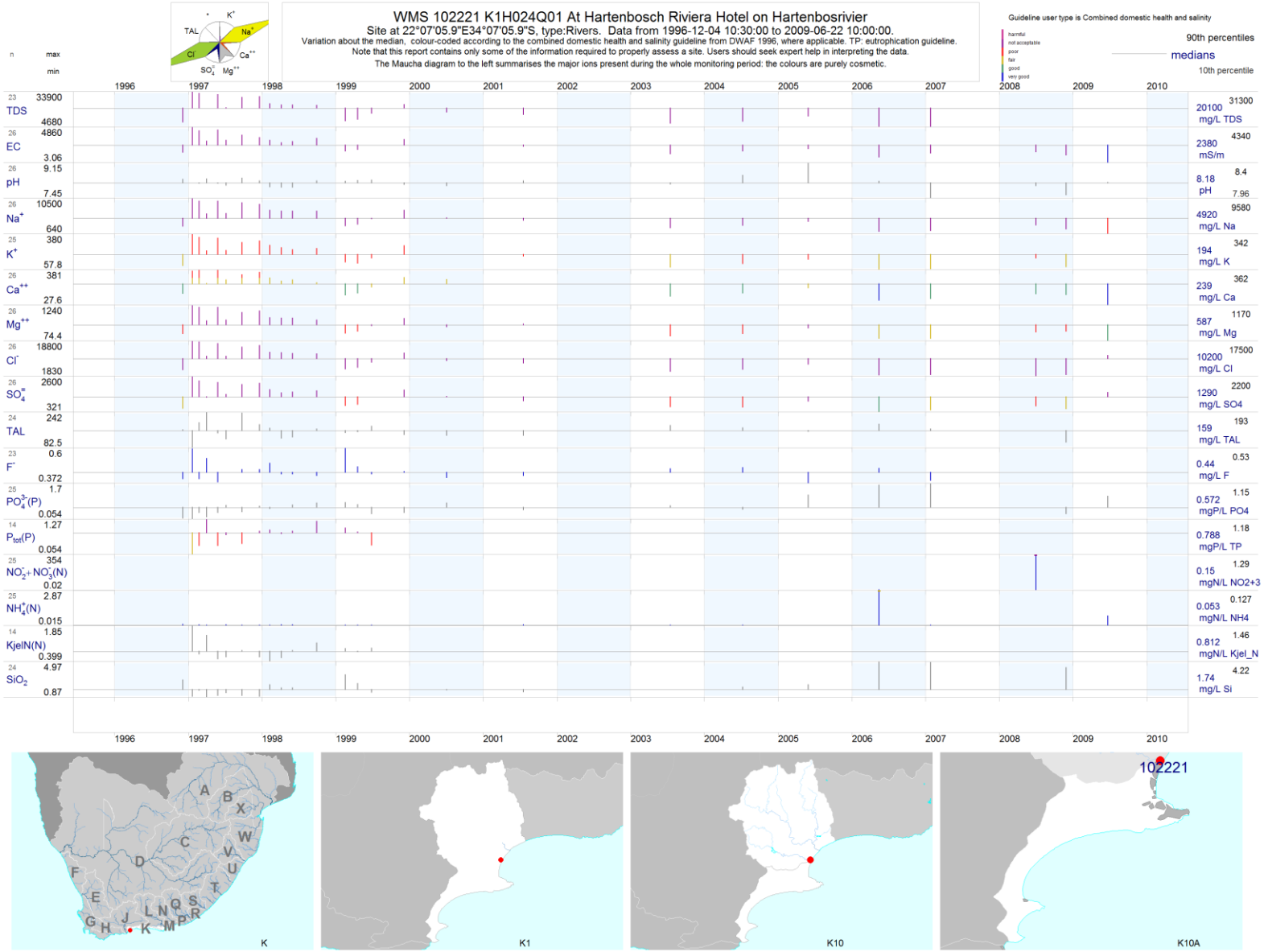
NCWQ Data for 102217 from the Department of Water and Sanitation databases. Labs: DWS-RQIS. Plotted at Resource Quality Information Services on 2018-05-21 15:17:03 using barcode R v16.8 (macro option) under R version 3.4.4 (2018-03-15). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs



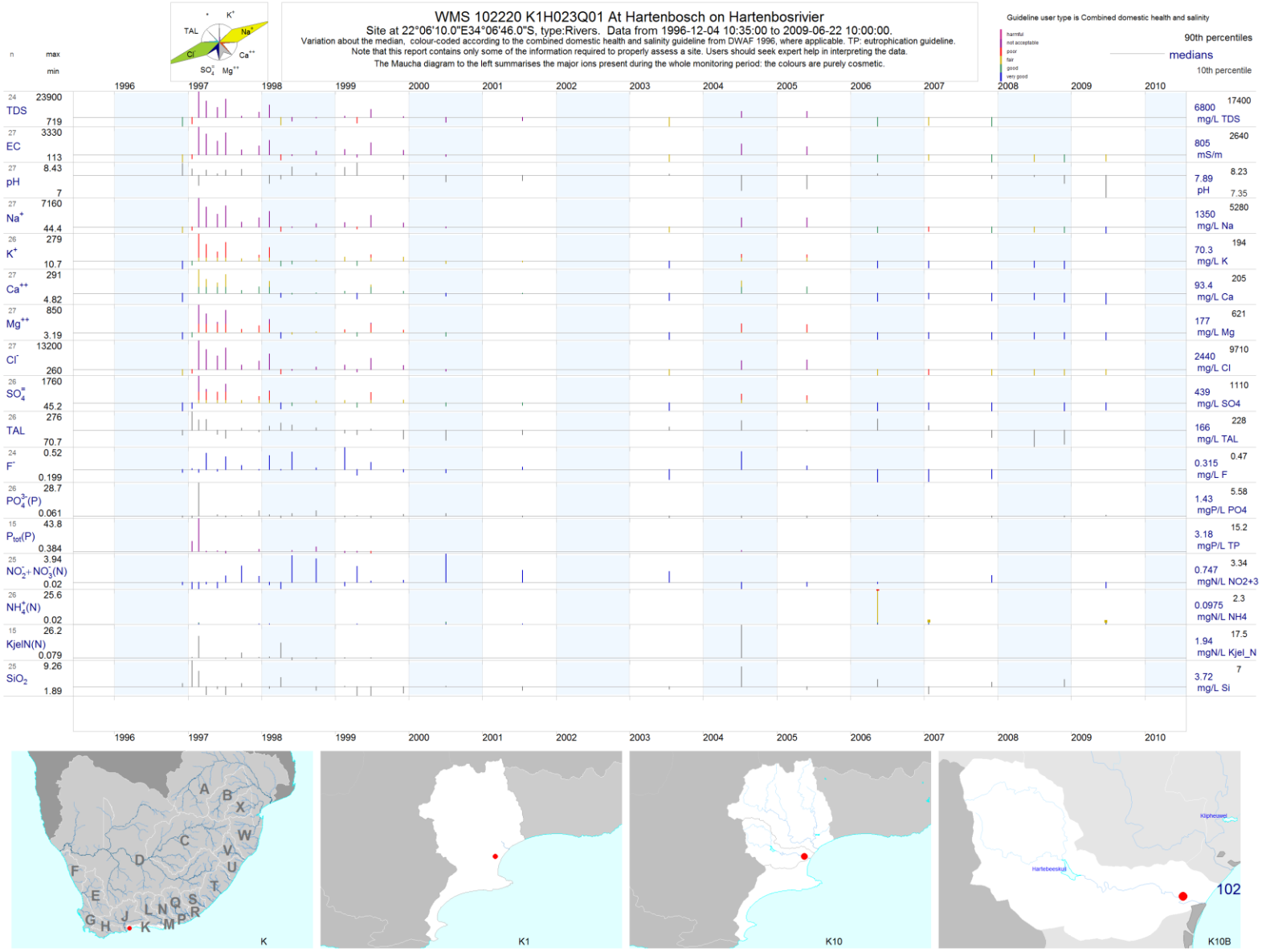
Data for 102218 from the Department of Water and Sanitation databases. Labs: DWS-RQIS, WC-TCS (SABS). Plotted at Resource Quality Information Services on 2018-03-18 20:56:54 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs


WMS 102219 K1H022Q01 At Hartenbosch on Hartenbosrivier
Site at 22°05'08.0"E34°06'35.9"S, type:Rivers. Data from 1996-12-04 10:28:00 to 2009-06-22 10:00:00.
Variation about the median, colour-coded according to the combined domestic health and salinity guideline from DWAF 1996, where applicable. TP: eutrophication guideline.
Note that this report contains only some of the information required to properly assess a site. Users should seek expert help in interpreting the data.
The Maucha diagram to the left summarises the major ions present during the whole monitoring period: the colours are purely cosmetic.
Guideline user type is Combined domestic health and salinity
harmful
not acceptable
poor
fair
good
very good
90th percentiles
medians
10th percentile
n max min
TDS 1690 497
EC 314 86.1
pH 8.44 6
Na+ 464 56.9
K+ 22.7 0.607
Ca++ 50.4 6.3
Mg++ 59.1 6.09
Cl- 841 200
SO4 106 35.3
TAL 183 51.4
F- 0.331 0.161
PO4(P) 0.08 0.005
Ptot(P) 3.54 0.012
NO2+NO3(N) 48.9 0.02
NH4(N) 0.6 0.015
KjelN(N) 0.691
SiO2 5.52 0.2
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
1190 mg/L TDS
1670
226 mS/m
282
8.04 pH
8.36
7.34
325 mg/L Na
399
7.22 mg/L K
9.08
36 mg/L Ca
48.5
43.5 mg/L Mg
51.8
594 mg/L Cl
752
53.6 mg/L SO4
68.9
120 mg/L TAL
158
0.25 mg/L F
0.32
0.021 mgP/L PO4
0.054
0.0255 mgP/L TP
0.246
0.02 mgN/L NO2+3
0.055
0.02 mgN/L NH4
0.074
0.856 mgN/L Kjel_N
1.05
1.06 mg/L Si
4.2
A B X W C V U D F E T Q S L N P R G H J K M
K
K1
K10
Klipheuwel
Harlebeesfontein
102219
K10B
Data for 102219 from the Department of Water and Sanitation databases. Labs: DWS-RQIS, WC-TCS (SABS). Plotted at Resource Quality Information Services on 2018-03-18 20:57:06 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs


WMS 102222 K1H025Q01 At Hartenbosch on Hartenbosrivier
Site at 22°06'08.9"E34°07'05.9"S, type:Rivers. Data from 1996-12-04 10:58:00 to 2005-05-30 10:05:00.
Variation about the median, colour-coded according to the combined domestic health and salinity guideline from DWAF 1996, where applicable. TP: eutrophication guideline.
Note that this report contains only some of the information required to properly assess a site. Users should seek expert help in interpreting the data.
The Maucha diagram to the left summarises the major ions present during the whole monitoring period: the colours are purely cosmetic.
Guideline user type is Combined domestic health and salinity
harmful
not acceptable
poor
fair
good
very good
90th percentiles
medians
10th percentile
n max min
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
TDS 20 31200 855 29300 18100 mg/L TDS
EC 20 4350 191 3820 2440 mS/m
pH 20 8.98 7.87 8.43 8.2 pH 7.88
Na+ 20 9390 272 8970 5600 mg/L Na
K+ 20 328 11.4 305 209 mg/L K
Ca++ 20 370 28.2 343 247 mg/L Ca
Mg++ 20 1130 34.2 1040 645 mg/L Mg
Cl- 20 17400 300 16200 10000 mg/L Cl
SO4 20 2370 67.9 2040 1310 mg/L SO4
TAL 20 249 115 238 159 mg/L TAL
F- 20 0.55 0.31 0.49 0.444 mg/L F
PO4(P) 20 1.34 0.051 1.3 0.608 mgP/L PO4
Ptot(P) 14 2.79 0.402 1.68 1.06 mgP/L TP
NO2+NO3(N) 20 1.33 0.02 0.528 0.106 mgN/L NO2+3
NH4(N) 20 0.228 0.015 0.175 0.0695 mgN/L NH4
KjelN(N) 14 4.73 0.835 1.71 1.33 mgN/L Kjel_N
SiO2 20 19.2 1.12 3.62 2.07 mg/L Si
A B X W C V U D F E T Q S L N P R G H J K M
K
K1
K10
Klipheuwel
Hartebeeskuil
102
K10B
Data for 102222 from the Department of Water and Sanitation databases. Labs: DWS-RQIS. Plotted at Resource Quality Information Services on 2018-03-18 20:57:28 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs



Data for 102221 from the Department of Water and Sanitation databases. Labs: DWS-RQIS, WC-TCS (SABS). Plotted at Resource Quality Information Services on 2018-03-18 20:53:39 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs



Data for 102220 from the Department of Water and Sanitation databases. Labs: DWS-RQIS, WC-TCS (SABS). Plotted at Resource Quality Information Services on 2018-03-18 20:57:17 using barcode.R v16.7 (macro option) under R version 3.4.1 (2017-06-30). Queries: SilberbauerM@dwa.gov.za, www.dwa.gov.za/iwqs

APPENDIX B: NATIONAL RESPONSE PROTOCOL FOR FISH KILLS

Large-scale fish kills have become a common phenomenon estuaries impacted by anthropogenic activities. The most recent fish kills in the Hartenbos Estuary occurred in January 2015, March and October 2016 and August 2017. An understanding of the causes of fish kills that may occur in future is fundamental in order to implement preventative measures to reduce their frequency and magnitude in the long-term. Grant *et al.* (2014) recognised the need for a nationally applicable response protocol for fish kills to streamline the investigation and reporting of fish kill incidents.

This protocol has four phases:

1. Pre-Incident Phase;
2. Trigger Phase;
3. Investigation Phase; and
4. Stand-down Phase.

The Protocol should be consulted for detailed explanations and actions to be taken to successfully complete each of these phases.

The pre-incident phase of a fish kill investigation represents any stage where no fish kill incident is reported or no fish kill investigation is active, and encompasses a range of ongoing tasks that will develop and maintain a level of preparedness in the event of a fish kill occurring. Such tasks include:

- interdepartmental and interdisciplinary communication;
- public awareness communication;
- obtaining and maintaining fish kill investigation kits and sample containers;
- identification and communication with relevant specialists and laboratories able to
- provide the necessary analyses; and
- training.

The remaining three phases, i.e. the Trigger Phase, the Investigation Phase and the Stand-down Phase are shown in form of decision tree diagrams in Figure B1. Figure B2 shows a recommended decision tree to establish whether a detailed fish kill investigation is required.

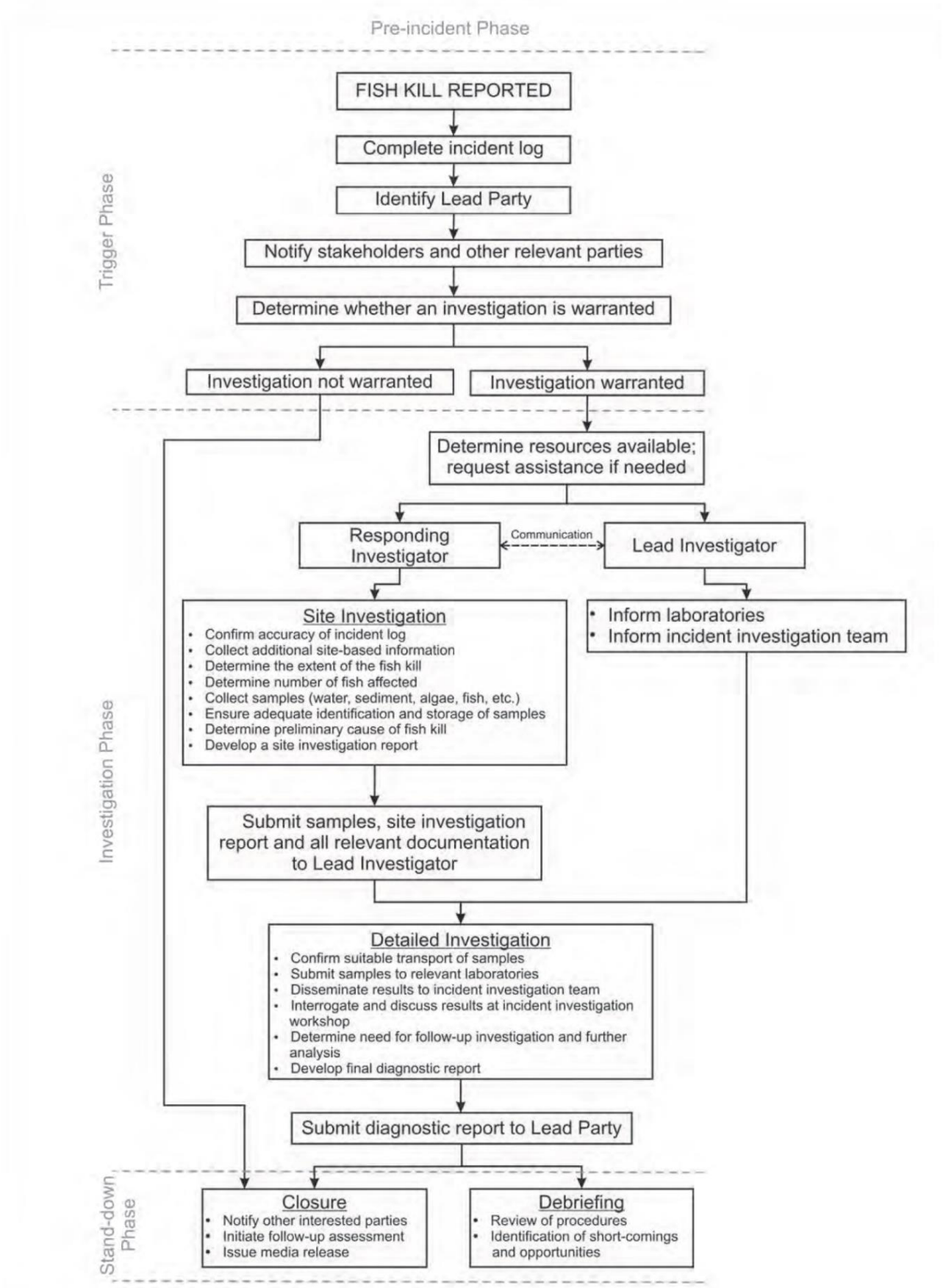


Figure B1: Fish kill investigation protocol showing steps to be taken during the Trigger, Investigation and Stand-down phases (Source: Grant et al. 2014).

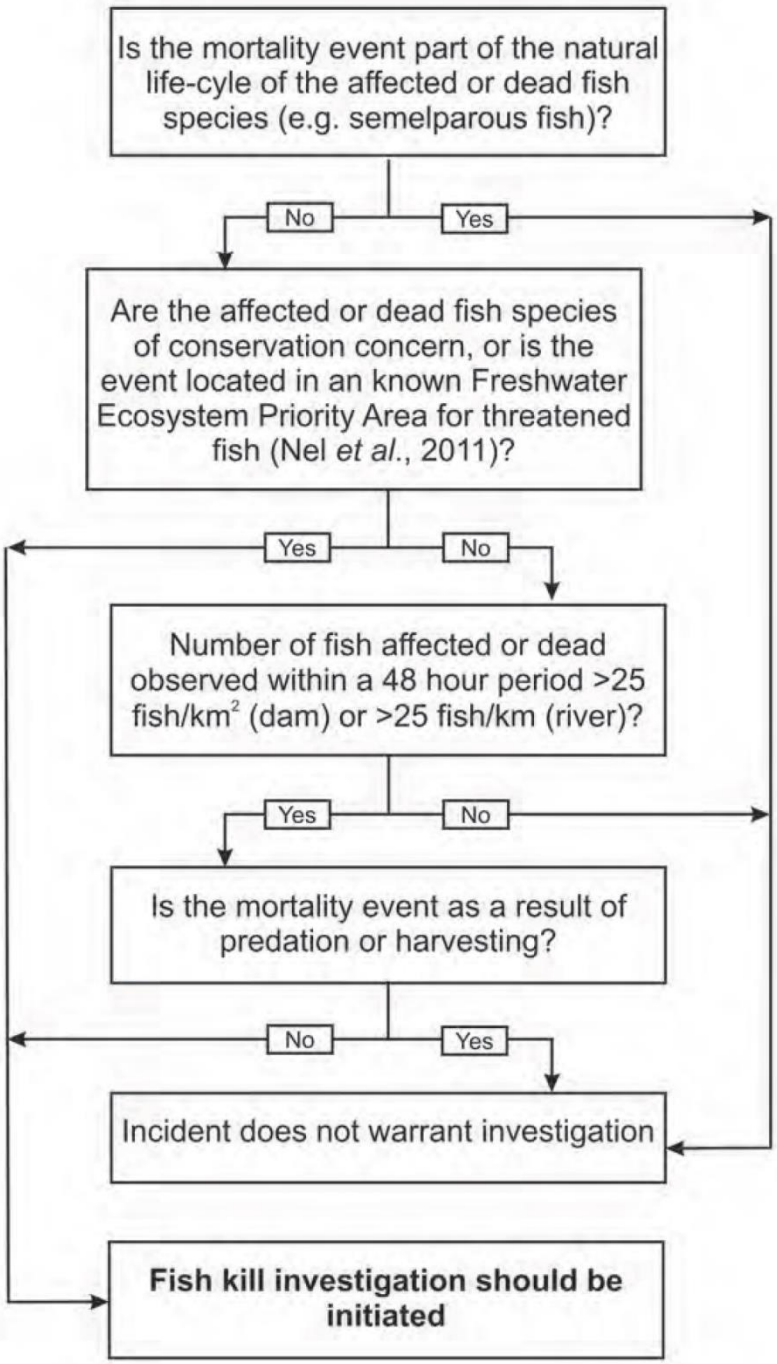


Figure B2: Recommended decision tree for determining the need for a detailed fish kill investigation (Source: Grant et al. 2014).