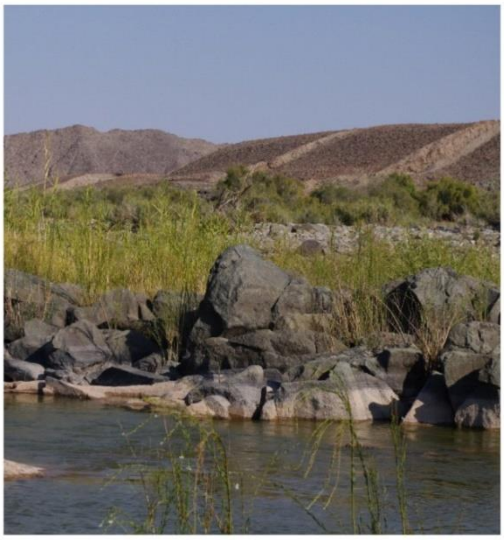
REPORT NUMBER: RDM/WMA06/00/CON/COMP/0316



PROJECT NUMBER: WP 10974

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

The Buffels, Swartlintjies, Spoeg, Groen and Sout Estuaries' Ecological Water Requirements

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

FBRUARY 2017

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

THE BUFFELS, SWARTLINTJIES, SPOEG, GROEN AND SOUT ESTUARIES ECOLOGICAL WATER REQUIREMENTS

Report Number: RDM/WMA06/00/CON/COMP/0316

February 2017

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa, February 2017. Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA. Buffels, Swartlintjies, Spoeg, Groen and Sout Estuaries Ecological Water Requirement . Authored by CSIR: L van Niekerk, J Adams, SJ Lamberth, S Taljaard for Rivers for Africa. DWS Report No: RDM/WMA06/00/CON/COMP/0316.

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DEPARTMENT OF WATER AND SANITATION
CHIEF DIRECTORATE: WATER ECOSYSTEMS

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

THE BUFFELS, SWARTLINTJIES, SPOEG, GROEN AND SOUT ESTUARIES ECOLOGICAL WATER REQUIREMENTS

Approved for RFA by:

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ACKNOWLEDGEMENTS

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The groundwater information used in this study was provided by Mr Karim Sami and was generated as as part of this study. The surface water hydrology was provided by WRP Consulting Engineers (Pty) Ltd. Delana Louw from Rivers for Africa undertook and provided cross-sectional surveys of the Buffels, Swartlientjies, Spoeg and Groen estuaries and undertook bird surveys and counts.

Report editor: Lara van Niekerk and Delana Louw

REPORT SCHEDULE

Version	Date
First draft	28 February 2017
Final	May 2017

EXECUTIVE SUMMARY

BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries and wetlands) and Groundwater in the Lower Orange Water Management Area (WMA). Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study.

PURPOSE OF REPORT

The purpose of this report is to:

- Summarise the ecological condition of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries and reflect the level of resource utilisation in their catchments and environs.
- Provide the desktop Ecological Water Requirements (EWRs) for the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries.

PRESENT ECOLOGICAL STATE (PES)

The assessment of the ecological condition of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries reflect the level of resource utilisation in their respective catchments and in their surrounding environs. A summary of some of the key pressures of the estuaries in the study area is provided in Table 1.

Table 1 Summary of the major pressures on the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Pressure	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Groundwater abstraction resulting in loss of freshwater input	●		◖	◖	
Road infrastructure/embankments trapping river inflow/floods	●	●	◖	◖	●
Mining activities (slimes dams, dust, salinization)	●	●	Future	Future	
Roads crossing in the Estuary Functional Zone	●	◖		◖	●
Floodplain development e.g. golf course, houses	●			◖	
Diffuse sewage runoff (e.g. golf course irrigation, ablution)	●			◖	
Grazing in the catchment changing sediment structure	◖	◖	◖	◖	◖
Invasive aliens, e.g. *Acacia cyclops* (rooikrans)	●				
Human disturbance/activities	●			●	●
Saltworks					●
Artificial breaching/mouth manipulation	●				?

At first glance the surface water resources were relatively untransformed. However, it was estimated that floods reaching the estuaries were significantly reduced in frequency and magnitude because of poorly designed local infrastructure (e.g. poorly designed pipe culverts in mining roads) that trapped floods and in affect act as "farm dams". This effect was especially apparent at the Buffels, Swartlintjies and Sout estuaries.

Ground water resources were severely over utilised in the Buffels Estuary catchment, while the Groen and Spoeg estuaries were also significantly affected by reduce groundwater input.

From a hydrodynamics perspective, estuary connectivity to the marine environment was disrupted, i.e. reduced breaching opportunities as a result of the reduced floods. Road infrastructure also severely impacted on the hydrodynamics (circulation and estuary longitudinal connectivity) of the Buffles and Sout estuaries - isolating the main water bodies from the upper and lower reaches. At the Buffels, Swartlintjies and Sout estuaries use of groundwater and mining activities have influenced interflow and ground water contribution to these systems, in turn changing the water table and the available water area and water depth.

Water quality showed the resulted of impact of reduced surface and groundwater input in the form of elevated salinities (Buffels and Spoeg) and extreme hyper salinity (Swartlintjies, Groen and Sout).

Except for the Buffels Estuary the water quality (as reflected in inorganic N and P, dissolved oxygen and turbidity) of the small systems in this WMA is still in a fairly good condition compared with reference. Because of the relatively high bird populations supported by these very small systems, avifauna is considered to contribute significantly to the nutrient loading. As a result, high algal productivity is often observed with ripple effects into turbidity and dissolved oxygen (associated with increased suspended algal growth/organic debris). However, in the case of the Buffels Estuary nutrient loading has increased markedly as a result of diffuse run-off from the adjacent golf course irrigated with sewage water. To a lesser extent, possible seepage from ablution facilities has increased loading in the Groen Estuary. A major uncertainty in terms of water quality relates to the extent to which extensive mining activities in the areas, as well as a salt works on the Sout Estuary, have contributed to the accumulation of toxic substances (e.g. trace metals) in these systems.

Road infrastructure has to a large extent impacted on most of the systems along this stretch of coast. Most of the estuaries had one or two roads a crossing them. Road berms have led to infilling of systems and consequential habitat destruction. Development in the floodplain and channel stabilisation has impacted circulation patterns and has resulted in localised disruption of scour and deposition processes. The catchment is also subjected to poor agricultural practise, overstocking and related increased sediment loads contributing to sedimentation and increased fines in the estuaries.

Because of the discontinuous nature of the estuaries microalgae did not show typical distribution patterns in biomass. Hypereutrophic conditions (>60 µg/l chlorophyll-a) were observed in the upper reaches of the Spoeg Estuary, lower reaches of the Groen Estuary and middle reaches of the Sout Estuary. In the Groen and Sout this was associated with hypersaline shallow conditions whereas in the Spoeg Estuary this was at a bird feeding site. Community composition reflected the prevailing salinity conditions; for example, the green alga*, Dunaliella salina* was abundant in hypersaline waters. Changes in the microalgae were in response to habitat loss i.e. decrease in water volume and increases in salinity as a result of surface and groundwater reduction.

In terms of the macrophytes the five small estuaries sampled represented a range of conditions and pressures; from the highly transformed Sout Estuary to the near pristine Spoeg Estuary. The Spoeg had patches of reeds in the upper and riverine reaches indicating seepage sites and the Groen had a stretch of reeds in the upper reaches indicating an important groundwater fed area. Submerged macrophytes only occurred in the fresher section of the Buffels and were abundant in the Spoeg Estuary indicating the biodiversity importance of this system. Macrophytes have mainly responded to the decrease in groundwater and increase in salinity as well as anthropogenic impacts that have disturbed or removed vegetation such as the mining activities at Buffels Estuary and the salt works at Sout Estuary.

Invertebrate diversity, abundance and community structure in all five estuarine systems were a function of changes in groundwater inflow, frequency and magnitude of floods, frequency and duration of breaching events and salinity gradients, including cycles within long periods of hypersalinity. Macroinvertebrates such as sandprawn Callichirus kraussi are absent from all five systems either from prolonged periods of low salinity (<16 psu) in the Buffels and Spoeg that preclude breeding or from the persistent and fatal hypersalinity in the Swartlintjies, Groen and Sout. The exceptions are freshwater crabs *Potamonautes* sp. in the pondweed and reed beds as well as in otter scat, in the upper reaches of the Groen and Spoeg and an anomalous population of the Caridean shrimp *Palaemon peringueyi* in a 70 m long pond / sump in the Sout. Based on historical accounts of the salt-works this population of *P. peringueyi* may have been isolated for more than 50 years. Small invertebrates in the Buffels, Spoeg and Groen (when not hypersaline) follow a salinity gradient with estuarine crustacean (amphipods, isopods) and oligochaetes in the lower reaches and insect larvae in the headwaters. The Swartlintjies, Sout and currently Groen are hypersaline each with a high biomass of brine shrimp *Artemia* spp. and limited diversity and abundance of halophilic Insecta. Broadly, *Artemia* hatch at salinities above 40 psu and encyst sinking to the bottom when salinities exceed 150 psu. Consequently, available biomass of *Artemia* in all three estuaries is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Lastly, three out of seven native *Artemia salina* populations in South Africa have been replaced by the invasive *Artemia franciscana* (Baxevanis *et al*., 2014). This includes the Berg Estuary Velddrift population so the status of those in other West Coast estuaries and wetlands needs to be verified.

Fish diversity, abundance and community structure in all five estuarine systems relies on recruitment that is largely a function of connectivity with the sea and driven by the frequency and duration of floods and breaching events and the degree of overwash during high seas. Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 psu. Safe return to the sea is usually during flood events and depends on a quick breaching and fish not suffocating in sediment-laden water backing up against the berm. This said, most recruitment is “suicidal” via overwash with survival depending on wave size and the height and width of the berm. Consequently, overwash recruitment diminishes with time away from a breaching event. Survival after overwash recruitment is unlikely in the hypersaline Swartlintjies and Sout and high to medium in the Spoeg, Buffels and Groen. Survival in the latter three systems depends on whether these dry up or become hypersaline before the next flood and breaching event. Survival of 8 - 10 year-old harder *Liza richardsonii* and flathead mullet *Mugil cephalus* in the Spoeg and Buffels is evidence of tolerable conditions over the 8 - 10 years since last recruitment. Previous studies have recorded *Mugil cephalus* and *Liza richardsonii* in the Groen and Spoeg Estuaries and no fish in the other three systems. The ECRU survey also recorded freshwater mullet *Myxus capensis* in the Spoeg Estuary but this needs verification. Fish in the Buffels Estuary have now been verified and again none in the hypersaline Swartlintjies and Sout. *L. richardsonii* and *M. cephalus* were sampled in the Buffels and Spoeg estuaries as well as a breeding population of goby *Caffrogobius* spp. in the latter system. Fish are currently absent in the Groen Estuary in its hypersaline state. With the possible exception of the Spoeg, hypersalinity and fish mortality are characteristic of these West Coast systems. In addition to this, fish mortalities in the Buffels Estuary are a “regular” occurrence arising from eutrophication and low oxygen events or from suffocation in floodwaters backed up against poorly planned roads and causeways.

MINING ACTIVITIES

A major concern is the planned escalation of mining activities in and around the Namaqualand National Park. Mining in close proximity to the estuaries can hold the following risk for the Swartlintjies, Spoeg and Groen estuaries:

- Disruption of subsurface flow.
- Wind-blown sand that smother estuarine and wetland vegetation.
- Increase sedimentation.
- Loss of salinity gradient in soil and water body (fresh at top and saline in lower reaches).
- Possible leaching of heave metals from mine dumps.

Table 2 provides a summary of the Ecological Categories of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries.

Table 2 Ecological categories of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Component Category	Buffels	Swartlintjies	Spoeg	Groen	Sout
Hydrology	D/E	B	B/C	C	D/E
Hydrodynamics	D	B	B	C	E/F
Water quality	D	B	A/B	B	D
Physical habitat alteration	D	B	A/B	A	E
Habitat health	D	B	B	B	D/E
Microalgae	D	B	A/B	B	E
Macrophytes	E	C	A	B	E/F
Invertebrates	D	C/D	A	C	E
Fish	E	B	A	B	E/F
Birds	D	A/B	A	B	E
Biotic health	D/E	B/C	A	B	E
PES	↓ D	B	A/B	B	E
Confidence	Low	Low	Low	Low	Low

ESTUARY IMPORTANCE

Ecological Importance

The Estuary Importance Score for an estuary takes size, the rarity of the estuary type within its biographical zone, habitat diversity and biodiversity importance of the estuary into account (DWAF, 2008). Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its natural condition. The scores were determined by specialists during the November 2016 EWR workshop (DWAF, 2008). The small estuaries of Lower Orange WMA were rated on a 0 to 100 scale to provide an indication of their biodiversity importance in the region (Table 3, 4 and 5) (DWAF, 2008).

Table 3 Importance rating

Importance score	Comment
0 - 20	Little
20.1 - 40	Some
40.1 - 60	Important
60.1 - 80	Very important
80.1 -100	Extremely important

The functional importance of an estuary provides a measure of the role a specific estuary plays in the larger land- and seascape. The functional importance of these systems was relatively high as collectively they contribute to a very rare and limited “wetland habitat type” for estuarine and coastal birds along the dry Namaqualand Coast.

Table 4 The Functional Importance of the estuaries of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Calculation of the functional importance score	Buffels	Swartlintjies	Spoeg	Groen	Sout
a) Estuary derived detritus and nutrients to the sea	20	20	20	20	20
b) Nursery function for marine-living fish	20	0	20	20	0
c) Movement corridor for river invertebrates and fish breeding in sea	0	0	0	20	0
d) Contribute to a very limited wetland type habitat for estuarine and coastal birds along arid coast	**80**	**60**	**80**	**60**	**60**
e) Catchment sediments provided to the sea	40	40	40	40	20
f) Coastal connectivity (way piont) for fish	40	10	40	10	0
g) Movement corridor for mammals (mongoose and otters)	40	40	40	40	20
Functional importance score Max (a) to (g)	**80**	**60**	**80**	**60**	**60**
Functional importance rating	**Very important**	**Important**	**Very important**	**Important**	**Important**

Table 5 The Estuarine Importance of the estuaries of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Estuarine Importance	Buffels	Swartlintjies	Spoeg	Groen	Sout
Size	50	70	70	70	100
Zonal Type Rarity	30	30	30	30	30
Habitat diversity	60	50	60	60	30
Biodiversity Importance	13	10	15	10	10
Functional importance	**80**	60	80	60	60
Estuarine Importance Score	**49**	44	52	46	43
Estuarine Importance	**Average Importance**	**Average Importance**	**Average Importance**	**Average Importance**	**Average Importance**

Conservation Importance of the Lower Orange WMA Estuaries

The National Biodiversity Assessment 2011 (NBA, 2011) (Van Niekerk and Turpie, 2012; Turpie *et al*., 2012) developed a biodiversity plan for the estuaries of South Africa by prioritising and establishing which of them should be assigned partial or full Estuarine Protected Area (EPA) status. This biodiversity plan followed a systematic approach that took pattern, process and biodiversity persistence into account. While the plan has not explicitly taken social and economic costs and benefits into consideration, it used ecosystem health as a surrogate for the former. This is because estuaries where the opportunity costs of protection are likely to be high are also likely to be heavily-utilised systems that are in a lower state of health.

The plan indicates that, on a national scale 133 estuaries (61 require full protection and 72 require partial protection) including those already protected, would be required to meet biodiversity targets (Turpie *et al*., 2012). Of these, three occur within the Lower Orange WMA, with a subset of two estuaries requiring full protection (Groen and Spoeg).

Fully protected estuaries are taken to be full no-take areas. Partial protection might involve zonation that includes a no-take area, or it might address other pressures with other types of action. In both these cases, the management objective would be to protect 50% of the biodiversity features of the partially protected estuary. Fully protected and partially protected estuaries can be considered Estuarine Protected Areas, whereas all other estuaries should be designated Estuarine Management Areas. All estuaries require a Management Plan and these plans should be guided by the results of this assessment.

RECOMMENDED ECOLOGICAL CATEGORY

The Recommended Ecological Category (REC) signifies the level of protection assigned to an estuary. The relationship between Estuary Health Index (EHI) score, PES and minimum REC is given in Table 6. Table 7 summarised the degree to which the REC for the Buffels, Swartlintjies, Groen, Spoeg and Sout estuaries needs to be elevated above the PES depending on the estuary **importance** and the level of **protection** (**conservation importance)** of a particular estuary (Table 6).

Table 6 Estuary protection status and importance, and the basis for assigning a recommended ecological reserve category (modified from DWA, 2008)

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area		
Extremely important (Ranked as 1)	PES + 1, min B	Highly important estuaries should be in an A or B category
Very Important (Ranked as 2)	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance (Ranked as 3)	PES, min D	Estuaries to remain in a D category

* BAS - Best Attainable State

The REC for the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries is listed in Table 7.

Table 7 The Recommended Ecological Category for the estuaries of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Component	Buffels	Swartlintjies	Spoeg	Groen	Sout
Present Ecological Status	↓ D	B	A/B	B	E
Functional Importance as wetland/estuary type in along arid coast	Very important	Important	Very important	Important	Important
Estuarine Importance	Average Importance	Average Importance	Average Importance	Average Importance	Average Importance
Conservation Importance (in Namaqualand National Park)			High	High	
Recommended Ecological Category	D	B	A/B	A/B	D

EWR RECOMMENDATIONS

Table 8 provides an overview of the PES, estuary importance, REC and associated EWR requirements. In all but one system no additional freshwater water is required to maintain/achieve the REC. In the case of the Spoeg Estuary provisional results indicate that the system require additional groundwater to achieve the REC. This requirement needs to refined with additional monitoring results (e.g. boreholes, estuary salinity) as very little information is available on the long term trends and responses to groundwater on this coast.

Table 8 Estuaries EWR and recommendations

Component	Estuary				
	Buffels	Swartlintjies	Spoeg	Groen	Sout
Reference MAR (Mm^3/a)	11.2	1.2	1.3	5.5	0.7
Reference groundwater discharge (Mm^3/a)	0.23	0.63	0.36	0.13	1.24
Present groundwater discharge (Mm^3/a)	-0.84	0.59	0.22	0.08	1.13
Present Ecological Status	↓ D	B	A/B	B	E
Estuarine Importance	Average Importance	Average Importance	Average Importance	Average Importance	Average Importance
Conservation Importance (in Namaqualand National Park)			**High**	**High**	
Recommended Ecological Category	D	B	A/B	A/B	D
Surface water flow mitigations	↑ floods (road culverts)	↑ floods (road culverts)			↑ floods (weir)
Groundwater mitigations				↑ 20%	
Water Quality Mitigations	×			×	
Non-Flow related Mitigations	×			×	×
Potential for further water resource development without impacting on ecology	No	No	No	No	No

Table 9 list interventions required to maintain or achive the REC the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries.

Table 9 Detail recommendations on interventions/actions required to maintain or achieve the REC

Estuary	Recommendations on interventions/actions
Buffels	▪ Develop an Estuary Management Plan (in progress) to evaluate to what extent functionality can be restored. ▪ Restore connectivity with the marine environment during floods by the complete removal of the remnants of the mining road that still transects the mouth. This would allow for rapid breaching during floods and prevent fish getting smother by high silt content in floodwaters. ▪ Improve estuarine connectivity / freshwater flow through the removal of roads at bird hide and above golf course; ▪ Address diffuse runoff from golf course to prevent nutrient enrichment and associated fish kills. ▪ Control wind-blown dust (smother plants) and wastewater (seawater increase soil salinities) from mining activities. ▪ Remove alien invasive plant species (rooikrans) in upper estuary (ongoing process). ▪ No driving on the beach to facilitate sedimentary processes and protect bird life (ongoing process).
Swartlintjies	▪ Develop an Estuary Management Plan (in progress) to evaluate to what extend old slimes dam is impacting on estuary and how functionality can be restored if required. ▪ Protect groundwater input to ensure hypersalinity is below <150 psu (brine shrimp goes to cyst). ▪ Restore catchment connectivity (i.e. improve surface water flow) - increase culvert size / culverts at ground level in road crossings. ▪ Estuary in the process of recovering from previous mining activities, allow this process to continue. A concern is the impact of future mining prospects
Spoeg	▪ Restore / protect groundwater. ▪ Allow regrowth of vegetation on derelict access roads crossing the upper reaches to continue. ▪ Impact of proposed mining: Wind blow sand & increase salinity via surface/ground water flow.
Groen	▪ Restore/improve groundwater flow by 20% from current levels of 60% utilisation to 80%. ▪ Investigate possible organic/nutrient seepage from ablution facilities of offices/homes at SANParks and means to address these. ▪ The estuary has a strong dependency on groundwater fed springs to maintain salinity gradient, maintain water levels, limit occurrence of extreme hyper salinity (<150 psu). ▪ Future pressures include an escalation of mining activities in the national park and related disruption of subsurface flow.
Sout	▪ Develop an Estuary Management Plan (Western Cape Government in the processes of prioritising this system for a plan) to evaluate to what extend the current design and/or operations of the salt works can be improved to restore estuarine habitat and functionality of the upper reaches. ▪ Improve circulation (e.g. culverts in roads). ▪ Restore connectivity with catchment, i.e. investigate if weir can be partially removed to allow connectivity with western arm of estuary.

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ABBREVIATIONS

BHN	Basic Human Needs
BAS	Best Attainable State
CD: WE	Chief Directorate: Water Ecosystems
DWS	Department of Water and Sanitation
DWA	Department Water and Sanitation
DWAF	Department Water and Sanitation and Forestry
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
EWR	Ecological Water Requirements
EHI	Estuarine Health Index
EPA	Estuarine Protected Area
EFZ	Estuary Functional Zone
EIS	Estuary Importance Score
HPLC	High-performance liquid chromatography
HF	Hydraulic fracturing
ICMA	Integrated Coastal Management Act
MAR	Mean Annual Runoff
MSL	Mean Sea Level
NBA	National Biodiversity Assessment
PSD	Particle Size Distribution
PES	Present Ecological State
PSP	Professional Service Provider
REC	Recommended Ecological Category
TOR	Terms of Reference
TPC	Threshold of Potential Concern
WMA	Water Management Area

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the ‘Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries, and Wetlands) and Groundwater in the Lower Orange Water Management Area (WMA).The appointed Professional Service Provider (PSP) to undertake this studywasRivers for Africa.

As per the Terms of Reference (TOR), there is a need to undertake detailed Ecological Water Requirement (EWR) and Basic Human Needs (BHN) studies for various water resource components due to mainly:

- Planned hydraulic fracturing (HF) undertaken in the WMA.
- Various water use licence applications.
- The conservation status of various Resources in this catchment; and
- The associated impacts of proposed developments will have on the availability of water.

1.2 STUDY AREA

As indicated in the TOR, the study area is the Lower Orange River WMA (previous WMA 14). It is the largest WMA in the country and covers almost the entire Northern Cape Province. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States, i.e. Lesotho (Senqu River originating in the highlands), Botswana in the north-eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa. The focus area of the study comprises only the South African portion of the Lower Orange River Catchment. The Eastern Boundary starts where the Vaal River enters the Orange River, and the Western Boundary is the Atlantic Ocean. The study area is downstream of the Upper Orange, Senqu, and the Integrated Vaal River System and as such, affected by the upstream activities in the highly developed river basin. The Orange River forms the border between the Republic of South Africa (RSA) and Namibia to the west of 20 degrees longitude over a distance of approximately 550 km.

1.3 PURPOSE OF THIS REPORT

This task consists of the EcoClassification and EWR determination of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries.

The purpose of this report is to summarise the following for the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries:

- The major pressures contributing to the condition of the systems;
- Determine the Present Ecological State (PES).
- Evaluate the Estuarine Importance.
- Set the Recommended Ecological Category (REC).
- Provide a desktop EWRs.
- Set the EcoSpecs for the RECs; and
- Develop an Estuary Monitoring Programme.

1.4 ASSUMPTIONS AND LIMITATIONS FOR THIS STUDY

The following assumptions and limitations should be taken into account:

- The accuracy and confidence of an Estuarine EWRs study are strongly dependent on the quality of the hydrology information. The overall confidence in the hydrology data supplied to the estuarine study team is of a low level, with a particular concern regarding the accuracy of the simulated floods reaching the estuary (Confidence = Low).
- The degree to which the Lower Orange WMA Estuary EWR study can address the objectives of the overall Lower Orange WMA study is seriously constrained by the lack of long-term monitoring data available in the study area (e.g. groundwater inflow and levels, river inflow and estuary water level data). Without supporting information, critical aspects such as the estuary specific responses to groundwater / surface water input and estuary mouth states and related water quality conditions cannot be resolved to any degree of confidence.
- No information were available on the degree to which local structure (roads and weirs) were reducing/preventing floods from reaching the estuaries in the study area. Estimates were made during the workshop, but needs to be confirmed in higher confidence studies by more in-depth analyse as the effect can be severe and lead direct to loss of connectivity with the sea.
- No information was available on the impact of the old mining slimes dam above the Swartlintjies Estuary on the salinity regime of the system. The slimes dam could be one of the major causes for the loss of a salinity gradient in the Swartlintjies. During this study the specialists assumed that the impact was limited, but it needs to be verified by boreholes and salinity measurements.

1.5 OUTLINE OF THIS REPORT

The report outline is provided below.

Chapter 1: Introduction
This chapter provides the background and an overview of the study area.

Chapter 2: Method
Chapter 2 explains the approach taken in delineating the five estuaries. It also provides detail on the determination of the PES, Estuary Importance and REC.

Chapter 3: Baseline Description and Health Assessment
This section provides the detailed findings on the Present Ecological State of the estuaries in this WMA.

Chapter 4: The Recommended Ecological Category
This chapter highlights the conservation and biodiversity importance of the estuaries in the region. The Recommended Ecological Category is then determined for the individual system based on its importance.

Chapter 5: EWR Recommendations
This section summarises the remedial actions required to improve the condition of individual systems.

Chapter 6: Estuary Baseline and Long-Term Monitoring Requirements in support of Higher Level EWR Studies
This section summarises the remedial actions required to improve the condition of individual systems as well the monitoring requirements to improve confidence in future studies.

Chapter 7: Resource Quality Objectives

This section provides the EcoSpecs for the small estuaries of the Lower Orange for the REC.

Appedix A to E offers the detail on the desktop EWR of the individual systems:

- Appendix A. The Buffels Estuary Desktop EWR.
- Appendix B. The Swartlintjies Estuary Desktop EWR.
- Appendix C. The Spoeg Estuary Desktop EWR.
- Appendix D. The Groen Estuary Desktop EWR.
- Appendix E. The Sout Estuary Desktop EWR.

Appedix F includes additional detail on the microalagae and macrophytes.

2 METHOD

2.1 DELINEATION OF LOWER ORANGE WMA ESTUARIES

Over longer time scales the total area occupied by the various estuarine habitat types tends to remain more or less constant, while the actual spatial location of these various estuarine habitats is highly likely to change between resetting events (e.g. larger floods). This relatively ephemeral nature of estuarine habitat presents an assessment and planning challenge. Water resource protection requires the delineation of the geographical boundaries of the resource. In order to do this it is important to define the space within which estuaries function to ensure their present and future health.

Mapping was undertaken of nearly 300 functional estuarine systems along the South African coastline as part of the National Biodiversity Assessment 2011 (NBA, 2011) (Van Niekerk and Turpie, 2012; Turpie *et al*., 2012). For each estuary the estuarine functional zone (estuarine ecosystem area) and open water areas were digitized using Spot 5 imagery (2008) and Google Earth. For the most part the images were relatively cloud free, but where cloudy conditions occurred on SPOT 5 images, Google images were used. The lateral boundaries included all the associated wetlands, intertidal mud and sand flats, beaches and foreshore environments that are affected by riverine or tidal flood events. The 5 m topographical contour (obtained from Chief Directorate Surveys and Mapping) was used as the boundary to delineate the estuarine functional zone. Where the 5 m contour was not available in digital format, orthophotos (1:10 000) were scanned, georeferenced and the 5 m contour was digitized. Were no contour data was available, i.e. Groen and Spoeg estuaries) vegetation was used as an indicator of elevation change. From the estuarine functional zone delineation, spatial data such as area, length and perimeter (estuary coastline) and distance to the next system could be inferred.

The estuary mouth was taken as the downstream boundary of an estuary 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, whichever penetrates furthest up the system. This is in line with recent scientific studies and the administrative definition of a South African estuary (DWAF, 2008).

Wherever possible the upstream boundary was derived from the literature, expert judgment or field observations. In a number of systems no data were available and the upper boundary was taken as the 5 m topographical contour (bearing in mind that the tidal range in South Africa is microtidal (< 2 m) and sand bars at closed estuary mouths can sometimes build up as high as + 4.5 m Mean Sea Level (MSL). Spatially, files were converted to GoogleEarth (KMZ formats) and reviewed during the desktop health for comment. Systems that need additional ground truthing were identified.

The delineation was ground truthed during the October 2016 field visit.

2.2 PRESENT ECOLOGICAL STATE

The Lower Orange WMA Estuarine Health Assessment was conducted as a desktop procedure during which a regional team of specialists evaluated estuary health based on the general characteristics of the estuaries. The method used was a standardized approach developed for determining the ecological water requirements of South Africa's estuaries which has been applied to about 30 systems along the coast and applied in the National Biodiversity Assessment in 2009

(Van Niekerk and Turpie, 2012). All the specialists that contributed to the assessment were familiar with the Estuarine Health Index (EHI) from previous DWS studies.

The health condition (also called the PES) of an estuary is typically defined on the basis of current condition (i.e., the extent to which it differs from its reference or natural condition). Based on the above, estuary condition is described using six Ecological Categories (EC), ranging from natural (A) to critically modified (F) (Table 2.1). The fact that the physical conditions in estuarine systems are more dynamic than those of other aquatic ecosystems means that severe degradation of an estuary may involve a shift from a dynamic to a more stable, or unidirectional, system. This means that the loss of dynamic function *per se* is an important indication of declining estuarine health (DWAF, 2008). Thus, in an estuarine health assessment, measures of these different states need to be sufficiently robust so that different practitioners/disciplines will arrive at the same categorisation.

Table 2.1 Ecological Categories (DWAF, 2008)

Health Condition	Description
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions and processes are essentially unchanged.
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions and processes are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions and processes have occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions and processes are extensive.
F	Critically/Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions and processes have been destroyed and the changes are irreversible.

The EHI was calculated through consideration of the following components (DWAF, 2008):

A. Abiotic	B. Biotic
▪ Hydrology (% change in Mean Annual Runoff - MAR) ▪ Hydrodynamics and mouth condition ▪ Water chemistry (salinity and combined score for other variables) ▪ Sediment processes	▪ Microalgae ▪ Macrophytes ▪ Invertebrates ▪ Fish ▪ Birds

The assessment was undertaken by a multidisciplinary group of estuarine scientists in a workshop setting, based on their collective understanding of the likely impacts affecting each system. Expert knowledge and available information were used to build a "picture" of the probable pristine state of each estuary and the changes under current conditions. The EHI is applied to all levels of ecological water requirement studies (comprehensive, intermediate or rapid), with only the level of information supporting the study and level of confidence varying. For each variable the conditions are estimated as a percentage (0 – 100%) of the pristine health. Scores are then weighted and aggregated so that the final score reflects the present health of the estuary as a percentage of the pristine state (Figure 2.1). Both abiotic and biotic variables are included as the relationships between the abiotic and biotic variables are often not well understood and because the biotic response to certain abiotic variables can be lagging.

For comparative reasons (with previous assessments) the individual health scores were aggregated as illustrated in Figure 2.2 and Table 2.2. In estuaries, unlike the terrestrial environment, degradation or loss of habitat seldom means a complete loss of system health or function. This can only happen if an estuary becomes completely degraded, e.g. changed into a parking lot or golf course. In most cases, degradation means loss of processes or loss of biological functionality, e.g. the estuarine space is filled with a different salinity condition or different species composition. This loss of functionally happens on a continuum, with estuaries which retain more than 90% of their natural processes and pattern being rated as Excellent and estuaries degraded to less of 40% of natural functionality rated as Poor.

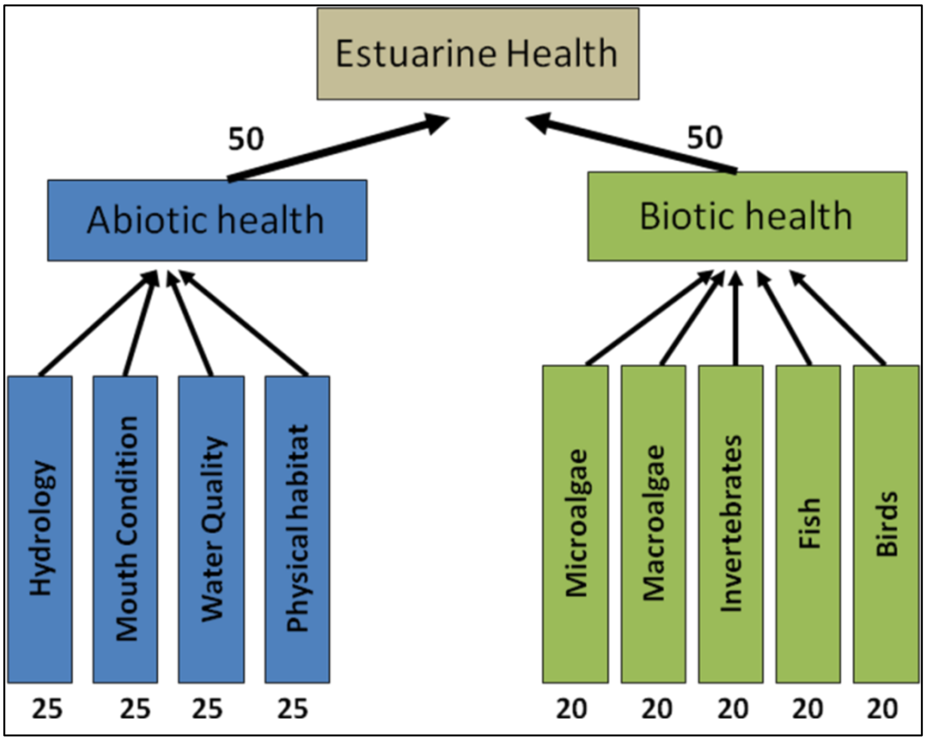

Figure 2.1 Components and weightings of the Estuarine Health Index (DWAF, 2008)

Table 2.2 Schematic illustration of the relationship between loss of ecosystem condition and functionality

Condition	≥91%	90-75	75 - 61	60 - 41	40-21	≤20
Category	A Natural	B Largely natural with few changes	C Moderately modified	D Largely modified	E Highly degraded	F Extremely degraded
State	Excellent	Good	Fair		Poor	
Functionality	Retain Process & Pattern (representation)		Loss of Process or Pattern		No Process & Pattern	

2.3 ESTUARY IMPORTANCE

The ecological importance of an estuary is an expression of its importance to the maintenance of biological diversity and ecological functioning on a regional, national or global scale. The national

Estuary Importance Score (EIS) for an estuary takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (DWAF, 2008). Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its natural condition.

2.4 RECOMMENDED ECOLOGICAL CATEGORY

The Recommended Ecological Category (REC) represents the level of protection assigned to an estuary. The first step is to determine the 'minimum' EC, based on its PES. The relationship between EHI score, PES and minimum REC is given in Table 2.3.

Table 2.3 Relationship between the EHI, PES and minimum REC

EHI score	PES	Description	Minimum EC
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

Thus PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of **importance** and level of **protection or desired** protection of a particular estuary (Table 2.4).

Table 2.4 Estuary protection status and importance, and the basis for assigning a recommended ecological reserve category (modified from DWAF, 2008).

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health.
Desired Protected Area		
Extremely important (Ranked as 1)	PES + 1, min B	Highly important estuaries should be in an A or B category.
Very Important (Ranked as 2)	PES + 1, min C	Important estuaries should be in an A, B or C category.
Of low to average importance (Ranked as 3)	PES, min D	Estuaries to remain in a D category.

* BAS - Best Attainable State.

2.5 DEFINITION OF CONFIDENCE LEVELS

The level of available historical data in combination with the level of effort expended during the assessment determines the level of confidence of the study. Three levels of study have been recognised in the past in terms of the effort expended during the assessment – rapid (low confidence), intermediate (medium confidence) and comprehensive (high confidence). In this study, effort lay somewhere between a low and medium confidence study, in that very limited historical field data were available that would allow for the correlation between river inflow, mouth state and water quality parameters. Therefore the confidence of the study is low. This is a situation that can only be remedied with some comprehensive and long-term data collection on the system. Criteria for the confidence limits attached to statements in this study are shown in Table 2.5.

Table 2.5 Confidence levels for an Estuarine EWR study (DWAF, 2008)

Confidence level	Situation	Expressed as percentage
Low	If no data were available for the estuary or similar estuaries	< 40 certainty
Medium	If limited data were available for the estuary or other similar estuaries	40 – 80% certainty
High	If sufficient data were available for the estuary	> 80% certainty

3 BASELINE DESCRIPTION AND HEALTH ASSESSMENT

3.1 PRESENT ECOLOGICAL STATE (PES)

The assessment of the ecological condition of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries reflect the level of resource utilisation in their respective catchments and in their surrounding environs.

Table 3.1 summarises some of the key pressures of the estuaries in the study area.

Table 3.1 Summary of the major pressures on the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Pressure	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Groundwater abstraction resulting in loss of freshwater input	●		◖	◖	
Road infrastructure/embankments trapping river inflow/floods	●	●	◖	◖	●
Mining activities (slimes dams, dust, salinization)	●	●	**Future**	**Future**	
Roads crossing in the Estuary Functional Zone (EFZ)	●	◖		◖	●
Floodplain development e.g. golf course, houses	●			◖	
Diffuse sewage runoff (e.g. golf course irrigation, ablution)	●			◖	
Grazing in the catchment changing sediment structure	◖	◖	◖	◖	◖
Invasive aliens, e.g. *Acacia cyclops* (rooikrans)	●				
Human disturbance/activities	●			●	●
Saltworks					●
Artificial breaching/mouth manipulation	●				?

Interflow is defined as discharge from unsaturated zone contributing to hydrograph recession following a large storm event. Discharge from perched water tables to springs located above low permeability layers, which may cause prolonged baseflow following rain events, even when the regional water table is below the stream channel. Groundwater baseflow is defined as discharge from the regional aquifer to surface water as baseflow to river channels, either to perennial effluent or intermittent streams; or as seepage to permanent or temporary wetlands. Baseflow is the portion of subsurface water which contributes to the low flow of rivers for the ecology It can originate as either from the regional groundwater body (groundwater baseflow), that portion of the total water resource that can either be abstracted as ground water or surface water, or via perched aquifers. In catchments with significant relief and geological heterogeneities, a large part of the baseflow fraction never passes through the regional aquifer. Therefore, not all recharge is a groundwater resource, only the portion of Baseflow re-emerging as groundwater baseflow can be impacted by abstraction. Subsurface water which does not flow through the regional aquifer (interflow) is not available to boreholes and cannot be impacted by boreholes. A distinction needs to be made between recharge entering the regional aquifer (aquifer recharge) and recharge which enters the subsurface zone.

At first glance the surface water resources were relatively untransformed. However, it was estimated that floods reaching the estuaries were significantly reduced in frequency and magnitude because of poorly designed local infrastructure (e.g. poorly designed pipe culverts in mining roads) that trapped floods and in affect act as “farm dams”. This effect was especially apparent at the Buffels, Swartlintjies and Sout estuaries.

Ground water resources were severely over utilised in the Buffels Estuary catchment, while the Groen and Spoeg estuaries were also significantly affected by reduce groundwater input.

From a hydrodynamics perspective, estuary connectivity to the marine environment was disrupted, i.e. reduced breaching opportunities as a result of the reduced floods. Road infrastructure also severely impacted on the hydrodynamics (circulation and estuary longitudinal connectivity) of the Buffles and Sout estuaries - isolating the main water bodies from the upper and lower reaches. At the Buffels, Swartlintjies and Sout estuaries use of groundwater and mining activities have influenced interflow and ground water contribution to these systems, in turn changing the water table and the available water area and water depth.

Water quality showed the resulted of impact of reduced surface and groundwater input in the form of elevated salinities (Buffels and Spoeg) and extreme hyper salinity (Swartlintjies, Groen and Sout).

Except for the Buffels Estuary the water quality (as reflected in inorganic N and P, dissolved oxygen and turbidity) of the small systems in this WMA is still in a fairly good condition compared with reference. Because of the relatively high bird populations supported by these very small systems, avifauna is considered to contribute significantly to the nutrient loading. As a result, high algal productivity is often observed with ripple effects into turbidity and dissolved oxygen (associated with increased suspended algal growth/organic debris). However, in the case of the Buffels Estuary nutrient loading has increased markedly as a result of diffuse run-off from the adjacent golf course irrigated with sewage water. To a lesser extent, possible seepage from ablution facilities has increased loading in the Groen Estuary. A major uncertainty in terms of water quality relates to the extent to which extensive mining activities in the areas, as well as a salt works on the Sout Estuary, have contributed to the accumulation of toxic substances (e.g. trace metals) in these systems.

Habitat modification: Road infrastructure has, to a large extent, impacted on most of the systems along this stretch of coast. Most of the estuaries had one or two roads a crossing them. Road berms have led to infilling of systems and consequential habitat destruction. Development in the floodplain and channel stabilisation has impacted circulation patterns and has resulted in localised disruption of scour and deposition processes. The catchment are also subjected to poor agricultural practise, overstocking and related increased sediment loads contributing to sedimentation and increased fines in the estuaries.

Because of the discontinuous nature of the estuaries microalgae did not show typical distribution patterns in biomass. Hypereutrophic conditions (>60 µg/l chlorophyll-a) were observed in the upper reaches of the Spoeg Estuary, lower reaches of the Groen Estuary and middle reaches of the Sout Estuary. In the Groen and Sout this was associated with hypersaline shallow conditions whereas in the Spoeg Estuary this was at a bird feeding site. Community composition reflected the prevailing salinity conditions; for example, the green alga, *Dunaliella salina* was abundant in hypersaline waters. Changes in the microalgae were in response to habitat loss i.e. decrease in water volume and increases in salinity as a result of surface and groundwater reduction.

In terms of the macrophytes the five small estuaries sampled represented a range of conditions and pressures; from the highly transformed Sout Estuary to the near pristine Spoeg Estuary. The

Spoeg had patches of reeds in the upper and riverine reaches indicating seepage sites and the Groen had a stretch of reeds in the upper reaches indicating an important groundwater fed area. Submerged macrophytes only occurred in the fresher section of the Buffels and were abundant in the Spoeg Estuary indicating the biodiversity importance of this system. Macrophytes have mainly responded to the decrease in groundwater and increase in salinity as well as anthropogenic impacts that have disturbed or removed vegetation such as the mining activities at Buffels Estuary and the salt works at Sout Estuary.

Invertebrate diversity, abundance and community structure in all five estuarine systems were a function of changes in groundwater inflow, frequency and magnitude of floods, frequency and duration of breaching events and salinity gradients, including cycles within long periods of hypersalinity. Macroinvertebrates such as sandprawn *Callichirus kraussi* are absent from all five systems either from prolonged periods of low salinity (<16 psu) in the Buffels and Spoeg that preclude breeding or from the persistent and fatal hypersalinity in the Swartlintjies, Groen and Sout. The exceptions are freshwater crabs Potamonautes sp. in the pondweed and reed beds as well as in otter scat, in the upper reaches of the Groen and Spoeg and an anomalous population of the Caridean shrimp *Palaemon peringueyi* in a 70 m long pond / sump in the Sout. Based on historical accounts of the salt-works this population of *Peringueyi* may have been isolated for more than 50 years. Small invertebrates in the Buffels, Spoeg and Groen (when not hypersaline) follow a salinity gradient with estuarine crustacean (amphipods, isopods) and oligochaetes in the lower reaches and insect larvae in the headwaters. The Swartlintjies, Sout and currently Groen are hypersaline each with a high biomass of brine shrimp *Artemia* spp. and limited diversity and abundance of halophilic Insecta. Broadly, *Artemia* hatch at salinities above 40 psu and encyst sinking to the bottom when salinities exceed 150 psu. Consequently, available biomass of *Artemia* in all three estuaries is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Lastly, three out of seven native *Artemia salina* populations in South Africa have been replaced by the invasive *Artemia franciscana* (Baxevanis *et al*., 2014). This includes the Berg Estuary Velddrift population so the status of those in other West Coast estuaries and wetlands needs to be verified.

Fish diversity, abundance and community structure in all five estuarine systems relies on recruitment that is largely a function of connectivity with the sea and driven by the frequency and duration of floods and breaching events and the degree of overwash during high seas. Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 psu. Safe return to the sea is usually during flood events and depends on a quick breaching and fish not suffocating in sediment-laden water backing up against the berm. This said, most recruitment is “suicidal” via overwash with survival depending on wave size and the height and width of the berm. Consequently, overwash recruitment diminishes with time away from a breaching event. Survival after overwash recruitment is unlikely in the hypersaline Swartlintjies and Sout and high to medium in the Spoeg, Buffels and Groen. Survival in the latter three systems depends on whether these dry up or become hypersaline before the next flood and breaching event. Survival of 8 - 10 year-old harder *Liza richardsonii* and flathead mullet *Mugil cephalus* in the Spoeg and Buffels is evidence of tolerable conditions over the 8 - 10 years since last recruitment. Previous studies have recorded *M. cephalus* and *L. richardsonii* in the Groen and Spoeg Estuaries and no fish in the other three systems. The ECRU survey also recorded freshwater mullet *Myxus capensis* in the Spoeg Estuary but this needs verification. Fish in the Buffels Estuary have now been verified and again none in the hypersaline Swartlintjies and Sout. *L. richardsonii* and *M.cephalus* were sampled in the Buffels and Spoeg estuaries as well as a breeding population of goby *Caffrogobius* spp. in the latter system. Fish are currently absent in the Groen Estuary in its hypersaline state. With the possible exception of the Spoeg, hypersalinity and fish mortality are characteristic of these West Coast systems. In addition to this, fish mortalities in the Buffels Estuary are a “regular” occurrence arising from eutrophication and low oxygen events or from suffocation in floodwaters backed up against poorly planned roads and causeways.

MINING ACTIVITIES

A major concern is the planned escalation of mining activities in and around the Namaqualand National Park. Mining in close proximity to the estuaries can hold the following risk for the Swartlintjies, Spoeg and Groen estuaries:

- Disruption of subsurface flow.
- Wind-blown sand that smother estuarine and wetland vegetation.
- Increase sedimentation.
- Loss of salinity gradient in soil and water body (fresh at top and saline in lower reaches).
- Possible leaching of heave metals from mine dumps.

Table 3.2 Ecological catogories of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Component Category	Buffels	Swartlintjies	Spoeg	Groen	Sout
Hydrology	D/E	B	B/C	C	D/E
Hydrodynamics	D	B	B	C	E/F
Water quality	D	B	A/B	B	D
Physical habitat alteration	D	B	A/B	A	E
Habitat health	D	B	B	B	D/E
Microalgae	D	B	A/B	B	E
Macrophytes	E	C	A	B	E/F
Invertebrates	D	C/D	A	C	E
Fish	E	B	A	B	E/F
Birds	D	A/B	A	B	E
Biotic health	D/E	B/C	A	B	E
PES	↓ D	B	A/B	B	E
Confidence	Low	Low	Low	Low	Low

3.2 ESTUARY IMPORTANCE

3.2.1 Ecological Importance

The Estuary Importance Score for an estuary takes size, the rarity of the estuary type within its biographical zone, habitat diversity and biodiversity importance of the estuary into account (DWA, 2008). Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its natural condition. The scores were determined by specialists during the November 2016 EWR workshop (DWAF, 2008).

The estuaries of Lower Orange WMA were rated on a 0 to 100 scale to provide an indication of their biodiversity importance in the region (

Table 3.3 and Table 3.5) (DWAF, 2008).

Table 3.3 Importance rating

Importance score	Comment
0 - 20	Little
20.1 - 40	Some
40.1 - 60	Important
60.1 - 80	Very important
80.1 -100	Extremely important

The functional importance (Table 3.4) of an estuary provides a measure of the role a specific estuary plays in the larger land- and seascape. The functional importance of these systems was relatively high as collectively they contribute to a very rare and limited "wetland habitat type" for estuarine and coastal birds along the dry Namaqualand Coast.

Table 3.4 The Functional Importance of the estuaries of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Calculation of the functional importance score	Buffels	Swartlintjies	Spoeg	Groen	Sout
a) Estuary derived detritus and nutrients to the sea	20	20	20	20	20
b) Nursery function for marine-living fish	20	0	20	20	0
c) Movement corridor for river invertebrates and fish breeding in sea	0	0	0	20	0
d) Contribute to a very limited wetland type habitat for estuarine and coastal birds along arid coast	**80**	**60**	**80**	**60**	**60**
e) Catchment sediments provided to the sea	40	40	40	40	20
f) Coastal connectivity (way piont) for fish	40	10	40	10	0
g) Movement corridor for mammals (mongoose and otters)	40	40	40	40	20
Functional importance score Max (a) to (g)	**80**	**60**	**80**	**60**	**60**
Functional importance rating	**Very important**	**Important**	**Very important**	**Important**	**Important**

Table 3.5 The Estuarine Importance of the estuaries of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Estuarine Importance	Buffels	Swartlintjies	Spoeg	Groen	Sout
Size	50	70	70	70	100
Zonal Type Rarity	30	30	30	30	30
Habitat diversity	60	50	60	60	30
Biodiversity Importance	13	10	15	10	10
Functional importance	**80**	60	80	60	60
Estuarine Importance Score	**49**	44	52	46	43
Estuarine Importance	**Average Importance**	**Average Importance**	**Average Importance**	**Average Importance**	**Average Importance**

3.2.2 Conservation Importance of the Lower Orange WMA Estuaries

The National Biodiversity Assessment 2011 (NBA, 2011) (Van Niekerk and Turpie, 2012; Turpie *et al*., 2012) developed a biodiversity plan for the estuaries of South Africa by prioritising and establishing which of them should be assigned partial or full Estuarine Protected Area (EPA) status. This biodiversity plan followed a systematic approach that took pattern, process and biodiversity persistence into account. While the plan has not explicitly taken social and economic costs and benefits into consideration, it used ecosystem health as a surrogate for the former. This is because estuaries where the opportunity costs of protection are likely to be high are also likely to be heavily-utilised systems that are in a lower state of health.

The plan indicates that, on a national scale 133 estuaries (61 require full protection and 72 require partial protection) including those already protected, would be required to meet biodiversity targets (Turpie *et al*., 2012). Of these, three occur within the Lower Orange WMA, with a subset of two estuaries requiring full protection (Groen and Spoeg). Fully protected estuaries are taken to be full no-take areas. Partial protection might involve zonation that includes a no-take area, or it might address other pressures with other types of action. In both these cases, the management objective would be to protect 50% of the biodiversity features of the partially protected estuary. Fully protected and partially protected estuaries can be considered EPAs, whereas all other estuaries should be designated Estuarine Management Areas. All estuaries require a Management Plan and these plans should be guided by the results of this assessment.

4 RECOMMENDED ECOLOGICAL CATEGORY

The REC signifies the level of protection assigned to an estuary. The relationship between EHI score, PES and minimum REC is given in Table 4.1. Table 4.2 summarised the degree to which the REC for the Buffels, Swartlintjies, Groen, Spoeg and Sout estuaries needs to be elevated above the PES depending on the estuary **importance** and the level of **protection** (**conservation importance)** of a particular estuary (Table 3.5).

Table 4.1 Estuary protection status and importance, and the basis for assigning a recommended ecological reserve category (modified from DWAF, 2008)

Protection status and importance	REC	Policy basis
Protected area	A or BAS	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area		
Extremely important (Ranked as 1)	PES + 1, min B	Highly important estuaries should be in an A or B category
Very Important (Ranked as 2)	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance (Ranked as 3)	PES, min D	Estuaries to remain in a D category

The REC for the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries is listed in Table 4.2.

Table 4.2 The Recommended Ecological Category for the estuaries of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries

Component	Buffels	Swartlintjies	Spoeg	Groen	Sout
Present Ecological Status	**↓ D**	**B**	**A/B**	**B**	**E**
Functional Importance as wetland/estuary type in along arid coast	Very important	Important	Very important	Important	Important
Estuarine Importance	Average Importance	Average Importance	Average Importance	Average Importance	Average Importance
Conservation Importance (in Namaqualand National Park)			High	High	
Recommended Ecological Category	**D**	**B**	**A/B**	**A/B**	**D**

5 EWR RECOMMENDATIONS

Table 5.1 provide an overview of the PES, estuary importance, REC and associated EWR requirements. In all but one system no additional freshwater water is required to maintain/achieve the REC. In the case of the Spoeg Estuary provisional results indicate that the system requires additional groundwater to achieve the REC. This requirement needs refinement with additional monitoring results (e.g. boreholes, estuary salinity) as very little information is available on the long term trends and responses to groundwater on this coast.

Table 5.1 Estuaries EWR and recommendations

Component	Estuary				
	Buffels	**Swartlintjies**	**Spoeg**	**Groen**	**Sout**
Reference MAR (Mm³/a)	11.2	1.2	1.3	5.5	0.7
Reference groundwater discharge (Mm³/a)	0.23	0.63	0.36	0.13	1.24
Present groundwater discharge (Mm³/a)	-0.84	0.59	0.22	0.08	1.13
Present Ecological Status	↓ D	B	A/B	B	E
Estuarine Importance	Average Importance	Average Importance	Average Importance	Average Importance	Average Importance
Conservation Importance (in Namaqualand National Park)			**High**	**High**	
Recommended Ecological Category	D	B	A/B	A/B	D
Surface water flow mitigations	↑ floods (road culverts)	↑ floods (road culverts)			↑ floods (weir)
Groundwater mitigations				↑ 20%	
Water Quality Mitigations	×			×	
Non-Flow related Mitigations	×			×	×
Potential for futher water resource development without impacting on ecology	No	No	No	No	No

Table 5.2 list interventions required to maintain or achieve the REC the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries.

Table 5.2 Detail recommendations on interventions/actions required to maintain or achieve the REC

Estuary	Recommendations on interventions/actions
Buffels	▪ Develop an Estuary Management Plan (in progress) to evaluate to what extent functionality can be restored. ▪ Restore connectivity with the marine environment during floods by the complete removal of the remnants of the mining road that still transects the mouth. This would allow for rapid breaching during floods and prevent fish getting smother by high silt content in floodwaters. ▪ Improve estuarine connectivity / freshwater flow through the removal of roads at bird hide and above golf course; ▪ Address diffuse runoff from golf course to prevent nutrient enrichment and associated fish kills. ▪ Control wind-blown dust (smother plants) and wastewater (seawater increase soil salinities) from mining activities. ▪ Remove alien invasive plant species (rooikrans) in upper estuary (ongoing process).

Estuary	Recommendations on interventions/actions
	▪ No driving on the beach to facilitate sedimentary processes and protect bird life (ongoing process).
Swartlintjies	▪ Develop an Estuary Management Plan (in progress) to evaluate to what extend old slimes dam is impacting on estuary and how functionality can be restored if required. ▪ Protect groundwater input to ensure hypersalinity is below <150 psu (brine shrimp goes to cyst). ▪ Restore catchment connectivity (i.e. improve surface water flow) - increase culvert size / culverts at ground level in road crossings. ▪ Estuary in the process of recovering from previous mining activities, allow this process to continue. A concern is the impact of future mining prospects
Spoeg	▪ Restore / protect groundwater ▪ Allow regrowth of vegetation on derelict access roads crossing the upper reaches to continue. ▪ Impact of proposed mining: Wind blow sand and increase salinity via surface/ground water flow.
Groen	▪ Restore/improve groundwater flow by 20% from current levels of 60% utilisation to 80%. ▪ Investigate possible organic/nutrient seepage from ablution facilities of offices/homes at SANParks and means to address these. ▪ The estuary has a strong dependency on groundwater fed springs to maintain salinity gradient, maintain water levels, limit occurrence of extreme hyper salinity (<150 psu). ▪ Future pressures include an escalation of mining activities in the national park and related disruption of subsurface flow.
Sout	▪ Develop an Estuary Management Plan (Western Cape Government in the processes of prioritising this system for a plan) to evaluate to what extend the current design and/or operations of the salt works can be improved to restore estuarine habitat and functionality of the upper reaches. ▪ Improve circulation (e.g. culverts in roads). ▪ Restore connectivity with catchment, i.e. investigate if weir can be partially removed to allow connectivity with western arm of estuary.

6 ESTUARY BASELINE AND LONG-TERM MONITORING REQUIREMENTS IN SUPPORT OF HIGHER LEVEL EWR STUDIES

Recommended minimum monitoring requirements to ascertain impacts of changes in freshwater flow to the estuary and any improvement or reductions therein are listed in Table 6.1.

Table 6.1 Recommended minimum requirements for long-term monitoring (Priority: Red = High; Orange = Medium, Yellow = Low, White = Not relevant)

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Hydro-dynamics	Record estuary water levels.	Continuous	In main water body					
	Measure groundwater level.	Continuous	Near head of estuary					
	Satellite photographs of estuary (30x 30 m).	Every 3 years	Entire estuary					
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 100 - 200 m intervals, but in more detail in the mouth. The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary					
	Set sediment grab samples (at cross section profiles) for analysis of Particle Size Distribution (PSD) and origin (i.e. using microscopic observations).	Every 3 years (with invert sampling)	Entire estuary					
Water quality	Water quality (e.g. system variables (e.g. pH, oxygen, turbidity), nutrients and toxic substances) measurements in Groundwater entering the head of the estuary.	Monthly continuous	Close proximity to head of estuary					
	Sewage volume and concentrations.	Monthly continuous	At source	Golf course			SANPark office	
	In situ salinity and temperature observations.	Continuous	In main water body (1 to 3 stations)					
	Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Every year at end of dry season	Entire estuary (3 - 5 stations)					

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
	Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples).	Seasonal surveys, every 3 years	Entire estuary (3 - 5 stations)					
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue.	Every 6 years	Focus on sheltered, depositional areas					
	Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater.	Use available literature	Seawater adjacent to estuary mouth at salinity 35					
	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae.	Summer survey every 3 years	Entire estuary					
Microalgae	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. High-performance liquid chromatography (HPLC).	Summer survey every 3 years	Entire estuary					
	Intertidal and subtidal benthic chlorophyll-a measurements.	Summer survey every 3 years	Entire estuary					
	Ground-truthed maps to document changes in macrophyte habitats over time. Document area covered by sensitive habitats i.e. submedged macrophytes.	Summer survey every 3 years	Entire estuary					
Macrophytes	Record number of macrophyte habitats, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	Summer survey every 3 years	Entire estuary					
	Note extent of macroalgal blooms, floating aquatic macrophytes and area occupied by invasive vegetation.	Summer survey every 3 years	Entire estuary					
	Take measurements of depth to water table and ground water salinity in reed beds.	Summer survey every 3 years	Upper reaches					
	Record species and abundance of zooplankton, based on samples collected across the estuary.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					*Palemo* population
Invertebrates	Record benthic invertebrate species and abundance, based on subtidal and intertidal grab samples at a series of stations up the estuary, and counts of hole densities.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					
	Measures of sediment characteristics at each station.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					
Fish	Record species and abundance of fish, based on seine net sampling.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Birds	Undertake counts of all water associated birds, identified to species level.	Annual winter (Jul/Aug) and summer (Jan/Feb) surveys	Entire estuary					

Recommended baseline monitoring requirements to improve on the confidance of future EWR assesments are listed in Table 6.2.

Table 6.2 Recommended baseline monitoring requirements (Priority: Red = High; Orange = Medium, Yellow = Low, White = Not relevant)

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Hydro-dynamics	Record estuary water levels.	Continuous	In main water body					
	Measure groundwater level.	Continuous	Near head of estuary					
	Satellite photographs of estuary (30x 30 m).	Once-off	Entire estuary					
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 100 - 200 m intervals, but in more detail in the mouth. The vertical accuracy should be about 5 cm.	Once-off (or in the case of a flood)	Entire estuary					
	Set sediment grab samples (at cross section profiles) for analysis of Particle Size Distribution (PSD) and origin (i.e. using microscopic observations).	Once-off (with invert sampling)	Entire estuary					
Water quality	Water quality (e.g. system variables (e.g. pH, oxygen, turbidity), nutrients and toxic substances) measurements in Groundwater entering the head of the estuary.	Breaching event, then quarterly for 2 years	Close proximity to head of estuary					
	Sewage volume and concentrations.	Breaching event, then quarterly for 2 years	At source	Golf course			SANPark office	
	In situ salinity and temperature observations.	Continuous	In main water body (1 to 3 stations)					
	Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
	Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples).	Breaching event, then quarterly for 2 years	Entire estuary (3-5 stations)					
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue.	Breaching event, then quarterly for 2 years	Focus on sheltered, depositional areas					
	Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater.	Use available literature	Seawater adjacent to estuary mouth at salinity 35					
Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae.	Breaching event, then quarterly for 2 years	Entire estuary					
	Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC.	Breaching event, then quarterly for 2 years	Entire estuary					
	Intertidal and subtidal benthic chlorophyll-a measurements.	Breaching event, then quarterly for 2 years	Entire estuary					
Macrophytes	Ground-truthed maps to document changes in macrophyte habitats over time. Document area covered by sensitive habitats i.e. submedged macrophytes.	Breaching event, then after 2 years	Entire estuary					
	Record number of macrophyte habitats, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	Breaching event, then after 2 years	Entire estuary					
	Note extent of macroalgal blooms, floating aquatic macrophytes and area occupied by invasive vegetation	Breaching event, then after 2 years	Entire estuary					
	Take measurements of depth to water table and ground water salinity in reed beds.	Breaching event, then after 2 years	Upper reaches					
Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					Palemo population
	Record benthic invertebrate species and abundance, based on subtidal and intertidal grab samples at a series of stations up the estuary, and counts of hole densities.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
	Measures of sediment characteristics at each station.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Fish	Record species and abundance of fish, based on seine net sampling.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
Birds	Undertake counts of all water associated birds, identified to species level.	Breaching event, then quarterly for 2 years	Entire estuary					

7 ECOSPECS FOR THE SMALL WEST COAST ESTUARIES

For the purpose of RQO determination, the following differentiation is made between EcoSpecs and RQOs (DWS, 2015). EcoSpecs are associated with the Ecological Reserve process and are usually provided per estuary. EcoSpecs are seen as detailed or numberical instream and riparian biota and habitat RQOs as they are quantifiable, measurable, verifiable and enforceable to ensure protection of all components of the resource, which make up ecological integrity (DWA, 2009a). Therefore, EcoSpecs are numerical and can be used for monitoring. Threshold of Potential Concern (TPCs) are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the following guidelines (Rogers and Bestbier, 1997) and are linked to EcoSpecs. When setting EcoSpecs, the work is usually based on field work that has been undertaken, a monitoring baseline is therefore available and monitoring to determine whether the specifications are being achieved (or Ecological Category) can be undertaken.

Where limted data is available RQOs are usually determined rather than EcoSpecs as the requirements for RQOs are broader or less detailed. This is inherently the case were detailed fieldwork has not been undertaken. Where a monitoring baseline is not available, EcoSpecs cannot be determined.

If sufficient data is not available to set specifications, broad objectives for the EC are provided only. RQOs in this format cannot be used in monitoring as is. Monitoring must be undertaken so that the objectives can be translated into EcoSpecs based on field surveys and the findings of the baseline monitoring.

7.1 FORMAT OF ECOSPECS COMPONENTS

EcoSpecs are set for the short-to medium term (5 to 10 year period) for the the following components:

- Overall flow requirment (hydrology).
- Mouth state (hydrodynamics).
- Water quality.
- Characteristics and condition of primary producers (e.g. macrophytes).
- Characteristics and condition of biota (e.g. fish).

Hydrological EcoSpecs are provided as a flow regime associated with the REC for the Buffels, Swartlintjies, Spoeg, Groen and Sout Estuaries with an indication if the various components of the flow regime (baseflows and floods) meet the EWR requirement.

Water quality EcoSpecs were set for all estuaries based on environmental requirements and national guidelines or standards. The water quality component is discussed in Section 2.3.3.

Habitat and biota is described as the habitat and biota associated with a REC. The format of the EcoSpecs is as follows:

- Overall PES, REC.
- PES for each component.
- Ecological objectives for components.

Where the PES does not meet the REC a "🡅" was used to indicate which individual components should improve to achieve the REC.

7.2 APPROACH FOLLOWED IN DEVELOPING ESTUARY ECOSPECS

7.2.1 Hydrodynamics

Very little information is available on the hydrodynamics of the small Lower Orange Systems. If an estuary is very sensitive to flow modification (e.g. very small or shallow), and/or in an A or B Category, a ±5% variation was allowed for over a 5 year period. However, if an estuary was deemed to be more robust (e.g. large size, mouth protected) from a flow perspective and/or in a C to F Category, a ±10% variance from the current data set was allowed for over a 5 year period. Were more information was available it was incorporated in the EcoSpecs.

7.2.2 Salinity

Salinity EcoSpecs were derived from measured data or extrapolated for similar systems. Key determining estuarine features used in setting the salinity EcoSpecs were: estuary size, estuary depth, % mouth open and mouth position (i.e. perched/not perched). Data sets used include CSIR Harrison observations and recent field data.

7.2.3 Water Quality

For estuaries, unlike for rivers, there are no official, numerical water quality EcoSpecs specified for various health categories because of the diverse and site specific nature of many of these variables in estuaries. Based on a general understanding of water quality characteristics in estuaries along this part of the coast, as well as expert knowledge, target ranges were proposed for various water quality health categories, where the condition of any parameter had to be <u>improved</u> (Table 7.1). Otherwise, the present (measured) water quality concentration was set as EcoSpecs.

Table 7.1 Proposed EcoSpecs for water quality where ecosystem health must be improved to higher category

Variable	Health Category			
	A	B	C	D
Dissolved oxygen	Average in estuary $\geq$ 6 mg/l		Average in estuary $\geq$4 mg/l	
Turbidity	Site specific, cannot provide generic EcoSpecs			
Dissolved inorganic nitrogen (DIN) in river inflow	50%ile <0.1 mg/l	50%ile <0.2 mg/l	50%ile <0.3 mg/l	50%ile <0.5 mg/l
Dissolved inorganic phosphate (DIP) in river inflow	50%ile <0.01 mg/l	50%ile <0.015 mg/l	50%ile <0.025 mg/l	50%ile <0.05 mg/l
Toxic substances	▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009). ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters Department of Water Affairs and Forestry (DWAF,1995).			

For this study the water quality EcoSpecs were equated to the corresponding REC allocated to an estuary. Where the PES category for water quality was below the REC category, water quality was identified as a potential risk and the water quality EcoSpecs equivalent to the REC category were proposed. Where the WQ PES category was higher than the REC, the EcoSpecs for the WQ PES were maintained as a precautionary approach until monitoring showed a relation was appropriate.

7.2.4 Macrophytes

The EcoSpecs were set for each estuary based on available data and recent field surveys. Macrophyte EcoSpecs are based on historical data and descriptions and are considered to be of low confidence. Expert opinion and Google images were used to make the assessments. EcoSpecs were generally set to maintain the distribution of current macrophyte habitats (<20% change in the area), maintain the integrity of the riparian zone and floodplain habitat.

7.2.5 Invertebrates

The EcoSpecs were set for each estuary based on analysis of available data and expert opinion informed by first-hand knowledge of the small west coast estuaries. Estuaries sampled by the researchers were roughly grouped into the two brackish and the three systems characterised by cycles of hypersalinity. EcoSpecs were generally set to maintain the diversity, abundance and cyclicity of invertebrate communities, in particular the brine shrimp populations.

7.2.6 Fish

The EcoSpecs were set for each estuary based on analysis of available data and expert opinion informed by first-hand knowledge of small west coast estuaries. Estuaries sampled by the researchers were categorised according to their salinity regime. Preliminary fish lists (% abundance and frequency of occurrence) were based on available information. These fish lists were used to establish EcoSpecs. EcoSpecs are expressed as requirements based on a sampling trip. For example, a requirement that 2 to 5 species should occur in an estuary implies that 2 to 5 species should be sampled over successive sampling trips. These EcoSpecs should be further developed and refined as part of the monitoring requirements of individual systems.

7.2.7 Birds

The EcoSpecs were set for each estuary based on analysis of available data and expert opinion informed by first-hand knowledge of small west coast estuaries.

7.3 BUFFELS ESTUARY

<table>
<tr><td>PES:</td><td>D (downwards trajectory)</td><td>REC:</td><td colspan="2">D</td></tr>
<tr><td colspan="5">The system is on a negative trajectory of change and therefore requires the following interventions to maintain the REC:
▪ Remove roads/causeways dividing the estuary in three isolated sections (i.e. remnant of mining road at mouth; road at bird hide; road above the golf course).
▪ Improve connectivity with catchment by increasing/establishing culverts in roads in catchments.
▪ Remove invasive alien plants (rooi krans) in upper reaches (in progress.
▪ Enforce the no driving on the beach legislation to allow for natural sediment processes to re-establish themselves and protect birds (in progress).
▪ Investigate mitigations to reduce nutrient enrichment from golf course irrigation.</td></tr>
<tr><td colspan="5">Flow</td></tr>
<tr><td>PES</td><td>nMAR (MCM)</td><td>Reference groundwater discharge (Mm³/a)</td><td colspan="2">Present groundwater discharge (Mm³/a)</td></tr>
<tr><td rowspan="2">D/E</td><td>11.2</td><td>0.23</td><td colspan="2">-0.84</td></tr>
<tr><td colspan="4">▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015).
▪ Groundwater needs to be maintained at present levels.
▪ Floods need to reach the estuary.</td></tr>
<tr><td colspan="5">Sediment processes</td></tr>
<tr><td>D</td><td colspan="4">▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream</td></tr>
</table>

	physical habitat). The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.
Mouth state	
D	Mouth open conditions should be maintained within the current range, but the rate at wich it breaches needs to increase (only take a short time to breach).
Water quality: Salinity	
D	The system needs variability in salinity regime, with a measurable increase in salinity in the upper and middle reaches during the winter season. ▪ Upper reaches: <5 psu. ▪ Lower reaches: <20 psu.
Water quality: Ecosystem health	
D	▪ DIN: Entire estuary, average <0.3 mg/l (aim for Category C). ▪ DIP: Entire estuary, average >0.025 mg/l (aim for Category C). ▪ DO: Entire estuary, average ≥4 mg/l. ▪ Turbidity: Entire estuary, average <20 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
D	▪ Maintain the distribution of different phytoplankton groups (diverse community composition). ▪ Control nutrient input from golf course to prevent microalgal blooms (>20 µg/l).
Macrophytes	
E↑	▪ Maintain the distribution of current macrophyte habitats, <20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Maintain habitat diversity including some freshwater wetland with reeds and rushes and submerged macrophytes such as pondweed (*Stukenia pectinata*). ▪ Growth of natural vegetation in areas where rooikrans is being removed.
Invertebrates	
D	As sampled by plankton net, grab and dip nets/traps (as appropriate): Population abundances of plankton and benthic assemblages (baselines to be set) should not deviate by more than 25% at any point in the opening and closure cycle. Invasive alien species should not occur.
Fish	
E↑	As sampled by seine in open waters: ▪ 2 to 3 species should occur and include estuarine resident and estuarine dependant marine fishes. ▪ No alien fish species should occur. ▪ Fish should be free of lesions and other anomalies related to water quality. ▪ No fish kills should occur.
Birds	
D	Should be dominated by waders and water birds that comprise >15 species and >100 individuals. The occurrence and cause of bird mortalities needs to be verified.

7.4 SWARTLINTJIES ESTUARY

PES:	**B**	**REC:**	**B**
Recommendations on how to maintain the PES/REC include: ▪ Develop an Estuary Management Plan (in progress) to evaluate to what extend old slimes dam is			

<table>
<tr><td colspan="4">impacting on estuary and how functionality can be restored if required.
▪ Protect groundwater input to ensure hypersalinity is below <150 psu (brine shrimp goes to cyst).
▪ Restore catchment connectivity (i.e. improve surface water flow) - increase culvert size / culverts at ground level in road crossings.
▪ Estuary in the process of recovering from previous mining activities, allow this process to continue.
▪ A concern is the impact of future mining prospects.</td></tr>
<tr><td colspan="4">Flow:</td></tr>
<tr><th>PES</th><th>nMAR (MCM)</th><th>Reference groundwater discharge (Mm^3/a)</th><th>Present groundwater discharge (Mm^3/a)</th></tr>
<tr><td rowspan="2">B</td><td>1.2</td><td>0.63</td><td>0.59</td></tr>
<tr><td colspan="3">▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015).
▪ Groundwater needs to be maintained at present levels.
▪ Floods need to reach the estuary.</td></tr>
<tr><td colspan="4">Sediment processes</td></tr>
<tr><td>B</td><td colspan="3">▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat).The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined).
▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.</td></tr>
<tr><td colspan="4">Hydrodynamics and Mouth state</td></tr>
<tr><td>B</td><td colspan="3">Mouth open conditions should be maintained within the current range.</td></tr>
<tr><td colspan="4">Water quality: Salinity</td></tr>
<tr><td>B</td><td colspan="3">Average salinity: <150 psu (hyper salinity).</td></tr>
<tr><td colspan="4">Water quality: Other</td></tr>
<tr><td>B</td><td colspan="3">▪ DIN: Entire estuary, average <0.1 mg/l.
▪ DIP: Entire estuary, average >0.01 mg/l.
▪ DO: Entire estuary, average <u>>6</u> mg/l.
▪ Turbidity: Entire estuary, average <10 NTU except during floods.
Toxic substances:
▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995).
▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).</td></tr>
<tr><td colspan="4">Microalgae</td></tr>
<tr><td>B↑</td><td colspan="3">Maintain the distribution of different phytoplankton groups and low biomass (<5 µg/l).</td></tr>
<tr><td colspan="4">Macrophytes (plants)</td></tr>
<tr><td>C</td><td colspan="3">▪ Maintain the distribution of current macrophyte habitats, <20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries).
▪ Water column salinity not greater than 150 psu to limit salt accumulation and dieback of salt marsh (Sarcocornia pillansii). Investigate historical slime dams input to ensure no salt input.
▪ Prevent further disturbance and development in the salt marsh and floodplain habitat.</td></tr>
<tr><td colspan="4">Invertebrates</td></tr>
<tr><td>C/D</td><td colspan="3">As sampled by plankton net, grab and dip nets/traps (as appropriate):
▪ Unincysted Brine shrimp should be present in the system for 75% of the time.</td></tr>
<tr><td colspan="4">Fish</td></tr>
<tr><td>B</td><td colspan="3">Not applicable. Hyper saline system.</td></tr>
</table>

Birds	
A/B	▪ Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present 75% of the time (during 40 – 150 psu and brine shrimp available). ▪ The occurrence and cause of bird mortalities needs to be verified.

7.5 SPOEG ESTUARY

PES:	A/B	REC:	A/B
Recommendations on how to maintain the PES/REC include: ▪ Restore / protect groundwater inflow. ▪ Allow regrowth of vegetation on derelict access roads crossing the upper reaches to continue; and ▪ Impact of proposed mining: Wind blow sand and increase salinity via surface/ground water flow.			

Flow

PES	nMAR (MCM)	Reference groundwater discharge (Mm³/a)	Present groundwater discharge (Mm³/a)
B/C	1.3	0.36	0.22
	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary.		

Sediment processes	
B	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat).The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.
Mouth state	
B	Maintain current connectivity with the marine environment.
Water quality: Salinity	
A/B	▪ The system needs variability in salinity regime, with a measurable increase in salinity in the lower and middle reaches during the winter season. ▪ Average Salinity: <35 psu.
Water quality: Other	
A/B	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average ≥6 mg/l. ▪ Turbidity: Entire estuary, average <10 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalagae	
A/B	▪ Maintain the distribution of different phytoplankton groups and low biomass in the lower reaches (<10 µg/l).
Macrophytes (plants)	
A	▪ Maintain the distribution of current macrophyte habitats, (<20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Maintain the salinity gradient to ensure habitat diversity including some freshwater wetland with

	reeds upstream and submerged macrophytes such as *Ruppia cirrhosa*. ▪ Prevent any further groundwater abstraction and increase in salinity that will lead to die-back of reeds and increase in dry bare saline areas in the salt marsh.
Invertebrates	
A	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Population abundances of plankton and benthic assemblages (baselines to be set) should not deviate by more than 25% at any point in the opening and closure cycle. ▪ Invasive alien species should not occur.
Fish	
A	As sampled by seine in open waters: ▪ 2 to 4 species should occur and include estuarine resident and estuarine dependant marine fishes. ▪ No alien fish species should occur. ▪ Fish should be free of lesions and other anomalies related to water quality. ▪ No fish kills should occur.
Birds	
A	▪ Should be dominated by waders and water birds that comprise >15 species and >50 individuals. ▪ The occurrence and cause of bird mortalities needs to be verified.

7.6 GROEN ESTUARY

PES:	**B**	**REC:**	**A/B**
Components that require interventions or protection to achieve the REC: ▪ Maintain groundwater flow to near natural levels. ▪ The estuary has a strong dependency on groundwater fed springs to maintain salinity gradient, maintain water levels, limit occurrence of extreme hyper salinity (<150 psu). ▪ Investigate possible organic/nutrient seepage from ablution facilities of offices/homes at SANParks and means to address these. ▪ Future pressures include an escalation of mining activities in the national park and related disruption of subsurface flow.			

Flow

PES	**nMAR (MCM)**	**Reference groundwater discharge (Mm^3/a)**	**Present groundwater discharge (Mm^3/a)**
C	5.5	0.13	0.08
	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary.		

Sediment processes	
A	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat).The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.
Hydrodynamics and Mouth state	
C	Mouth open conditions should be maintained within the current range.
Water quality: Salinity	
B	▪ Upper reaches: <80 psu (hyper salinity). ▪ Middle Reaches: <100 psu (hyper salinity). ▪ Lower reaches: <150 psu (hyper salinity).

Water quality: Other	
B	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average >6 mg/l. ▪ Turbidity: Entire estuary, average <15 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
B↑	Maintain the distribution of different phytoplankton groups along the salinity gradient.
Macrophytes (plants)	
B	▪ Maintain the distribution of current macrophyte habitats (<20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Maintain the salinity gradient to ensure habitat diversity including the upstream freshwater seepage area where salinity should be less than 10 psu. ▪ Prevent any further groundwater abstraction and increase in salinity that will lead to die-back of reeds and increase in dry bare saline areas in the salt marsh.
Invertebrates	
C	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Unincysted Brine shrimp should be present in the system for 75% of the time.
Fish	
B	As sampled by seine in open waters: ▪ 2 species *(M. cephalus, L. richardsonii)* should occur when salinities are less than 50 psu in the salinity cycle. ▪ No alien fish species should occur. ▪ Fish should be free of lesions and other anomalies related to water quality. ▪ No fish kills should occur.
Birds	
B	▪ Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present 75% of the time (during 40 – 150 psu and brine shrimp available). ▪ The occurrence and cause of bird mortalities needs to be verified.

7.7 SOUT ESTUARY

PES:	**E**	**REC:**	**D (5 year target D/E)**
Components that require interventions to achieve the REC: ▪ Develop an Estuary Management Plan (Western Cape Government in the processes of prioritising this system for an plan) to evaluate to what extend the current design and/or operations of the salt works can be improved to restore estuarine habitat and functionality of the upper reaches. ▪ Improve circulation (e.g. culverts in roads). ▪ Restore connectivity with catchment, i.e. investigate if weir can be partially removed to allow connectivity with western arm of estuary.			
Flow			
PES	**nMAR (MCM)**	**Reference groundwater discharge (Mm^3/a)**	**Present groundwater discharge (Mm^3/a)**
D/E ↑	0.7	1.24	1.13
	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary (at present significantly reduced by weir above estuary.		
Sediment processes			

E	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat).The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.
Hydrodynamics and Mouth state	
E/F↑	Improved connectivity with the different water bodies and restored connectivity with the catchment through removal/modification of weir at the head of the estuary.
Water quality: Salinity	
E ↑	Upper reaches: < 120 psu (hyper salinity). Middle Reaches: < 80 psu (hyper salinity). Lower reaches: < 60 psu (hyper salinity).
Water quality: Other	
D	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average >6 mg/l. ▪ Turbidity: Entire estuary, average <10 NTU except during floods Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalagae	
E↑	Maintain the distribution of different phytoplankton groups and low biomass in the lower reaches (<10 µg/l).
Macrophytes (plants)	
E/F↑	▪ Maintain the distribution of current macrophyte habitats, (<20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Water column salinity not greater than 50 psu in the lower reaches to limit salt accumulation and dieback of salt marsh (*Sarcocornia pillansii*). ▪ Prevent further disturbance and development in the salt marsh and floodplain habitat through salt works activities.
Invertebrates	
E↑	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Unincysted Brine shrimp should be present in the system for 75% of the time.
Fish	
E/F↑	Not applicable. Hyper saline system.
Birds	
E↑	▪ Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present 75% of the time (during 40 – 150 psu and brine shrimp available). ▪ The occurrence and cause of bird mortalities needs to be verified.

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9 APPENDIX A: THE BUFFELS ESTUARY DESKTOP EWR

Appendix A provides the detailed methods and scores for the abiotic and biotic componentsof the Buffels Estuary.

9.1 DELINEATION

The Buffels Estuary is situated 150 km south of the Orange Estuary at the mining town Kleinsee. The geographical boundaries of the Buffels Estuary are defined as follows (Figure 9.1):

Downstream boundary:	29°40'37.01"S 17° 3'4.41"E (Estuary mouth)
Upstream boundary:	29°40'18.21"S 17° 4'3.30"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 9.1 Buffels Estuary: Geographical boundaries based on the EFZ

9.2 MAJOR PRESSURES

The major pressures on the Buffels Estuary include:

- Loss of freshwater input as a result of groundwater abstraction.
- Mining activities (surrounding environs and catchment) resulting in destruction of habitat and change in sediment structure.
- Approximately five roads crossing the system obstructing floods and freshwater underflow.
- Grazing in the catchment changing sediment structure.
- Development in the floodplain such as the golf course.
- Fish kills due to eutrophication and disconnection with lower reaches (limit wind mixing).
- Run-off from the golf course has encouraged reed growth.
- Extensive stands of *Acacia cyclops* (rooikrans) occur in the water course of the upper reaches.

9.3 HYDROLOGY

The catchment area of the Buffels River is 9 375 km^2. The Buffels River is about 150 km long from the mouth to where it divides into the Brak and the Riembreek rivers. The catchment falls predominantly within the winter rainfall area and episodic floods occur occasionally (Heinecken, 1981a). Annual precipitation vary from 200 - 250mm/a in the headlands to 75 - 100 mm/a at the sea. The river and its tributaries are ephemeral with surface flow only occurring after substantial rainfall.

Summary of monthly flows under Reference conditions is provided in Table 9.1. Desktop simulations of the surface hydrology indicate little change in the surface water flows, however this does not take into consideration the impact of road infrastructure throughout the catchment, and specifically just above the estuary that acts as instream "farm dams". These structures have significant influence floods to the Buffels Estuary and therefore the opportunity for breaching. Assume a 30% impact on magnitude of floods reaching the estuary.

Table 9.1 Buffels Estuary: Simulated monthly flows (in 10^6 m^3) under Reference Conditions

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breach*
1920	0.4	0.1	0.0	0.0	2.4	0.8	0.1	0.0	66.5	22.7	0.5	0.2	93.7	1
1921	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	4.2	1.4	6.2	1
1922	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	14.3	4.9	0.1	0.1	19.4	1
1923	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1924	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	105.7	38.2	2.3	0.4	146.8	1
1925	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.3	0.0	1.5	0
1926	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.4	2.6	0
1927	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1928	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.4	0.1	1.6	0
1929	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.4	0.5	11.7	4.3	18.1	1
1930	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0
1931	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.3	0
1932	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.2	0.5	0.1	3.7	0
1933	0.0	0.0	0.0	0.0	0.1	1.5	0.5	0.2	0.1	0.0	0.0	0.0	2.4	0
1934	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.8	0.5	0.1	2.3	0
1935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	3.0	3.1	1
1936	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	1.9	0
1937	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0
1938	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	24.7	8.4	33.5	1
1939	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.2	0.7	0
1940	0.1	6.5	2.1	0.1	0.0	0.0	0.2	4.4	6.8	1.9	0.5	0.2	22.7	1
1941	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	4.9	1.7	0.0	0.0	7.4	1
1942	0.2	0.1	0.0	0.0	0.0	0.0	0.0	1.9	0.9	0.2	1.0	0.3	4.5	0
1943	0.0	0.6	0.2	0.0	0.0	0.0	0.0	1.1	0.7	0.1	0.6	0.2	3.5	0
1944	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	1.4	0.6	0.0	2.7	0
1945	2.7	0.9	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	2.1	6.5	1
1946	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.5	0.1	0.0	0.0	2.8	0
1947	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.0	0.5	0
1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1949	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1.1	0.0	5.1	1.7	0.8	12.0	1
1950	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.4	12.5	4.1	0.1	0.0	18.4	1
1951	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	21.1	8.6	0.5	30.6	1
1952	0.0	0.0	0.0	0.0	0.4	0.1	4.5	1.6	0.0	0.4	2.1	0.7	9.7	1
1953	0.0	0.0	2.9	1.0	0.0	0.4	0.1	5.8	2.0	10.3	3.6	0.1	26.0	1
1954	0.0	0.0	0.0	0.0	1.8	0.6	0.0	0.0	0.0	0.9	7.8	2.5	13.7	1
1955	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.2	0.8	0.6	0.1	0.0	2.0	0
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.7	1.5	0.8	0.2	4.9	0
1957	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	1.1	0
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	4.4	0.1	0.1	0.0	17.7	1
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breach*
1960	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.2	0.5	0.1	0.2	4.0	0
1961	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	4.4	12.8	4.3	34.0	1
1962	0.1	0.3	0.1	0.0	0.0	0.0	0.1	0.2	1.4	0.6	2.0	0.7	5.4	0
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.4	0.0	0.1	1.7	0
1964	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0
1965	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0
1966	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.5	8.2	2.8	0.1	0.0	12.8	1
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.0	0.0	0.5	0
1968	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.4	0.2	0.0	0.9	0
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.2	1.0	4.9	1
1971	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	2.1	0.7	0.0	0.0	3.0	1
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.1	0.8	0
1973	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	2.3	0.8	14.8	5.0	23.0	1
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	2.2	0.0	0.0	0.0	8.6	1
1975	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	4.6	2.3	0.3	0.0	7.9	1
1976	0.0	0.3	0.2	0.0	0.0	0.0	0.2	1.4	0.7	0.4	0.2	0.0	3.5	0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.7	0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.3	0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.1	0.6	0.2	5.2	1
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	6.1	2.1	8.5	1
1981	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	1.4	0.5	0.0	2.3	0
1982	0.1	0.0	0.0	0.0	0.0	0.0	0.0	17.7	6.7	0.4	0.1	0.7	25.6	1
1983	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.0	0.0	0.0	1.4	0
1984	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	1.2	0
1985	0.0	0.0	6.5	2.2	0.0	0.0	0.0	0.0	38.6	13.3	0.3	0.1	61.0	1
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.6	3.1	1.5	0.2	5.5	1
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.7	0.4	0.2	3.2	1
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.3	0.0	0.1	0.2	0.1	1.5	0
1989	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.2	1.6	1.1	0.2	0.0	5.6	0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.1	0.1	0.4	3.6	0
1991	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.7	0
1992	1.1	0.4	0.0	0.0	0.0	0.0	12.6	4.4	0.8	0.5	0.1	0.0	19.9	1
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	6.7	3.2	0.3	0.0	10.4	1
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	2.0	0.0	1.4	0.8	10.1	1
1995	0.2	1.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	13.7	7.2	4.6	28.0	1
1996	1.3	0.3	0.1	0.0	0.0	0.1	0.0	6.7	24.0	7.4	0.2	0.1	40.2	1
1997	0.0	0.7	0.2	0.0	0.0	0.0	0.0	1.6	0.5	0.0	0.0	0.0	3.0	0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	4.9	5.7	1
1999	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.6	0.0	4.0	0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	6.1	0.5	20.8	1
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.2	0.2	0.3	1.5	0
2002	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.1	10.4	41.6	1
2003	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0
2004	0.3	0.1	0.0	0.3	0.1	0.0	1.6	1.0	0.2	0.0	0.0	0.0	3.5	0

* Years that the Buffels Estuary could have potentially breached is indicated by 1.

Groundwater is estimated to be significantly modified. With ground water use far exceeding the recharge of the aquafer.

Table 9.2 Buffels Estuary: Groundwater recharge and discharge

Groundwater parameter	Value
Groundwater catchment area	977.0
Estuary catchment area	977.0
Reference recharge to estuary Mm^3/a	0.2
Reference Estuary discharge Mm^3/a	0.2
Use in Catchment Mm^3/a	1.068
Present Estuary Mm^3/a	-0.838
Use as % discharge	-0.069833333
% Similarity	-364.3
Ground water TDS mg/l	3523.0
Reference total salt load from groundwater (tons/a)	810

Table 9.3 provides the hydrology similarity EHI scores for the Buffels Estuary.

Table 9.3 Buffels Estuary: Similarity scores for hydrology relative to the Reference condition

Variable	Present
a. % similarity Groundwater	20
b. % similarity frequency and magnitude of floods	70
Hydrology score	**40**

Score = (0.6*a.) + (0.4*b.)

9.4 HYDRODYNAMICS

9.4.1 Connectivity

Impacts on the hydrodynamics of the Buffels Estuary that reduce connectivity include the remnant of the mining road over the mouth, causeways in the lower and middle reaches, a road with culverts in the upper reaches, a golf course (with a 700 m levee that protects the golf course from flooding) (Figure 9.2).

Between 1942 and 1976 first dwellings on the south side at Kleinzee appeared. During this time the estuary was freely connected to the sea and split into three sections in the upper reaches. By 1985 the golf course had been vegetated (it was previously unvegetated), along with the construction of the presently tarred road. The causeway across the mouth of the estuary was also in place, along with a number of other access roads across the lower reaches. The tarred road that crosses the system 1.7 km from the mouth forms the inland boundary of this study.

In 2003 the causeway across the mouth was washed away by a flood (but rebuild in about 2 days time (*Pers. Comm*. R Maree). The same flood also scoured the estuary wide open. By 2006 the road was washed away again, and again reinstated within a short period, while vegetation adjacent to the golf course had increase (presumably the reeds).

The haul road 0.3 km from the mouth was washed away in the flood of June 1997 (estimated at 1:100). A bird hide have recently been built on the northern side on the remnants of this road. Another causeway occurs 1.1 km from the mouth also show signs of flood damage, e.g. a number of large slumped pipes are still visible and exposed.

9.4.2 Mouth State

The Buffels Estuary is classified as a temporarily open/closed system (Van Niekerk and Turpie, 2012), however the estuary is very seldom connected to the sea. Natural breaching by flood waters is estimated to have occurred every 3 to 7 years during. Open mouth conditions would only prevail for short periods (days to a week or two) as flood peaks in arid catchments generally is a matter of hours with little follow up flow. However, under the reference condition overtopping of the sand bar at the mouth would have occurred regularly at high spring tides even after mouth closure. During these overtopping events, species dependent on both the estuary and sea (e.g. fish and invertebrates) move between the two environments.

Key obstructions to flow at the Buffels Estuary: (a) The remnants of the road crossing the mouth of the estuary about 3 – 4 m above water level; (b) The road crossing the system at the birdhide bisecting the lower reaches; (c) Reed encroachment at the golf course preventing a free circulation of water; (d) The road crossing the estuary above golf course with small pipe culverts at very high levels obstructing flood flows and preventing scouring of sediment; (e) Culverts in the upper reaches where the main road cross the Buffels Estuary.

Figure 9.2 Buffels Estuary: Key obstructions to flow in the estuary

Residents report that the mouth was open and flowing in 1976 and in 1980 when it destroyed parts of the golf course (Heinecken, 1981a). They also report that the river used to flood every third year. Heinecken (1981a) reports open mouth states for 1945, 1961, 1962 and 1963 after flood events. Chand (1998) reports a 1:100 flood in June 1997 which washed away two existing earth bridges. Similar magnitude floods are said to have occurred in 1976 and the late 1920s. Flooding also occurred in 1976, 1980, 1986, 1996, 1997 and 2006 (Chand, 1998.) At the time of the Chand study (1998) there was still substantial water in the lower reaches even though flooding had occurred 18 months prior to the field trip.

Aerial photographs and satellite imagery shows significant movement of the mouth over time to its present position.

Table 9.4 Buffels Estuary: Summary of the mouth state based on available imagery

Year	Source	Mouth state (Open/closed)
2014	National Geo-Spatial Information (Surveys and Mapping)	Closed
2013	Google Earth	Closed
2012	Google Earth	Closed
2011	Google Earth	Closed
2011	National Geo-Spatial Information (Surveys and Mapping)	Closed
2006	Google Earth	Open (or just closed)
2004	Google Earth	Closed
2003	National Geo-Spatial Information (Surveys and Mapping)	Closed
1990	National Geo-Spatial Information (Surveys and Mapping)	Closed
1985	National Geo-Spatial Information (Surveys and Mapping)	Closed
1976	National Geo-Spatial Information (Surveys and Mapping)	Closed
1942	National Geo-Spatial Information (Surveys and Mapping)	Closed

9.4.3 Openwater area

The major modification to the open water area is attributed to mining activities and the abstraction of water from the aquifer for Kleinzee residents.

Ground water abstraction has significantly decreased the input of freshwater into the system over time. The first well was drilled by De Beers in 1980s (Anton Meyer, *Pers. Comm*.). Since 1976 openwater area appears to have decreased markedly (Figure 9.3). Although not evident in the change in openwater area over time, there has been increased freshwater input into the estuary near the golf course. This is due to irrigation of the golf course with treated waste water. This has increased the reed beds over time, personal observations (2005 to 2016) and anecdotal evidence from local residents confirming this (see vegetation section for more detail). Seepage of freshwater from the golf course probably also lowers the salinity of the water column further increasing reed encroachment.

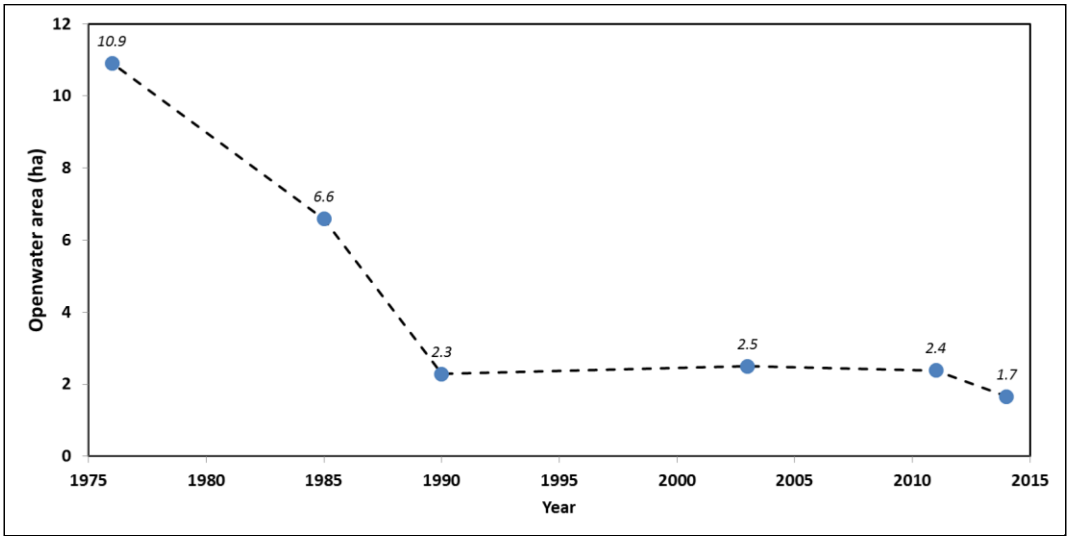


Figure 9.3 Marked decline in the openwater area (ha) of the Buffels Estuary mapped from aerial photographs and satellite imagery

The decrease in open water area may also be the result of the changes in the peak flood velocities, i.e. culverts and structures are now causing the same size flood to occur over a longer period, but with a smaller flood peak. Thus, in turn, reducing scouring and resetting of the system.

The shifts in the hydrodynamics are largely due to structures (culverts, remnants of roads) and reduce groundwater input to the system. With estuarine connectivity being severely reduce, both within the system and to the catchment and marine environment. Table 9.5 provides the hydrodynamics similarity EHI scores for the Buffels Estuary.

Table 9.5 Buffels Estuary: Similarity scores for hydrodynamics under the various operation scenarios relative to the Reference Condition

Variable	Present	Confidence
a. Mouth condition	70	Low
b. Circulation (connectivity)	50	Medium
c. Water level	70	Low
Hydrodynamics score*	**50**	**Low**

*Score = Minimum (a, b, c)

9.5 WATER QUALITY

Figure 9.4 shows locality map of sampling sites in the Buffels Estuary.

Figure 9.4 Buffels Estuary: Water Quality sampling stations

Very little historical information exists on the water quality of Buffels Estuary. What little there is suggests that the Buffels Estuary tends to be brackish in nature. Heinecken (1980) attributes this to the presence of a high water table fed by an aquifer in the lower part of the river resulting in relative stable salinity conditions prevailing. Salinity fluctuating between 6 and 30 (with seawater 35 g per litre) in the lower reaches and between 3 and 5 in the middle and upper reaches. Heinecken (Oct 1980) measured 16 in the lower reaches. Harrison (unpublished data) recorded 6 in the lower reaches and 3 in the middle reaches in September 1993.

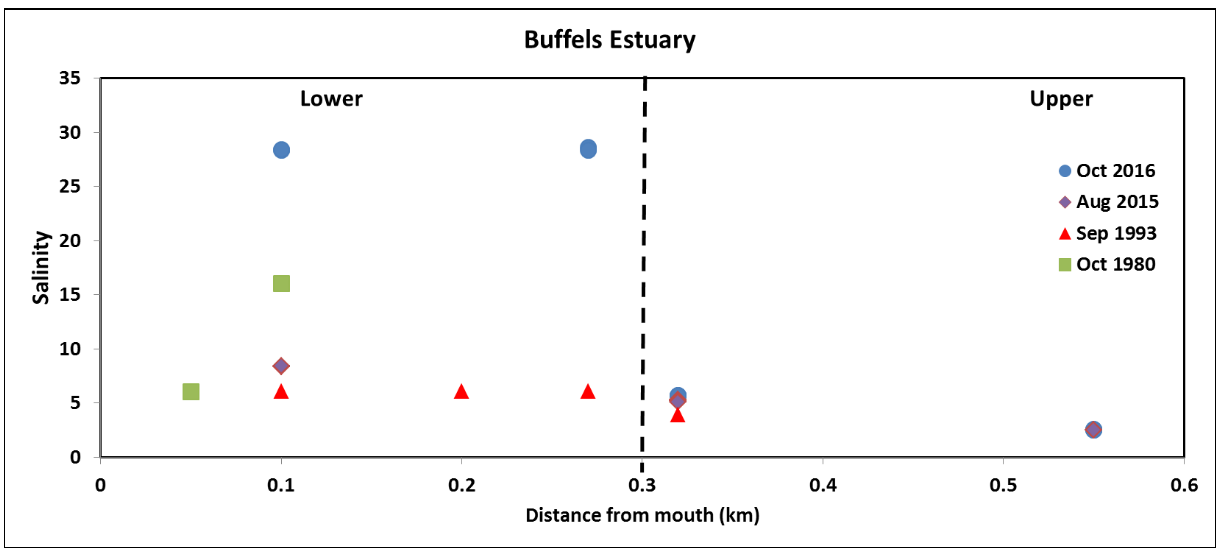


Figure 9.5 Buffels Estuary: Available salinity data

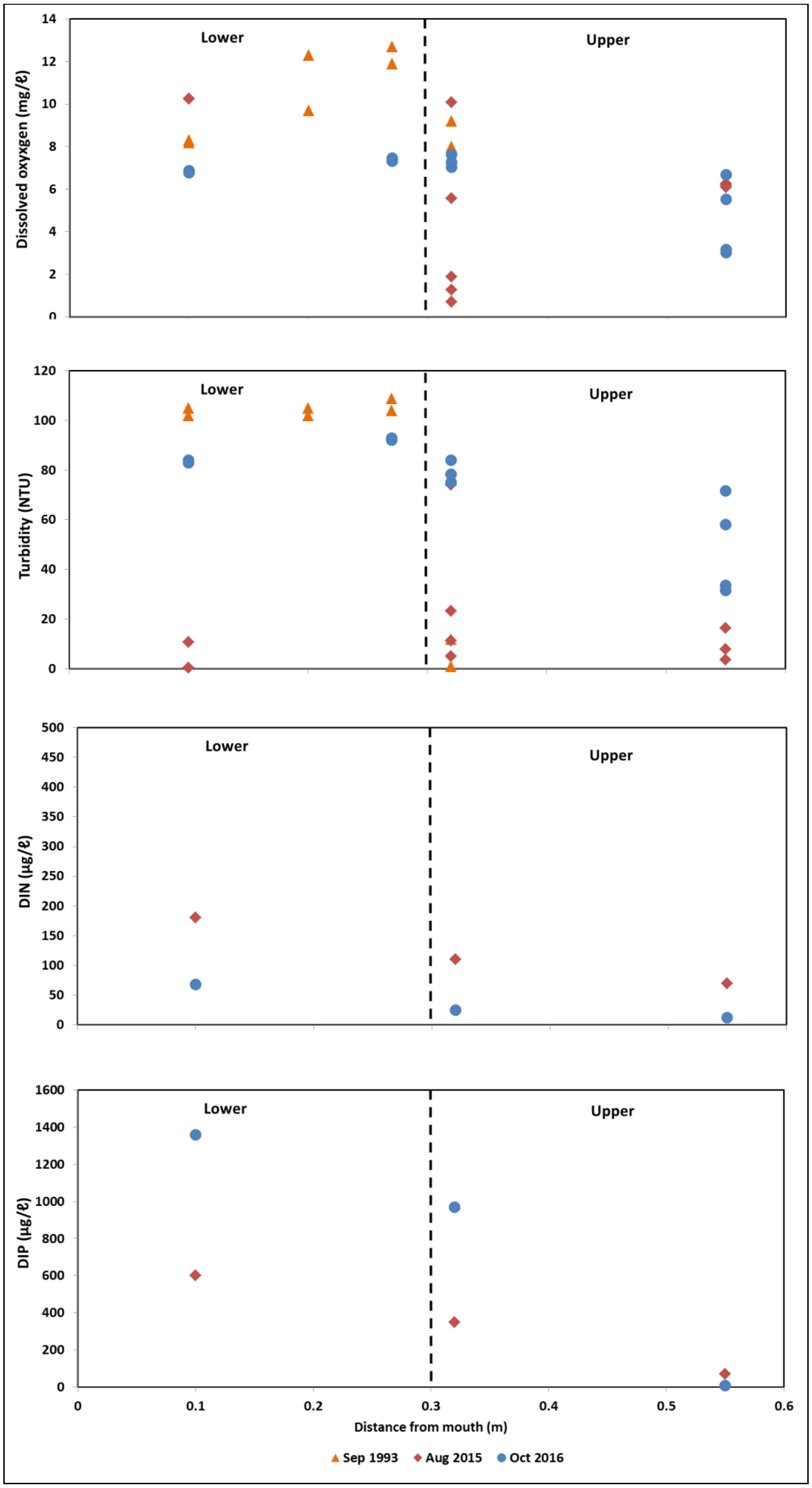


Figure 9.6 Buffels Estuary: Available data for dissolved oxygen, turbidity and inorganic nutrients

The October 2016 observations were the only data sets that showed elevated salinities in the lower reaches. This is attributed to overwash from the sea and lowering/partial removal of the mining road at the mouth (done in 2008, *Pers. Comm*. Anton Meyer). During the October 2016 survey the lower reaches were cut-off from the upper reaches by a road crossing the system diagonally (see sampling map), therefore confining the influence of the overwash to the lower reaches. However, the elevated salinity can also be partially the result of ground water usage by the mining town of Kleinzee.

Available data on the water quality of the Buffels Estuary is limited (Figure 9.4) (Heinecken, 1981a, Harrison, 1998; DAFF, unpublished data; this study). Data on dissolved oxygen (DO) suggest super-saturation occurring in the lower reaches at times with vertical stratification in the deeper section of the upper reaches. Super-saturation is most likely attribute to high algal productivity during the day. However, it can be indicative of hypoxia developing at night associated with high respiration rates. Turbidity in the estuary is high. Harrison (1998) attributed the high turbidity measured in the lower reaches during September 1993 to high concentrations of suspended algae concentrations occurring at the time. DIN concentrations ranged between 10 - 180 µg/l, mostly in the form of Total Ammonia-N (typical non-enriched concentrations in estuaries ~50 µg/l). Unlike DIN, DIP concentrations were exceptionally high towards the lower reaches of the estuary, ranging between 600 - 1300 µg/l (typical non-enriched concentrations in estuaries <10 µg/l). The reason why exceptionally high levels were not evident in DIN maybe linked to it being a limiting nutrient (i.e. already taken up in the algal production). Studies on freshwater wetland have demonstrated the importance of water birds as sources of P and N loading (e.g. Hahn *et al*., 2007 and 2008), which may also be the case in this small estuary, even under the reference condition. However, diffuse runoff from the Kleinzee golf course (adjacent to the estuary), that is irrigated with sewage water, is considered the major anthropogenic contributor to increased nutrient loading under the present, especially P. This nutrient enrichment is typically associated with increased algal productivity, rippling to DO (fluctuating between super-saturation/hypoxia), as well as increased turbidity (i.e. suspended algal matter and/or suspended organic debris). No data on toxic substances were available, but it is assumed that diffuse runoff golf course and adjacent mining activities have contributed to some toxic contamination in the system.

Based on very limited data and information and expert opinion, the average water quality condition under each of the abiotic states, for reference, present and future scenarios are estimated as follows:

Salinity	**Reference**	**Present**
Lower	15 (10 - 20)	20 (5 - 30)
Upper	5	5
DIN (µg/l)	**Reference**	**Present**
Lower	100	300
Upper	50	100
DIP (µg/l)	**Reference**	**Present**
Lower	20	800
Upper	10	200
DO (mg/l)	**Reference**	**Present**
Lower	6	3
Upper	6	3
Turbidity (NTU)	**Reference**	**Present**
Lower	20	80
Upper	10	50

Table 9.6 provides the water quality similarity EHI scores for the Buffels Estuary.

Table 9.6 Buffels Estuary: Summary of changes and calculation of the water quality health score

Variable		Present	Confidence
1	**Salinity**		
	Similarity in salinity *(similarity score adjusted for hyper salinity)*	70	Low
2	**General water quality**		
a	DIN and DIP concentrations	33	Low
b	Turbidity	37	Low
c	Dissolved oxygen	67	Low
d	Toxic substances	70	Low
	Water quality score*	**48**	**Low**

*Score = (0.6 x Salinity + 0.4 x General water quality (min (a to d))

9.6 PHYSICAL HABITAT

Most of the area around the mouth consists of low scrub-covered dunes of windblown sand which overlie fossilised Aeolian dunes which show evidence of crossbedding in places. Inland, outcrops of calcrete eroded by marine terraces can be found. There is also some evidence of strong metamorphic action. The sediments at the mouth consist of a fine to medium quarzitic sand with fine silt in places. In the shallow mouth area, layers of fine organic silt and mud occurred.

The lower reaches consists of flat dune slacks between well formed barchan dunes, which tends to shift northwards under prevailing south-westerly wind conditions. Under natural conditions the Buffels Estuary would have had a relative low sandbar at its mouth which would have allowed for regular overtopping during high spring tides. Heinecken (1981a) recorded berm level of 1.2 m above MSL.

As mentioned before at present the remnant of a mining road crossing the mouth prevents significant overtopping from the seaside.

Overall the Buffels Estuary shows show signs of significant infilling and shallowing throughout the system (with a focus in subtidal and intertidal), resulting from loss of floods (and associated scouring), poor land-use practises causing an increase in sediments from the catchment and the ingress of reeds increasing the sediment trapping efficiency.

The Supratidal and Intertidal sediment structure is expected to be relative similar to that of the Reference Condition, but a there may have been a significant increase in the organic sediment fraction of in subtidal areas of the estuary as a result of enrichment. Table 9.7 below provides a summary of the EHI scores for the physical habitat of the Buffels Estuary.

Table 9.7 Buffels Estuary: Similarity EHI scores for physical habitat

Variable	Present	Confidence
a. Supratidal area and sediments	60	Low
b. Intertidal areas and sediments	60	Low
c. Subtidal area and sediments	50	Low
d. Estuary bathymetry/water volume	25	Low
Physical habitat score*	**49**	**Low**

*Score = Average a. to d.

9.7 MICROALGAE

The estuary is highly transformed which is reflected in the present state of the microalgae. In October 2016 microalgal samples were taken at four sites. Two on the west of the berm, one to the east and the fourth site was adjacent to the golf course (Tee 13) over a small wooden bridge. This was in a freshwater wetland area where *Phragmites australis* was dominant with some *Typha capensis*. This forms part of a reed lined former channel. Salinity at site 1 was 28.3 psu, 4.1 psu at Site 3 and Site 4 was 3 psu. Phytoplankton biomass was extremely low except for Site 3 which showed bloom conditions (chlorophyll-a 25.8 ± 1.5 µg/l). The phytoplankton community was largely comprised of *Chaetoceros* sp. (Bacillariophyceae) and *Cryptomonas* sp. (Cryptophyceae), with density of *ca*. 700 cells/ml for both. Table 9.8 provides the microalgae similarity EHI scores for the Buffels Estuary. Most of the changes were from anthropogenic influences (80%) and 20% from decreases in groundwater input and floods.

Table 9.8 Buffels Estuary: Microalgae similarity EHI scores

Variable	Present State	Score	Confience
a. Species richness	The loss of connectivity, changes in water volume, salinity and nutrients has decreased species richness.	50	Low
b Abundance	Fresh standing pools of water (e.g. Site 3) can have fairly high phytoplankton biomass which would increase in response to nutrient input from wastewater input used on the golf course.	45	Low
c. Community composition	Possibly a complete alteration in community structure due to changes in the water body, the system is no longer a continuous water body and has been severely impacted due to infilling and roads.	45	Low
Score min (a to c)		**45**	**Low**

9.8 MACROPHYTES

To confirm present vegetation types a field trip to the Buffels Estuary took place on 5 October 2016 (Figure 9.6). The mouth was closed at the time with the sand berm at the mouth very wide and low. The vegetation was mapped to the end of the tarred road which is approximately 1.6 km from the mouth of the estuary. Adjacent to the estuary mouth is Namaqualand Seashore Vegetation, characterized by hummocks of *Sarcocornia pillansii* and *Cladoraphis cyperoides (Eragrostis cyperoides*). Namaquland Coastal Duneveld occurs behind the Arid Estuarine Salt Marsh and merges into Namqualand Strandveld on the higher elevations. Arid Estuarine Salt Marsh occurred on the northern side of the open water at the mouth reaching 10 m in places. Species included *Sarcocornia pillansii*, *Cladoraphis cyperoides (Eragrostis cyperoides*) and *Sporobolus virginicus*. Cover varied between 50 to 100 % with bare open sand in between. Arid Estuarine Salt Marsh merged into

Namaqualand Riviere with *Acacia cyclops* dominant. The lower section below the tarred road is very disturbed. At the time of the site visit the Rooikrans was being cut by a subcontractor for firewood.

There was no surface water in the upper reaches and so holes were augured to assess the depth to the water table and water table salinity. There was groundwater near a *Juncus kraussii* stand in the upper reaches. This was at approximately 1 m depth with a salinity of 2.4 - 3.1 psu. Reeds and sedges occur within the Arid Estuarine Salt Marsh /Namaqualand Riviere mix. These are predominantly *Phragmites australis* with some *Typha capensis* (bulrush) at the wooden bridge. Reed beds start at the bird hide located on the broken access road. They cover almost the complete water course from side to side with a small channel of open water in the middle. They are particularly abundant, tall and robust in the area adjacent to the golf course. These reeds are often backed by a narrow band of *Sarcocornia pillansii* and are also associated with *Juncus kraussii* in the Namaqualand Riviere further upstream.

The submerged macrophytes *Potamogeton pectinatus* (now *Stuckenia pectinata*) occurs in the open standing water adjacent to the reeds along with *Potamogeton pectinatus*. Macroalgae were not mapped as the area they covered was too small but they were noted as present. A golf course occupies a large part of what would have been Namaqualand Coastal Duneveld.

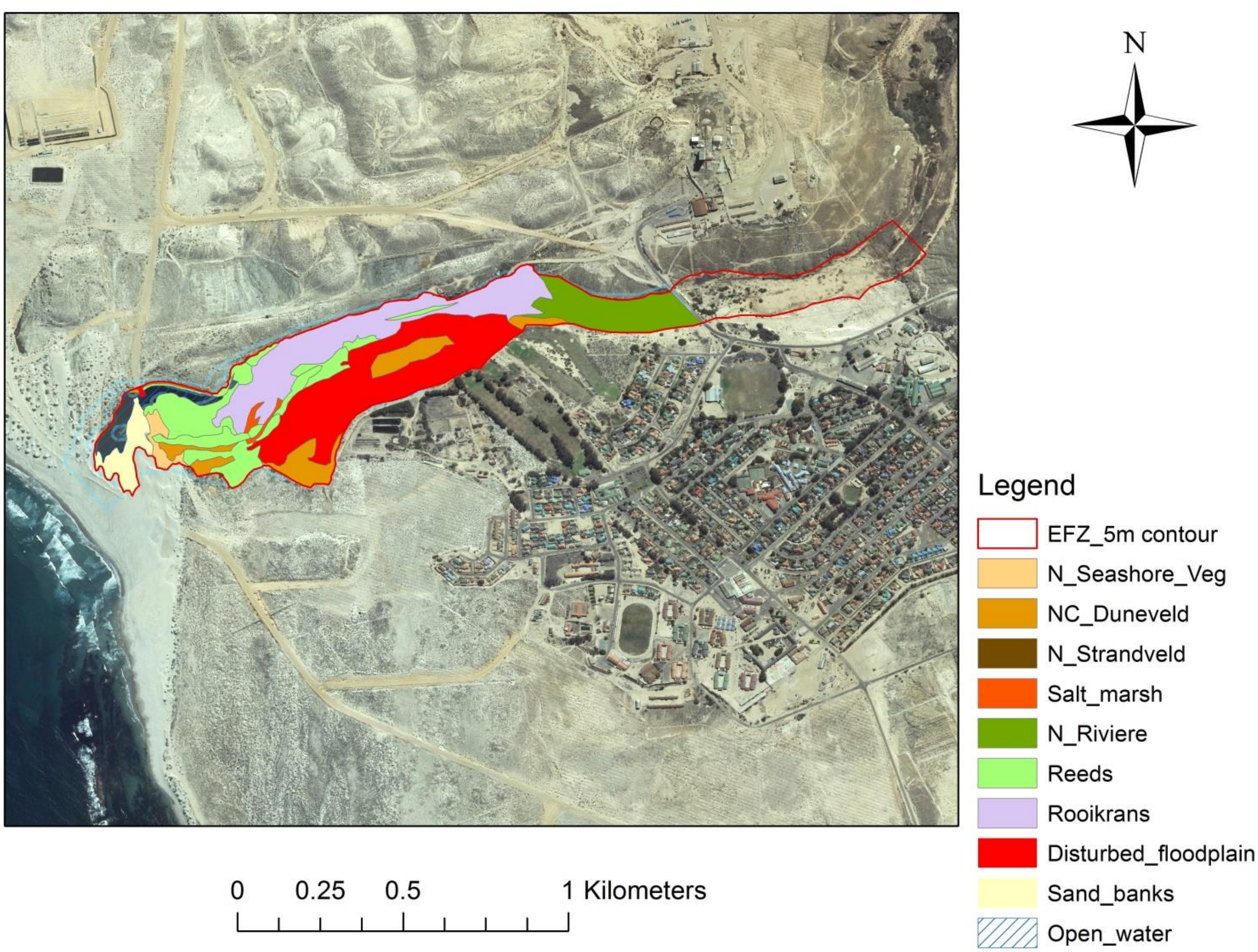


Figure 9.7 Buffels Estuary: Vegetation map for the EFZ based on the 2014 aerial images

Disturbance in the floodplain has led to the loss of habitat and species richness. This is due to the many minor access roads, culverts, levee and golf course. The main habitat impacted would be the Arid Estuarine Salt Marsh (supratidal salt marsh – 50% decrease) and floodplain vegetation (Namaqualand Coastal Duneveld – 30% decrease). There has been an increase in invasive species through the planting of rooikrans in the water course. Reeds have increased (50%) due to watering of the golf course using wastewater. Sand banks and seashore vegetation around the mouth might have increased due to the abstraction of water from the estuary and surrounding recharge areas. Open water has decreased over time (50%) due to abstraction for mining and human consumption and overgrowth of reeds into the water column.

A number of disturbances have taken place in the EFZ over time. The major modification to the estuary is the abstraction of water from the aquifer for Kleinzee residents and mining activities. This decreased the input of freshwater into the system over time as can be seen by attempts to map change in open water area over time (1976 – 10.91, 1985 – 6.59 ha, 1990 – 2.28 ha, 2003 – 2.5 ha, 2011 – 2.38 ha, 2014 – 1.66 ha).

Although not evident in the change in open water area over time, there has been increased freshwater input into the estuary near the golf course. This is due to irrigation of the golf course with treated waste water. This has increased the extent of the reed beds although not evident on the images due to their poor quality. Between 2011 and 2014 the area covered by the reed beds has been stable. Seepage of freshwater from the golf course probably also lowers the salinity of the water column further increasing reed encroachment. Localised mats of macroalgal growth could also be due to seepage of the nutrient rich water from the golf course, especially as water level drops. Other modifications to the Buffels Estuary include causeways, road with culverts, golf course, walk ways around the dunes on the southern side of the mouth, a 700 m levee that protects the golf course from flooding and the planting of rooikrans in the water course.

The site visit confirmed extensive transformation of the estuarine habitat. That said ongoing rehabilitation efforts should be encouraged e.g. removal of rooikrans, no driving on the beach, management of the golf course. The old roads and causeway in the main river channel should be removed to restore habitat connectivity. The freshwater wetland area fed by the golf course creates habitat diversity in this arid environment. Table 9.9 provides themacrophyte similarity EHI scores for the Buffels Estuary.

Table 9.9 Buffels Estuary: Macrophyte similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Loss of species due to loss and disturbance of floodplain and supratidal salt marsh habitat. Invasion of the upper reaches by *Acacia cyclops* would have also caused loss of species.	40	Medium
b Abundance	Approximately 50% of the supratidal salt marsh and 30% of the floodplain habitat has been lost or disturbed. Freshwater and nutrient input from the golf course has encouraged the development of a freshwater wetland area which has compensated for some habitat lost.	30	Medium
c. Community composition	Disturbed areas are dry, barren and saline. Some dry areas have been transformed to freshwater wetland / reed habitat.	30	Medium
Score min (a to c)		**30**	**Medium**

9.9 INVERTEBRATES

There have been no directed invertebrate surveys of the Buffels Estuary up until now. Limited identification of the rocky shore and sandy habitat invertebrates adjacent to the mouth as well as “dry pans” of the estuary were reported in the 1980 ECRU survey (Heinecken, 1981). At that time, the dried-out mudpans were being turned over and aerated by burrowing carabid beetles *Pagonus lamprus*, kelp-wrack foraged by kelp beetles *Pachyphaleria capensis* and one isopod *Pontogeloides latipes* was collected in the berm. They also report a single scoop-net sample from the estuary containing a large number of aquatic invertebrates but failed to identify them. More recently directed sampling of brine-shrimp in the salt-pans adjacent to the river verified the Kleinzee and Buffels estuary population as the indigenous *Artemia salina* and not the invasive *Artemia franciscana* that has replaced it in the Berg Estuary saltpans at Veldrift and other sites in South Africa (Baxevanis *et al*., 2014). The brine shrimp populations in the other West Coast systems still need to be assessed.

Then as now, there have never been any records of sandprawn *Callichirus kraussi* or other large macroinvertebrates in the estuary. There are also no records of freshwater crab Potamonautes sp. usually common in reed habitats. A 2m 500 micron seine during the October 2016 trip yielded a large and diverse catch of crustaceans (Amphipods, Isopods), insects (e.g. water boatmen Corixidae, backswimmers Notonectidae), insect larvae (e.g. dragonflies Gomphidae, flies Chironomidae) and oligochaetes in the lower estuary. Identification and quantification of this sample still needs to be completed.

Under reference conditions with no groundwater abstraction or wastewater-irrigation, return flow open water area would have been greater as would have associated macroinvertebrate and zooplankton biomass. Absence of the two roads / road remnants would have seen a lower berm and recruitment of nearshore macrocrustaceans such as shrimp Palaemonidae into the system. Similarly, absence of the “old road” berm bisecting the estuary at the bird-hide would have seen greater connectivity as well as a salinity gradient between the sea, lower, middle and upper reaches of the estuary. The periods between floods are likely to have seen the system becoming more stable and open water area decrease with evaporation and growth of *Phragmites* beds. Consequently, there would have been a gradual switch from open water to reed habitat and associated species dominating the system.

In the present day the open-water area has decreased and been bisected by the sand-berm on the “old road” and the high seawards berm on the “new road” prevents any overwash recruitment of invertebrates and fish from the sea. The berms, causeways and other obstructions also prevent invertebrates from swimming between reaches and escaping deteriorating conditions in parts of the estuary. Undue mortalities thus occur. Another consequence of these obstructions is that the gradual change in physical-chemical characteristics between flood events experienced under reference are now likely to be more abrupt and again cause stress and mortalities of biota.

Table 9.10 Buffels Estuary: Invertebrates similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Estuarine brackish species in lower reaches below bird hide (old road) and freshwater species above. Decline in zooplankton, open water species but increase in diversity of freshwater species associated with pondweed and *Phragmites*. Lower reaches currently dominated by amphipods, oligochaetes and insect larvae in the benthos.	70	Low

b Abundance	Loss of saltmarsh and floodplain invertebrates (predominantly insects and insect larvae). Loss of inundated benthic habitat and associated species e.g. Oligochaetes.	50	Low
c. Community composition	Then and now community composition would have changed with the habitat over the 8 - 10 years of mouth closure.	70	Low
Score min (a to c)		**50**	**Low**

9.10 FISH

Previous studies in the Buffels Estuary recorded no fish in the system. The 1980 ECRU survey (Heinecken, 1981a) reported seeing a shoal of *L. richardsonii* in the surf-zone but no fish in the estuary whereas Harrison (2002) failed to catch or see any fish there. De Beers environmental officers reported pre and post flood mortalities of harders *L. richardsonii* and flathead mullet *M. cephalus* in 2003/4 whereas Lamberth *et al*. sampled both live and dead *L. richardsonii* and *M. cephalus* in February 2005. Fish mortalities were again reported during a flood in October 2005. Since then, Kleinzee residents reported ongoing mortalities of *L. richardsonii* and *M. cephalus* in 2015. Follow up sampling in August 2015 found 100% mortalities of fish upstream of the bird-hide and 30 - 50 *L. richardsonii* and *M. cephalus* surviving by being isolated between the two berms. Flood-related mortalities were mostly associated with high-sediment loads, gill-clogging and suffocation whereas the 2015 mortalities were due to eutrophication, plant respiration, decay and oxygen depletion in the middle and upper reaches.

Reference conditions in the Buffels Estuary are also likely to have been dominated by *M. cephalus* and *L. richardsonii* but in much greater abundance than present as the absence of the roads and much lower berm would have seen a much higher incidence (i.e. >1/10 years) of overwash recruitment. The probability of recruitment of more rare species such as white steenbras *Lithognathus lithognathus* would also have been higher. Post recruitment survival would have been higher in the absence of eutrophication and low-oxygen events and in the absence of back-flooding of sediment-laden water against the road berm and resultant gill-clogging and suffocation of fish. Community composition would have been more complex under reference due to the occasional recruitment of the rarer fish species and the occurrence of two or more age cohorts (occupying different “niches”) as compared to the one or none in the present day. Table 9.11 provides the fish similarity EHI scores for the Buffels Estuary.

Figure 9.8 Fish smothered by silt during prolonged breaching (2005) and example of mullet in Buffels Estuary

Table 9.11 Buffels Estuary: Fish similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Similar to reference but recruitment and survival a lot less due to old and new roads across the estuary. Survival and recruitment facilitated by overwash Prolonged mouth closure with no overwash would only see hardy species i.e. harder. *L. richardsonii* and flathead mullet *M. cephalus* persist in the system. Nowadays absolutely no chance of other species such as white steenbras *L. lithognathus* surviving after recruitment into the estuary.	60	Low
b Abundance	Artificial berm (road), recruitment decline, loss of open-water area and increase in low-oxygen events would have seen a drastic decline in survival and abundance.	30	Low
c. Community composition	Then and now community composition would have changed with the habitat over the 8-10 years of mouth closure but mostly confined to *M. cephalus* and *L. richardsonii*. However, nowadays with the absence of overwash recruitment, recruitment would only occur after floods so at any-one-time, there would only be one year-class of any species in the system.	60	Low
Score min (a to c)		**30**	**Low**

9.11 BIRDS

Information on the birds of the Buffels Estuary is limited. Three counts since 1980 to the present have recorded 48 bird species at the Buffels Estuary (Table 9.12). The 1980 ECRU survey recorded 29 species and the 2015 and 2016 counts 19 and 16 species respectively. The higher 1980 count included 12 terrestrial species, which the more recent ones did not.

Table 9.12 Buffels Estuary: Recorded birds

Species	14 Oct 1980 (Heinecken 1980)	16 Aug 2015 (Grant Smith)	5 Oct 2016 CSIR	Max no
White-fronted Sandplover	60		1	60
Curlew Sandpiper	17		1	17
Turnstone	5			5
White-breated Cormorant	37	1		37
Cape Wagtail	11		3	11
Coot	1		12	12
Ringed Plover	4		1	4
Ruff	5			5
Cape Cormorant	27			27
Southern Black-backed Gull	150	3		150
Hartlaub's Gull	355	12		355
Grey-headed Gull	4	8		4
Common Sandpiper	1			1
Stilt	2			2
South African Shelduck	2	2		2

Species	14 Oct 1980 (Heinecken 1980)	16 Aug 2015 (Grant Smith)	5 Oct 2016 CSIR	Max no
White-throated Swallow	2			2
Greenshank	1			1
Blacksmith Plover	3			3
Karoo Scrub Robin	4			4
Masked Weaver	2			2
Pied Starling	1			1
Wattled Starling	12			12
Red Bishop bird	54			54
Stone Chat	1			1
Namaqua Dove	3			3
Rock Pigeon	1			1
Cape Sparrow	abundant			1
Brown throated martin	4		50 plus	50
Sacred ibis		2	10	10
Cape teals		2	11	11
Flamingo greater		30	1	30
Lesser flamingo			1	1
King fisher pied			1	1
Cape shoveler		5	2	5
Black crake			heard	1
Egyptian goose			heard	1
Stilt			11	11
Grebe black necked		4	2	4
Little grebe		7		7
Grey heron		1		1
Red billed teal		2		2
African fish eagle		1		1
Common moorhen		16		16
Red-knobbed coot		71		71
Mute / domestic swan		1		1
Water thick-knee		1		1
Swift tern		3		3
Total species	**28**	**19**	**16**	**48**
Total number	**769**	**172**	**57**	**998**

Consequently, the 16 waders and waterbirds recorded then are similar to the numbers in the present day and suggest bird species composition to have been stable over the past three decades. However, a closer look shows the 1980 counts to have been dominated by roosting gulls, sandplovers and cormorants, 2015 by waterbirds and flamingos and 2016 almost exclusively by brown-throated martin. All three counts are reflective of salinity and water volume at the time of sampling these being high salinity and low water in the 1980s, low salinity and abundant nesting and foraging habitat for waterbirds in August 2015 and water surface area having shrunk to at least half of this with higher salinity by October 2016. The increase in flamingos in 2015 may have been due to the ultra high salinity and unavailability of brine shrimp food in the Swartlintjies and Groen estuaries at the time. The one mute swan observed in 2015 is one of a group that regularly visit the Buffels Estuary from a private collection 15 km away at the Houthoop Guest-lodge.

Overall, bird abundance and species composition in the Buffels Estuary has not changed much from reference and is mostly a function of salinity, water volume, surface area and available food, foraging and nesting habitat in this and adjacent systems. Most of the change is likely disturbance and loss of habitat as a result of mining operations and infrastructure, including the roads and causeways that crisscrossed the estuary. Although mining traffic has ceased, disturbance remains in the form of illicit quad-bike and other recreational vehicular use at the mouth of the estuary. Table 9.13 provides the birds similarity EHI scores for the Buffels Estuary.

Table 9.13 Buffels Estuary: Birds similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Some loss of species as a result of higher salinity, reduce water volume and surface area and reduced foraging and nesting habitat in this and adjacent systems.	75	Low
b Abundance	Reduce abundance as a result of higher salinity, reduce water volume and surface area, less available food, and reduced foraging and nesting habitat in this and adjacent systems.	60	Low
c. Community composition	Significant shift as a higher salinity, reduce water volume and surface area, less available food, and reduced foraging and nesting habitat in this and adjacent systems.	50	Low
Score min (a to c)		**50**	**Low**

10 APPENDIX B: THE SWARTLINTJIES ESTUARY DESKTOP EWR

Appendix B provides the detailed methods and scores for the abiotic and biotic components of the Swartlintjies Estuary.

10.1 DELINEATION

The Swartlintjies Estuary is situated approximately 6.5 km south of Hondeklip Bay within a strict security area of the Koignaas mining concession. This area was previously mined by De Beers and West Coast Resources is currently re-establishing diamond mining operations in the vicinity of the estuary. The estuary is situated within the Cool temperate biogeographic region of South Africa (van Niekerk and Turpie, 2012) and spans the Kamiesberg and Nama Khoi Local Municipalities (part of the Namaqua District Municipality) in the Northern Cape Province.

The Swartlintjies Estuary was classified as a small ephemeral river outlet and not considered one of the 289 functional estuaries in South Africa (Van Niekerk and Turpie, 2012), however observation made by the Northern Cape Government indicate that the system supports a waterbody for most of the time. Thus warranting a revisit of the estuary classification and highlighting the need for an EWR study.

An estuary is defined in terms of the National Environmental Management: Integrated Coastal Management Act (ICMA) (Act No. 24 of 2008) and the NEMA 2014 EIA Regulations as “a body of surface water that is permanently or periodically open to the sea; in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the body of surface water is open to the sea; or in respect of which the salinity is higher than fresh water as a result of the influence of the sea, and where there is a salinity gradient between the tidal reach and the mouth of the body of surface water.’’ While this definition is in line with those used internationally in respect of estuary water bodies it is considered somewhat limited inasmuch as it encapsulates only the estuary water body and not the adjacent physical and biological processes and habitats required to support estuarine function and health. Thus, as part of the Estuary Component of the NBA (Van Niekerk and Turpie, 2012) a definition for the EFZ was formulated which extended the lateral boundaries of an estuary up to the 5 m contour, with the downstream boundary taken as the estuary mouth and the upstream boundary taken as the limits of tidal variation or salinity penetration, whichever penetrates furthest.

Therefore the geographical boundaries of the Swartlintjies Estuary are defined as follows (Figure 10.1):

Downstream boundary:	30°15'44.33"S 17°15'36.39"E (Estuary mouth)
Upstream boundary:	30°15'45.73"S 17°17'8.36"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 10.1 Swartlintjies Estuary: Geographical boundaries based on the EFZ

10.2 MAJOR PRESSURES

The major pressures on the Swartlintjies Estuary include:

- Obstruction of freshwater flow.
- Destruction of habitat through as road infrastructure and sumps.
- Alien vegetation.
- Nearby slime dams potentially introduce saline water and dust from the mine dumps.

10.3 HYDROLOGY

The estuary is fed by the Swartlintjies River, which is approximately 65 km long with a catchment size of 1748.48 km^2 (DWA, 2009b). The ephemeral Swartlintjies River only flows for short periods of time after rainfall events which occurring mostly between April and August. The Swartlintjies River and its tributaries have zero flow for more than 75% of the time and hence the catchment receives a low MAR of 1.2 Mm^3.

The riverbed in the upper catchment is deeply incised and the presence of braided channels indicates that the river should, if unhindered, come down in flood during episodic rainfall events (Heinecken, 1980). As is the case with other west coast rivers, the Swartlintjies is young in geological terms and is fast flowing when in flood. Such floods cause considerable erosion and the river is expected to deposit its silt load in the coastal flood plain (Heinecken, 1980).

Summary of monthly flows under Reference conditions is provided in Table 10.1. Desktop simulations of the surface hydrology indicate little change in the surface water flows, however this does not take into consideration the impact of road infrastructure throughout the catchment, and specifically just above the estuary.

Flow in the lower catchment and into the estuary has been severely reduced as a result of the construction of roads through the riverbed. The road connecting Hondeklip Bay with the Koingnaas mining entrance crosses the river 9 km from the mouth connecting the river on either side by a pipe with a diameter of approximately 50 cm (Massie and Clark, 2016). The pipe is not visible on the upstream side of the gravel road and it is suspected that the inlet is buried, causing the road to act as a flood attenuating, and minimally permeable barrier (Massie and Clark, 2016). The haul road situated 3 km upstream of the mouth within the restricted mining concession area of the WCR represents another barrier to the flow of the Swartlintjies River, preventing runoff from much of the catchment from reaching the estuary and the river from reaching the floodplain. In an attempt to connect the river to the estuary, a number of pipes have been buried in the gravel of the haul road. These pipes are, however, ineffectual as the inlets for the pipes are elevated approximately 1 m above the river bed (Massie and Clark, 2016). Two smaller roads situated 1 km and 2.2 km from the mouth are no longer in use but are still in place and are further impeding the very limited flow that would otherwise reach the estuary.

These structures have significant influence floods and baseflows to the Swartlintjies Estuary and therefore the opportunity for breaching. Assume a 30% reduction in the magnitudes of floods reaching the estuary as a result of local structures.

Table 10.1 Swartlintjies Estuary: Simulated monthly flows (in 10^6 m^3) under Reference Conditions

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breaching**
1920	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	6.9	2.3	0.1	0.0	9.6	1
1921	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	1.0	0.4	1.7	1
1922	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.4	0.1	0.9	0
1923	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1924	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1.1	0.0	0.0	4.5	1
1925	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1926	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	1.0	0
1927	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1928	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0
1929	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	1.0	0
1930	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1931	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0
1932	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.5	0
1933	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.1	0.0	0.6	0
1935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0
1936	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.7	0
1937	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1938	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.9	3.6	1
1939	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0
1940	0.0	2.3	0.8	0.0	0.0	0.0	0.1	0.7	0.8	0.2	0.3	0.1	5.3	1
1941	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.0	0.0	1.1	0
1942	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.2	0.1	0.9	0
1943	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.6	0.4	0.1	0.1	0.0	1.5	0
1944	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.1	0.0	0.5	0
1945	1.9	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	2.7	1
1946	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.3	0
1947	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1949	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.8	0.3	0.4	2.0	0
1950	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.0	1.5	0
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.4	0.0	1.5	1
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.0	0.3	0.1	1.0	0

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breaching**
1953	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.6	0.2	0.6	0.2	0.0	1.9	0
1954	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.1	0.7	0.2	1.6	0
1955	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.4	0
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.4	0
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.8	0
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.1	0.1	0.0	0.0	0.8	0
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	1.2	0.2	0.1	4.9	1
1962	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.8	0
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.5	0
1964	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1965	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.5	0
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.4	0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.3	0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	1.6	0.5	2.6	1
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.6	0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.5	0.1	0.0	1.5	0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.4	0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.1	0.0	1.1	0
1980	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	1.3	0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.1	0.0	0.7	0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.7	0.1	0.0	0.1	2.9	1
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0
1985	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	4.7	1.6	0.0	0.0	6.6	1
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.3	0.0	1.1	0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.6	0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.7	0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.1	0.0	0.8	0
1991	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0
1992	0.0	0.0	0.0	0.0	0.0	0.0	5.5	2.2	0.3	0.1	0.0	0.0	8.3	1
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.0	0.0	1.1	0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.4	0
1995	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.3	1.2	0
1996	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.8	1.4	0.3	0.0	0.0	3.7	1
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0
1999	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.7	0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	1.0	0.1	3.4	1
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.5	0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.8	3.1	1
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2004	0.3	0.1	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.8	0

* Years that the Swartlintjies Estuary could have potentially breached is indicated by 1.

Groundwater is estimated to be similar to Reference condition.

Table 10.2 Swartlintjies Estuary: Groundwater recharge and discharge estimates

Groundwater	F40D
Groundwater catchment area	739.0
Estuary catchment area	489.0
Reference recharge to estuary Mm^3/a	1.0
Reference Estuary discharge Mm^3/a	0.6
Use in Catchment Mm^3/a	0.036
Present Estuary Mm^3/a	0.59262
Use as % discharge	0.049385
% Similarity	94.3
Ground water TDS mg/l	3251.0
Reference Total salt from groundwater (tons/a)	2044

Table 10.3 provides the hydrology similarity EHI scores for the Swartlintjies Estuary.

Table 10.3 Swartlintjies Estuary: Similarity scores for hydrology relative to the Reference condition

Variable	Present	Confidence
% similarity Groundwater	94	Low
% similarity frequency and magnitude of floods	70	Low
Hydrology score	**84**	

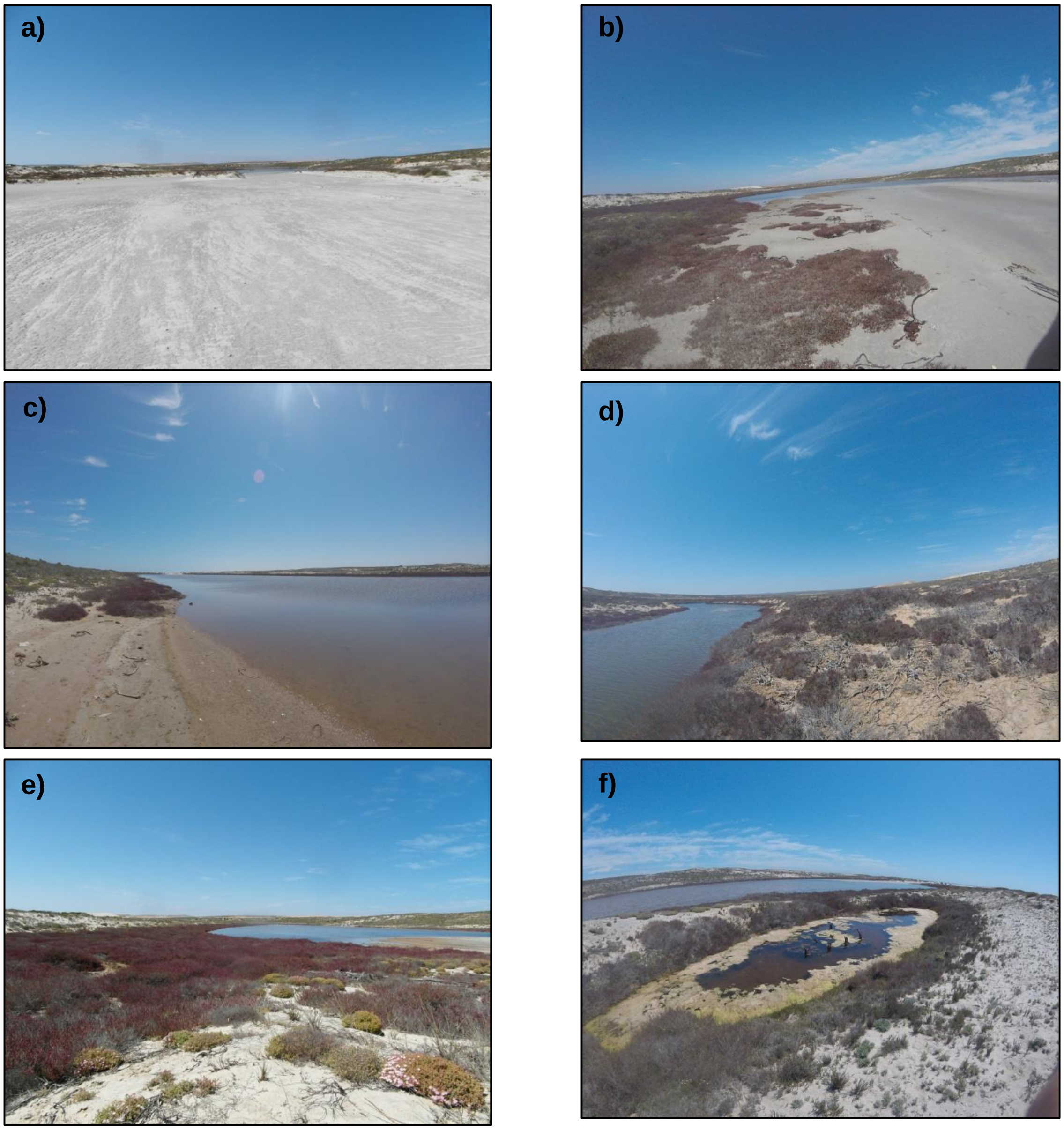
10.4 HYDRODYNAMICS

10.4.1 Mouth State

The Swartlintjies EFZ covers 1.4 km^2. The lower reaches of the Swartlintjies Estuary characterised by two extended meanders that widen out into the floodplain that was created by an extensive network of braided flood channels. The floodplain is approximately 400 m wide and 1.8 km long. The estuary then narrows into a channel that is flanked by low-lying vegetated dunes but widens again slightly towards the mouth, which opens northwards into a small bay (Heinecken, 1980). Low hummock dunes can be found south of the flat sandbar (approximately 0.5 m above Mean High Water Spring tide level) (Heinecken, 1980) that separates the mouth from the sea. Parts of the barchanoid dunes to the north of the mouth were removed permanently during trench excavation in the past.

The Swartlintjies Estuary is very seldom connected to the sea through an open mouth. Natural breaching by flood waters is estimated to have occurred every 3 to 10 years during floods. Open mouth conditions would only prevail for short periods (days to weeks) as flood peaks in arid catchments generally is a matter of hours with little follow up flow. The sand bar at the mouth of the Swartlintjies is very low and overtopping occurs regularly at high spring tides even after mouth closure. Marine sediment intrusion at the mouth is evident about 500 m from the mouth as a result of this marine intrusion (Heinecken, 1980; Massie and Clark, 2016). The presence of recent and bleached dried kelp 500 m upstream confirms observations made during earlier surveys and indicates that seawater regularly penetrates the system at spring tide. Aerial photographs and satellite imagery shows significant movement of the mouth over time to its present position.

The mouth of the Swartlintjies Estuary was artificially breached by DBCDM in August 1978 and December 1978 to allow seawater into the estuary. It closed naturally shortly thereafter. Artificial breaching was also done in early 1980 and the estuary contained water for approximately 6 months after the breaching (Massie and Clark, 2016).



(a) and (b) The exceptionally low berm at the mouth with signs of regular overwash; (c) The middle reaches of the estuary; (c) The upper reaches; (e) An overview of the relatively untransformed EFZ; (f) The remnant sumps along the banks of the Swartlintjies Estuary.

Figure 10.2 Swartlintjies Estuary: Key Features

The reduction in in episodic floods due to obstructions to flow in the lower catchment and the EFZ potentially significantly reduces the opportunity for mouth breaching, but impossible to quantify with a high degree of confidence without a detail flood evaluation study.

Table 10.4 Swartlintjies Estuary: Summary of the mouth state based on available imagery

Year	Source	Mouth state (Open/closed)
2014	National Geo-Spatial Information (Surveys and Mapping)	Closed
2011	National Geo-Spatial Information (Surveys and Mapping)	Closed
2006	Google Earth	Closed
2003	National Geo-Spatial Information (Surveys and Mapping)	Closed
2003	Google Earth	Closed (very green….)
1996	National Geo-Spatial Information (Surveys and Mapping)	Closed
1989	National Geo-Spatial Information (Surveys and Mapping)	Closed
1985	National Geo-Spatial Information (Surveys and Mapping)	Closed
1976	National Geo-Spatial Information (Surveys and Mapping)	Closed
1965	National Geo-Spatial Information (Surveys and Mapping)	Closed
1958	National Geo-Spatial Information (Surveys and Mapping)	Closed
1942	National Geo-Spatial Information (Surveys and Mapping)	Closed

10.4.2 Openwater area and water levels

In 2016 the estuary was filled with hypersaline seawater of up to 50 cm depth and a continuous water body extended approximately 450 m inlands from the berm. Stagnant pools and water in narrow channels extended up to approximately 980 m upstream above this point.

Hypersaline conditions and stagnant water with signs of eutrophication 980 m from the mouth indicates that estuarine water possibly penetrates 1 km inland during spring tides and higher flow events and thereafter forming a salt crust as it evaporates slowly.

Unfortunately, very little high quality imagery exists that allows for the mapping over time of the openwater area of the small Swartlintjies Estuary. All available aerial imagery is listed in Table 10.5 below. The imagery quality in the earlier years made it difficult to calculate open water area and data therefore carries a low confidence level. What is available shows little change varying between 1.2 and 1.8 ha, i.e. can vary by as much as a third in area, but this can be a reflect of tidal interactions or fresh water input.

Additional concern is the fact that the estuary was completely dried out in 1980, but recent observations (pers comm Klaas van Zyl, Northern Cape Government) indicate that this have not happened in recent history. Thus, raising the concern that seepage from the adjacent mining areas may be contributing to a raised water table and the more stable water levels in the system at present.

Table 10.5 Swartlintjies Estuary: Change in open water area over time

Year	Open water area (ha)
2014	1.17
2011	1.37
2006	
2003	
2003	1.79 (quality poor so low confidence)
1996	
1989	Quality too poor
1985	Looks about 85% of 2014…
1976	Quality too poor
1965	Quality too poor
1958	Quality too poor
1942	Quality too poor

Two excavated sumps on the estuary banks just north of the estuary mouth contained stagnant and eutrophic water at the time of the field survey for this study. They were presumably created for water to be pumped to mining activities -the base of an old pump was observed as well as an abandoned pipe.

At the time of the ECRU survey in 1980, these trenches contained water to a depth of 20 cm. The water level in these hollows was approximately 1.25 m below the level of the dry riverbed, indicating a relatively high water table. These sumps were filled with filamentous algae at the time of the October 2016 trip.

Over all the Swartlintjies hydrodynamics shows a moderate level change overtime, with the degree of flood modification (related impact on breaching) and raised water table due to mining activities significant unknown factor.

Table 10.6 Swartlintjies Estuary: Similarity scores for hydrodynamics under the various operational scenarios relative to the Reference Condition

Variable	Present	Confidence
Mouth condition	80	Low
Circulation (connectivity)	95	Medium
Water level	80	Low
Hydrodynamics score	**80**	**Low**

10.5 WATER QUALITY

Figure 10.3 shows locality map of sampling sites in the Swartlintjies Estuary.

Figure 10.3 Swartlintjies Estuary: Water Quality sampling stations

Very little historical information exists on the water quality of Swartlintjies Estuary. What little there is suggests that the estuary tends to be hypersaline in nature. For example, the Swartlintjies estuary was dry during the 1980 ECRU Survey, i.e. no data.

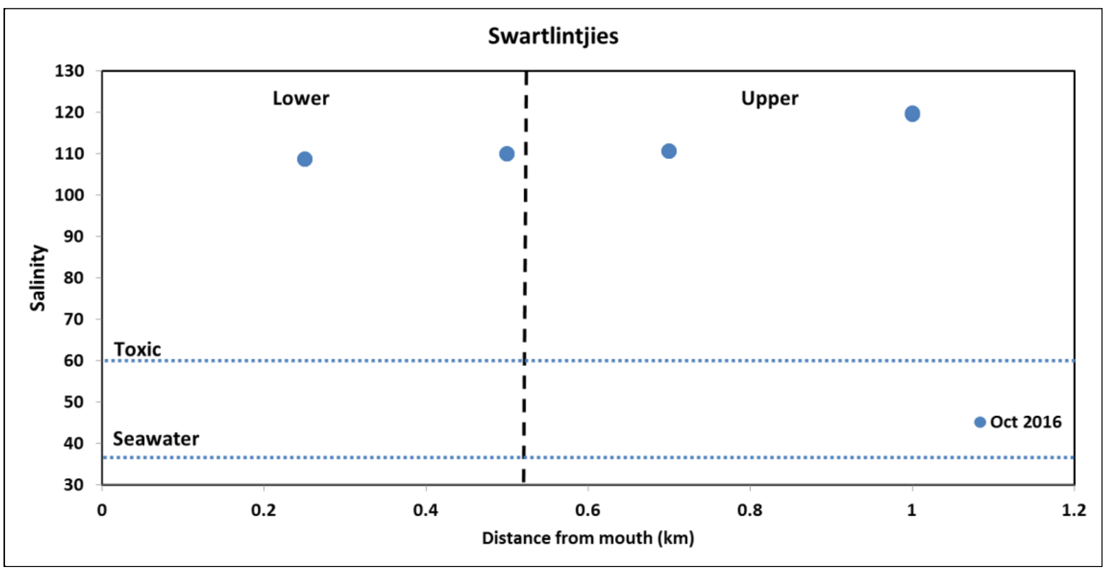


Figure 10.4 Swartlintjies Estuary: Available salinity data

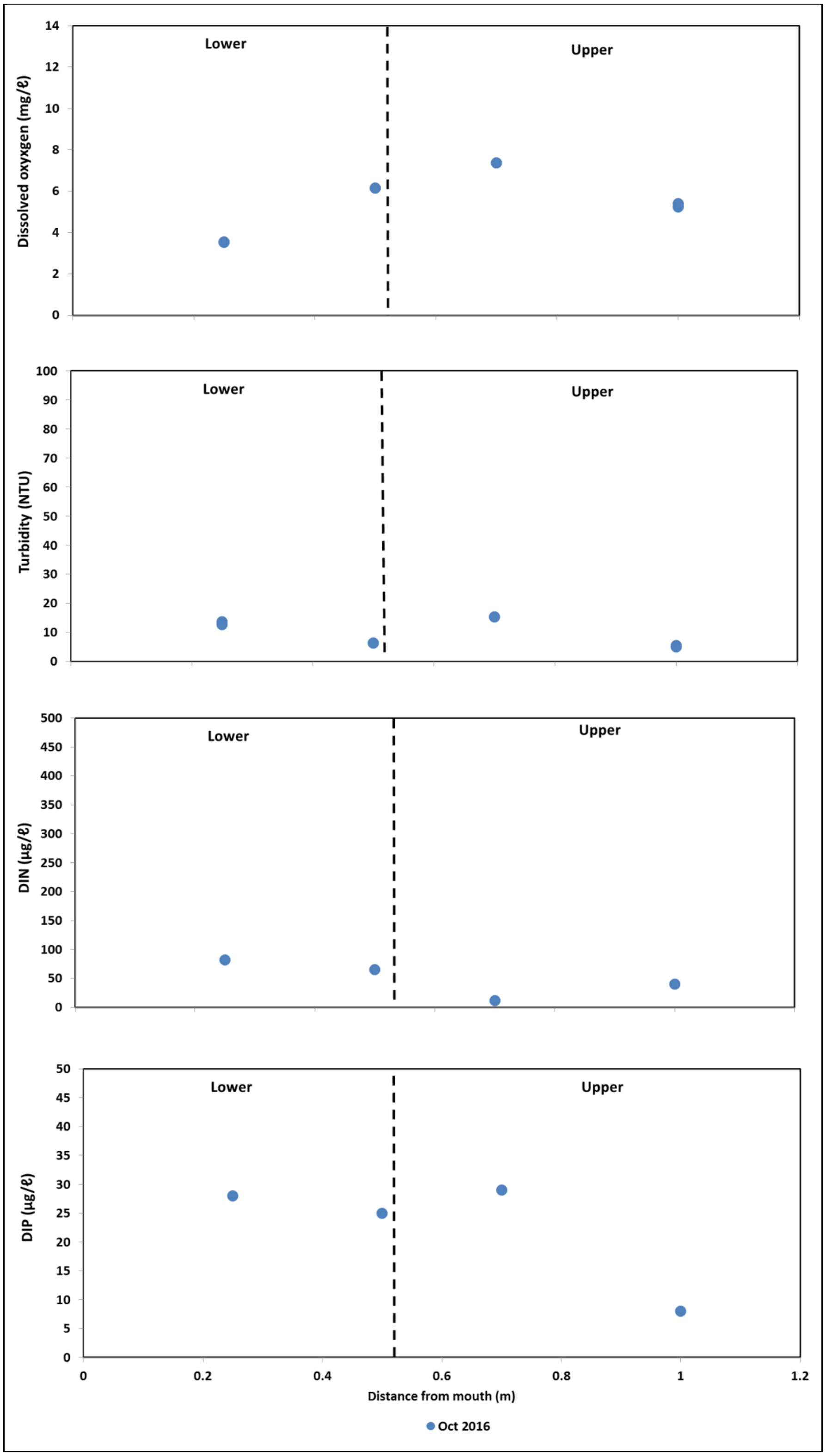


Figure 10.5 Swartlintjies Estuary: Available data for dissolved oxygen, turbidity and inorganic nutrients

Harrison (unpublished data on 18 January 1990 recorded in 40 in the lower reaches of the Swartlintjies. Anchor Environmental sampled the system on 22 June 2016 and recorded hypersaline conditions through out the system with conductivity ranging from 147 - 172 mS/cm (>100 psu salinity).

During the October 2016 CSIR survey salinity fluctuating between 110 and 120 psu (with seawater 35 g per litre) with a slight tendency towards a reverse gradient towards the upper reaches.

The primary reason for hypersalinity is the regular intrusion of seawater during spring tides. Seawater overtops the berm at the mouth and remains trapped in the system, evaporating slowly and leaving salts behind. This is combined with the fact that episodic floods no longer reach the estuary due to obstructions to flow in the lower catchment and the EFZ. The little surface water runoff that occurs in the estuary environs are not enough to substantially dilute the water.

Rainfall also carries salts from sediments outside the floodplain into the riverbed, which is responsible for the saline conditions within the dry flood plain (saltmarsh vegetation dominates in the main river channel). Generally, the Namaqualand area experiences higher evaporation rates than precipitation, which naturally leads to the formation of salt pans (Heinecken, 1980; DWA, 2009b).

Lastly, it is possible that the abandoned slimes dam north of the estuary leaches additional salt into the riverbed. A saltpan is present in the river bed below the abandoned slime dam (Massie and Clark, 2016).

Other water quality information on the Swartlintjies Estuary is limited to the data collected during October 2016 (this study) (Figure 10.3) (during a survey conducted in October 1980 the estuary was dry – Heinecken, 1981b). DO ranged between 3.2 - 7.4 mg/l, with lower concentration occurring in the lower reaches. Turbidity was relative low ~10 NTU. DIN concentrations ranged between 10 - 80 µg/l, mostly in the form of Total Ammonia-N (typical non-enriched concentrations in estuaries ~50 µg/l). DIP concentrations ranged between 10 - 30 µg/l (typical non-enriched concentrations in estuaries <10 µg/l). Based on the above, water quality in the Swartlintjies is assumed to still be near pristine. Considering the small size of this system, birds contribute to nutrient loading (e.g. Hahn *et al*., 2007 and 2008), especially in the lower reaches both under reference and present.

The slight increase in nutrients in the lower reaches (under present) is associated with reduced freshwater inflow (i.e. less overall volume receiving same nutrient loading) which then ripples through DO and turbidity (both associated with slight increase in suspended algal growth/organic debris). It is assumed that seepage from the mine slime dams adjacent to estuary introduced some toxics to the system.

Based on very limited data and information and expert opinion, the average water quality conditions under each of the abiotic states, for reference, present and future scenarios are estimated as follows:

Salinity	Reference	Present
Lower	80	100
Upper	100	120
DIN (µg/l)	**Reference**	**Present**
Lower	80	100
Upper	50	50
DIP (µg/l)	**Reference**	**Present**

Lower	20	30
Upper	10	10
DO (mg/l)	**Reference**	**Present**
Lower	6	4
Upper	6	6
Turbidity (NTU)	**Reference**	**Present**
Lower	10	15
Upper	10	10

Table 10.7 provides the water quality similarity EHI scores for the Swartlintjies Estuary.

Table 10.7 Swartlintjies Estuary: Summary of changes and calculation of the water quality health score

Variable		Present	Confidence
1	**Salinity**		
	Similarity in salinity *(similarity score adjusted for hyper salinity)*	80	Low
2	**General water quality**		
a	DIN and DIP concentrations	92	Low
b	Turbidity	90	Low
c	Dissolved oxygen	90	Low
d	Toxic substances	90	Low
	Water quality score	**80**	**Low**

10.6 PHYSICAL HABITAT

The basement rock of the area falls within the Namaqualand – Natal belt of metamorphism and granitisation and is overlain by a number of sedimentary sequences. The sediments of the Swartlintjies Estuary and surroundings are derived from these sequences and are locally known as the Koignaas Complex (Heinecken, 1980).

The soil type has been categorised as “Red and yellow, well drained sandy soils with high base status” (Massie and Clark, 2016). More detailed information was provided by Heinecken (1980), who described three distinct bands of surface soil formations. The triangle of barchanoid dunes north of the estuary were not vegetated in 1980 but have since then been colonised by Namaqualand Seashore Vegetation (Massie and Clark, 2016). However, these dunes have been largely destroyed by mining activities along the coast. Inland of the barchanoid dunes, a band of vegetated white dunes approximately 400 m wide were followed by vegetated red sands with darker termitaria “heuweltjies” extending inland. Vegetated white dunes approximately 400 m wide were followed by vegetated red sands with darker termitaria “heuweltjies” extending inland.

A 1 cm salt crust covered grey riverbed sand mixed with black organic sludge. Particle size analysis of the sediment showed that sand was coarse and poorly sorted at the mouth, suggesting the presence of marine sediments that were transported into the lower estuary by spring tides. In the middle and upper reaches the sand is medium-grained and sorted moderately and poorly respectively.

From reference to present, there is little to moderate level of change in the physical habitat and associated sediment structure of the Swartlintjies. Most changes is associated with poor land use practises in the catchment increasing the sediment load and a reduction in the flood peaks due to road infrastructure leading to reduce scouring and infilling in the lower reaches.

Table 10.8 below provides a summary of the EHI scores for the physical habitat of the Swartlinjies Estuary.

Table 10.8 Swartlintjies Estuary: Similarity EHI scores for physical habitat

Variable	Present	Confidence
a. Supratidal area and sediments	85	Low
b. Intertidal areas and sediments	85	Low
c. Subtidal area and sediments	75	Low
d. Estuary bathymetry/water volume	75	Low
Physical habitat score*	**75**	**Low**

*Score = min a to d

10.7 MICROALGAE

The 2016 survey showed that microalgal biomass was less than 5 µg/l which is indicative of oligotrophic conditions. The estuary was hypersaline with many brine shrimp in the filtered water particularly for Sites 1 and 2. The dominant microalgal species was the halophilic Chlorophyte, *Dunaliella salina* with a cell density of 145 to 1262 cells/ml and distribution throughout the hypersaline system. Table 10.9 provides the microalgae similarity EHI scores for the Swartlintjies Estuary.

Table 10.9 Swartlintjies Estuary: Microalgae similarity EHI scores

Variable	Present State	Score	Confience
a. Species richness	Some changes in species richness due to an increase in salinity as a result of groundwater abstraction and slimes dam input. However, the system has always been hypersaline.	90	Low
b Abundance	Swartlintjies remains a hypersaline system where brine shrimp are dominant and therefore phytoplankton biomass is low. Small changes in biomass from reference conditions due to a loss in water volume and subtidal habitat.	80	Low
c. Community composition	Some changes in community composition due to an increase in salinity. The halophilic chlorophyte *Dunaliella salina* was dominant in 2016.	80	Low
Score min (a to c)		**80**	**Low**

10.8 MACROPHYTES

The Swartlinjies Estuary was visited on 6 October 2016 and the upstream boundary of the estuary was taken up to the tarred road approximately 1.8 km from the start of the open water (Figure 10.6). The “end” of the estuary could not be found as the salt tolerant *Sarcocornia pillansii* extended upstream. Around the mouth Namaqualand Seashore Vegetation occurs with *Cladoraphis cyperoides*

(*Eragrostis cyperoides*) hummocks, interspersed with *Sporobolus virginicus*. The open water surface area at the time of study extended to *circa* 850 m upstream. Hypersaline conditions occurred throughout the estuary and adjacent to the water body 100 % cover of *Sarcocornia pillansii* occurred. *Sarcocornia natalensis* occurred on the water's edge. In some areas there was distinct zonation of macrophytes along an elevation gradient with *Sarcocornia pillansii* closest to the water's edge, followed by the grass *Sporobolus virginicus* and then the succulent *Ruschia bina*. The open water column forms braided flooded channel in the upper reaches and was characterized by 50:50 % live: dead cover of *Sarcocornia pillansii.* This dead cover is probably a result of increased sediment salinity as water evaporates leaving behind salt crusts that accumulate over time. It is not known to what extent this was influenced by slimes dam input in the past.

Disturbance to the EFZ at the time of the site visit appeared minimal. However the mouth of the Swartlintjies fell within the Koingnaas mining concession of De Beers Consolidated Diamond Mines and intensive open cast mining for diamonds was carried out on either side of the system (Heinecken, 1980). Two pans occur *circa* 100 m from the start of the open water suggest they might have also been created for water to be pumped to mining activities. The base of an old pump was observed as well as an abandoned pipe. These pans were filled with filamentous algae at the time of the field trip. Further upstream an old borehole was found with water 1.2 m below ground. Other obstructions include an old causeway 750 m from the start of the open water. It appears to have been washed away in the middle. The causeway was evident in the 1976 and 1985 aerial images but not in the 2011 or 2014 images. These access points were used to carry gravel from the Koingnaas mine on the southern bank and would have disturbed the vegetation at the time.

From aerial photographs the surrounding vegetation seems to have changed little over time. Massie and Clark (2016) state that 17.8 ha of vegetation have been impacted by mining activities in the functional zone. Open water area has remained relatively stable over time (2003 – 1.79, 2011 – 1.37 ha, 2014 – 1.17 ha) although the image quality in the early years is poor and therefore this assessment has a low confidence. Table 10.10 provides the macrophyte similarity EHI scores for the Swartlintjies Estuary.

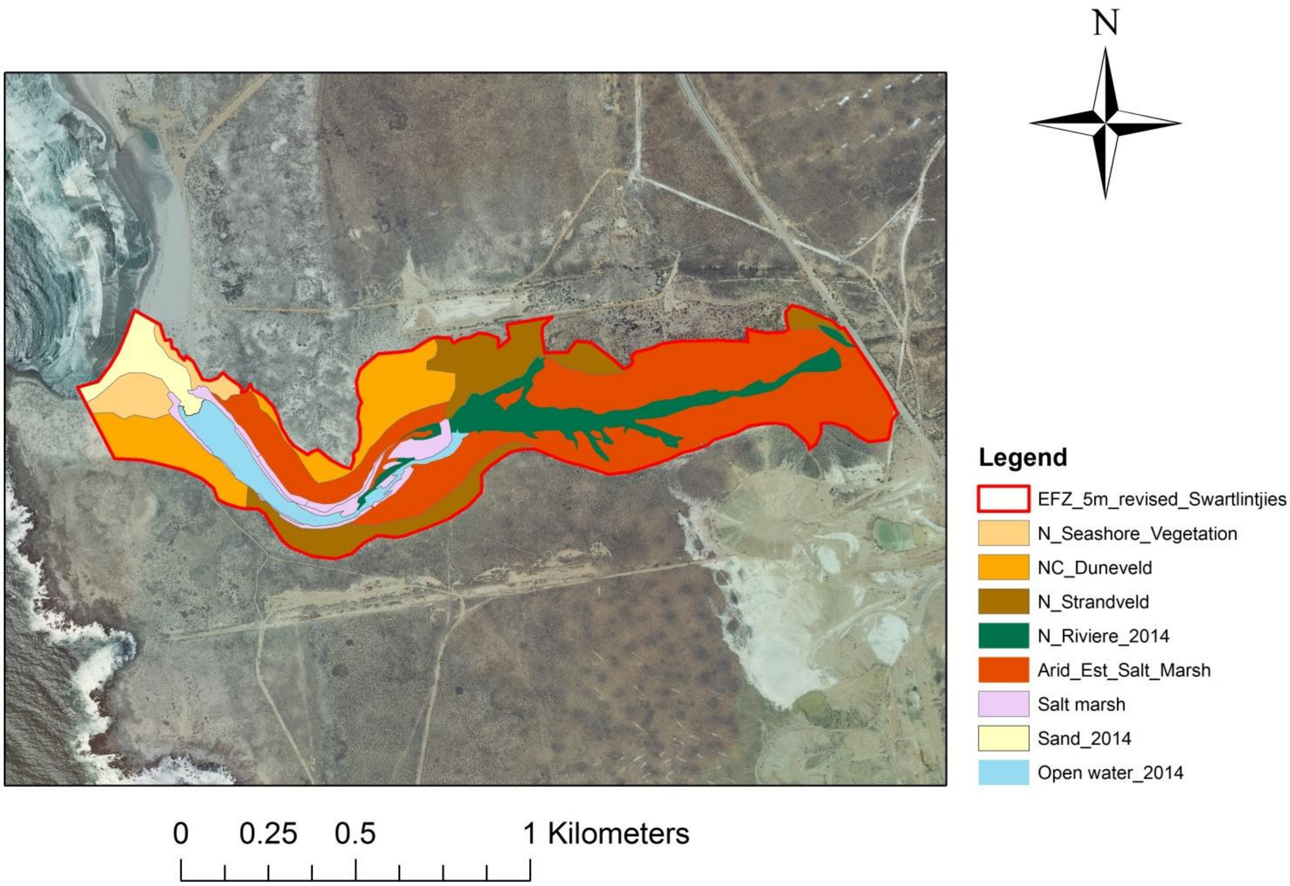


Figure 10.6 Swartlintjies Estuary: Vegetation map for the EFZ based on the 2014 aerial images

Table 10.10 Swartlintjies Estuary: Macrophyte similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Species have been lost in the floodplain vegetation due to access roads and other disturbances from mining. Nearby slimes dam inputs have increased salinity.	75	Low
b Abundance	Loss of floodplain habitat and supratidal / arid estuarine salt marsh due to floodplain disturbance as a result of mining.	70	Low
c. Community composition	Increase in sand banks and bare areas in the arid estuarine salt marsh due to groundwater abstraction, a reduction in flooding and saline slimes dam inputs.	70	Low
Score min (a to c)		**70**	**Low**

10.9 INVERTEBRATES

There have been two previous reports on invertebrates in the Swartlintjies Estuary these being the ECRU Survey in 1980 (Heinecken, 1981b) and the recent EIA in 2016 (Massie and Clark, 2016). The 1980 ECRU Survey saw very little water with most invertebrates recorded in hypersaline pools, from the berm or from dead carapaces washed up from the sea. In that study, the giant beach pill bug *Tylos granulatus* was found alive on the berm with numerous dried out shells on the estuary bed; most likely animals washed from their burrows and carried into the estuary and drowned during overwash events. Larvae and adult Hydrophilid beetles *Berosus spretus* were found in the hypersaline pools / sumps adjacent to the estuary. Adult and larval Harpacticoid copepods were also found but its not clear whether these were from the pools in or adjacent to the estuary. No mention is made of brine shrimp *Artemia* in the estuary or saline pools. Massie and Clark (2016) sampled but found no benthic invertebrates but do mention a high biomass of *Artemia* throughout the system. To reiterate from the previous section, the indigenous *Artemia salina* has been replaced by the invasive *Artemia franciscana* in the Berg Estuary saltpans at Veldrift and other sites in South Africa (Baxevanis *et al*., 2014). The brine shrimp populations in the Swartlintjies and other West Coast systems still need to be assessed. Macroinvertebrates such as sandprawn *Callichirus kraussi* are absent from the Swartlintjies due to prolonged periods of fatal hypersalinity. Overall, invertebrate diversity, abundance and community structure in the Swartlintjies Estuary is a function of changes in groundwater inflow, frequency and magnitude of floods, frequency and duration of breaching and overwash events and salinity gradients, including cycles within long periods of hypersalinity. In particular, *Artemia* hatch at salinities above 40 psu and encyst sinking to the bottom when salinities exceed 150 psu. Consequently, the available biomass of *Artemia* in the Swartlintjies is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Table 10.11 provides the invertebrates similarity EHI scores for the Swartlintjies Estuary.

Table 10.11 Swartlintjies Estuary: Invertebrates similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Estuary dominated by halophilic species notably brine shrimp with lesser numbers of Harpacticoid copepods and Hydrophilid beetles the latter recorded above the water line. Loss of less salt tolerant species from headwaters due to roads and other obstructions.	60	Low
b Abundance	Brine shrimp still dominant numerically and by mass in the system. However, obstruction to surface and subsurface flow likely to have seen a more rapid and frequent progression to salinities above 150	70	Low

Variable	Present State	Score	Confidence
	psu causing brine shrimp to encyst and become unavailable to flamingos and other birds and animals that feed upon them.		
c. Community composition	Brine shrimp still dominant but loss of less salt tolerant species such as copepods and Hydrophilid beetles from headwaters due to roads and other obstructions and reverse salinity gradient developing in the system. In addition, more frequent and prolonged encystment when salinity exceeds 150 psu sees brine shrimp dormant and no grazing on phytoplankton or other activity in the system.	70	Low
Score min (a to c)		**50**	**Low**

10.10 FISH

Fish diversity, abundance and community structure in the Swartlintjies and other small West Coast estuaries relies on recruitment that is largely a function of connectivity with the sea and driven by the frequency and duration of floods and breaching events and the degree of overwash during high seas. Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 psu. Safe return to the sea is usually during flood events and depends on a quick breaching and fish not suffocating in sediment-laden water backing up against the berm. This said, most recruitment is "suicidal" via overwash with survival depending on wave size and the height and width of the berm. Consequently, overwash recruitment diminishes with time away from a breaching event. This said, survival after overwash recruitment is unlikely in the hypersaline Swartlintjies as seawater intrusion is usually not sufficient to dilute the brine in the estuary to below 40 psu. That suicidal recruitment does occur is borne out of the fact that mullet *L. richardsonii* and *M. cephalus* frequently recruit into flooded mining excavation trenches and sumps adjacent to the Swartlintjies Estuary and elsewhere on the West Coast, surviving long enough and large enough to be netted for human consumption (this study; Heinecken, 1981b). Table 10.12 provides the fish similarity EHI scores for the Swartlintjies Estuary.

Table 10.12 Swartlintjies Estuary: Fish similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Similar to reference with suicidal overwash recruitment and limited survival of larval and juvenile fish that were in the surf-zone at the time. Loss of inflow probably shortened survival period of recruits.	80	Low
b Abundance	Similar to reference with suicidal overwash recruitment and limited survival of larval and juvenile fish that were in the surf-zone at the time. Loss of inflow probably shortened survival of recruits.	80	Low
c. Community composition	*M. cephalus* and *L. richardsonii* would have survived until 60 psu or longer depending on freshwater flow into the headwaters.	80	Low
Score min (a to c)		**80**	**Low**

10.11 BIRDS

Very little information is available on the birds of the Swartlintjies. A total of 28 bird species have been recorded at the Swartlintjies Estuary and on the floodplain to date (Table 10.13). The waterbirds of the Swartlintjies Estuary can be divided into five taxonomic orders, the most species-rich being the Charadriiformes, which include the waders, gulls and terns.

Three bird-counts exist for the Swartlintjies estuary these being the October 1980 ECRU survey, June 2016 by Anchor Environmental and three months later in October 2016 by the CSIR. Estuarine birds remained fairly constant with nine, nine and seven recorded in the 1980 and 2015 surveys respectively. The June 2016 count was the most comprehensive recording an additional 13 terrestrial species, including ostrich evidenced by footprints and an abandoned nest and eggs just above the shoreline. In June 2016, greater flamingos, avocets, black-winged stilts and Cape teal were recorded feeding on brine shrimp near the mouth (Massie and Clark, 2016). Five juvenile flamingos were also recorded which suggests that nesting occurred either in the estuary or another nearby water body. Brine shrimp biomass remained high with flamingo numbers increasing to 29 in October 2016. In comparison, the 1980 ECRU survey reported neither brine shrimp nor flamingos, which suggests either a recent breaching event or ultra-hypersaline conditions then. Other brine shrimp feeders were also few or absent.

Under reference and the present day, the Swartlintjies Estuary has been mostly hypersaline with a high biomass of brine shrimp *Artemia* spp. and limited diversity and abundance of halophillic Insecta. Broadly, *Artemia* hatch at salinities above 40 *psu* and encyst sinking to the bottom when salinities exceed 150 psu*.* Consequently, available biomass of *Artemia* in the Swartlintjies is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Also worth mentioning again is that at least seven native *Artemia salina* populations in South Africa have been replaced by the invasive *Artemia franciscana* (Baxevanis *et al*., 2014). Birds and damp bird feathers are known vectors of shrimp eggs so the status and identity of the Artemia in the Swartlintjies and other West Coast estuaries and wetlands needs to be verified.

Table 10.13 Swartlintjies Estuary: Recorded bird species

Common name	CSIR Oct 1980	Anchor Jun 2016	CSIR Oct 2016	Maximum count
Cape Teal		11	16	16
South African Shelduck	6			6
Red-knobbed Coot	10			10
Greater flamingo		17 (5 juveniles)	29	29
White-fronted plover	19	7	2	19
Black-winged stilt	2	30	8	30
Pied avocet	1	6		6
Three-banded plover	2			2
Sanderling	12			12
Curlew sandpiper	23			23
Blacksmith lapwing	4			4
Common-ringed plover		1		1
Kelp gull		1	2	2
Hartlaub's gull		2		2
Antarctic tern		1		1
Cape wagtail	6	3	2	6
Grey-backed cisticola		11		11
African stonechat	2	6		6

Common name	CSIR Oct 1980	Anchor Jun 2016	CSIR Oct 2016	Maximum count
Yellow canary		10		10
Bokmakierie		3		3
Cape long-billed lark		7		7
Rufus-eared Warbler		2		2
Southern double-collared sunbird		1		1
Karoo prinia		2		2
Pied crow	3	2		3
Sand martin	2	11		11
Common ostrich		(Footprints)	Abandoned nest	1
Sandpiper Common			4	4
Total species counted	**13**	**22**	**8**	**28**
Total number birds counted	**92**	**117**	**63**	**272**

In addition to the above, Hartlaub's gull and kelp gull roost around the estuary and Cape wagtails, white-fronted plovers and common-ringed plover feed in the mud and shallow water near the edges of the water body as well as on halophyllic insects and their larvae just above the shoreline. Table 10.14 provides the birds similarity EHI scores for the Swartlintjies Estuary.

Table 10.14 Swartlintjies Estuary: Birds similarity EHI

Variable	Present State	Score	Confidence
a. Species richness	Very similar to Reference.	90	Low
b Abundance	Very similar to Reference.	90	Low
c. Community composition	Very similar to Reference.	90	Low
Score min (a to c)		**90**	**Low**

11 APPENDIX C: THE SPOEG ESTUARY DESKTOP EWR

Appendix C provides the detailed methods and scores for the abiotic and biotic componentsof the Spoeg Estuary.

11.1 DELINEATION

The Spoeg Estuary is situated 230 km south of the Orange Estuary. The geographical boundaries of the Spoeg Estuary are defined as follows (Figure 11.1):

Downstream boundary:	30°28'20.54"S 17°21'34.07"E (Estuary mouth)
Upstream boundary:	30°28'17.92"S 17°22'32.83"E
Lateral boundaries:	5 m contour above MSL along each bank

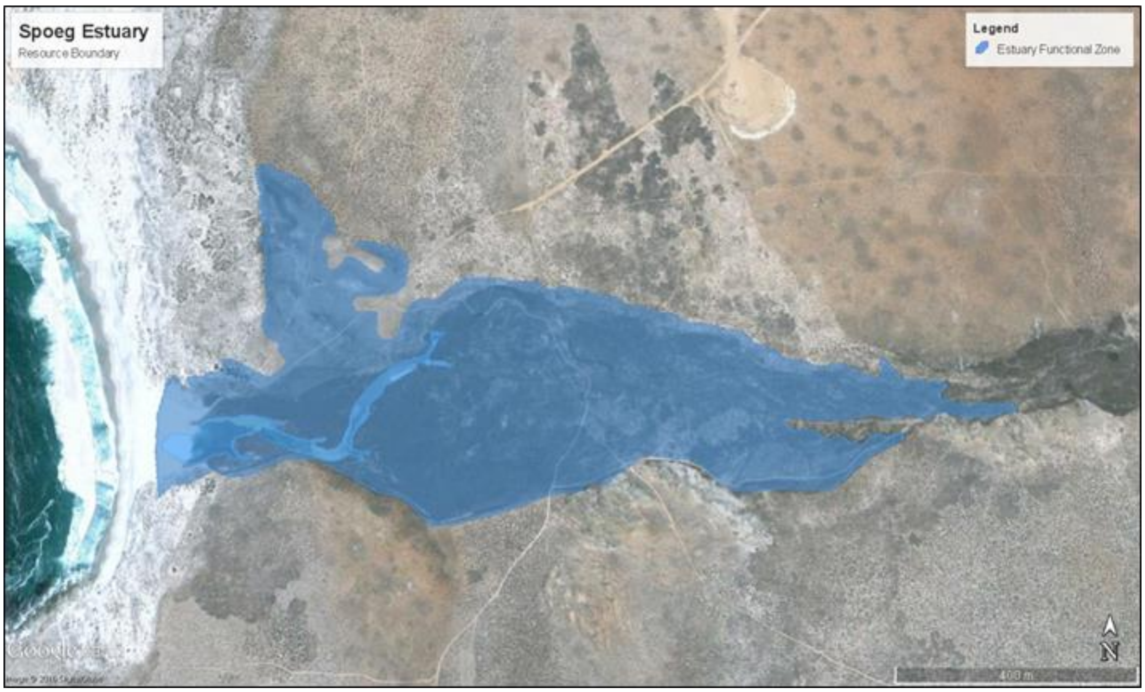


Figure 11.1 Spoeg Estuary: Geographical boundaries based on the EFZ

11.2 MAJOR PRESSURES

The major pressures on the Spoeg Estuary include:

- Grazing in the catchment.
- Limited Loss of freshwater input from groundwater abstraction.
- Future pressures include an escalation of mining activities in the national park any disruption of subsurface flow.

11.3 HYDROLOGY

The catchment area of the Spoeg River is 1 375 km^2. The catchment falls predominantly within the winter rainfall area and episodic floods occur occasionally (Bickerton, 1981). Annual precipitation vary from 200 – 250 mm/a in the headlands to 50 – 100 mm/a at the sea. The river is ephemeral with surface flow only occurring after substantial rainfall.

Summary of monthly flows under Reference conditions is provided in Table 11.1. Desktop simulations of the surface hydrology indicate little change in the surface water flows, however this does not take into consideration the impact of road infrastructure throughout the catchment. This is estimated at about 90% similar to Reference Condition.

Table 11.1 Spoeg Estuary: Simulated monthly flows (in 10^6 m^3) under Reference conditions

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breaching
1920	0.21	0.04	0.00	0.00	0.07	0.02	0.00	0.00	7.24	2.45	0.07	0.02	10.13	1
1921	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.26	0.09	1.09	0.37	1.82	0
1922	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.28	0.10	0.38	0.13	0.95	0
1923	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0
1924	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.52	1.19	0.01	0.00	4.72	1
1925	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.06	0
1926	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.23	1.04	0
1927	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
1928	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.12	0
1929	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.72	0.25	1.04	0
1930	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.01	0.01	0.08	0
1931	0.21	0.07	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.32	0
1932	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.23	0.14	0.03	0.54	0
1933	0.00	0.00	0.00	0.00	0.00	0.08	0.03	0.02	0.01	0.00	0.00	0.00	0.14	0
1934	0.00	0.04	0.01	0.00	0.00	0.00	0.01	0.27	0.10	0.12	0.07	0.01	0.62	0
1935	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.41	0.42	0
1936	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.21	0.03	0.00	0.78	0
1937	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.06	0
1938	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	2.84	0.95	3.85	1
1939	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.04	0.00	0.09	0.24	0
1940	0.03	2.44	0.79	0.01	0.00	0.00	0.12	0.78	0.80	0.21	0.32	0.11	5.62	1
1941	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.82	0.28	0.00	0.00	1.13	0
1942	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.29	0.10	0.17	0.06	0.93	0
1943	0.00	0.17	0.06	0.00	0.00	0.00	0.00	0.64	0.45	0.08	0.14	0.05	1.59	0
1944	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.06	0.16	0.12	0.02	0.52	0
1945	2.01	0.66	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.10	2.85	1
1946	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.21	0.07	0.00	0.35	0
1947	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.05	0
1948	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.06	0
1949	0.01	0.00	0.00	0.00	0.00	0.00	0.35	0.12	0.00	0.88	0.30	0.43	2.08	0
1950	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.03	0.35	0.04	0.01	1.58	0
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.16	0.43	0.01	1.61	0
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.27	0.06	0.01	0.30	0.10	1.04	0
1953	0.00	0.00	0.12	0.04	0.00	0.10	0.04	0.67	0.23	0.62	0.21	0.00	2.02	0
1954	0.00	0.00	0.00	0.00	0.39	0.13	0.00	0.00	0.00	0.15	0.77	0.24	1.68	0
1955	0.00	0.00	0.00	0.00	0.00	0.17	0.06	0.05	0.08	0.04	0.01	0.00	0.40	0
1956	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.07	0.13	0.05	0.00	0.38	0
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.04	0
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.21	0.00	0.01	0.00	0.83	0
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.22	0.13	0.08	0.02	0.00	0.80	0
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.57	1.21	0.26	0.09	5.14	1
1962	0.00	0.36	0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.08	0.10	0.03	0.81	0
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.13	0.00	0.00	0.53	0
1964	0.00	0.06	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0
1965	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.15	0
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.05	0.26	0.09	0.00	0.00	0.54	0
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.03	0
1968	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0

1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.01	0.00	0.07	0
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.21	0.05	0.40	0
1971	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.20	0.07	0.00	0.00	0.28	0
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.06	0
1973	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.38	0.13	1.65	0.56	2.73	0
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.16	0.00	0.00	0.00	0.66	0
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.53	0.07	0.00	1.60	0
1976	0.00	0.04	0.02	0.00	0.04	0.02	0.00	0.08	0.05	0.13	0.07	0.01	0.47	0
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.05	0
1978	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.09	0
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.65	0.25	0.15	0.05	1.11	0
1980	0.00	0.37	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.63	0.22	1.35	0
1981	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.01	0.07	0.42	0.13	0.00	0.71	0
1982	0.02	0.01	0.00	0.00	0.00	0.00	0.00	2.01	0.77	0.06	0.01	0.13	3.01	1
1983	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.04	0.00	0.00	0.00	0.20	0
1984	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.08	0.03	0.00	0.00	0.00	0.15	0
1985	0.00	0.00	0.17	0.06	0.00	0.00	0.00	0.00	4.96	1.70	0.03	0.01	6.92	1
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.13	0.68	0.30	0.03	1.15	0
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.13	0.04	0.01	0.00	0.19	0
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.15	0.00	0.02	0.03	0.01	0.66	0
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.52	0.18	0.00	0.00	0.74	0
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.33	0.07	0.02	0.85	0
1991	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.01	0.00	0.23	0
1992	0.04	0.02	0.00	0.00	0.00	0.00	5.84	2.33	0.35	0.12	0.02	0.00	8.72	1
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.35	0.02	0.00	1.21	0
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.08	0.00	0.03	0.13	0.46	0
1995	0.09	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.28	0.31	1.30	0
1996	0.10	0.07	0.03	0.00	0.00	0.00	0.00	1.85	1.50	0.31	0.01	0.00	3.88	0
1997	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.75	0.79	0
1999	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.14	0.00	0.79	0
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.52	1.02	0.06	3.60	1
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.10	0.04	0.04	0.01	0.49	0
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.43	0.81	3.24	1
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
2004	0.37	0.12	0.00	0.00	0.00	0.00	0.21	0.13	0.02	0.00	0.01	0.00	0.87	0

* Years that the Spoeg Estuary could have potentially breached is indicated by 1.

Groundwater is estimated to be moderately modified. With groundwater use is estimated at about by about 37%.

Table 11.2 Spoeg Estuary: Groundwater recharge and discharge estimates

Groundwater parameter	F40F
Groundwater catchment area	681.0
Estuary catchment area	346.0
Reference recharge to estuary Mm^3/a	0.7
Reference Estuary discharge Mm^3/a	**0.4**
Use in Catchment Mm^3/a	0.132
Present Estuary Mm^3/a	**0.223653**
Use as % discharge	0.018638
% Similarity	62.9
Groundwater TDS mg/l	7937.0
Reference total salt load from groundwater (tons/a)	**2823**

Table 11.3 provides the hydrology similarity EHI scores for the Spoeg Estuary.

Table 11.3 Spoeg Estuary: Similarity scores for hydrology relative to the Reference condition

Variable	Present	Confidence
% similarity Groundwater	63	Low
% similarity frequency and magnitude of floods	90	Low
Hydrology score	**74**	

11.4 HYDRODYNAMICS

The Spoeg Estuary is classified as a temporarily open/closed system (Van Niekerk and Turpie, 2012).

11.4.1 Connectivity and circulation

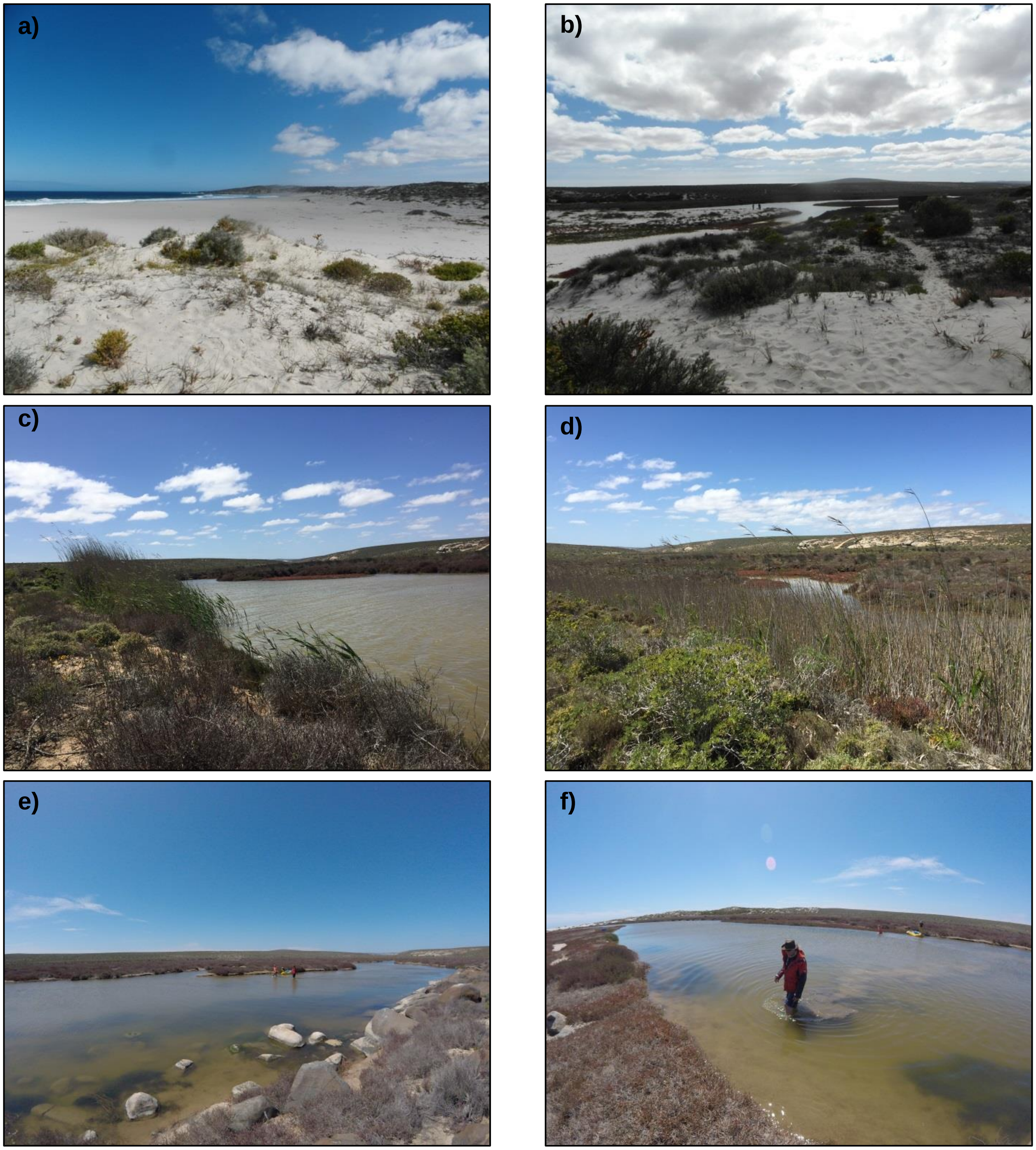
While there are farm roads and diamond mining fences between these roads and the mouth (200 m, 800m, 2 km and 5.5 km respectively), the system is still relatively undisturbed. In the lower reaches near the Spoeg Caves there are minor access roads, first evident in the 1985 images. Some of these have since become unused and overgrown with natural vegetation. The open water area has also changed little over time (Table 11.4).

11.4.2 Mouth State

The mouth of the Spoeg Estuary is predominantly closed as can be seen from available imagery (Table 11.4). The berm at the mouth of the Spoeg is high and does not allow for regular overwash.

Table 11.4 Spoeg Estuary: Summary of the mouth state based on available imagery

Year	Source	Mouth state (Open/closed)
2014	National Geo-Spatial Information (Surveys and Mapping)	Closed
2011	National Geo-Spatial Information (Surveys and Mapping)	Closed
2006	Google Earth	Closed
2003	National Geo-Spatial Information (Surveys and Mapping)	Closed
2003	Google Earth	Closed
1996	National Geo-Spatial Information (Surveys and Mapping)	Closed
1989	National Geo-Spatial Information (Surveys and Mapping)	Closed
1985	National Geo-Spatial Information (Surveys and Mapping)	Closed
1976	National Geo-Spatial Information (Surveys and Mapping)	Closed
1965	National Geo-Spatial Information (Surveys and Mapping)	Closed
1958	National Geo-Spatial Information (Surveys and Mapping)	Closed
1942	National Geo-Spatial Information (Surveys and Mapping)	Closed



(a) and (b) The wide berm at the Spoeg Estuary mouth showing some signs of overwash; (c) The middle reaches where wind mixing were stirring up the bottom turbidity; (d) the upper reaches of the system; (e) Algal growth in the lower reaches; (f) Fine sediments being stirred up by movement.

Figure 11.2 Spoeg Estuary: Key features

Table 11.5 Spoeg Estuary: Similarity scores for hydrodynamics under the various operational scenarios relative to the Reference Condition

Variable	Present	Confidence
Mouth condition	90	Low
Circulation (connectivity)	95	Medium
Water level	80	Low
Hydrodynamics score	**80**	**Low**

11.5 WATER QUALITY

Figure 11.3 shows locality map of sampling sites in the Spoeg Estuary.

Figure 11.3 Spoeg Estuary: Water Quality sampling stations

Very little information is available on the salinity of the Spoeg Estuary. Historical information suggests that the Spoeg Estuary has always been a brackish system. Bickerton reported in October 1980 that the salinity in the system hovered around 25 in the lower reaches to 20 in the top. While Harrison (unpublished data) reported salinity around 15 in the lower and middle reaches. During the August 2015 sampling trip the estuary was again around 21. The October 2016 field trip yielded the highest recorded salinity for the system at 25 in the lower reaches and 22 in the middle and upper reaches.

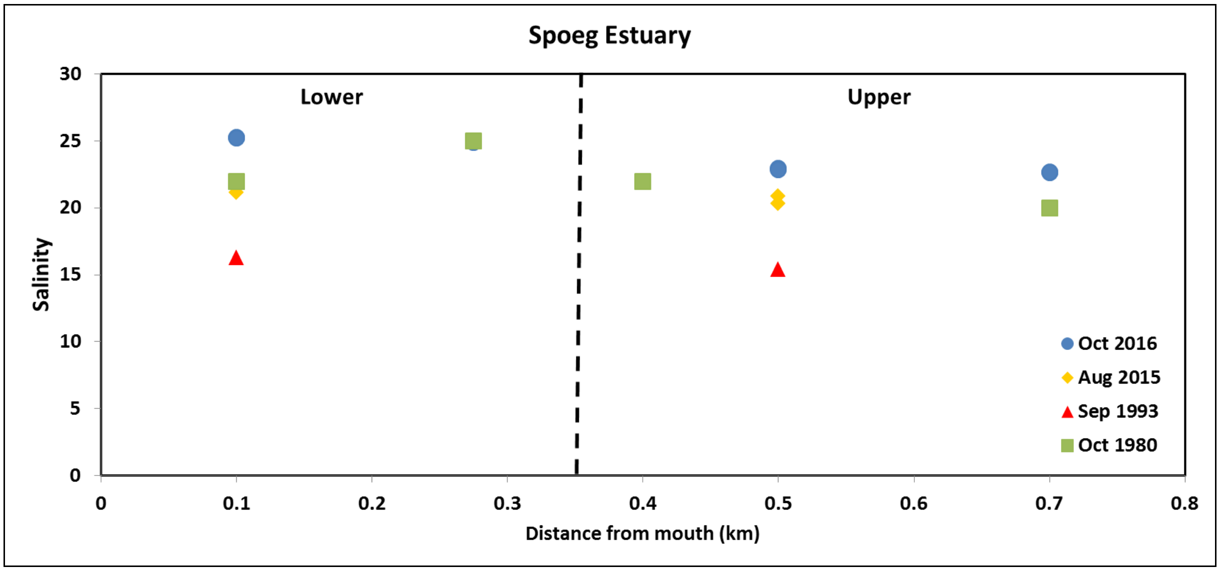


Figure 11.4 Spoeg Estuary: Available salinity data

Available data on other water quality parameters is also limited (Heinecken, 1981c, Harrison, 1998; DAFF, unpublished data, this study) (Figure 11.4). Data on DO suggest super-saturation, especially in the upper reaches. Super-saturation is most likely attribute to high algal productivity during the day. However, it can be indicative of hypoxia developing at night associated with high respiration rates). Turbidity levels average ~ 15 NTU, with occasional higher levels were probably associate algal production/bacterial blooms (Heinecken, 1981c). Grazing in the catchment could also contribute to slight increase in turbidity under the present. Measured DIN concentrations ranged between 50 - 160 µg/l, mostly present as Total Ammonia-N (typical non-enriched concentrations in estuaries ~50 µg/l). DIP concentrations were below detection in both August 2015 and October 2016 (<10 µg/l) (typical non-enriched concentrations in estuaries <10 µg/l). Heinecken (1981c) attributed algal growth to high nutrients associated with large flocks of ducks on the systems. Considering the small size of this system, it is likely that birds contribute to nutrient loading (e.g. Hahn *et al*., 2007 and 2008), but that it is taken up by algal and do not accumulate in the water column (therefore the relatively low measured data). However, this would have been the case in the reference condition as well. The slight increase in nutrients in the lower reaches (under present) is associated with reduced freshwater inflow (i.e. less overall volume receiving same nutrient loading) which then ripples through DO (associated with slight increase in suspended algal growth/organic debris). Some toxic accumulation is expected to have occurred due to extensive mining (or historical mining) activities in the catchment.

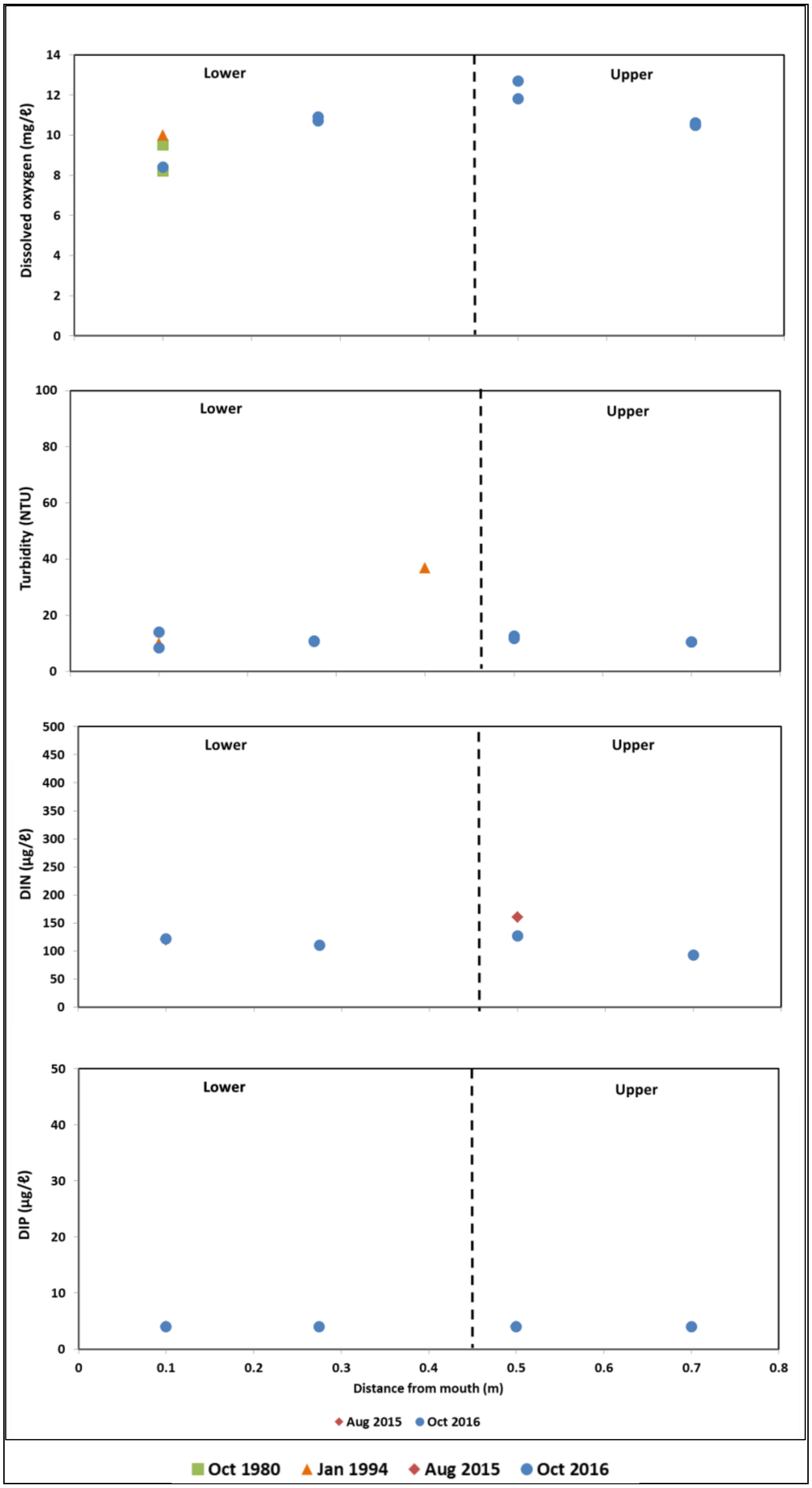


Figure 11.5 Spoeg Estuary: Available data for dissolved oxygen, turbidity and inorganic nutrients

Based on very limited data and information and expert opinion, the average water quality conditions under each of the abiotic states, for reference, present and future scenarios are estimated as follows:

Salinity	Reference	Present
Lower	20	25
Upper	15	20
DIN (µg/l)	**Reference**	**Present**
Lower	100	110
Upper	100	110
DIP (µg/l)	**Reference**	**Present**
Lower	10	10
Upper	10	10
DO (mg/l)	**Reference**	**Present**
Lower	7	7
Upper	6	5
Turbidity (NTU)	**Reference**	**Present**
Lower	10	11
Upper	10	12

Table 11.6 provides the water quality similarity EHI scores for the Spoeg Estuary.

Table 11.6 Spoeg Estuary: Summary of changes and calculation of the water quality health score

Variable		Present	Confidence
1	**Salinity**		
	Similarity in salinity *(similarity score adjusted for hyper salinity)*	85	Low
2	**General water quality**		
a	DIN and DIP concentrations	98	Low
b	Turbidity	93	Low
c	Dissolved oxygen	95	Low
d	Toxic substances	95	Low
	Water quality score	**90**	**Low**

11.6 PHYSICAL HABITAT

The geology of the river bed and inland catchment is dominated by granites of the Namaqua-Natal metamorphic complex. Along the coast the bed rock granites are over laid by unconsolidated sands, with fluvial and terrestrial gravels, shells, limestone and calcrete cappings. The Spoeg, as is the case with other Namaqualand rivers, has been incised into granite bedrock and can be seen as a small water coarse running done a wide shallow valley. The valley is filled with alluvium and rounded granite boulders. Granite outcrops can be seen in places in the valley and also along the coast line.

The Spoeg Estuary consists of a long straight floodplain bounded by rocks and cliffs on the southern side. The mouth was closed and a low flat berm of about 200 m formed across the mouth of the estuary. Generally the estuary has a fine-grained muddy bottom.

There are rocky granitic points to the north and south of the Spoeg mouth. The beach is steeply sloping and characterise by cusps and trough's indicating circulation cells and rip currents.

The physical habitat of the Spoeg Estuary is very similar to that of the Reference Condition. There has been some loss of Supratidal areas due to road infrastructure, change in the sediment structure of the intertidal and subtidal due to loss of floods and poor farming practises. Table 11.7 below provides a summary of the EHI scores for the physical habitat of the Spoeg Estuary.

Table 11.7 Spoeg Estuary: Similarity EHI scores for physical habitat

Variable	Present	Confidence
a. Supratidal area and sediments	90	Low
b. Intertidal areas and sediments	90	Low
c. Subtidal area and sediments	90	Low
d. Estuary bathymetry/water volume	90	Low
Physical habitat score*	**90**	**Low**

11.7 MICROALGAE

Phytoplankton biomass at Sites 1 - 3 were low (<20 µg/l) whereas Site 4 had hypereutrophic conditions (77.9 ± 9.2 µg/l). This was possibly due to localized conditions i.e. sheltered waters in these upper reaches where flocks of birds occurred. Phytoplankton composition was indicative of the brackish conditions. Blooms at Sites 3 and 4 consisted primarily of a *Peridinium* sp. (Dinophyceae), with density of *ca*. 700 and 2100 cells/ml, respectively. Additionally, at Site 4 the diatom *Diploneis didyma* was evident (*ca*. 840 cells/ml); whilst the 'flagellate' grouping was present at high density throughout the estuary ranging from 2950 (upper reaches) to 8850 cells/ml (lower reaches). Table 11.8 provides the microalgae similarity EHI scores for the Spoeg Estuary.

Table 11.8 Spoeg Estuary: Microalgae similarity EHI scores

Variable	Present State	Score	Confience
a. Species richness	Small change from reference due to groundwater abstraction and an increase in salinity. Loss of salt intolerant species.	90	Low
b Abundance	Some changes as a result of change in water volume and subtidal habitat - loss of water volume and habitat.	90	Low
c. Community composition	Greater retention in the upper reaches and more saline conditions could influence community composition.	90	Low
Score min (a to c)		**90**	**Low**

11.8 MACROPHYTES

Ground truthing of the Spoeg Estuary took place on 7 October 2016 and mapping was done up to *circa* 1.5 km from the mouth. At the time of the visit the vegetation was lush and healthy due to the brackish conditions. This system is of high biodiversity importance as it is one of few remaining brackish habitats in a dry saline area. There was a healthy stand of reeds marking areas of freshwater input. This was one of the few estuaries to have submerged macrophytes i.e. *Ruppia cirrhosa.* It was also one of the few estuaries sampled that had a salinity gradient from 25 near the mouth to 8.2 where a path crosses the upper reaches. We drove to the caves and walked to the reeds in the river course. Here the standing water had a salinity of 9.5 psu.

The Spoeg Estuary consists of a long straight floodplain bounded by rocks and cliffs on the southern side. Within this floodplain Arid Estuarine Salt Marsh mixes with Namaqualand Riviere, particularly in the upper areas, making a separation of the two vegetation types difficult. It has been mapped as Arid Estuarine Salt Marsh. Around the mouth Namaqualand Seashore Vegetation and Namaqualand Coastal Duneveld occurs, with large monospecific stands of two *Sarcocornia* in the lower reaches; *Sarcocornia natalensis* in the lower elevation and *Sarcocornia pillansii* in the higher elevations. Namaqualand Strandveld occurs on the higher elevations. Reed beds (*Phragmites australis*) occur *circa* 400 m upstream and are often associated with patches of *Juncus kraussii* at freshwater seepage sites or areas where the water table is high. These patches of *Juncus* and *Phragmites* continue up the river course. Reeds and sedges were difficult to map and might represent an overestimation due to their patchy nature. The vegetation of the Spoeg Estuary remains relatively unchanged and in a good condition. Small disturbances are from farm roads and diamond mining fences. Table 11.9 provides the macrophtye similarity EHI scores for the Spoeg Estuary.

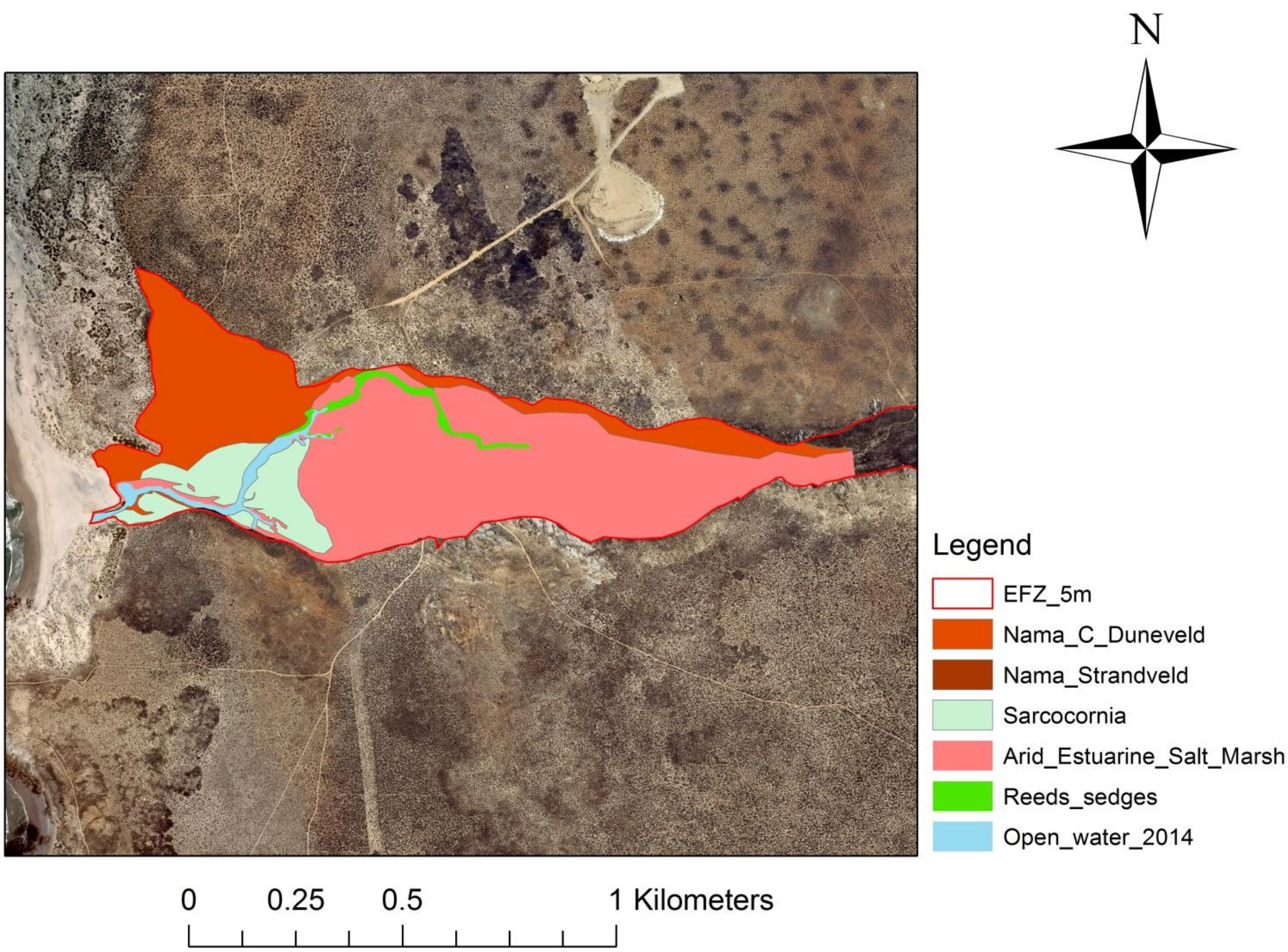


Figure 11.6 Spoeg Estuary: Vegetation map for the EFZ based on the 2014 aerial images

Table 11.9 Spoeg Estuary: Macrophyte similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Disturbance in the upper reaches may have resulted in some loss of species.	95	Medium
b Abundance	There have been minor losses in floodplain and salt marsh vegetation due to access roads around the mouth and in the region of the caves. Some of these are no longer used and are returning to natural vegetation.	95	Medium
c. Community composition	Groundwater abstraction and an increase in salinity could change reed habitat to dry barren areas or salt marsh.	95	Medium
Score min (a to c)		**95**	**Medium**

11.9 INVERTEBRATES

A cursory "list" identifying estuarine as well as the sandy beach and rocky shore invertebrates adjacent to the mouth were reported in the 1980 ECRU survey of the Spoeg Estuary (Heydorn and Grindley, 1981). These included the giant beach pill-bug *Tylos granulatus* in the berm and burrowing otter shell *Lutraria lutraria* in the immediate subtidal. In the estuary, high numbers of the brack-water amphipod *Melita zeylanica* were associated with inundated saltmarsh and water boatmen Corixidae were present. Fine-mesh seine samples taken in October 2016 have yet to be sorted and identified but again contained high abundances of *Melita zeylanicaI* and water boatmen Corixidae as well as Isopoda and some other insect taxa predominantly Chironimidae, Gomphidae and Notonectidae larvae. Crab, probably *Potamonautes* and mollusc shells were evident in water-mongoose *Atilax paludinosus* scat. The assumption being that otter and therefore otter scat do not occur in this arid region.

Reference conditions would have been similar to the present day with prolonged periods of closure (8 - 10 years) punctuated by flood and overwash resetting events. Overwash recruitment of marine species e.g. *Palaemon*, decreases with time after closure and build-up of the berm. The relative abundances of freshwater and estuarine / brackish invertebrates follow a salinity gradient from the mouth to the upstream spring and vary according to overwash, evaporation and freshwater flow. *Callichirus kraussi* have probably always been absent from the system due to prolonged periods of salinity below 16 psu and absence of breeding. Table 11.10 provides the invertebrates similarity EHI scores for the Spoeg Estuary.

Table 11.10 Spoeg Estuary: Invertebrates similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Estuary currently dominated by brackish and freshwater species (Insecta, amphipods, isopods, copepods) amongst the Ruppia, reeds and root mass along the banks. No *Callichirus* or similar macro invertebrates but crab shells found in otter scat. Insects and molluscs amongst the saltmarsh.	95	Medium
b Abundance	Brackish and freshwater species close to reference abundance under these conditions.	95	Medium
c. Community composition	The relative abundances of freshwater and estuarine / brackish invertebrates follow a salinity gradient from the mouth to the upstream spring and vary according to overwash, evaporation and freshwater flow. Brackish and freshwater species close to	95	Medium

Variable	Present State	Score	Confidence
	reference composition under these conditions.		
Score min (a to c)		**95**	**Medium**

11.10 FISH

Previous studies in the Spoeg Estuary recorded few fish there. During the ECRU Survey, 16 hours of gillnetting overnight yielded only two large *M. cephalus* and one *M. capensis* (Heydorn and Grindley, 1981). The latter record if correct represents a range expansion and the western most distribution of this species. Harrison (2002) with seine and gillnetting only managed to catch two harder *L. richardsonii* but this may have been a reflection of lower sampling intensity. The 50 – 57 cm *M. cephalus* in the ECRU survey suggests a mouth-opening event and recruitment 6-8 years prior to their 1981 sampling visit. Recent seine and gillnet sampling in the Spoeg in August 2015 and during this study in October 2016 provided estimates of about 50 *M. cephalus*, 10 *L. richardsonii* and >1 000 gobies *Caffrogobius* sp. in the system. The 60 – 70 cm size range of *M. cephalus* suggested that these fish recruited during a mouth-opening event and overwash 8 - 10 years previously. T he *Caffrogobius* ranged from 10 mm post larvae to adults of 140 mm in length.

As with all the small West Coast systems fish diversity, abundance and community structure in the Spoeg relies on recruitment that is largely a function of connectivity with the sea and driven by the frequency and duration of floods and breaching events and the degree of overwash during high seas. Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 psu. Safe return to the sea is usually during flood events and depends on a quick breaching and fish not suffocating in sediment-laden water backing up against the berm. This said, most recruitment is "suicidal" via overwash with immediate survival depending on wave size and the height and width of the berm. Consequently, overwash recruitment diminishes with time away from a breaching event. Compared to the other West Coast estuaries, survival after overwash recruitment in the Spoeg is relatively high and can at least partly be attributed to the headwater spring. Survival in the latter three systems depends on whether these dry up or become hypersaline before the next flood and breaching event. Survival of 8 - 10 year-old harder *L. richardsonii* and flathead mullet *M. cephalus* in the Spoeg is evidence of tolerable conditions over the 8 - 10 years since last recruitment. A robust breeding population of goby *Caffrogobius* spp. further supports this contention. In turn, the Spoeg may not experience the frequent hypersalinity and fish mortalities characteristic of other temporarily open-closed West Coast systems. Table 11.11 provides the fish similarity EHI scores for the Spoeg Estuary.

Table 11.11 Spoeg Estuary: Fish similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Similar to reference with opportunistic overwash recruitment and medium survival of larval and juvenile fish that were in the surf-zone at the time. Populations of species that can breed in estuaries e.g. *Caffrogobius* for extended periods of closure provided salinity does not exceed 40 psu. Existing population of about 50 *M. cephalus* recruited 8 - 10 years ago.	90	Low
b Abundance	Similar to reference with opportunistic overwash recruitment survival probably a function of predation by piscivorous birds.	90	Low
c. Community	*M. cephalus* and *L. richardsonii* would have survived until 60 psu or	90	Low

Variable	Present State	Score	Confidence
composition	longer depending on freshwater flow into the headwaters. ECRU recorded freshwater mullet *M.s capensis* in the estuary. All mullet species would be feeding on benthic algae, epiphytes and zooplankton (Isopods etc.). *Caffrogobius* has a healthy population amongst the aquatic vegetation.		
Score min (a to c)		**30**	**Low**

11.11 BIRDS

Information on the birds of the Spoeg Estuary is limited. Three counts since 1980 to the present have recorded 25 bird species at the Spoeg Estuary (Table 11.12). The 1980 ECRU survey recorded 15 species and the 2015 and 2016 counts 4 and 14 species respectively. The 2015 count was limited to the lower reaches and only four species were recorded. The higher 1980 count was predominantly waders and waterbirds with no flamingos reported whereas flamingos and piscivorous species dominated the 2016 count. The prolific population of gobies *Caffrogobius* sp. probably sustains the latter group in the system. The presence of flamingos in 2015 and 2016 is probably due to the unsuitability of the Groen and other regional water-bodies at that time.

Under reference conditions, the Spoeg Estuary was relatively stable compared to other West Coast systems and a veritable oasis when ultra hypersaline conditions occurred elsewhere, Present-day conditions are close to reference and the relative lack of disturbance probably sees birds persist for longer than in adjacent systems. Table 11.13 provides the birds similarity EHI scores for the Spoeg Estuary.

Table 11.12 Spoeg Estuary: Recorded bird species

Species	CSIR Oct 1980	August 2015 Grant Smith	CSIR Oct 2016	Maximum count
Dabchick	1			1
South African Shelduck	2			2
Cape Teal	14		2	14
Red-knobbed coot	20	5	2	20
White-fronted Sandplover	8		2	8
Crowned Plover	2			2
Blacksmith Plover	2			2
Curlew Sandpiper	14			14
Little Stint	1			1
Sanderling	4			4
Ruff	6			6
Common Sandpiper	2			2
Avocet	7	2	2	7
Hartlaub's Gull	2		1	2
Caspian Tern	1		1	1
Black necked grebe			11	11
Greater flamingo		5	30	30

Species	CSIR Oct 1980	August 2015 Grant Smith	CSIR Oct 2016	Maximum count
Little Egret			1	1
Little swifts			11	11
Black-headed heron			1	1
Pale chanting goshawk			1	1
Bokmakierie			1	1
Hadeda			heard	1
Lesser flamingo			5	5
Kelp gull		5		5
Total species counted	**15**	**4**	**15**	**25**
Total number birds counted	**86**	**17**	**71**	**174**

Table 11.13 Spoeg Estuary: Birds similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Very similar to Reference.	90	Low
b Abundance	Very similar to Reference.	90	Low
c. Community composition	Very similar to Reference.	90	Low
Score min (a to c)		**90**	**Low**

12 APPENDIX D: THE GROEN ESTUARY DESKTOP EWR

Appendix D provides the detailed methods and scores for the abiotic and biotic componentsof the Groen Estuary.

12.1 DELINEATION

The Groen Estuary is a coastal inlet situated along the cool temperate, arid west coast of South Africa. The geographical boundaries of the Groen Estuary are defined as follows (Figure 12.1):

Downstream boundary:	30°50'49.05"S 17°34'35.72"E (Estuary mouth)
Upstream boundary:	30°49'38.26"S 17°34'40.18"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 12.1 Groen Estuary: Geographical boundaries based on the EFZ

The major pressures on the Groen Estuary include:

- Habitat loss due to access road.
- Grazing in the catchment.
- Loss of freshwater input from groundwater abstraction.
- Mining activities in catchment.
- Future pressures include an escalation of mining activities in the national park and any disruption of subsurface flow.

12.2 HYDROLOGY

The Groen Estuary catchment area is estimated at about 4 500 km^2 (Bickerton, 1981) to 4 670 (van Niekerk *et al*., 2015). Mean annual rainfall in the catchment varies from 100 - 200 mm. Detailed spring and seep surveys by CSIR (1981) and SWS (2013 to 2015) found only one discrete point of perennial discharge into the estuary. This spring is located in the wetland area ca 1 km upstream of the estuarine lagoon. SWS (2015) recorded a downstream flow rate of ca 1l/s in February 2014. Summary of monthly flows under Reference and Present Day conditions is provide below in **Error! Reference source not found.**.

Table 12.1 Groen Estuary: Simulated monthly flows (in 10^6 m^3) under Reference Conditions

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breachings
1920	0.37	0.10	0.03	0.02	0.51	0.18	0.02	0.02	26.92	9.18	0.33	0.32	38.00	1
1921	0.29	0.25	0.22	0.18	0.16	0.14	0.13	0.11	0.86	0.28	2.82	1.00	6.44	1
1922	0.12	0.10	0.09	0.07	0.06	0.05	0.05	0.17	1.81	0.67	0.93	0.31	4.43	0
1923	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.11	0.04	0.49	0
1924	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	21.13	7.18	0.26	0.22	28.89	1
1925	0.19	0.16	0.13	0.11	0.09	0.07	0.07	0.06	0.05	0.16	0.06	0.04	1.19	0
1926	0.39	0.13	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	1.82	0.63	3.11	0
1927	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.20	0
1928	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.03	0.10	0.09	0.45	0.72	0
1929	0.15	0.01	0.01	0.01	0.00	0.00	0.01	0.04	0.32	0.11	3.60	1.29	5.55	1
1930	0.05	0.04	0.03	0.03	0.02	0.02	0.16	0.05	0.01	0.01	0.12	0.13	0.67	0
1931	0.72	0.24	0.02	0.01	0.05	0.02	0.01	0.02	0.07	0.03	0.01	0.00	1.20	0
1932	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.93	0.94	0.55	0.12	2.55	0
1933	0.02	0.02	0.01	0.01	0.01	0.27	0.10	0.09	0.05	0.04	0.01	0.03	0.66	0
1934	0.02	0.03	0.01	0.00	0.00	0.00	0.04	0.76	0.29	0.36	0.25	0.05	1.81	0
1935	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.03	0.01	0.02	0.14	2.08	2.33	1
1936	0.70	0.03	0.02	0.02	0.02	0.01	0.01	0.01	1.29	0.76	0.12	0.02	3.01	0
1937	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.07	0.22	0
1938	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	17.42	6.07	23.60	1
1939	0.20	0.17	0.13	0.11	0.09	0.08	0.06	0.06	0.41	0.14	0.04	0.27	1.76	0
1940	0.09	1.22	0.43	0.21	0.07	0.03	0.61	4.52	3.13	0.77	0.96	0.34	12.38	1
1941	0.08	0.07	0.06	0.05	0.04	0.03	0.04	0.21	3.27	1.12	0.06	0.05	5.08	1
1942	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.26	0.39	0.45	0.99	0.32	2.62	0
1943	0.03	1.46	0.51	0.03	0.03	0.03	0.02	1.09	1.21	0.30	0.36	0.12	5.19	0
1944	0.03	0.03	0.02	0.02	0.02	0.02	0.01	1.39	0.59	0.99	0.55	0.07	3.74	0
1945	4.56	1.58	0.08	0.06	0.05	0.04	0.17	0.06	0.03	0.03	0.03	0.55	7.24	1
1946	0.20	0.02	0.02	0.02	0.02	0.01	0.01	0.13	0.05	1.18	0.41	0.03	2.10	0
1947	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.39	0.14	0.03	0.68	0
1948	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.14	0.25	0.44	0
1949	0.07	0.01	0.00	0.00	0.00	0.00	0.55	0.19	0.01	1.28	0.44	1.18	3.73	0
1950	0.42	0.03	0.02	0.02	0.02	0.01	0.01	0.02	4.29	1.48	0.26	0.09	6.67	1
1951	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.07	0.05	3.32	1.62	0.21	5.48	1
1952	0.05	0.04	0.03	0.03	0.02	0.02	4.36	2.02	0.19	0.13	0.87	0.29	8.05	1
1953	0.05	0.04	0.15	0.05	0.03	0.18	0.07	1.61	0.56	5.33	1.94	0.09	10.10	1
1954	0.08	0.07	0.05	0.04	0.53	0.18	0.03	0.03	0.05	1.06	2.20	0.66	4.98	1
1955	0.05	0.04	0.03	0.03	0.02	0.13	0.04	0.08	0.77	1.07	0.30	0.03	2.59	0
1956	0.03	0.02	0.02	0.01	0.07	0.02	0.01	1.46	1.55	1.14	0.73	0.16	5.22	0
1957	0.08	0.03	0.03	0.03	0.02	0.02	0.02	0.22	0.08	0.02	0.02	0.01	0.58	0
1958	0.01	0.01	0.01	0.01	0.01	0.01	0.01	4.32	1.48	0.06	0.19	0.06	6.18	1
1959	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.24	0
1960	0.01	0.01	0.01	0.01	0.00	0.00	5.15	1.81	0.32	0.21	0.08	0.05	7.66	1
1961	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.01	32.17	10.93	0.88	0.30	44.48	1
1962	0.28	1.09	0.36	0.17	0.14	0.12	0.10	0.09	0.19	0.54	0.64	0.16	3.88	0
1963	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	3.70	1.28	0.10	0.05	5.42	1
1964	0.05	0.77	0.27	0.04	0.03	0.07	0.42	0.14	0.03	0.02	0.02	0.02	1.88	0
1965	0.12	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.05	0.06	0.50	0
1966	0.02	0.01	0.01	0.01	0.01	0.02	2.18	0.76	2.52	0.88	0.06	0.05	6.53	1
1967	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.21	0.31	0.10	0.02	0.02	0.86	0
1968	0.06	0.02	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.21	0
1969	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.35	0.21	0.36	0.12	0.01	1.08	0
1970	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.25	1.30	0.42	2.01	0

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breachings
1971	0.02	0.02	0.01	0.01	0.01	0.36	0.14	0.01	0.42	0.19	0.01	0.01	1.21	0
1972	0.01	0.01	0.01	0.00	0.00	0.04	0.01	0.00	0.00	0.18	0.24	0.06	0.56	0
1973	0.01	0.00	0.13	0.04	0.00	0.00	0.00	0.00	6.04	2.07	9.15	3.17	20.61	1
1974	0.17	0.14	0.11	0.09	0.07	0.06	0.05	1.02	0.36	0.05	0.04	0.04	2.20	0
1975	0.03	0.03	0.02	0.02	0.14	0.05	0.01	0.01	2.77	2.82	0.69	0.06	6.65	1
1976	0.05	0.31	0.18	0.03	0.04	0.02	0.05	1.33	0.65	0.19	0.11	0.05	3.01	0
1977	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.37	0.13	0.63	0
1978	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.04	0.06	0.02	0.00	0.00	0.16	0
1979	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.20	0.41	0.74	0.27	2.65	0
1980	0.02	0.03	0.01	0.01	0.01	0.07	0.02	0.01	0.01	0.22	1.82	0.64	2.87	0
1981	0.03	0.02	0.02	0.02	0.01	0.03	0.04	0.01	0.21	0.66	0.21	0.02	1.28	0
1982	0.09	0.03	0.01	0.01	0.01	0.01	0.01	4.43	1.65	0.08	0.05	0.22	6.60	1
1983	0.07	0.04	0.03	0.02	0.02	0.02	0.01	0.36	0.13	0.01	0.01	0.01	0.73	0
1984	0.20	0.07	0.02	0.01	0.01	0.01	0.01	0.12	0.04	0.01	0.00	0.00	0.50	0
1985	0.00	0.00	4.40	1.51	0.05	0.04	0.04	0.03	9.35	3.26	0.14	0.12	18.94	1
1986	0.10	0.08	0.07	0.05	0.05	0.04	0.15	0.05	0.53	1.08	0.50	0.08	2.78	0
1987	0.03	0.03	0.02	0.02	0.01	0.01	0.03	0.01	0.59	0.21	0.02	0.03	1.01	0
1988	0.01	0.01	0.01	0.01	0.00	0.00	1.67	0.58	0.02	0.19	0.16	0.09	2.75	0
1989	0.02	0.01	0.01	0.01	0.01	0.01	0.81	0.29	0.14	0.05	0.01	0.01	1.38	0
1990	0.01	0.01	0.01	0.04	0.01	0.00	0.00	0.00	0.38	2.31	0.76	0.15	3.68	1
1991	0.66	0.22	0.03	0.02	0.02	0.02	0.01	0.01	0.11	0.22	0.08	0.01	1.41	0
1992	0.16	0.06	0.01	0.01	0.01	0.00	7.69	4.74	1.38	0.55	0.18	0.10	14.89	1
1993	0.08	0.07	0.06	0.05	0.04	0.03	0.03	0.02	2.67	1.01	0.05	0.05	4.16	1
1994	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.34	0.13	0.07	0.21	0.17	1.08	0
1995	1.19	3.06	1.01	0.05	0.04	0.03	0.03	0.02	0.02	5.19	2.00	0.79	13.43	1
1996	0.40	0.71	0.22	0.05	0.04	0.04	0.03	9.32	5.00	0.66	0.15	0.13	16.75	1
1997	0.11	0.17	0.07	0.06	0.05	0.04	0.04	0.20	0.07	0.03	0.03	0.02	0.89	0
1998	0.02	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.14	1.71	2.00	0
1999	0.58	0.03	0.02	0.02	0.07	0.11	0.03	0.01	0.01	1.83	0.64	0.03	3.38	0
2000	0.03	0.02	0.02	0.02	0.01	0.01	0.11	0.05	0.01	8.05	4.02	0.51	12.86	1
2001	0.11	0.09	0.07	0.06	0.05	0.04	0.04	1.08	0.39	0.36	0.31	0.09	2.69	0
2002	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	6.58	2.26	9.03	1
2003	0.09	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.07	0.03	0.02	0.02	0.55	0
2004	0.77	0.27	0.02	0.82	0.29	0.37	2.34	0.90	0.05	0.04	0.04	0.03	5.94	1

* Years that the Groen Estuary could have potentially breached indicated with a 1.

Very little change has occurred in the surface water from an utilisation perfective. Some small change however is expected, especially in the higher flows and flood component, due to the presence of roads and embankments in the catchment acting as small farm dams and trapping surface water upstream of road infrastructure. Groundwater is estimated to be moderately modified. With groundwater use is estimated at about by about 40%.

Table 12.2 Groen Estuary: Groundwater recharge and discharge estimates

Groundwater parameter	F50G
Groundwater catchment area	774.0
Estuary catchment area	574.0
Reference recharge to estuary Mm^3/a	0.2
Reference Estuary discharge Mm^3/a	**0.1**
Use in Catchment Mm^3/a	0.05
Present Estuary Mm^3/a	**0.076**
Use as % discharge	0.0063
% Similarity	60.3

Groundwater parameter	F50G
Ground water TDS mg/l	7691.0
Reference total salt load from groundwater (tons/a)	**970**

Table 12.3 provides the hydrology similarity EHI scores for the Groen Estuary.

Table 12.3 Groen Estuary: Similarity scores for hydrology relative to the Reference condition

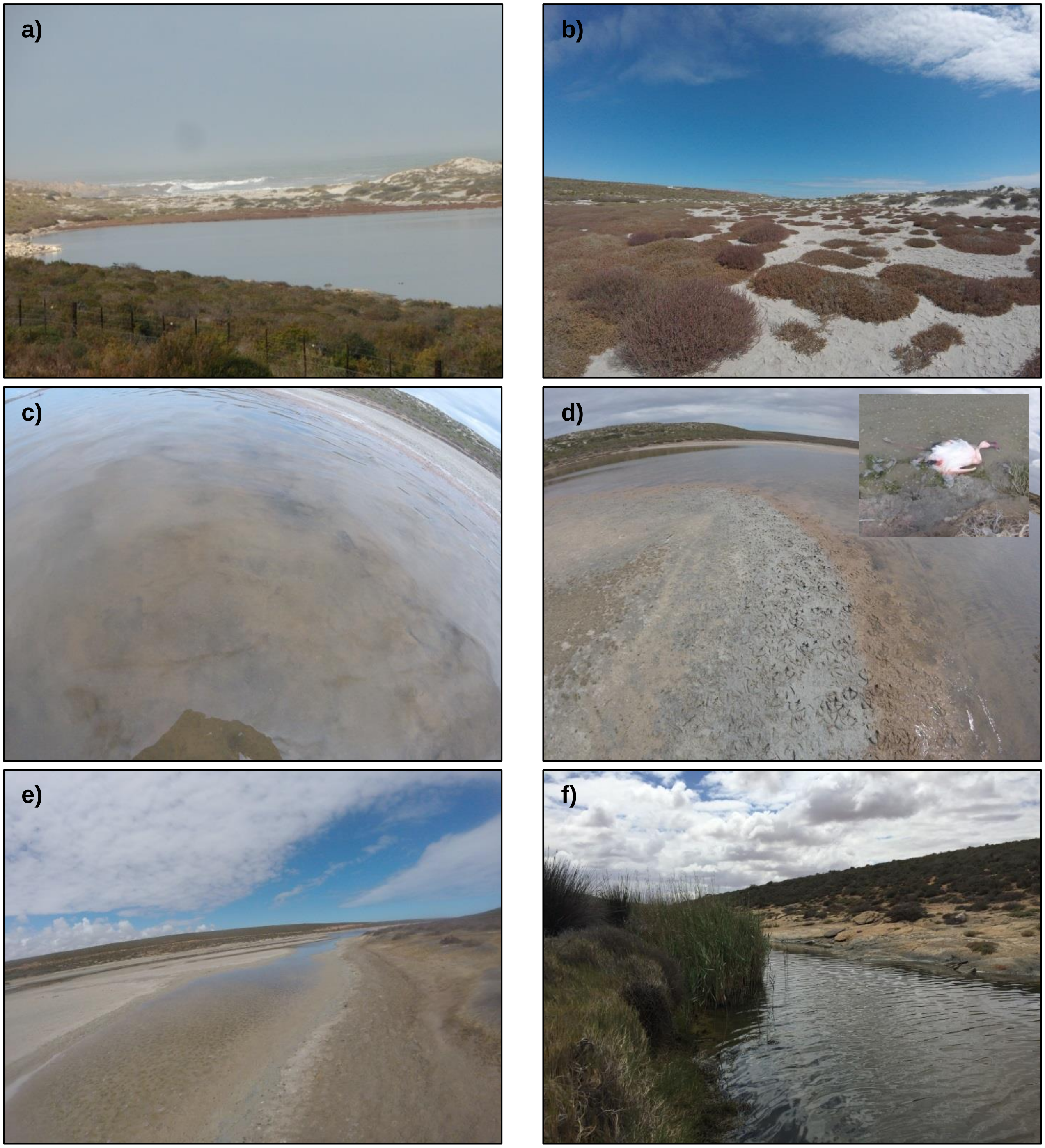
Variable	Present	Confidence
% similarity Groundwater	60	Low
% similarity frequency and magnitude of floods	90	Low
Hydrology score	**72**	

12.3 HYDRODYNAMICS

The Groen Estuary is classified as a temporarily open/closed system (Van Niekerk and Turpie, 2012). Very little is known about the estuary because of its small size and remote location.

12.3.1 Connectivity and circulation

The Estuary Functional Zone of the Groen Estuary is largely untransformed. With the most significant impact, a causeway running through the upper reaches to the local Namaqualand National Parks office. As the road is at a low level, the impact of it on floods is judged to be limited.



(a) The very high berm and (b) well establish plant cover at the mouth of the Groen Estuary indicating very little connectivity with the sea; (c) and (d) The middle reaches of the system showing high degree of sediment disturbance by birds; (e) Salt rings indicating that at times the water level in the system is much higher than the October 2016 survey; (f) The upper reaches of the Groen Estuary with reeds indicating brackish conditions.

Figure 12.2 Groen Estuary: Key features

12.3.2 Mouth State

Bickerton (1981) reported that surface water is probably always present in the estuary, maintained by the springs feeding into the upper estuary. Occasional freshwater inflow dilutes the highly saline surface water and transient tidal conditions may occur when the mouth opens. The river flows infrequently and the estuary remains closed for long periods, with reports from farmers in the 1980s indicating that flow only occurs during heavy flooding roughly every 5 years (Bickerton, 1981).

During low or no flow conditions the estuary becomes highly saline with salinity readings of 125 psu recorded in the lower reaches. Springs at the head of the estuary maintain a lower salinity in the upper reaches. Detailed spring and seep surveys by CSIR (1981) and SWS (2013 to 2015) found only one discrete point of perennial discharge into the estuary. This spring is located in the wetland area ca 1 km upstream of the estuarine lagoon. SWS (2015) recorded a downstream flow rate of ca 1l/s in February 2014.

Table 12.4 Groen Estuary: Summary of the mouth state based on available imagery

Year	Source	Mouth state (Open/closed)
2014	National Geo-Spatial Information (Surveys and Mapping)	Closed
2011	National Geo-Spatial Information (Surveys and Mapping)	Closed
2006	Google Earth	Closed
2003	National Geo-Spatial Information (Surveys and Mapping)	Closed
2003	Google Earth	Closed
1996	National Geo-Spatial Information (Surveys and Mapping)	Closed
1989	National Geo-Spatial Information (Surveys and Mapping)	Closed
1985	National Geo-Spatial Information (Surveys and Mapping)	Closed
1976	National Geo-Spatial Information (Surveys and Mapping)	Closed
1965	National Geo-Spatial Information (Surveys and Mapping)	Closed
1958	National Geo-Spatial Information (Surveys and Mapping)	Closed
1942	National Geo-Spatial Information (Surveys and Mapping)	Closed

12.3.3 Openwater area and water levels

The total estuarine area up to 2.5 km from the mouth was approximately 28 ha whereas the total open water area was 13 ha (Bickerton, 1981). The areal extent of the estuary was reported in Bickerton (1981) to be around 28 ha, and at the time of the survey, in October 1980, the approximate area of openwater in the lagoon was 13 ha. The area contained within the EFZ of the Groen Estuary is 52.4 ha and open water area covered an area of 8 ha in 2011 and 2014. In 1943 the approximate area of open water was 13 ha. In 1985 open water occupied an area of roughly 11 ha. The water surface area in the lower reaches of the estuary has decreased over time.

Table 12.5 Groen Estuary: Change in open water area over time

Year	Open water area (ha)
2014	8
2011	8
1985	11
1981	13
1980	13

Year	Open water area (ha)
1943	13

While there is little change in the surface water feeding the system, it is assumed that fluctuations in the openwater area and associated water levels may be driven by the decline in groundwater to the system.

Table 12.6 Groen Estuary: Similarity scores for hydrodynamics under the various operational scenarios relative to the Reference Condition

Variable	Present	Confidence
Mouth condition	90	Low
Circulation (connectivity)	95	Medium
Water level	70	Low
Hydrodynamics score	**70**	**Low**

12.4 WATER QUALITY

Figure 12.3 shows locality map of sampling sites in the Groen Estuary.

Figure 12.3 Groen Estuary: Water Quality sampling stations

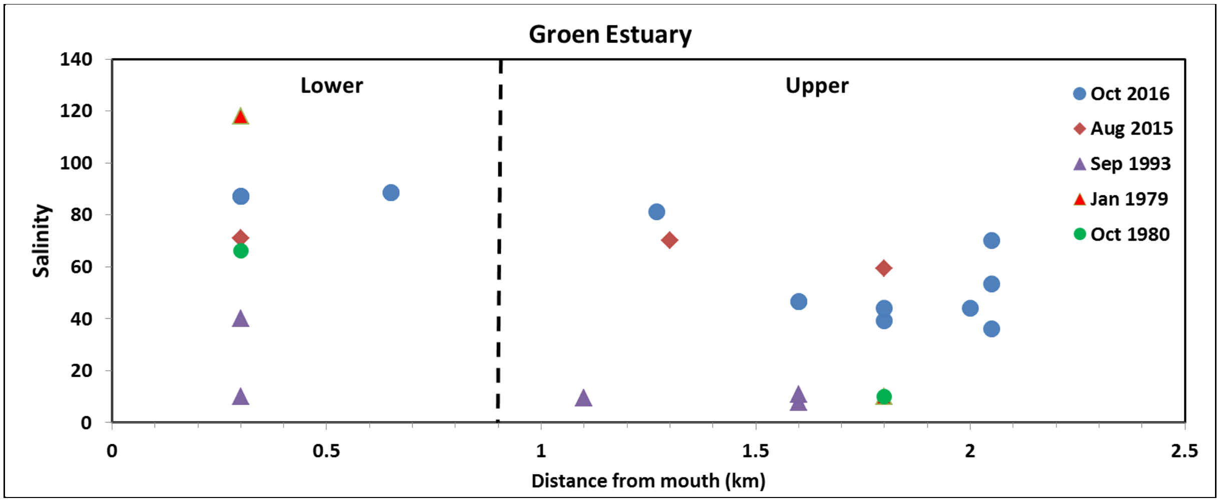


Figure 12.4 Groen Estuary: Available salinity data

Available data on other water quality parameters is also limited (Bickerton, 1981; Harrison, 1998; DAFF, unpublished data; Adams et al. 2015; this study) (Figure 12.4). Data on DO show large variation in concentrations with average values in the lower and upper estuary at 4 mg/l and 5 mg/l, respectively. Average turbidity also varied by averaged around 20 NTU across estuary. Grazing in the catchment could also contribute to slight increase in turbidity under the present. Measured DIN concentrations averaged ~60 µg/l in lower reaches increasing to ~70 µg/l in upper reaches, mostly present as Total Ammonia-N (typical non-enriched concentrations in estuaries ~50 µg/l). DIP concentrations in the lower reaches remained low (<10 µg/l), but levels in the upper reaches averaged ~30 µg/l, showing a distinct increasing trend moving upstream. The small size and bird population are indicative of nutrient loading from birds (also under reference) (e.g. Hahn *et al*., 2007 and 2008). Thus although reduction in flow could have contributed to relatively higher loading from birds, the increasing trend towards the upper reaches (especially in DIP) suggests that diffuse runoff from ablution of the houses/offices adjacent to the upper estuary is a more likely driver of this increase. Some mining in catchment could have contributed to toxic accumulation in this system.

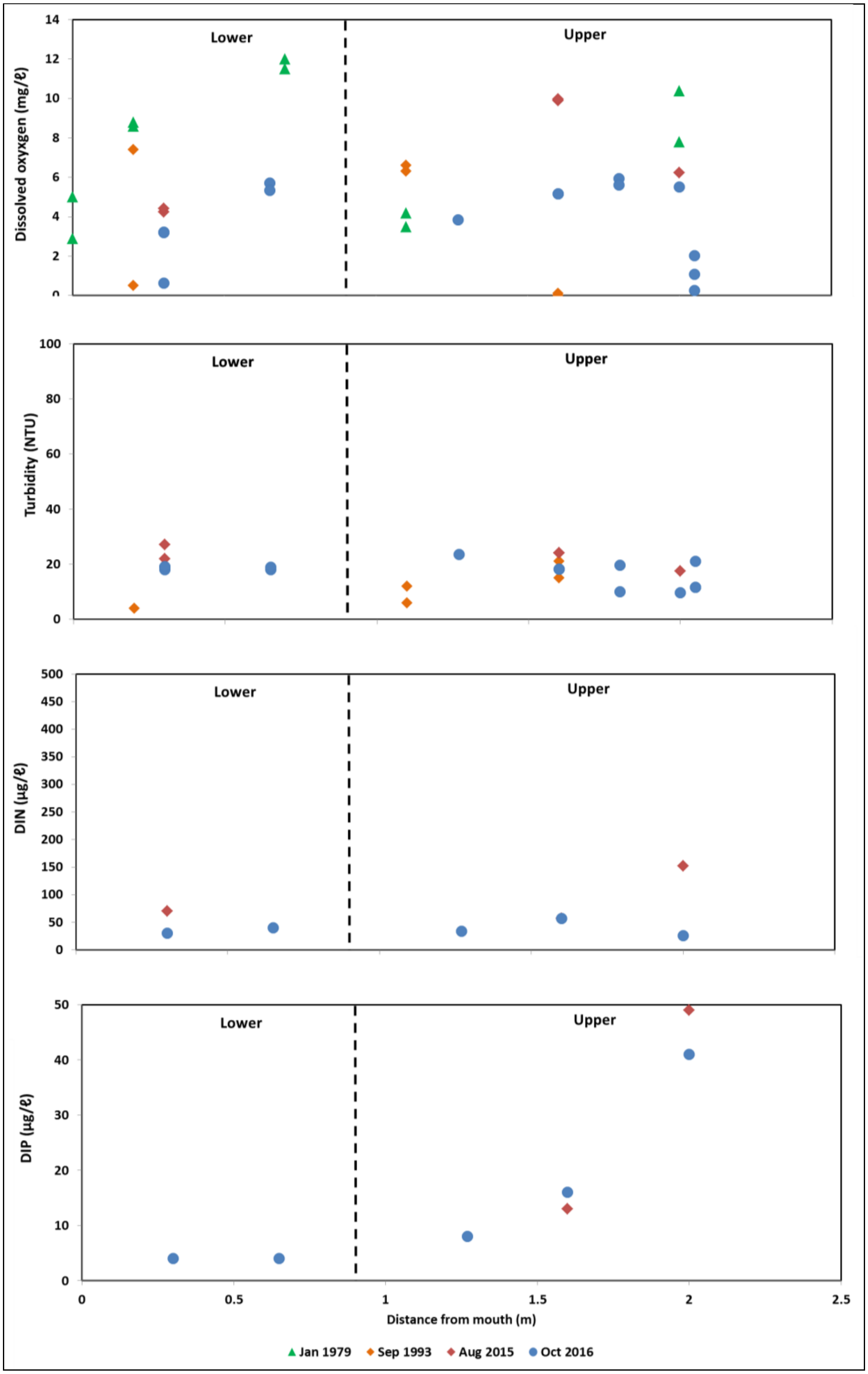


Figure 12.5 Groen Estuary: Available data for dissolved oxygen, turbidity and inorganic nutrients

Based on very limited data and information and expert opinion, the average water quality conditions under each of the abiotic states, for reference, present and future scenarios are estimated as follows:

Salinity	Reference	Present
Lower	60 (40 – 100)	100 (70 – 220)
Upper	40	50
DIN (µg/l)	**Reference**	**Present**
Lower	50	60
Upper	50	70
DIP (µg/l)	**Reference**	**Present**
Lower	10	10
Upper	10	30
DO (mg/l)	**Reference**	**Present**
Lower	5	4
Upper	7	5
Turbidity (NTU)	**Reference**	**Present**
Lower	15	20
Upper	15	20

Figure 12.7 provides the water quality similarity EHI scores for the Groen Estuary.

Table 12.7 Groen Estuary: Summary of changes and calculation of the water quality health score

Variable		Present	Confidence
1	**Salinity**		
	Similarity in salinity *(similarity score adjusted for hyper salinity)*	80	Low
2	**General water quality**		
a	DIN and DIP concentrations	81	Low
b	Turbidity	86	Low
c	Dissolved oxygen	86	Low
d	Toxic substances	95	Low
	Water quality score	**81**	**Low**

12.5 PHYSICAL HABITAT

Bickerton (1981), described the substrate in the lower estuary as sandy, with anoxic conditions prevailing a short distance away from the water's edge. The sediment in the upper estuary was described as fine anoxic silt. Table 12.8 below provides a summary of the EHI scores for the physical habitat of the Groen Estuary.

Table 12.8 Groen Estuary: Similarity EHI scores for physical habitat

Variable	Present	Confidence
a. Supratidal area and sediments	95	Low
b. Intertidal areas and sediments	95	Low
c. Subtidal area and sediments	90	Low
d. Estuary bathymetry/water volume	95	Low
Physical habitat score*	**90**	**Low**

12.6 MICROALGAE

Sites 1 and 2 had high phytoplankton biomass and cell density. The water was yellow and only 250 ml was filtered due to clogging of the filters and the presence of brine shrimps. This was due to a Dinophyceae bloom of the species *Gymnodinium* sp. (1401 to 10139 cells/ml); with the hypersaline tolerant *D. salina* (Chlorophyceae) also abundant (442 to 2335 cells/ml). With the exception of Site 5, 'flagellates' were abundant (> 10000 cells/ml) throughout the estuary; however, despite this, their low contribution to overall biomass levels is evident at Site 4 where bloom concentrations were absent (< 20 µg/l). A community shift was evident as in the upper reaches of the Groen Estuary (Site 5) a *Chaetoceros* sp. (Bacillariophyceae) was dominant (*ca*. 3400 cells/ml). In this system biomass decreased with a decrease in salinity upstream which could possibly be attributed to competition from macroalgal and dense benthic cyanobacterial mats that were common in the upper reaches. Groundwater abstraction, an increase in salinity and decrease in open water surface area over time have influenced the present state of the microalgae. Table 12.9 provides the microalgae similarity EHI scores for the Groen Estuary.

Table 12.9 Groen Estuary: Microalgae similarity EHI scores

Variable	Present State	Score	Confience
a. Species richness	Groundwater abstraction and increase in salinity could decrease species richness.	90	Low
b Abundance	Stagnant conditions and possible nutrient input in the upper reaches could promote blooms, however there is competition from macroalgae and benthic mats. Lots of open water surface area means less available habitat.	85	Low
c. Community composition	Persistent saline conditions in lower reaches favour saline groups.	85	Low
Score min (a to c)		**85**	**Low**

12.7 MACROPHYTES

The Groen Estuary was mapped in February 2015 (Adams *et al*., 2015). The dominant habitat was supratidal salt marsh with the dominant species *Sarcocornia pillansii* that covered 8 ha. Intertidal salt marsh represented by *Sarcocornia natalensis* and *Salicornia meyeriana* occurred along the banks of the estuary mostly along the lower reaches of the northern bank. Terrestrial species including, *Lampranthus* sp., *Lycium strandveldense* and *Mesembryanthemum guerichianum,* that were present in the ecotone between the supratidal zone and terrestrial habitat (Namaqualand Coastal Duneveld). The reed and sedge habitat, represented by common reed (*Phragmites australis*), fringed the steeper channel in the upper reaches. This habitat is important as it indicates freshwater seepage in the upper reaches of the estuary. Salt pans were present in the lower and middle reaches of the estuary. These waterlogged areas were devoid of vegetation. The filamentous cyanobacteria *Lyngbya* sp. were abundant in the water column. These species formed free floating mats and also attached to the substrate. No submerged macrophytes were observed in 2015 or in 2016.

On 8 October 2016 the estuary was visited to see if any major changes had occurred. New seedling growth of *Sarcocornia* spp. were observed in the middle reaches possibly in response to the lower salinity in 2016 compared to 2015. In both years' salinity was measured in the reed beds where there was no longer open water surface area. Holes were augured and allowed to fill with water. In 2015 the salinity at both reed sites was 9 psu whereas in 2016 this dropped to 6 psu just below the causeway in line with the first SANParks houses. At this site water occurred at 30 cm depth.

The low-level road crossing, fences, agriculture and development in the floodplain has decreased the health of the Groen Estuary. Groundwater abstraction and increases in salinity have had the greatest effect on the macrophytes potentially decreasing the abundance of reeds and sedges. Table 12.10 provides the macrophyte similarity EHI scores for the Groen Estuary.

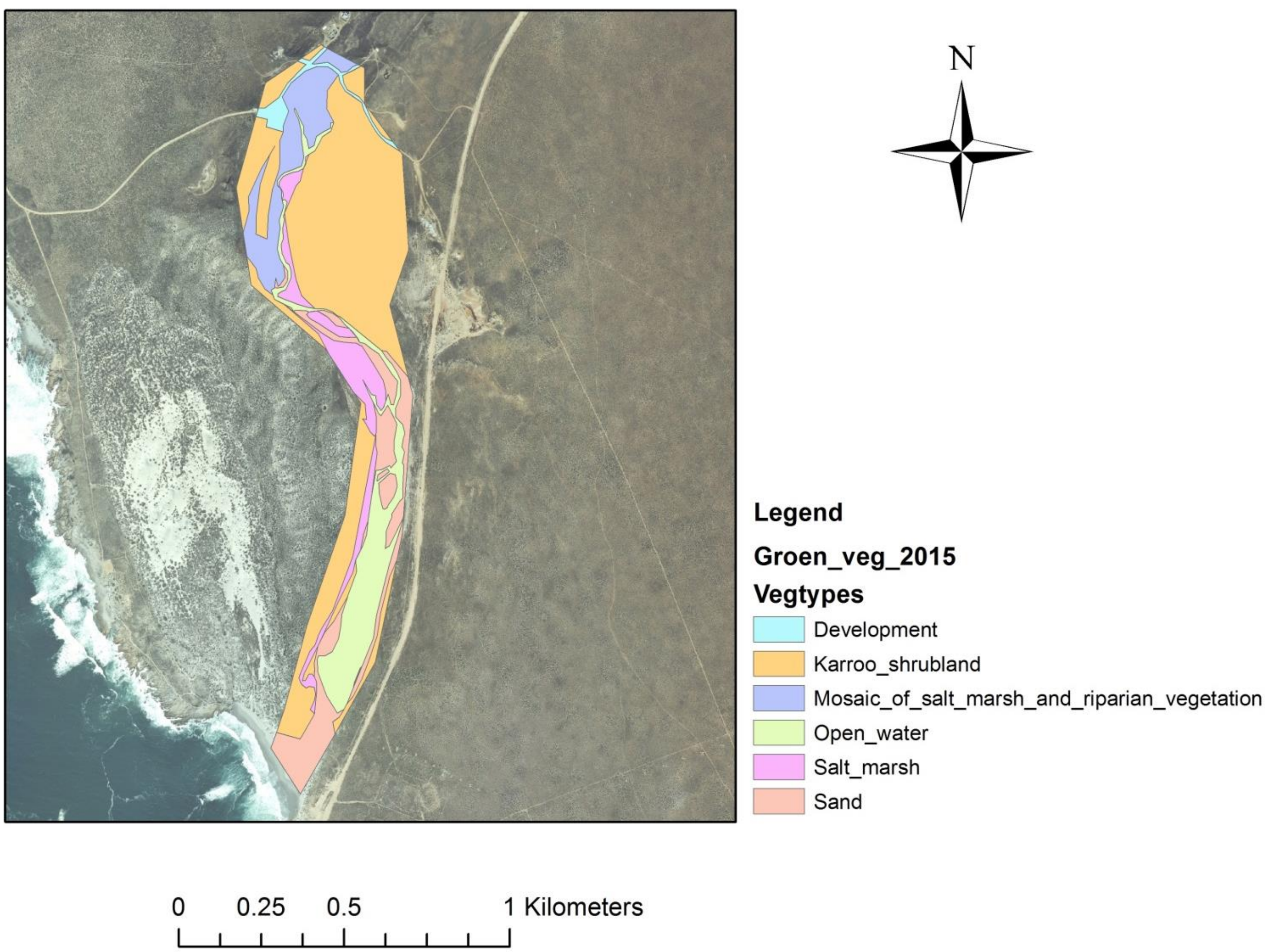


Figure 12.6 Groen Estuary: Vegetation map of the Greon Estuary for the EFZ based on the 2014 aerial images

Table 12.10 Groen Estuary: Macrophyte similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Disturbance in the upper reaches due to road and buildings may have resulted in some loss of species.	85	Medium
b Abundance	Groundwater abstraction and increases in salinity will have decreased reed, sedge and salt marsh abundance.	85	Medium
c. Community composition	Groundwater abstraction and an increase in salinity could change reed habitat to dry barren areas or salt marsh.	85	Medium
Score min (a to c)		**85**	**Medium**

12.8 INVERTEBRATES

Historical data on the Groen Estuary invertebrate fauna is limited to Grindley (1979), the cursory ECRU assessment by Heinecken 1981C and more recently Adams *et al*. (2015). Grindley (1979) reported six species of zooplankton but these and samples caught using the same gear in the 1981 ECRU survey were not identified. ECRU did report the intertidal giant beach pill-bug *Tylos granulatus* and sandhoppers (amphipods) *Talochorchestia* sp. in the berm as well as freshwater crab *Potamonautes perlatus* in the pondweed *Potamogeton* beds at the head of the estuary. Mention is also made of a failed attempt to introduce burrowing prawns (sandprawn *Callichirus* or mudprawn *Upogebia*) into the estuary and attributed this to the instability and frequent ultra-hypersalinity of the system.

More recently, no macro-invertebrates were present in benthic samples collected at seven sites in February 2015 (Adams *et al*., 2015). Salinity ranged from 70 to 223 psu in the main water body to 9 to 31 psu in the spring-fed headwaters. An anoxic black layer was present immediately below the surface of the sediment and extended down to a depth of at least 0.5 m. Any disturbance of the sediment (even superficial) resulted in a strong smell of Hydrogen sulphide (H_2S). Zooplankton samples showed the same pattern – reflecting an absence of zooplankton in the water column. However, 26 insect larvae (ca 20 ind/m^3) were collected in the upper reaches in February 2015 where a salinity of 26 psu was recorded. These insects were associated with the underside of the carpet of algae floating at the water surface. No brine shrimp *Artemia salina* were reported from anywhere in the estuary. Similarly, a sampling visit six months later in August 2015 had seen salinity drop to 70 psu but *Artemia* had yet to hatch out of encystment (Lamberth unpublished data). On both occasions, the unavailability of *Artemia* was evident in the virtual absence of flamingos and other avian predators. The only invertebrates seen in August 2015 were blue green flies perhaps kelp-flies *Thinophilus* sp. associated with burrows and tiny sand-heaps above the waterline. These animals were been foraged by Kittlitz's sandplover *Charadrius pecuarius* one of the few bird species present at the time.


a)


b)


c)

Figure 12.7 Groen Estuary: Blue green flies perhaps kelp-flies *Thinophilus sp*. associated with burrows and tiny sand-heaps above the waterline (a); brine shrimp *Artemia salina* (b); and carpet of algae floating at the water surface (c)

By October 2015 and this study, *Artemia salina* had hatched out of encystment and recovered to high biomass levels as had their Avian predators and despite a slight increase in salinity to 80 psu in the lower reaches. Overall, in a repeat of the synopsis of the Swartlintjies and other salinity driven estuarine ecosystems, invertebrate diversity, abundance and community structure in the Groen Estuary is a function of changes in groundwater inflow, frequency and magnitude of floods, frequency and duration of breaching and overwash events and salinity gradients, including cycles within long periods of hypersalinity. In particular, *Artemia* hatch at salinities above 40 psu and encyst sinking to the bottom when salinities exceed 150 psu. Consequently, the available biomass of *Artemia* in the Groen Estuary and adjacent systems is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Cyclicity in invertebrate species richness, abundance and community composition in the Groen Estuary is unlikely to have deviated much from reference. Table 12.11 provides the invertebrate similarity EHI scores for the Groen Estuary.

Table 12.11 Groen Estuary: Invertebrates similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Estuary dominated by halophylic species notably brine shrimp, hydrophilid beetles and kelp / brine flies *Thinophilus* sp. the latter two recorded above the water line. Less salt tolerant species confined to freshwater seep in upper reaches.	70	Low
b Abundance	Dominant brine shrimp still in the system but 100% dieback (encystment) in 2015 at > 150 psu which led to most flamingos and other birds being absent at the time. Brine shrimp hatched in abundance once salinity levels dropped below 150 psu to around 70 psu.	70	Low
c. Community composition	Brine shrimp still dominant but decline in less salt tolerant species from headwaters due to roads and other obstructions. Insects and molluscs amongst the saltmarsh and freshwater crab *Potamonautes perlatus* in the upper reaches (and in scat).	70	Low
Score min (a to c)		**70**	**Low**

12.9 FISH

The size of the *M. cephalus* and *L. richardsonii* caught in the 1982 ECRU survey suggested two recruitment events 2 to 5 years previously, as did the size of those caught 21 months previously Grindley (1979). Both of these samples are probably reflecting the same recruitment events but if growth slowed over the intervening time-period; a likely scenario given the stress associated with hypersalinity, then there may have been only one recruitment event. The mention of Clinidae (and Gobidae) in the rock-pools adjacent to but no records of these fish in Groen Estuary, suggest that overwash recruitment is likely to occur but survival limited. Harrison (2002) also reported no fish caught. No fish were caught or seen during a February 2015 field survey of the Groen Estuary (Adams *et al*., 2015) neither during sampling in August 2015 and October 2016 (Lamberth unpublished data). Salinity during all sampling events from 1994 onwards exceed 50 psu the tolerance threshold of most hardy estuarine fish species.

As with all the small West Coast systems fish diversity, abundance and community structure in the Groen relies on recruitment that is largely a function of connectivity with the sea and driven by the frequency and duration of floods and breaching events and the degree of overwash during high seas. Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 psu. Safe return to the sea is usually during flood events and depends on a quick breaching and fish not suffocating in sediment-laden water backing up against the berm. This said, most recruitment is “suicidal” via overwash with immediate survival depending on wave size and the height and width of the berm. Consequently, overwash recruitment diminishes with time away from a breaching event. Compared to the Spoeg, survival after overwash recruitment in the Groen is low and seems to be restricted to mullet species. Survival is probably prolonged by the headwater spring but dampened by the low habitat heterogeneity relative to the Spoeg and Buffels systems. Survival depends on whether the Groen dries up or becomes hypersaline before the next flood and breaching event. Historical records of 6 - 8 year-old harder *L. richardsonii* and flathead mullet *M. cephalus* in the Groen in the 1980s is evidence of tolerable conditions over the 6-8 years since last recruitment then. Table 12.12 provides the fish similarity EHI scores for the Groen Estuary.

Table 12.12 Groen Estuary: Fish similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Similar to reference with suicidal overwash recruitment and limited survival of larval and juvenile fish that were in the surf-zone at the time. Survival of recruits and return to the sea hinges on salinity not exceeding 60 - 70 psu before the next flood and breaching. Loss of inflow probably shortened survival of recruits. Only *M. cephalus* and *L. richardsonii* recorded in the system as survival of recruits from other species limited.	80	Low
b Abundance	Similar to reference with suicidal overwash recruitment and limited survival of larval and juvenile fish that were in the surf-zone at the time. Loss of inflow probably shortened survival of recruits.	80	Low
c. Community composition	*M. cephalus* and *L. richardsonii* would have survived until 60 psu or longer depending on freshwater flow into the headwaters.	80	Low
Score min (a to c)		**80**	**Low**

12.10 BIRDS

Six bird-counts exist for the Groen Estuary, these being three thirty years ago in January 1979, January 1980 and October 1980 (Grindley, Cooper and ECRU) and three more recently in February 2015, August 2015 and October 2016 respectively (Adams *et al*. Smith EWT & CSIR) (Table 12.13). A total 1 738 birds of 49 species have been recorded of which 40 are estuarine and 9 terrestrial. Numbers of the five numerically dominant species varied between the four visits, with Greater

Flamingo (maximum 282), Curlew Sandpiper (maximum 106), Black necked Grebe (maximum 82), Red-knobbed Coot (maximum 72), and Little Stint (maximum 61) heading the list.

Bird diversity and abundance in the Groen Estuary vary mostly according to salinity and the availability of brine shrimp on which they feed. To illustrate, 7 - 15 species of 60 – 200 birds were recorded in February 1979, February 2015 and August 2015 when salinity exceeded 150 psu throughout most of the system. Salinity levels of 40 - 80 psu in January 1980, October 1980 and October 2016 saw a relatively uniform 400- 500 birds of 27 – 28 species. Greater and lesser flamingo dominated at these times. When salinity exceeded 150 psu in February and August 2015, brine shrimp encysted and most birds disappeared from the system. The few remaining e.g. little stint and chestnut banded plover were feeding almost exclusively on halophylic fly and beetle larvae found in burrows above the waterline at the time.

Table 12.13 Groen Estuary: Recorded bird species

Species	Jan 1979 Grindley	Jan 1980 Cooper	Oct 1980 ECRU	Feb 2015 (Adams *et al.*)	Aug 2015 G Smith (EWT)	Oct 2016 CSIR	Max no
Greater Flamingo		49	282	13	35	108	282
Curlew Sandpiper	106	73	32		5		106
Black necked Grebe		12	10		8	82	82
Red-knobbed Coot	4	72	50				72
Little Stint	25	61	3	15		13	61
Red bishop						50	50
Lesser Flamingo			13		2	40	40
Cape Teal	30	34	38	9	1	15	38
Avocet	19	24	3			3	24
Black-winged Stilt	5	9	2	2	1	20	20
Three-banded Sandplover		18	3	5		2	18
Hartlaub's gull						13	13
Yellow-billed Duck		12					12
European Swallow	12						12
Hadeda						12	12
Sanderling		1	10	4		9	10
Ruff		9	3				9
Cape Wagtail	5	9	8			5	9
White-fronted Sandplover	3	5	8	4		6	8
Greenshank	8	2	3				8
Ringed Plover		7	2			3	7
White breasted Cormorant		5	3	24		6	24
Kittlitz's Sandplover		6	2	8		3	8
Southern black-backed Gull			6	9		1	9
Blacksmith Plover		5	4			heard	5

Species	Jan 1979 Grindley	Jan 1980 Cooper	Oct 1980 ECRU	Feb 2015 (Adams *et al.*)	Aug 2015 G Smith (EWT)	Oct 2016 CSIR	Max no
Marsh Sandpiper		5				2	5
Bokmakierie						5	5
Cape Dabchick		4	1				4
Grey Heron		1	4				4
African Sand Martin	4						4
Chesnut-banded Sandplover	3			2		1	3
White-winged Black Tern	3	3					3
Grey tit						3	3
South African Shelduck		2	2			2	2
Black Harrier			2				2
Common Sandpiper	1		2			2	2
Ringed Plover						2	2
Cape Cormonrant			1				1
Egyptian Goose			1	2		1	2
Cape Shoveller		1					1
Grey Plover		1					1
Wood Sandpiper		1					1
Caspian Tern	1						1
Glossy ibis						1	1
Feral pigeon						1	1
Red-billed Teal				1			1
Ostrich				4			4
Spur-winged Goose				7			7
Hartlaubs gull					8		
Total species	**15**	**27**	**27**	**15**	**7**	**28**	**49**
Total number	**229**	**431**	**498**	**109**	**60**	**411**	**1738**

Under reference and the present day, the Groen Estuary is characterised by infrequent floods, breaching and connectivity to the sea. The availability of fish to piscivorous birds is limited to the time between recruitment and mortality when salinity exceeds 50 psu. The few fish that survive are too large for cormorants and terns and probably only preyed on by fish eagles and ospreys when and if they occur.

The dominant state of the Groen Estuary is hypersaline with a limited salinity gradient maintained by the freshwater spring in the upper reaches. Under these conditions, available food comprises a high biomass of brine shrimp *Artemia* spp. and limited diversity and abundance of halophylic Insecta. Broadly, *Artemia* hatch at salinities above 40 psu and encyst sinking to the bottom when salinities exceed 150 psu. Consequently, available biomass of *Artemia* in the Groen Estuary is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Table 12.14 provides the birds similarity EHI scores for the Groen Estuary.

Table 12.14 Groen Estuary: Birds similarity EHI scores

Variable	Score	Confidence
a. Species richness	80	Low
b Abundance	80	Low
c. Community composition	90	Low
Score min (a to c)	**90**	**Low**

13 APPENDIX E: THE SOUT ESTUARY DESKTOP EWR

Appendix E provides the detailed methods and scores for the abiotic and biotic componentsof the Sout Estuary.

13.1 DELINEATION

The Sout Estuary is situated 60 km north of the Olifants Estuary. The geographical boundaries of the Sout Estuary are defined as follows (Figure 13.1):

Downstream boundary:	31°14'37.66"S 17°50'52.55"E (Estuary mouth)
Upstream boundary:	31°12'38.88"S 17°53'24.41"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 13.1 Sout Estuary: Geographical boundaries based on the EFZ

13.2 MAJOR PRESSURES

The major pressures on the Sout Estuary include:

- Significant habitat modification for salt works.
- Numerous artificial channels and diversion of the water course.
- Access roads bisecting the estuary.
- Some loss of freshwater input from groundwater abstraction.
- Mining activities.

13.3 HYDROLOGY

The catchment area of the Sout River is estimated at 1 442 km^2. The catchment falls predominantly within the winter rainfall area and episodic floods occur occasionally. The annual precipitation of the area is very low. The river is ephemeral with surface flow only occurring after substantial rainfall.

A summary of monthly flow volumes under Reference conditions is provided in **Error! Reference source not found.**. Very little information is available on the hydrology, desktop estimates indicate that there is very little surface flow reduction. However, a weir above the estuary and local road infrastructure is estimated to impact on the magnitude of floods to the system, with similarity in floods to reference condition estimated at 80%.

Table 13.1 Sout Estuary: Simulated monthly flows (in 10^6 m^3) under Reference Conditions

Year	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Total	Breaching*
1920	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.51	0.17	0.03	0.03	1.07	0
1921	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.13	0.05	0.39	0
1922	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.15	0.05	0.20	0.07	0.61	0
1923	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0
1924	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.10	0
1925	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.02	0.00	0.09	0
1926	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.04	0
1927	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0
1928	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.02	0.06	0
1929	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.11	0.45	0
1930	0.01	0.01	0.01	0.00	0.00	0.00	0.08	0.03	0.00	0.00	0.11	0.04	0.27	0
1931	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.04	0
1932	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.08	0.02	0.01	0.25	0
1933	0.00	0.00	0.00	0.00	0.01	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.12	0
1934	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.11	0
1935	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0
1936	0.07	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.02	0.00	0.21	0
1937	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0
1938	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.13	0.50	0
1939	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.05	0
1940	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.16	0.11	0.03	0.03	0.01	0.36	0
1941	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.14	0.05	0.01	0.00	0.26	0
1942	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.01	0.08	0
1943	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.03	0.08	0.02	0.03	0.01	0.21	0
1944	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.02	0
1945	0.08	0.03	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.09	0.23	0
1946	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.06	0
1947	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.03	0
1948	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
1949	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.02	0.03	0.10	0
1950	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.08	0.00	0.00	0.30	0
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.11	0.05	0.01	0.17	0
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.11	0.01	0.08	0.05	0.01	0.51	0
1953	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.19	0.06	0.53	0.23	0.02	1.07	0
1954	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.10	0.11	0.11	0.03	0.40	0
1955	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.10	0.04	0.01	0.24	0
1956	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.14	0.09	0.02	0.06	0.02	0.39	0
1957	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0
1958	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.51	0.18	0.02	0.03	0.01	0.80	0
1959	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0
1960	0.01	0.01	0.05	0.02	0.01	0.01	2.60	0.89	0.17	0.07	0.03	0.03	3.90	0
1961	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	6.90	2.35	0.11	0.08	9.61	0
1962	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.11	0.18	0.05	0.82	0
1963	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.90	0.33	0.03	0.03	1.49	0

1964	0.02	0.20	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.45	0
1965	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.18	0
1966	0.02	0.02	0.02	0.02	0.01	0.01	0.11	0.04	0.44	0.16	0.02	0.02	0.86	0
1967	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.02	0.02	0.02	0.23	0
1968	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.11	0
1969	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.02	0.01	0.00	0.08	0
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.05	0
1971	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0
1973	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.01	0.31	0.11	0.91	0.32	1.68	0
1974	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.08	0.03	0.01	0.01	0.01	0.21	0
1975	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.83	0.53	0.09	0.02	1.50	0
1976	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.29	0.14	0.09	0.05	0.01	0.64	0
1977	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.03	0.19	0
1978	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0
1979	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.17	0.06	0.16	0.05	0.51	0
1980	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.11	0.20	0.06	0.44	0
1981	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.02	0.01	0.14	0
1982	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.64	0.27	0.02	0.02	0.01	1.01	0
1983	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.05	0.01	0.01	0.01	0.29	0
1984	0.08	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.19	0
1985	0.00	0.00	0.23	0.08	0.01	0.01	0.01	0.01	1.51	0.54	0.02	0.02	2.43	0
1986	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.07	0.11	0.04	0.02	0.34	0
1987	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.02	0.01	0.01	0.16	0
1988	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.02	0.02	0.02	0.01	0.01	0.17	0
1989	0.01	0.01	0.01	0.01	0.01	0.01	0.32	0.14	0.19	0.07	0.01	0.01	0.77	0
1990	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.35	0.12	0.01	0.56	0
1991	0.08	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.19	0
1992	0.05	0.02	0.01	0.01	0.01	0.01	1.40	0.61	0.06	0.11	0.05	0.02	2.35	0
1993	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.26	0.13	0.02	0.02	0.54	0
1994	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.13	0
1995	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.03	0.02	0.17	0
1996	0.01	0.04	0.02	0.01	0.01	0.01	0.01	0.30	0.30	0.07	0.01	0.01	0.76	0
1997	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.12	0.05	0.01	0.01	0.01	0.24	0
1998	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.20	0.30	0
1999	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.33	0.12	0.01	0.60	0
2000	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	4.95	2.10	0.18	7.30	0
2001	0.07	0.06	0.05	0.05	0.05	0.05	0.04	0.40	0.14	0.48	0.34	0.06	1.79	0
2002	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	1.85	0.65	2.83	0
2003	0.05	0.05	0.05	0.04	0.04	0.04	0.08	0.03	0.16	0.05	0.03	0.03	0.64	0
2004	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.05	0.02	0.34	0

* Years that the Sout Estuary could have potentially breached are indicated by 1.

Table 13.2 Sout Estuary: Groundwater recharge and discharge estimates

Groundwater parameter	Estimated value (low confidence)
Groundwater catchment area	1 420.0
Estuary catchment area	897
Reference recharge to estuary Mm^3/a	2.0
Reference Estuary discharge Mm^3/a	**1.2**
Use in Catchment Mm^3/a	0.11
Present Estuary Mm^3/a	**1.128**
Use as % discharge	0.09
% Similarity	91
Ground water TDS mg/l	7 468

Groundwater parameter	Estimated value (low confidence)
Reference total salt load from groundwater (tons/a)	**9 246**

Table 13.3 provides the hydrology similarity EHI scores for the Sout Estuary.

Table 13.3 Sout Estuary: Similarity scores for hydrology relative to the Reference condition

Variable	Present	Confidence
% similarity Groundwater	20	Low
% similarity frequency and magnitude of floods	70	Low
Hydrology score	**40**	

13.4 HYDRODYNAMICS

The Sout Estuary is classified as a temporarily open/closed system (Van Niekerk and Turpie, 2012). Very little is known about the estuary because of its small size and remote location.

13.4.1 Connectivity and circulation

Connectivity and circulation in the Sout Estuary has been severely modified and at present the system is characterised by three water bodies separated by causeways in the lower and middle reaches. Three roads bisect the estuary, the closest being at about 300 m and the other about 1 km from the mouth, with most of the EFZ disturbed around the mouth area. An extensive salt works is situated in the upper reaches of the system. Very limited connectivity exists between the different water bodies. What little there is, seems to be mostly through a series of channels and pumping schemes. The weir in the upper reaches also prevents connectivity with the catchment of the Sout River.

(a) A very high and wide berm showing little signs of overwash or vegetation growth; (b) The lower reaches cut off by road from main water body; (c) Channels connecting the lower reaches with middle reaches and road bisecting the lower reaches; d) The middle reaches teaming with bird life; (e) and (f) Saltworks in the upper reaches of the Sout Estuary.

Figure 13.2 Sout Estuary: Key features

13.4.2 Mouth State

Historical imaginary indicate that the Sout Estuary is nearly always closed to the sea. The limited runoff simulated for this catchment confirms that breaching is likely to occur at very low return periods, e.g. 1:100 years. However the relative lack of vegetation on the berm near the mouth indicates that a breaching of the system to the sea must have occurred in the last few decades.

Table 13.4 Sout Estuary: Change in open water area over time

Year	Source	Mouth state (Open/closed)
2014	National Geo-Spatial Information (Surveys and Mapping)	Closed
2013	National Geo-Spatial Information (Surveys and Mapping)	Closed
2010	National Geo-Spatial Information (Surveys and Mapping)	Closed
2003	National Geo-Spatial Information (Surveys and Mapping)	Closed

Year	Source	Mouth state (Open/closed)
1976	National Geo-Spatial Information (Surveys and Mapping)	Closed
1958	National Geo-Spatial Information (Surveys and Mapping)	Closed
1942	National Geo-Spatial Information (Surveys and Mapping)	Closed

13.4.3 Openwater area

The openwater area seems to have increased with the causeways and possible upstream weir development. The causeway across the mouth is visible in the 1942 image. The salt works is visible in the 1958 image, while the 1976 image shows no damming upstream. The 2013 potentially shows some damming 3.5 km upstream and thereby increasing the open water area.

Table 13.5 Sout Estuary: Summary of the mouth state based on available imagery

Year	Mouth state (Open/closed)	Open water area (ha)
2013	Closed	74.13 (seems high - sand banks look like water)
2010	Closed	18.92
2003	Closed	26.03 (poor quality – difficult to see if pans or dry river bed)
1976	Closed	Quality too poor
1958	Closed	Too poor quality
1942	Closed	9.79 (very poor quality, difficult to see sand from water)

Table 13.6 S Sout Estuary: imilarity scores for hydrodynamics under the various operational scenarios relative to the Reference Condition

Variable	Present	Confidence
Mouth condition	95	Low
Circulation (connectivity)	20	Medium
Water level	20	Low
Hydrodynamics score*	**20**	**Low**

Figure 13.3 Sout Estuary: Roads, diverted channels, salt works and weir

13.5 WATER QUALITY

Figure 13.4 shows locality map of sampling sites in the Sout Estuary.

Figure 13.4 Sout Estuary: Water Quality sampling stations

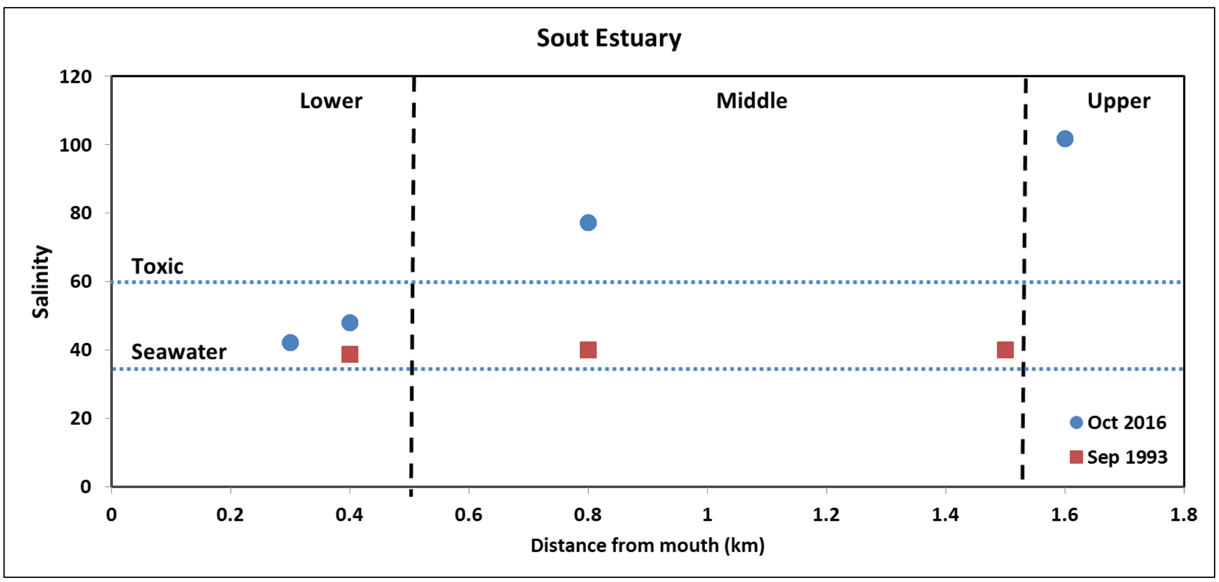


Figure 13.5 Sout Estuary: Available salinity data

What little salinity information is available for this system indicates that it is always in a hyper saline state, with salinity between 38 and 101 recorded. In September 1993 (Harrison, unpublished data) the system varied between 38 in the lower reaches to greater than 40 in the upper reaches. During the October 2016 field survey salinity hovered around 40 in the lower reaches, while in the middle and upper reaches salinities elevated to 80 and 101 respectively.

How much of the hyper salinity in the system is natural (due to evaporation over a large surface area) and how much is the result of the saltworks is nearly impossible to estimate as there was evidence of seawater pumping near the saltworks.

For this study hyper salinity values of up to 60 is assumed to be representative of near natural conditions, while elevated values of 101 is seen as the possible result of sea water pumping.
Available data on other water quality parameters is also limited (Harrison, 1998; DAFF; this study) (Figure 13.5). Limited data on DO suggest slightly lower level in the lower reaches compared with middle and upper. Turbidity in the lower and upper reaches (~10 NTU) appeared to be lower compared with middle reaches (~40 NTU). The latter is attributed to the presence of flamingos in the middle reach that increased turbidity in this shallower water.

Under reference flamingos would have occupied large shallow upper reaches (so highest turbidity would have been in that reach). Both DIN and DIP concentrations were highest in lower reach (250 µg/l and 30 µg/l, respectively) compared with the rest of the estuary (<50 µg/l and, <10 µg/l, respectively). The high nutrients in the confined lower reaches under present are associated with high (concentrated) biological productivity which then rippled through lower DO (organic loading). Activities associated with salt work could have contributed to toxic accumulation in this system (e.g. leachate from rusting equipment etc).

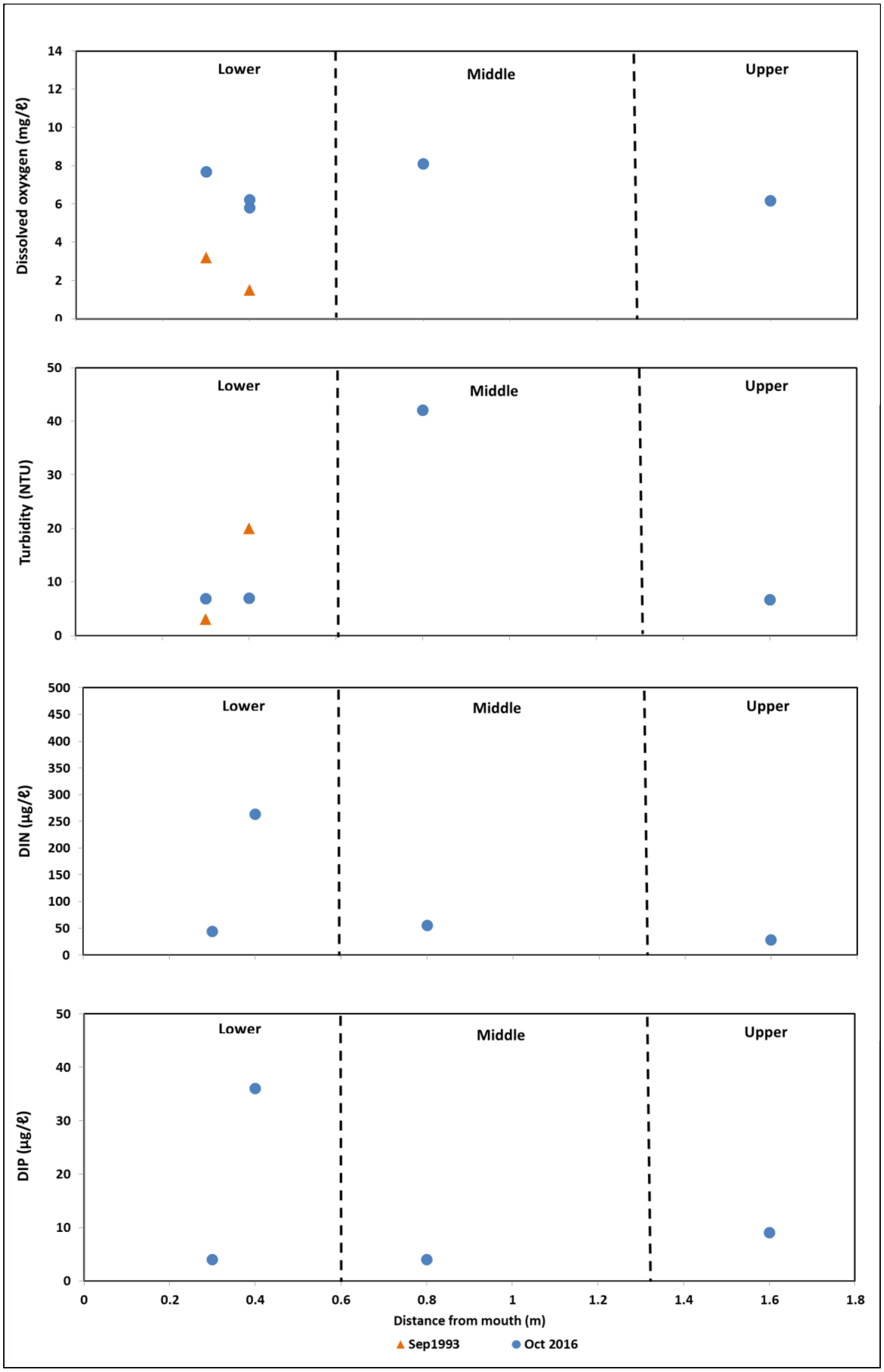


Figure 13.6 Sout Estuary: Available data for dissolved oxygen, turbidity and inorganic nutrients

Based on very limited data and information and expert opinion, the average water quality conditions under each of the abiotic states, for reference, present and future scenarios are estimated as follows:

Salinity	Reference	Present
Lower	35 - 45	45 - 50
Middle	50	80
Upper	80	100
DIN (µg/l)	**Reference**	**Present**
Lower	50	150
Middle	50	50
Upper	50	50
DIP (µg/l)	**Reference**	**Present**
Lower	10	30
Middle	10	10
Upper	10	10
DO (mg/l)	**Reference**	**Present**
Lower	6	4
Middle	8	8
Upper	8	6
Turbidity (NTU)	**Reference**	**Present**
Lower	10	10
Middle	10	20
Upper	15	10

Table 13.7 provides the water quality similarity EHI scores for the Sout Estuary.

Table 13.7 Sout Estuary: Summary of changes and calculation of the water quality health score

Variable		Present	Confidence
1	**Salinity**		
	Similarity in salinity *(similarity score adjusted for hyper salinity)*	20	Low
2	**General water quality**		
a	DIN and DIP concentrations	80	Low
b	Turbidity	84	Low
c	Dissolved oxygen	88	Low
d	Toxic substances	80	Low
	Water quality score	**56**	**Low**

13.6 PHYSICAL HABITAT

The Sout Estuary is a highly transformed system. Road infrastructure has severely modified the lower reaches, filling in some of the supratidal and intertidal areas. The subtidal areas are also significantly transformed with channel diversions and infilling. The upper reaches as severely degraded by the presence of a salt works that have diverted some of the main channels modifying the intertidal and subtidal areas significantly. Table 13.8 below provides a summary of the EHI scores for the physical habitat of the Sout Estuary.

Table 13.8 Sout Estuary: Similarity EHI scores for physical habitat

Variable	Present	Confidence
a. Supratidal area and sediments	50	Low
b. Intertidal areas and sediments	45	Low
c. Subtidal area and sediments	30	Low
d. Estuary bathymetry/water volume	20	Low
Physical habitat score*	**75**	**Low**

13.7 MICROALGAE

The lower and middle reaches of the Sout Estuary are highly disturbed due to the salt works. There are numerous artificial channels, diversions of the water course, access roads and freshwater reduction. There is little resemblance to the natural state which would be reflected in the microalgal condition. The estuary supports a large flamingo population and fringing salt marsh that grows in the disturbed habitat. Microalgal samples were taken in two isolated ponds near the mouth (Sites 1 and 2), in a hypersaline flamingo area (Site 3 – salinity 78 psu) and at an intake site (Site 4 – salinity 101 psu) where the water was clearer than that at Site 3. The water at Site 3 had fine silt, 1 or 2 brine shrimp and many small black particles (possibly brine shrimp larvae). Phytoplankton biomass was low except for Site 3 (62.2 ± 0.6 µg/l) where the halophilic Chlorophyte, *Dunaliella salina* (*ca*. 2800 cells/ml) was dominant. Table 13.8 provides the microalgae similarity EHI scores for the Sout Estuary.

Table 13.9 Sout Estuary: Microalgae similarity EHI scores

Variable	Present State	Score	Confience
a. Species richness	The estuary bears little resemblance to its natural state and thus loss of microalgae species has occurred.	35	Low
b Abundance	Changes in the bathymetry and structure of the estuary have led to major changes in the microalgae.	25	Low
c. Community composition	Unnatural ponds in the lower reaches and salt pans in the upper reaches have transformed the community composition.	25	Low
Score min (a to c)		**25**	**Low**

13.8 MACROPHYTES

No prior information exists on the vegetation of the Sout Estuary. The system was mapped on 9 October 2016 and checked to approximately 1.2 km upstream (Figure 13.7). Mapping of the upper reaches was done based on changes in vegetation colour from the aerial images and confidence is low. Around the mouth of the Sout Estuary Namaqualand Seashore Vegetation occurs. Adjacent to this and along sections of the estuary there is Namaqualand Coastal Duneveld. Arid Estuarine Salt Marsh is the predominant vegetation type in the EFZ, often with pure stands of *Limonium*, *Sporobolus virginicus* and *Sarcocornia pillansii*. *Sarcocornia pillansii* forms bands in places along the edges of the water channel. In the middle reaches of the estuary large open sand flats devoid of vegetation are common due to the hypersaline conditions. Most of the original Arid Estuarine Salt Marsh has been replaced by the salt works. The water channel splits into two channels and approximately 3.3 km from the mouth it appears to be dammed.

At the coast the system has been largely altered and is characterised by three water bodies separated by road causeways. The saltworks is situated in the middle reaches of the system. An analysis of available past aerial photographs indicated that the water area seems to have increased with causeways and possible upstream damming. Open water surface area has changed over time but was difficult to map and distinguish water from sand (1942 – 9.79 ha, 2003 – 26.03 ha, 2010 – 18.92 ha, 2013 – 74.13 ha). Table 13.10 provides the macrophyte similarity EHI scores for the Sout Estuary.

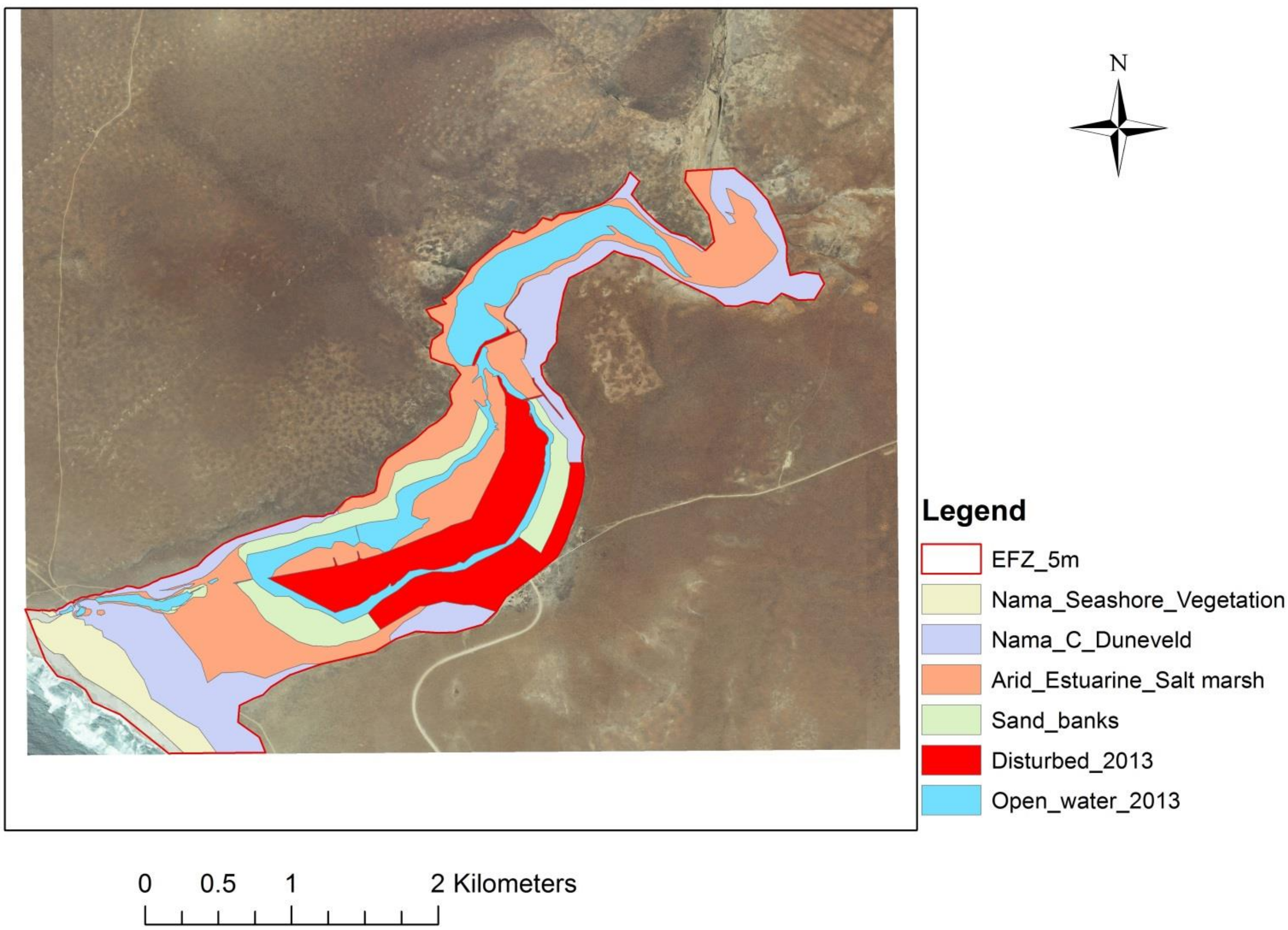


Figure 13.7 Sout Estuary: Vegetation map for the EFZ based on the 2014 aerial images

Table 13.10 Sout Estuary: Macrophyte similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	The estuary bears little resemblance to its natural state, it is now mostly a salt pan and loss of habitat would have decreased species richness.	30	Low
b Abundance	Floodplain and arid estuarine salt marsh has been removed by the salt works and access roads. Windblown salt and saline sediment conditions cause die-back of the surrounding vegetation.	20	Low
c. Community composition	Unnatural ponds in the lower reaches and salt pans in the upper reaches have transformed the community composition.	20	Low

Variable	Present State	Score	Confidence
Score min (a to c)		**20**	**Low**

13.9 INVERTEBRATES

There is no available historical information on the fish or invertebrates of the Sout Estuary. Connectivity with the sea is limited and current breaching frequency is thought to be about once in a 100 years; but there may have been one event in the last few decades. Salt-work's infrastructure and production has completely altered the estuary and invertebrates are mostly brine shrimp with lower abundance of Harpacticoid copepods and Hydrophilid beetles in the younger pans that have not yet evaporated. Brine shrimp are probably feeding exclusively on the halophilic Chlorophyte *Dunaliella salina* the dominant microalgae in the system. This said, there is an anomalous isolated population of *Palaemon* sp. in very high densities in an old sump and salinity of 40 psu. It's unlikely that they were under stress as this species is tolerant of warm and hypersaline conditions in intertidal rock-pools. There's also the possibility that this population of *Palaemon* may have been isolated for the more than 50 years since the sump was last operational.

As with the Swartlintjies and Groen, brine shrimp are dominant numerically and by mass in the system. Most other invertebrates excluded due to persistent hypersalinity of the salt-works. Probably also a more rapid and frequent progression to salinities above 150 psu causing brine shrimp to encyst and become unavailable to flamingos and other birds and animals that feed upon them. However, with the ponds at different levels of evaporation and salinity, brine shrimp may be consistently available to birds, which therefore persist in the estuary not having to move elsewhere. Birds are probably also predators on the *Palaemon* sp. but this need to be verified. Table 13.11 provides the invertebrate similarity EHI scores for the Sout Estuary.

Figure 13.8 Harpacticoid copepods, Palaemon sp and Hydrophilid beetles in the Sout Estuary

Table 13.11 Sout Estuary: Invertebrates similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Estuary completely altered but still dominated by halophilic species notably brine shrimp with lesser numbers of harpacticoid copepods and hydrophilid beetles the latter recorded above the water line. Loss of less salt tolerant species from headwaters due to roads, weirs and other obstructions arising from the development of the salt-works. Anomalous isolated population of *Palaemon* sp. in old sump.	30	Low
b Abundance	Brine shrimp still dominant numerically and by mass in the system. Most other invertebrates excluded due to persistent hypersalinity of the salt-works. Probably also a more rapid and frequent progression to salinities above 150 psu causing brine shrimp to	30	Low

Variable	Present State	Score	Confidence
	encyst and become unavailable to flamingos and other birds and animals that feed upon them. However, ponds at different levels of evaporation may see brine shrimp and birds persist. Population of *Palaemon* sp. in old sump at very high densities.		
c. Community composition	Brine shrimp still dominant but loss of less salt tolerant species from headwaters due to roads, weirs and other obstructions arising from the development of the salt-works. In addition, more frequent and prolonged encystment when salinity deliberately sent above 150 psu sees brine shrimp dormant and no grazing on phytoplankton or other activity in the system. Anomalous population of *Palaemon* sp. in old sump may have been isolated for the more than 50 years since it was operational.	30	Low
Score min (a to c)		**30**	**Low**

13.10 FISH

There are no previous records of fish in the Sout Estuary. Reference conditions are likely to have seen rare suicidal overwash recruitment and short-term survival of larval and juvenile fish that were in the surf-zone at the time. Only *M. cephalus* and *L. richardsonii* would have possibly persisted for a week or two at any time. Present day conditions are similar to reference but more obstructions and time since last breaching would have limited survival and recruitment even more. This said, the existence of *Palaemon* in the old sump suggests that fish egg, larval and juvenile "recruitment" is likely to have been a regular event when the pump was operational more than 50 years ago. Unlike Palaemon, none of the recruited fish are likely to have bred in the sump and would have gradually been preyed on by until extinct from the system. Table 13.12 provides the fish similarity EHI scores for the Sout Estuary.

Table 13.12 Sout Estuary: Fish similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Similar to reference with very rare suicidal overwash recruitment and limited survival of larval and juvenile fish that were in the surf-zone at the time. Only Mugil cephalus and Liza richardsonii would have possibly persisted for any time.	20	Low
b Abundance	As above.	20	Low
c. Community composition	As above.	20	Low
Score min (a to c)		**20**	**Low**

13.11 BIRDS

No historical bird-counts exist for the Sout Estuary so this study is limited to the 15 species and 120 individuals recorded during the site visit in October 2016 (see Table 13.13). However, the main drivers of invertebrate, fish and bird diversity and abundance are the cycles of hypersalinity characteristic of the Groen and Swartlintjies systems. With the exception of kelp gull and Caspian tern that were roosting on the estuary, the avifauna was exclusively comprised of birds such as flamingos, avocets, black-winged stilts and Cape teal, that feed on brine shrimp and halophylic insects. Fifty-percent of these were lesser and greater flamingo. Terns, waders and waterbirds all feed on *Palaemon* shrimps but none were observed foraging or roosting within the vicinity of the population in the old sump.

Table 13.13 Sout Estuary: Recorded bird species

Common name	Scientific name	October 2016
Cape Teal	*Anas capensis*	4
Greater flamingo	*Phoenicopterus ruber*	47
White-fronted plover	*Charadrius marginatus*	11
Pied avocet	*Recurvirostra avosetta*	5
Three-banded plover	*Charadrius tricollaris*	7
Sanderling	*Calidris alba*	4
Curlew sandpiper	*Calidris ferruginea*	5
Southern Black-backed Gull	*Larus dominicanus*	3
Cape wagtail	*Motacilla capensis*	2
Ethiopian snipe	*Gallinago nigripennis*	1
Chestnut banded plover	*Charadrius pallidus*	7
Marsh Sandpiper	*Tringa stagnatilis*	1
Lesser flamingo	*Phoeniconaias minor*	16
Common Sandpiper	*Actitis hypoleucos*	6
Caspian tern	*Hydroprogne caspia*	1
Total species counted		**15**
Total number birds counted		**120**

Under reference and the present day, the Sout Estuary has been mostly hypersaline with a high biomass of brine shrimp *Artemia* spp. and limited diversity and abundance of halophilic Insecta. Broadly, *Artemia* hatch at salinities above 40 psu and encyst sinking to the bottom when salinities exceed 150 psu. Consequently, similar to the other West Coast estuaries, available biomass of *Artemia* in the Sout is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them. Unlike the other systems, overwash and connectivity to the sea no longer occurs except perhaps under the extreme flood events of 1 in 100 hundred or more. This said, the salt-works have completed altered the system but also ensure that at least some of the evaporative ponds have the salinity window of 40 – 150 required for brine shrimp to breed and hatch out of encystment and ultimately be available to the birds that feed upon them. This suggests that the present-day bird community of the Sout Estuary may be more stable than other hypersaline West Coast systems. One rider to this is that it needs to be confirmed that birds are not actively discouraged by bird-repellent reflective-discs, bird-bangers or similar methods used by salt-works countrywide.

Given that the Sout Estuary is mostly salt-works, we need to reiterate that at least seven native *Artemia salina* populations in South Africa, including those in salt-works have been replaced by the invasive *Artemia franciscana* (Baxevanis *et al*., 2014). Birds and damp bird feathers are known vectors of shrimp eggs so the status and identity of the *Artemia* in the Sout and other West Coast estuaries and wetlands needs to be verified. Table 13.14 provides the birds similarity EHI scores for the Sout Estuary.

Table 13.14 Sout Estuary: Birds similarity EHI scores

Variable	Present State	Score	Confidence
a. Species richness	Loss of species as result of increased in frequency and intensity of hyper salinity and human disturbance in the flood plain.	30	Low
b Abundance	Reduce abundance as a result of reduced food valaibility and human disturbance.	30	Low
c. Community composition	Significant shit in the community composition as a result of shift in salinity regime, reduced area and human disturbance in the flood plain.	30	Low
Score min (a to c)		**90**	**Low**

14 APPENDIX F: MICROALGAE AND MACROPHYTE DETAILED SPECIALIST REPORT

Macrophytes and Microalgae of the small west coast estuaries

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November 2016

SUMMARY

The five small estuaries sampled represented a range of conditions and pressures; from the highly transformed Sout Estuary to the near pristine Spoeg Estuary. Swartlintjies, Bitter and Groen were hypersaline. Buffels, Spoeg and Groen had salinity gradients up the length of the estuary. The golf course and water run-off probably lowers salinity in the Buffels and introduces nutrients. The Spoeg had patches of reeds in the upper and riverine reaches indicating seepage sites and the Groen had a stretch of reeds in the upper reaches indicating an important groundwater fed area. Because of the arid highly saline conditions *Sarcocornia pillansii* was dominant. This plant grows in extreme saline dry environments. Brakgras *Sporobolus virginicus* was co-dominant. Where there was a more gradual elevation gradient then *Sarcocornia natalensis* was found growing closer to the water's edge (Spoeg and Groen). Submerged macrophytes only occurred in the fresher section of the Buffels and were abundant in the Spoeg Estuary indicating the biodiversity importance of this system. Macrophytes have mainly responded to the decrease in groundwater and increase in salinity as well as anthropogenic impacts that have disturbed or removed vegetation such as the mining activities at Buffels Estuary and the salt works at Sout Estuary.

Because of the discontinuous nature of the estuaries microalgae did not show typical distribution patterns in biomass. Hypereutrophic conditions (> 60 µg/l chlorophyll-a) were observed in the upper reaches of the Spoeg Estuary, lower reaches of the Groen Estuary and middle reaches of the Sout Estuary. In the Groen and Sout this was associated with hypersaline shallow conditions whereas in the Spoeg Estuary this was at a bird feeding site. Community composition reflected the prevailing salinity conditions; for example, the green alga, *Dunaliella salina* was abundant in hypersaline waters. Changes in the microalgae were in response to habitat loss i.e. decrease in water volume and increases in salinity as a result of surface and groundwater reduction.

14.1 STUDY APPROACH

The five estuaries were visited in October 2016. The assessment of the present status of the estuaries was based on this site visit as well as available information (Table 14.1). The distribution of macrophyte habitats was mapped in the field and the estuary boundary delineated where possible. Unidentified plant species were collected for identification. The water column was sampled for microalgae by collecting replicate surface water samples at sites up the length of the estuary. Phytoplankton biomass (chlorophyll a concentration) was measured by collecting 500 ml samples that were gravity-filtered through glass-fibre filters (Whatman© GF/C) and frozen until laboratory analysis. Chlorophyll a was extracted by placing the frozen filters into glass vials containing 10 ml of 95% ethanol (Merck 4111). After extraction for 24 h in a cold (ca. 1 – 2°C), dark room, spectrophotometric determinations of chlorophyll *a* were performed according to Nusch (1980). Absorbance before and after (only when absorbance ≥0.2) acidification of extracts with 1N HCl were read using a UV/VIS spectrophotometer at 665 nm.

Phytoplankton community composition was also assessed. Water samples of 200 ml were collected from each site and preserved using two drops of undiluted glutaraldehyde. The Coulon and Alexander (1972) method was used to settle the samples overnight in 26.5 mm diameter settling chambers. Two drops of Rose Bengal were added to 50 ml of preserved water samples and then allowed to settle for 24 hours before identification. Once settled, a Zeiss IM 35 inverted microscope was used to count and identify the microalgal groups at a magnification of 630X during which either a minimum of 200 frames or 200 cells were counted. The cells were classified according to different algal groups/classes, i.e. Bacillariophyceae (diatoms), Dinophyceae (dinoflagellates), Cyanophyceae (blue-green algae), Chlorophyceae (green algae), and flagellates. Cell density (cells ml^{-1}) was calculated using the following equation of Snow (2008).

Table 14.1 Available botanical information for the five small west coast estuaries

Estuary	Literature
Buffels	Heydorn and Grindley, 1981a; Harrison, 1997; Clark, 1988
Spoeg	Bickerton, 1981
Swartlintjies	Heinecken, 1980; Massie and Clark, 2016
Groen	Bickerton 1981b; Adams et al. 2015; Wooldridge et al. 2016
Sout	None available

Vegetation mapping was done using 2014 aerial images obtained from National Geo-Spatial Information (Surveys and Mapping). The scale of mapping varied between 1:1 500 and 1:2 500 depending on the quality of the images. These images have a spatial resolution of 50 cm. Historical images were also obtained to determine the change in present condition from the reference condition. Google Earth images were also used to verify habitats and all available information is listed under each estuary. All estuaries were digitised in ESRI ArcMap Version 10.2. A comprehensive report was done for the Groen Estuary in 2015 (Adams *et al*., 2015). Using the South African National Vegetation Map the EFZ_5m shapefile was used to extract the macrophyte habitats for each estuary within the 5 m lateral boundary. Groundtruthing was done during the site visit on 5 October (Buffels), 6 October (Swartlintjies), 7 October (Spoeg), 8 October (Groen) and 9 October 2016 (Sout). The Bitter Estuary was briefly visited but not mapped. During each site visit macrophyte habitats and the 5m EFZ were verified. Waypoints were taken using the Application Avenza Maps (PdfMaps). It uses preloaded GeoTiff images and uses GPS signal, irrespective of cellphone signal. Geotagged photos were also taken and both these were added as layers to ArcMap to assist with habitat identification.

Because these systems are not considered typical estuaries and rather ephemeral systems, they remain closed and dry for long periods of time. Flash floods open the mouth where after it closes again by a sandbar. There is often only water in the lower reaches of the estuary (*circa* 500 m to 1 km) and isolated pans and standing water often occur further upstream. Breaching occurs after high rainfall events and the presence of groundwater seepage and overtopping during high seas maintains water in the lower reaches, often with hypersaline conditions. Rainfall can reduce salinity in the standing water bodies. Rainfall also carries salts from sediments outside the EFZ into the riverbed, which is responsible for the saline conditions within the dry flood plain (Massie and Clark, 2016). Generally, the Namaqualand area experiences higher evaporation rates than precipitation, which naturally leads to the formation of salt pans (Massie and Clark, 2016). Because of the long closed dry periods the riverbeds are colonized by a mixture of salt marsh and terrestrial riverine shrubland and the typical habitats identified for estuaries are difficult to define. The habitat within the estuary river course is listed as Arid Estuarine Salt Marshes in the national vegetation map. Available literature was used to assess changes over time in species composition, abundance and community composition (Table 14.1).

14.2 MICROALGAE

14.2.1 Salinity and Temperature

Hypersaline conditions (> 50) were observed in the Groen (43.9 to 88.5), Swartlintjies (108.7 to 119.8) and Sout (42.2 to 101.8) estuaries. The Buffels (2.5 to 28.5) and Spoeg (22.9 to 25.2) estuaries had lower brackish conditions. Expected longitudinal gradients (i.e. decreasing from the lower to the upper reaches), indicating some degree of freshwater inflow, were observed in the Groen, Buffels and Spoeg estuaries; whilst the Swartlintjies and Sout had inverse gradients. The temperatures recorded were largely in line with those expected for early to mid-spring, i.e. 17 to 20°C. Exceptions to this trend (>20°C) were associated with hypersaline conditions that indicate extended periods of residence time, i.e. Groen, Swartlintjies and Sout estuaries.

14.2.2 Phytoplankton Biomass and Community Composition

Phytoplankton biomass, measured as chlorophyll *a* concentration, provides a useful proxy with which to assess the condition of an estuary. With the exception of Swartlintjies (1.8 to 4.7 µg/l), all of the estuaries displayed bloom conditions (> 20 µg/l) (Figure 14.2). Of particular interest, hypereutrophic conditions (> 60 µg/l) (Lemley *et al*., 2015) were observed in the Spoeg (77.9 ± 9.2 µg l^{-1}), Groen (144.5 ± 2.4 µg/l; and 82.3 ± 0.6 µg/l), and Sout (62.2 ± 0.6 µg/l) estuaries. In terms of spatial distribution, biomass maxima were recorded in the mid- to upper reaches of all the estuaries; with Groen being the only exception (~ peaks in lower reaches). These peaks in biomass often occurred at hypersaline sites in saline pans. Competition from benthic algae and macroalgal blooms may have restricted phytoplankton biomass in the upper reaches of the Groen Estuary. In terms of phytoplankton community composition, the 'flagellates' component (i.e. small, indistinguishable cells) were excluded from the graphs (Figure 14.3) as they are small and numerous but contribute little phytoplankton biomass; however, where applicable, the cell density is reported below. In the Buffels Estuary, the bloom conditions at the brackish Site 3 (25.8 ± 1.5 µg/l) were largely comprised of *Chaetoceros* sp. (Bacillariophyceae) and *Cryptomonas* sp. (Cryptophyceae), will densities of *ca*. 700 cells ml^{-1} for both. Although oligotrophic conditions (< 5 µg/l) presided in the Swartlintjies Estuary, the halophilic Chlorophyte, *Dunaliella salina* was dominant (145 to 1262 cells/ml) in the hypersaline conditions present throughout the system. In the brackish-dominated Spoeg Estuary, bloom concentrations at Site 3 and 4 consisted primarily of a *Peridinium* sp. (Dinophyceae), with density of *ca*. 700 and 2100 cells/ml, respectively. At Site 4 the diatom *Diploneis didyma* was evident (*ca*. 840 cells/ml); whilst the 'flagellate' grouping was present at high densities throughout the system, ranging from 2950 (upper reaches) to 8850 cells/ml (lower reaches).

The primary bloom constituent present at Sites 1 to 3 in the Groen Estuary was a Dinophyceae species, *Gymnodinium* sp. (1401 to 10139 cells/ml); with the hypersaline tolerant *D. salina* (Chlorophyceae) also abundant (442 to 2335 cells/ml). With the exception of Site 5, 'flagellates' were abundant (> 10000 cells/ml) throughout the estuary; however, despite this, their low contribution to overall biomass levels is evident at Site 4 where bloom concentrations were absent (< 20 µg/l). A community shift was evident in the upper reaches of the Groen Estuary (Site 5) with a *Chaetoceros* sp. (Bacillariophyceae) dominating (*ca*. 3400 cells/ml) bloom conditions. Finally, similarly to the other hypersaline systems, the elevated biomass (62.2 ± 0.6 µg/l) observed at Site 3 in the Sout Estuary was largely comprised of the halophilic Chlorophyte, *D. salina* (*ca*. 2800 cells ml^{-1}).

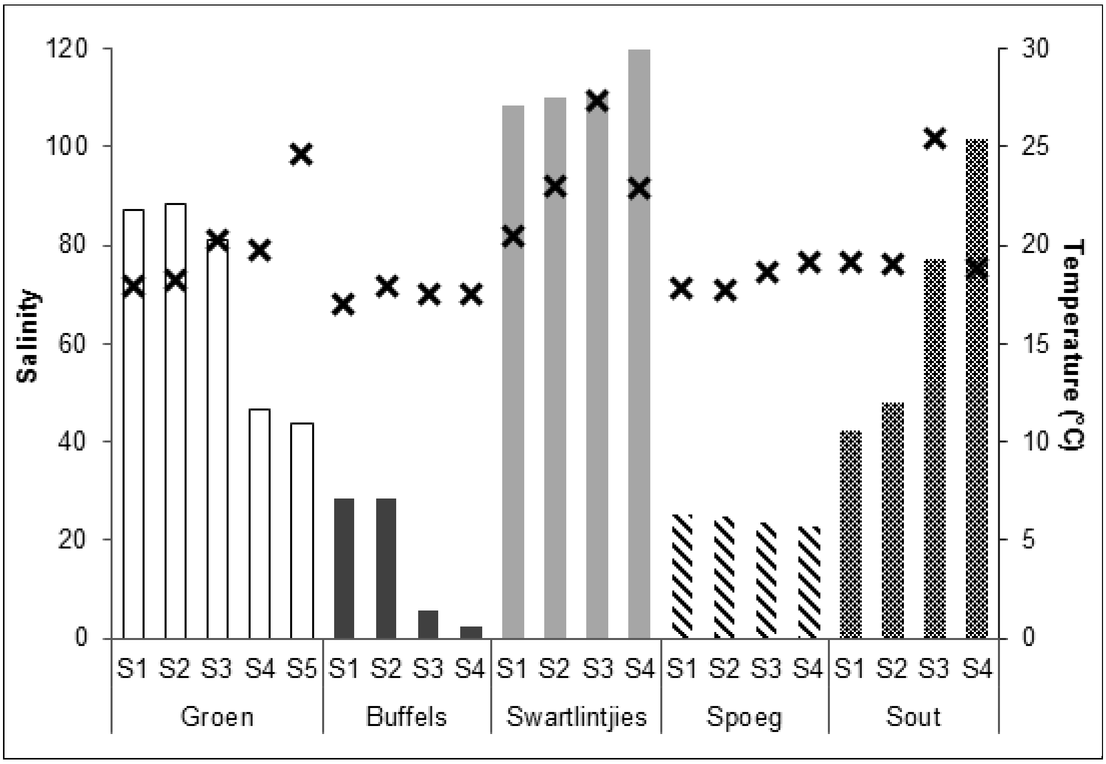

Figure 14.1 Salinity (*bars; primary y-axis) and temperature (*crosses; secondary y-axis) distribution profiles along five South African west coast estuaries

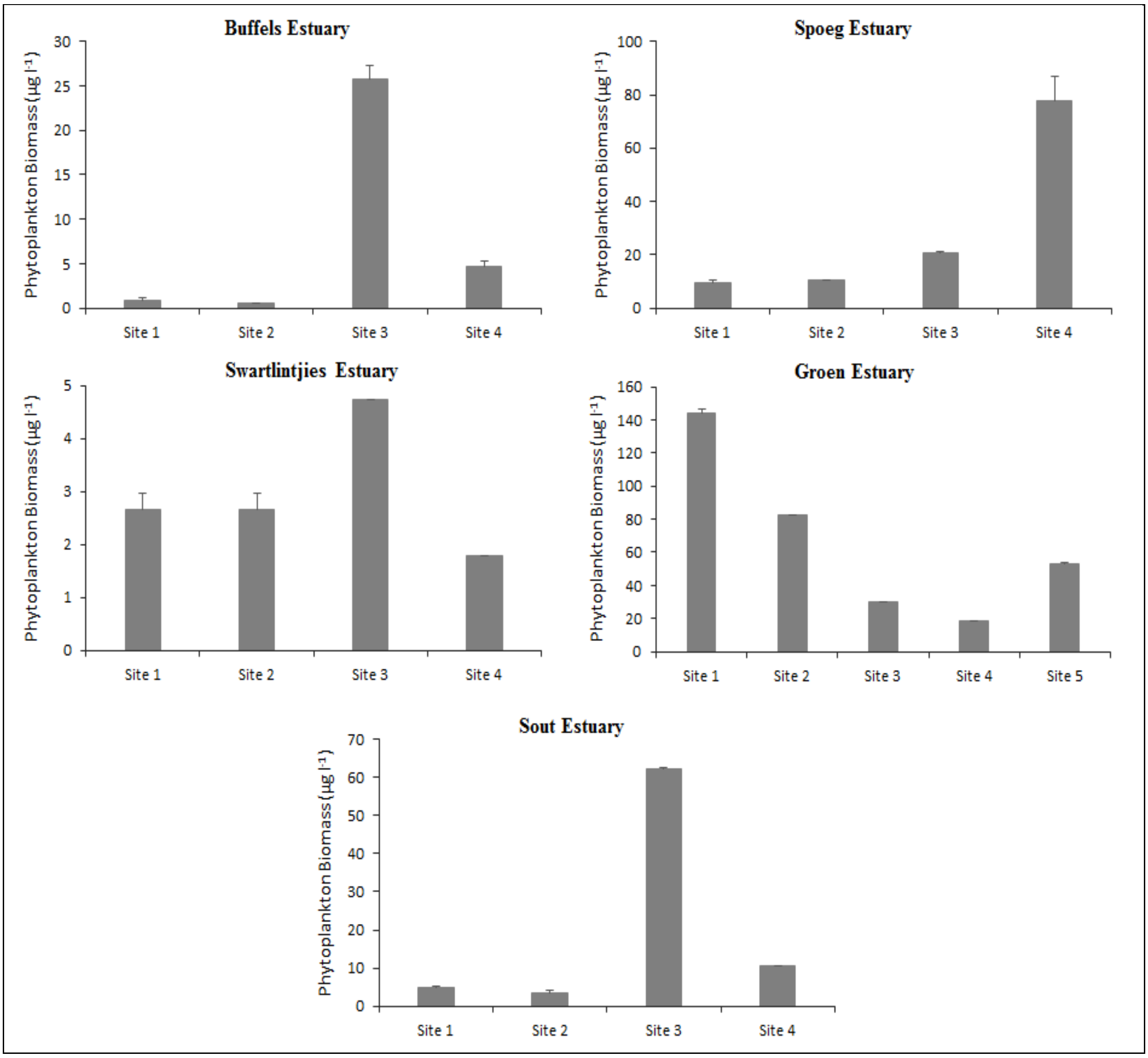

Figure 14.2 Spatial distribution of phytoplankton biomass along the length of five South African west coast estuaries

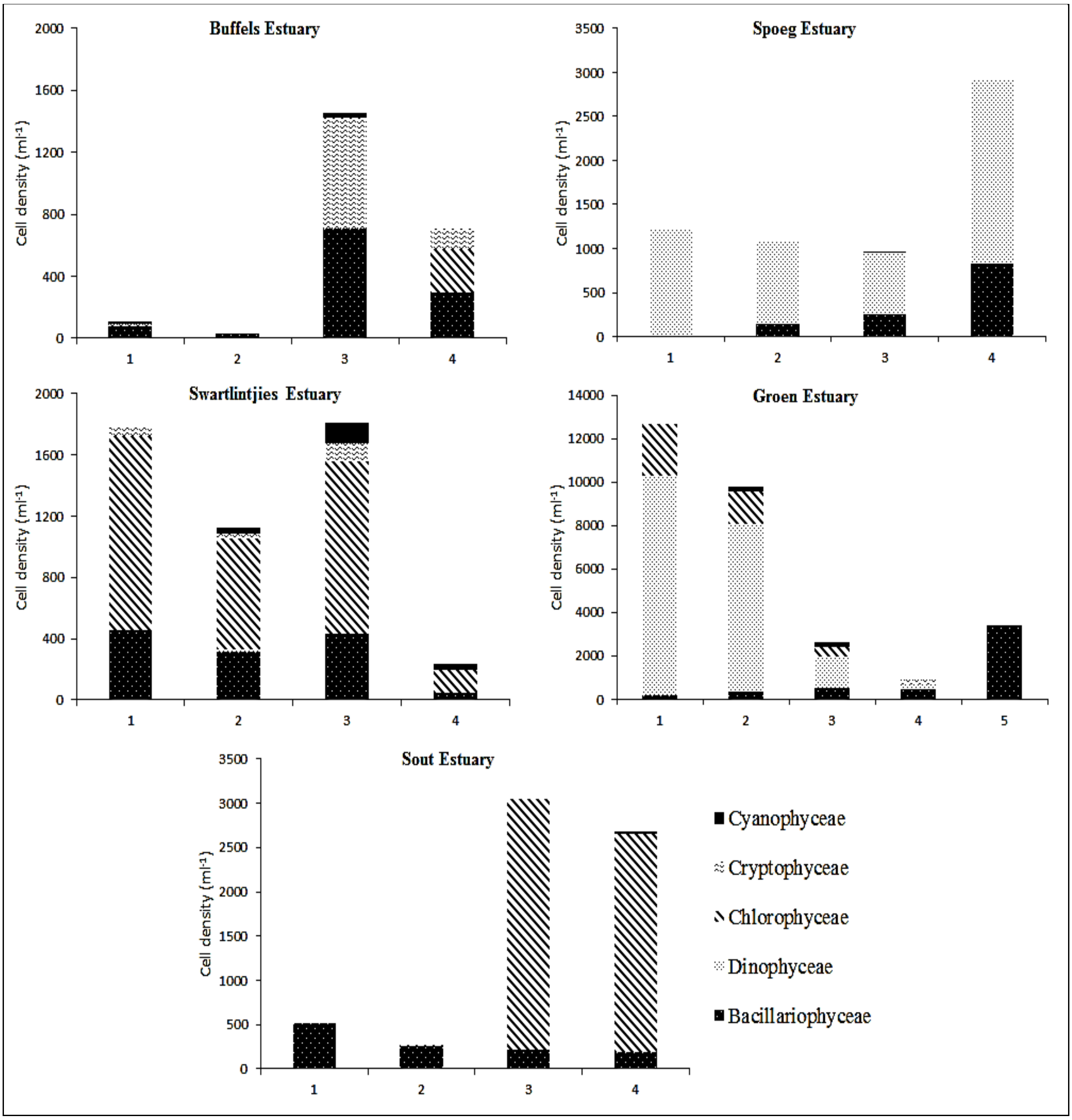

Figure 14.3 Phytoplankton community composition along the length of five South African west coast estuaries

14.3 MACROPHYTES - BACKGROUND INFORMATION

Based on the South African National Vegetation Map (Mucina and Rutherford, 2006; SANBI, 2016), the vegetation of the five estuaries within the 5 m EFZ falls within three biomes, namely Coastal Vegetation, Succulent Karoo and Inland Azonal Vegetation. The Sout Estuary has a small portion of Knersveld Quartz Vygieveld. The Biomes are further broken into the following Bioregions and vegetation units:

- Coastal Vegetation
  - Estuarine Vegetation - **Arid Estuarine Salt marsh** (AZei)
  - Seashore Vegetation - **Namaqualand Seashore Vegetation** (AZd2)
- Succulent Karoo
  - Namaqualand Sandveld - **Namaqualand Coastal Duneveld** (SKs8)
  - Namaqualand Strandveld (SKs7)
- Inland Azonal Vegetation
  - Inland Saline Vegetation - **Namaqualand Riviere** (AZi1)

Succulent Karoo forms a long belt between the Strandveld of the coast and the mountains of the escarpment in Namaqualand. It is mainly determined by the presence of low winter rainfall and extreme summer aridity. During summer, temperatures in excess of 40°C are common. Fog is common nearer the coast. Frost is infrequent. Desiccating, hot, Berg Winds may occur throughout the year. Succulent Karoo is characterized by low to dwarf, open shrubland, with plants dominated by stem and leaf succulents. Low trees are common along the river courses forming woodland corridors. A short description of each vegetation type follows as per Mucina and Rutherford (2006).

Arid Estuarine Salt Marsh (AZei) occurs at the mouths of the Orange, Buffels, Swartlintjies, Spoeg, Bitter, Groen, South and Olifants rivers. They occur as patches of supratidal salt marshes on elevated terraces. The vegetation is formed of mainly low succulent dwarf shrubland patches, forming a mosaic with creeping grassy mats and patches of reed beds. They are very different to the other estuarine salt marshes and represent more saltwater-soaked flats in poorly drained coastal lagoons, rather than true tidal salt marsh. Important species include the submerged macrophyte (*Potamogeton pectinatus*), tidal salt marsh species (*Bassia diffusa, Cotula coronopifolia, Triglochin striata, Salicornia meyeriana, Juncus kraussii, Sporobolus virginicus, Ficinia nodosa, Juncus acutus* and *Juncus rigidus*) and supratidal terraces (*Salsola zeyheri, Suaeda fructicosa, Psilocaulum dinteri, Odyssea paucinervis* and *Phragmites australis*).

Namaqualand Seashore Vegetation (AZd2) is distributed along the Northern Cape coastline, in a very narrow strip above the high water mark, from Holgat River to Olifants River. It is typically found on alkaline coastal dunes, and is a sparse vegetation community of partly succulent hummock-forming and spreading dwarf shrubs, grasses and herbs. Important species include *Zygophyllum cordifolium, Psilocaulum dinteri, Arctotheca populifolia, Mesembryanthemum guerichianum, Frankenia repens, Sarcocornia littorea, Crassula plegmatoides, Crassula tomentosa, Dideltia carnosa, Lycium tetrandrum, Othonna floribunda, Stoebe utilis, tetragonia decumbens, Zygophyllum morgsana, Atriplex vestitia, Lebeckia cinerea, Asparagus capensis, Hebenstretia codata, Dasispermum suffructicosum, Polygonum maritimum, Trachyandra divaricate, Cladophoris cyperoides* and *Sporobolus virginicus*.

Namaqualand Coastal Duneveld (SKs8) is situated on the inland side of the Seashore Dunes, and eventually merges with Namaqualand Strandveld further inland. Vegetation is dwarf shrubland dominated by erect succulent shrubs as well as nonsucculent shrubs. Spiny grasses are a common sight on wind-blown semistable dunes, with 1 - 2 m erect to spreading shrubs mostly with malacophyllous leaves protected from the wind between dunes. Common species include *Didelta, Othonna, Rushcia, Tetragonia, Tripteris, Zygophyllum, Eriocephalus, Lebeckia, Pteronia, Salvia* and the spiny grass *Cladophoris*.

Namaqualand Strandveld (SKs&) occurs mainly deeply inland (approximately 40 km but can occur on the coast near the river mouths of the Buffels River, Swartlintjies River, Spoeg River, Bitter River and Groen River. Vegetation is low species-rich shrubland dominated by erect and creeping shrubs represented by *Cephalophyllum, Didelta, Othonna, Ruschia, Tetragonia, Tripteris, Zygophyllum, Eriocephalus, Lebeckia, Pteronia* and *Salvia*.

Inland Azonal Vegetation includes Namaqualand Riviere (AZi1) that occurs along dry riverbeds. It is characterised by a complex of alluvial shrubland interspersed with patches of tussock graminoids (grasses). Soils are often strongly saline, as reflected by the presence of salt tolerant species such as *Sarcocornia* and *Salicornia*. The vegetation unit forms a complex of alluvial shrubs such as *Suaeda fructicosa*, *Zygophyllum morgsana*, *Ballota africana* and *Dideltia spinosa*, patches of tussock grasses occupying riverbeds and banks of intermittent rivers. In places low thickets of *Acacia karroo* and *Tamarix usneoides* are found, and *Phragmites* reeds are common in areas with more regular surface water.

14.4 BUFFELS ESTUARY

14.4.1 Previous studies

The vegetation of the Buffels Estuary and surrounding area was mapped by Grindley and Heydorn (1981). They describe the area adjacent to the estuary as being sparsely vegetated by Strandveld of an open semi-succulent scrub nature, with Riverbed Dwarf Shrubland of 0.2 m and shrubland common. The estuary has reed beds, salt marsh and grassland (the extent of which was reduced significantly by the 1997 floods). Clark (1998) reports the vegetation of the estuary and river bed (up to 3 km from the mouth). Species listed by Heydorn and Grindley (1981) include *Eragrostis sabulosa (*grassland*), Cotula coronopifolia, Juncus kraussii, Sarcocornia pillansii* (supratidal salt marsh) and *Phragmites australis* (reed and sedge). *Sarcocornia pillansii* cover was 100 %. Reed swamp was estimated to be 3.37 ha and salt marsh 1.48 ha by Heydorn and Grindley (1981b), hosting a number of bird species. The authors also report dumping of grass cutting from the alien grass Kikuyu *Pennisetum clandestinium* taking place near the *Phragmites* stands at the river bed. They list other alien species as Wild Tobacco (*Nicotina glauca*) and Rooikrans (*Acacia cyclop*s) which grows in the dry riverbed. There are no data on phytoplankton or diatoms for the system but the greenish and milky colour of the pools suggests the presence of unicellular algae besides bacterial activity. Filamentous algae have been reportedly growing on roots and debris of other vegetation in the pans and channel near the mouth (Heydorn and Grindley, 1981b). The following marine algae were reported in the intertidal zone near the mouth: *Caulacanthis divaricatus, Ecklonia maxima, Mainaria pallida, Cladophora capensis, Ulva sp., Corraline alga, Bifurcaria brassicaeformis, Codium duthiae, Chaetomorpha sp., Lithothamnion spp., Porphyra capensis* and *Suhria vitata*.

14.4.2 Field survey (2016)

To confirm present vegetation types a field trip to the Buffels Estuary took place on 5 October 2016. The mouth was closed at the time with the sand berm at the mouth very wide and low. The estuary was bisected in two by an old berm and road. The berm was approximately 23 m in length and 1.2 m in height. The vegetation was mapped to the end of the tarred road which is approximately 1.6 km from the mouth of the estuary.

Adjacent to the estuary mouth is Namaqualand Seashore Vegetation, characterized by hummocks of *Sarcocornia pillansii* and *Cladoraphis cyperoides (Eragrostis cyperoides*) (Figure 14.4). Namaquland Coastal Duneveld occurs behind the Arid Estuarine Salt Marsh and merges into Namqualand Strandveld on the higher elevations. Arid Estuarine Salt Marsh occurred on the northern side of the open water at the mouth reaching 10 m in places. Species included *Sarcocornia pillansii*, *Cladoraphis cyperoides (Eragrostis* cyperoides) and *Sporobolus virginicus* (Figure 14.4). Cover varied between 50 to 100 % with bare open sand in between. Arid Estuarine Salt Marsh merged into Namaqualand Riviere with *Acacia cyclops* dominant. The lower section below the tarred road is very disturbed. *Acacia cyclops* (Rooikrans) was planted by De Beers and forms a large component of the river course below the tarred road. At the time of the site visit the Rooikrans was being cut by a subcontractor for firewood. There was a lot of cut timber and leaf litter left in the dry water course. Namaqualand Riviere and Arid Estuarine Salt Marsh in the Buffels Estuary is associated with *Sarcocornia pillansii, Juncus kraussii* and grasses commonly

Sporobolus virginius (Figure 14.4). Succulent species like *Ruschia bina* are common making the distinction between these two vegetation types difficult.

There was no surface water in the upper reaches and so holes were augured to assess the depth to the water table and water table salinity. There was groundwater near a *Juncus kraussii* stand in the upper reaches. This was at approximately 1 m depth with a salinity of 2.4 - 3.1 psu. Reeds and sedges occur within the Arid Estuarine Salt Marsh /Namaqualand Riviere mix. These are predominantly *Phragmites australis* with some *Typha capensis* (bulrush) at the wooden bridge (Figure 14.5). Reed beds start at the bird hide located on the broken access road. They cover almost the complete water course from side to side with a small channel of open water in the middle. They are particularly abundant, tall and robust in the area adjacent to the golf course. These reeds are often backed by a narrow band of *Sarcocornia pillansii* and are also associated with *Juncus kraussii* in the Namaqualand Riviere further upstream. The submerged macrophytes *Potamogeton pectinatus* (now *Stuckenia pectinata*) occurs in the open standing water adjacent to the reeds along with *Potamogeton pectinatus*. Macroalgae were not mapped as the area they covered was too small but they were noted as present. A golf course occupies a large part of what would have been Namaqualand Coastal Duneveld. A species list is provided in Section 14.9 and vegetation map in Figure 14.4.

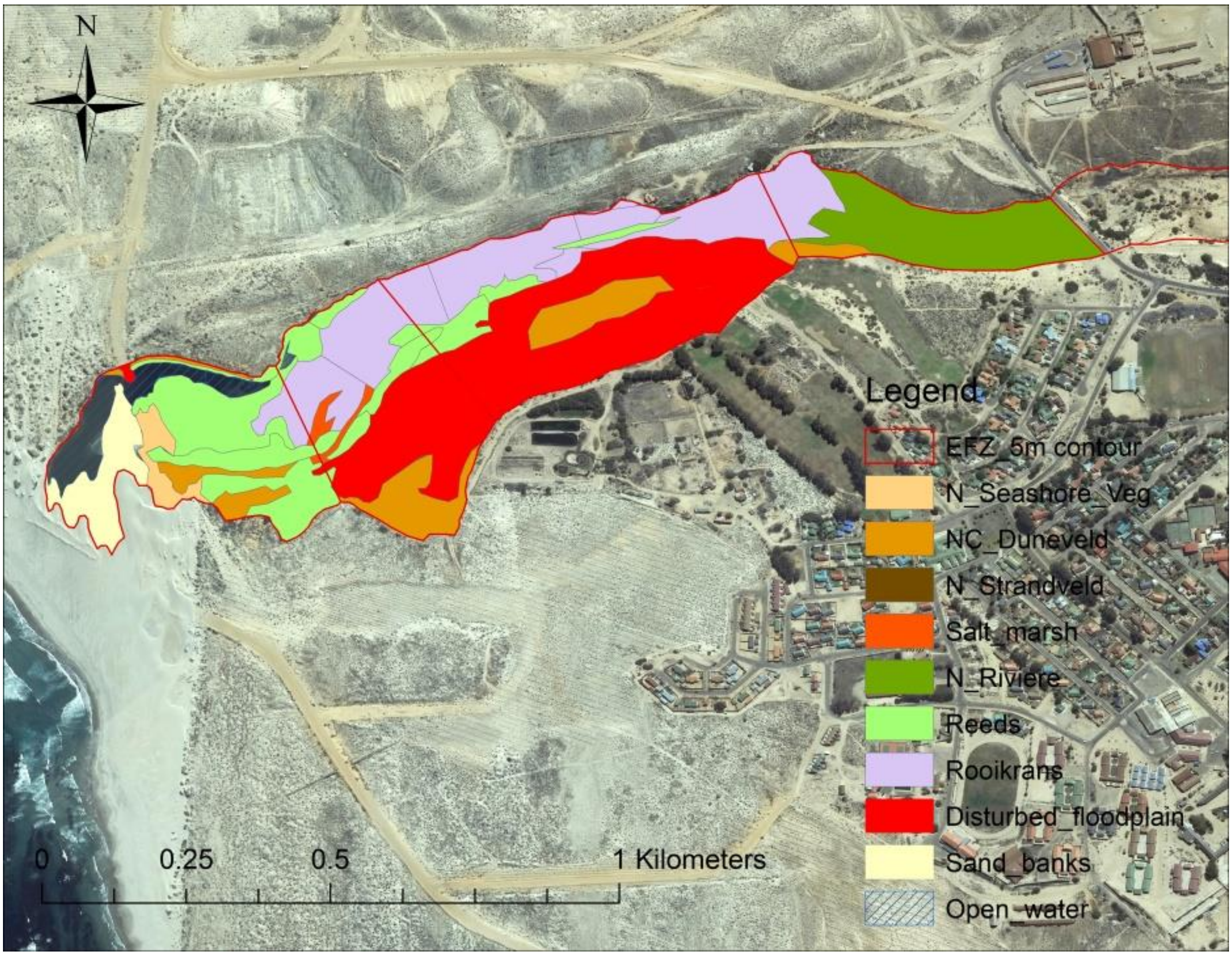

Figure 14.4 Vegetation map of the Buffels Estuary for the Estuarine Functional Zone based on the 2014 aerial images

Figure 14.5 Top) Salt marsh at the mouth of the Buffels Estuary, northern side, Middle) Namaqualand Riviere vegetation type, and Bottom) reed beds

14.4.3 Present state

A number of disturbances have taken place in the EFZ over time. The major modification to the estuary is the abstraction of water from the aquifer for Kleinzee residents and mining activities. This decreased the input of freshwater into the system over time as can be seen by attempts to map change in open water area over time (1976 – 10.91, 1985 – 6.59 ha, 1990 – 2.28 ha, 2003 – 2.5 ha, 2011 – 2.38 ha, 2014 – 1.66 ha). Floods and groundwater input have decreased. The first well was drilled by De Beers in 1980s and since 2005 open water area appears to have decreased.

Although not evident in the change in open water area over time, there has been increased freshwater input into the estuary near the golf course. This is due to irrigation of the golf course with treated waste water. This has increased the extent of the reed beds although not evident on the images due to their poor quality. Between 2011 and 2014 the area covered by the reed beds has been stable. Seepage of freshwater from the golf course probably also lowers the salinity of the water column further increasing reed encroachment. Localised mats of macroalgal growth could also be due to seepage of the nutrient rich water from the golf course, especially as water level drops. Other modifications to the Buffels Estuary include causeways, road with culverts, golf course, walk ways around the dunes on the southern side of the mouth, a 700 m levee that protects the golf course from flooding and the planting of rooikrans in the water course (Figure 14.6). Rooikrans spreads rapidly and could easily outcompete indigenous vegetation. Rehabilitation is taking place at the mouth on the southern side in the dunes.

Between 1942 and 1976 the first dwellings on the south side at Kleinzee were visible. There was no causeway at the mouth and the channel at the mouth split into three. By 1985 the golf course had been vegetated (previously unvegetated), along with the construction of the presently tarred road. The causeway across the mouth of the estuary had also been constructed, along with a number of other access roads across the lower reaches. By 2003 the causeway across the mouth was removed (by storm in 1997?) and vegetation adjacent to the golf course had increased in cover. Between 2011 and 2014 no changes were apparent.

The haul road 0.26 km from the mouth was washed away in the 1:100 flood that occurred in June 1997. A bird hide has been built on the northern side. Another causeway occurs 1.1 km from the mouth but seems to have been washed away. Two large pipes are still visible and exposed. The tarred road occurs 1.7 km from the mouth and formed the inland boundary of this study.

The site visit confirmed extensive transformation of the estuarine habitat. That said ongoing rehabilitation efforts should be encouraged e.g. removal of rooikrans, no driving on the beach, management of the golf course. The old roads and causeway in the main river channel should be removed to restore habitat connectivity. The freshwater wetland area fed by the golf course creates habitat diversity in this arid environment.

Table 14.2 Description of changes in macrophyte habitats for the Buffels Estuary

Present estuary habitats
Floodplain vegetation: (30% decrease) ▪ Namaqualand Seashore vegetation - 0.663 ha ▪ Namaqualand Coastal Duneveld - 3.683 ▪ Namaqualand Strandveld - 1.327 ha Supratidal habitat: (50% decrease) ▪ Arid Estuarine Salt Marsh: 0.326 ha ▪ Namaqualand Riviere: 4.231 ha Reeds: (50% increase) - 6.357 ha Sand banks (10% increase) - 1.639 ha Open water (50% decrease) - 1.657 ha

Table 14.3 Assessment of present state for the macrophytes in the Buffels Estuary

Variable	Present State	Score	Confidence
a. Species richness	Loss of species due to loss and disturbance of floodplain and supratidal salt marsh habitat. Invasion of the upper reaches by *Acacia cyclops* would have also caused loss of species.	40	Medium
b Abundance	Approximately 50% of the supratidal salt marsh and 30% of the floodplain habitat has been lost or disturbed. Freshwater and nutrient input from the golf course has encouraged the development of a freshwater wetland area which has compensated for some habitat lost.	30	Medium
c. Community composition	Disturbed areas are dry, barren and saline. Some dry areas have been transformed to freshwater wetland / reed habitat.	30	Medium
Score min (a to c)		**30**	**Medium**

Figure 14.6 Obstructions and modifications to the Buffels Estuary Top) minor access roads in the river course, Middle) remaining pipes after the bridge washed away and two large culverts at the tarred road, and Bottom) golf course within the EFZ and 700 m long levee to protect the golf course from flooding

14.5 SWARTLINTJIES ESTUARY

14.5.1 Previous studies

Heinecken (1980) mapped the Swartlintjies Estuary in 1998. Grassland covered 19.22 ha, dwarf shrubland (6.5 ha) and salt marsh (2.84 ha). Salt marsh plants included *Sarcocornia natalensis* and *Sarcocornia pillansii* with 100 % cover and lower species diversity (2 species). *Eragrostis sabulosa* (Dune Grassland) occurred above the spring high tide. Together with *Eragrostis cyperoides* this habitat was the most diverse (18 spp) but with low cover (25 %). Algae recorded in the intertidal zone were *Ecklonia maxima, Ulva* sp., *Cladophora capensis, Porphyra capensis, Caulacanthus divaricatus, Chaetanginum ovale*, and *Champia lumbricalis*. Macroalgal and phytoplankton blooms occurred in adjacent excavated trenches.

Massie and Clark (2016) give a full species list for each vegetation type that includes a total of 36 semi-aquatic and terrestrial plant species from 15 families. Three were found to be endemic to the area, namely *Limonium equisetinum*, *Chaetobromus involucratus* subsp*. dregeanus* and *Eragrostis sabulosa*. The latter two species are important and unique to the Namaqualand Strandveld and Namaqualand Coastal Duneveld respectively. Massie and Clark (2016) report patches of *Sarcocornia* sp. on slightly elevated beach sand near the mouth. Namaqualand Seashore vegetation was mapped as 10.6 ha, Namaqualand Coastal Duneveld as 17.7 ha, Namaqualand Strandveld as 3.4 ha and Arid Estuarine Salt Marsh as 36.3 ha.

14.5.2 Field Survey (2016)

The Swartlinjies Estuary was visited on 6 October 2016 and the upstream boundary of the estuary was taken up to the tarred road approximately 1.8 km from the start of the open water. The "end" of the estuary could not be found as the salt tolerant *Sarcocornia pillansii* extended upstream (Figure 14.8). Around the mouth Namaqualand Seashore Vegetation occurs with *Cladoraphis cyperoides (Eragrostis cyperoides*) hummocks, interspersed with *Sporobolus virginicus*. The open water surface area at the time of study extended to *circa* 850 m upstream. Hypersaline conditions occurred throughout the estuary and adjacent to the water body 100 % cover of *Sarcocornia pillansii* occurred. *Sarcocornia natalensis* occurred on the water's edge (Figure 14.8). In some areas there was distinct zonation of macrophytes along an elevation gradient with *Sarcocornia pillansii* closest to the water's edge, followed by the grass *Sporobolus virginicus* and then the succulent *Ruschia bina* (Figure 14.8).

In places past the bend of the main channel, plant cover declined to 50 % (Figure 14.8). This formed a definite zone and was backed by Namaqualand Coastal Duneveld. The open water column forms braided flooded channel in the upper reaches and was characterized by 50:50 % live: dead cover of *Sarcocornia pillansii.* This dead cover is probably a result of increased sediment salinity as water evaporates leaving behind salt crusts that accumulate over time. It is not known to what extent this was influenced by slimes dam input in the past.

Namaqualand Coastal Duneveld had species such as *Lycium*, *Mesembryanthemum (Cryophytum) crystallinum*, *Eragrostis sabulosa*, *Lampranthus, Ruschia* and *Limonium, Zygophyllum morgsana, Arctotis decurens, Dimorphotheca sinuata, Ruschia bina, Othonna cylindrica, Osteospermum oppositifolia, Chaetobromus involucratus* and the sand lily in places. This vegetation type forms a transitional mix of both salt marsh species and low shrubs. There is a small patch of Namaqualand Strandveld inland of the causeway.

14.5.3 Present State

Disturbance to the EFZ at the time of the site visit appeared minimal. However the mouth of the Swartlintjies fell within the Koingnaas mining concession of De Beers Consolidated Diamond Mines and intensive open cast mining for diamonds was carried out on either side of the system (Heinecken, 1980). Two pans occur *circa* 100 m from the start of the open water suggest they might have also been created for water to be pumped to mining activities. The base of an old pump was observed as well as an abandoned pipe. These pans were filled with filamentous algae at the time of the field trip (Figure 14.9).

Further upstream an old borehole was found with water 1.2 m below ground. Other obstructions include an old causeway 750 m from the start of the open water. It appears to have been washed away in the middle. The causeway was evident in the 1976 and 1985 aerial images but not in the 2011 or 2014 images. These access points were used to carry gravel from the Koingnaas mine on the southern bank and would have disturbed the vegetation at the time.

The mouth of the Swartlintjies Estuary was artificially breached by De Beers in August 1978 and December 1978 to allow seawater into the estuary. It closed naturally shortly thereafter. Artificial breaching was also done in early 1980 and the estuary contained water for approximately 6 months after the breaching. Now days kelp in the mouth area is evident of regular seawater intrusion possibly at spring tide. This regular input of seawater could maintain the hypersaline conditions in this system compared to the other small estuaries investigated. There is no salinity gradient.

In the NBA (Van Niekerk and Turpie, 2012) macrophyte health was given as F. However from this field trip the vegetation appears to be recovering, and in fairly good condition. From aerial photographs the surrounding vegetation seems to have changed little over time. Massie and Clark (2016) state that 17.8 ha of vegetation have been impacted by mining activities in the functional zone. Open water area has remained relatively stable over time (2003 – 1.79, 2011 – 1.37 ha, 2014 – 1.17 ha) although the image quality in the early years is poor and therefore this assessment has a low confidence. The present state of the Swartlintjies Estuary is summarised in Tables 14.4 and 14. 5. A future threat is the resumption of mining activity by West Coast Resources.

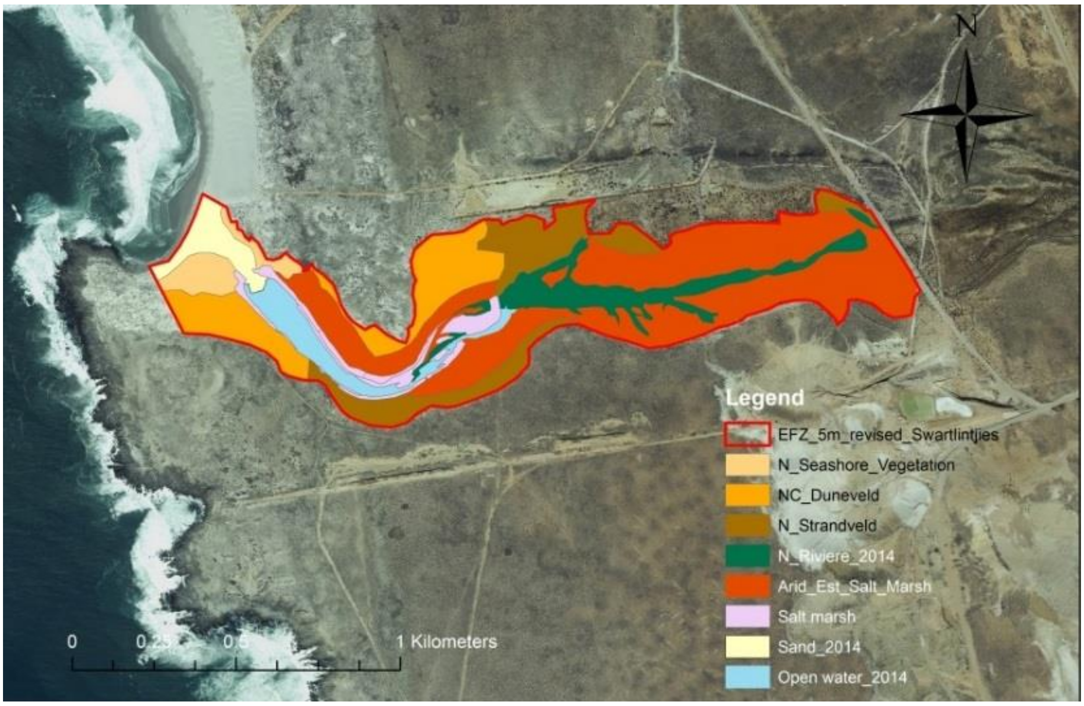

Figure 14.7 Vegetation map of the Swartlintjies using 2014 NGI aerial imagery

Table 14.4 Description of changes in macrophyte habitats for the Swartlintjies Estuary

Present estuary habitats
Floodplain: ▪ Namaqualand Seashore vegetation - 2.891 ha ▪ Namaqualand Coastal Duneveld - 9.606 ha ▪ Namaqualand Strandveld - 9.640 ha Supratidal: ▪ Arid Estuarine Salt Marsh: 29.048 ha + 3.374 salt marsh (some change due to access roads crossing estuary, also possible increase due to salinization) ▪ Namqualand Riviere: 6.905 ha Sand banks: 2.278 ha (possibly slight increase due to abstraction) Open water: 3.367 ha (some change due to groundwater abstraction)

Arid estuarine salt marsh with the dominant *Sarcocornia pillansii* (red colour) extending into upper reaches.

Clear zonation along elevation gradient.

Dead *S. pillansii* plants in saline areas.

Namaqualand Seashore Vegetation to the north of the mouth.

Mine dumps in the distance.

Figure 14.8 Photographs showing the dominant macrophyte habitats

Figure 14.9 Photographs of disturbance in the Swartlintjies Estuary (Left: an old trench in the lower reaches of the Swartlintjies Estuary probably used for the extraction of water, Middle: unused access road and Right: old borehole)

Table 14.5 Assessment of present state for the macrophytes in the Swartlintjies Estuary

Table 14.6 Assessment of present state for the macrophytes in the Buffels Estuary

Variable	Present State	Score	Confidence
a. Species richness	Species have been lost in the floodplain vegetation due to access roads and other disturbances from mining. Nearby slimes dam inputs have increased salinity.	70	Low
b Abundance	Loss of floodplain habitat and supratidal / arid estuarine salt marsh due to floodplain disturbance as a result of mining.	70	Low
c. Community composition	Increase in sand banks and bare areas in the arid estuarine salt marsh due to groundwater abstraction, a reduction in flooding and saline slimes dam inputs.	70	Low
Score min (a to c)		**30**	**Low**

14.6 SPOEG ESTUARY

14.6.1 Previous studies

The vegetation of the Spoeg Estuary was previously mapped by Heydorn and Grindley (1981). They mapped Riverbed Dwarf Shrubland (23 species), salt marsh (*Sarcocornia natalensis*; one species with 100 % cover; 4.87 ha) and grassland. Hummock dune grassland had *Eragrostis cyperoides* with creeping Cyperaceae also occurring near the mouth. Reed swamp in the river course occupied an area of 0.01 ha. Estuarine vegetation occurred up to 3 km from the mouth. Salt marsh included species such as *Sarcocornia pillansii, Limonium scabrum, Triglochin bulbosum, Scirpus nodosus, Juncus kraussii, Phragmites australis, Eragrostis sabulosa* and *Paspalum vaginatum.* The submerged macrophyte *Potamogeton pectinatus* was found in the river and the pools near the mouth. *Ruppia maritima* has been found near the mouth. The pools in the north-west corner of the estuary were surrounded by *Phragmites australis*. These pools are prone to eutrophication and can be an opaque milky – green colour due to unicellular algae and bacterial blooms. In 1979 aerial photography seems to indicate a bloom in the lower reaches of the estuary. These blooms may be facilitated by flocks of ducks settling in these ponds. Blue-green algae were found floating in some of these pools (Heydorn and Grindley, 1981a). The lagoon at the mouth supports a large number of bird species particularly waders (15 species) and in the river bed up to 3 km from the mouth 21 species have been recorded (Heydorn and Grindley, 1981a). According to the SANBI National vegetation map, Arid Estuarine Salt Marsh, Namaqualand Seashore Vegetation, Namaqualand Coastal Duneveld and Namaqualand Strandveld occurs within the 5m EFZ.

14.6.2 Field survey (2016)

Ground truthing of the Spoeg Estuary took place on 7 October 2016 and mapping was done up to *circa* 1.5 km from the mouth. At the time of the visit the vegetation was lush and healthy possibly as a result of the brackish conditions. This system is of high biodiversity importance as it is one of few remaining brackish habitats in a dry saline area. There was a healthy stand of reeds marking areas of freshwater input. This was one of the few estuaries to have submerged macrophytes i.e. *Ruppia cirrhosa.* It was also one of the few estuaries sampled that had a salinity gradient from 25 near the mouth to 8.2 where a path crosses the upper reaches. We drove to the caves and walked to the reeds in the river course. Here the standing water had a salinity of 9.5 psu.

The Spoeg Estuary consists of a long straight floodplain bounded by rocks and cliffs on the southern side. The mouth was closed and a low flat berm of about 200 m formed across the mouth of the estuary. Within this floodplain Arid Estuarine Salt Marsh mixes with Namaqualand Riviere, particularly in the upper areas, making a separation of the two vegetation types difficult. It has been mapped as Arid Estuarine Salt Marsh (Figure 14.10). Around the mouth Namaqualand Seashore Vegetation and Namaqualand Coastal Duneveld occurs, with large monospecific stands of two *Sarcocornia* in the lower reaches; *Sarcocornia natalensis* in the lower elevation and *Sarcocornia pillansii* in the higher elevations (Figure 14.10, mapped as *Sarcocornia*). Namaqualand Strandveld occurs on the higher elevations. *Ruppia cirrhosa* is abundant in the lower reaches along the channels adjacent to the *Sarcocornia* stands. Reed beds (*Phragmites australis*) occur *circa* 400 m upstream and are often associated with patches of *Juncus kraussii* at freshwater seepage sites or areas where the water table is high (Figure 14.11). These patches of *Juncus* and *Phragmites* continue up the rivercourse. Reeds and sedges were difficult to map and might represent an overestimation due to their patchy nature. A species list is given in Section 14.9. Within the Namaqualand Coastal Duneveld mole holes were plentiful, probably Grant's Golden mole (*Eremitalpa granti*) and Namaqua Dune Molerat (*Bathyergus janetta*).

14.6.3 Present state

The vegetation of the Spoeg Estuary remains relatively unchanged and in a good condition. Although there are farm roads and diamond mining fences between these roads and the mouth (200 m, 800 m, 2 km and 5.5 km respectively), the system is relatively undisturbed. In the lower reaches near the Spoeg caves there are minor access roads, first evident in the 1985 images. Some of these have since become unused and overgrown with natural vegetation. The open water area has also changed little over time (2003 – 1.79 ha, 2011 – 1.37 ha, 2014 – 1.17 ha). The unique features of this estuary are the salinity gradient, upstream reeds and submerged macrophytes.

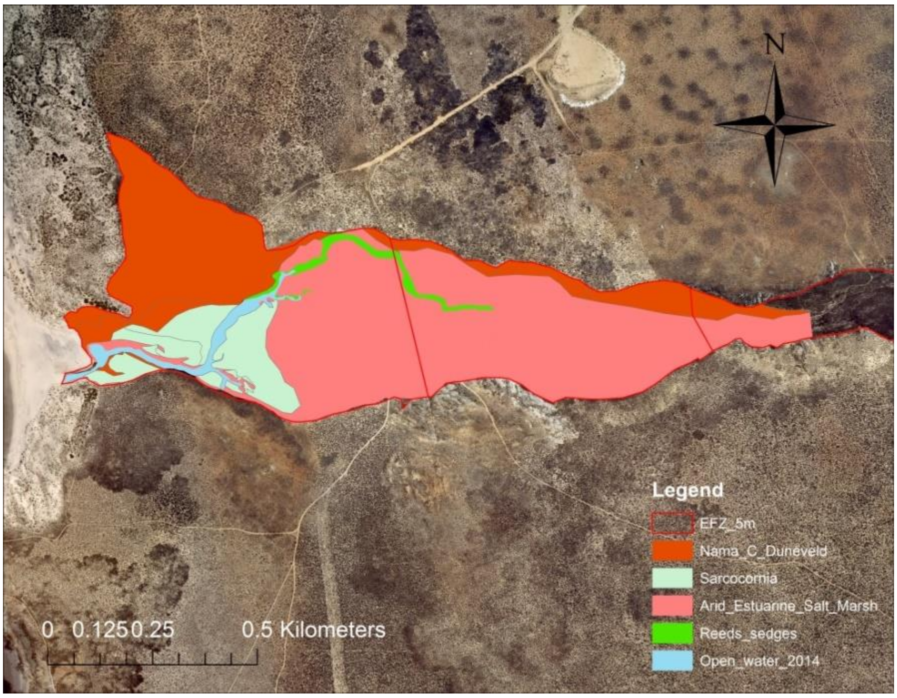

Figure 14.10 Vegetation map of the Spoeg Estuary for the estuarine functional zone based on the 2014 aerial images.

Figure 14.11 Macrophyte habitats of the Spoeg Estuary. Top) *Sarcocornia* stands in the lower reaches and mix of Arid Estuarine Vegetation and Namaqualand Riviere in the water course, Bottom) *Ruppia cirrhosa* and macroalgae in standing water and *Phragmites australis* and *Juncus kraussii* stands in seepage/standing water areas

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Table 14.7 Description of changes in macrophyte habitats for the Spoeg Estuary

Present estuary habitats
Floodplain: ▪ Namaqualand Seashore vegetation – None shown in the EFZ ▪ Namaqualand Coastal Duneveld - 13.441 ha (above might be included, small changes in north of mouth due to access roads) Supratidal: Arid Estuarine Salt Marsh - 31.295 ha (little change due to access roads to caves and on north of the estuary) includes Namqualand Riviere as difficult to separate from Arid Estuarine Salt Marsh Reeds: - 0.908 ha. This habitat should form part of the Namaqualand Riviere but due to the patchy nature of their distribution, it is probably underestimated. Open water area – 1.167 ha

Table 14.8 Assessment of present state for the macrophytes in the Spoeg Estuary

Variable	Present State	Score	Confidence
a. Species richness	Disturbance in the upper reaches may have resulted in some loss of species.	70	Medium
b Abundance	There have been minor losses in floodplain and salt marsh vegetation due to access roads around the mouth and in the region of the caves. Some of these are no longer used and are returning to natural vegetation.	70	Medium
c. Community composition	Groundwater abstraction and an increase in salinity could change reed habitat to dry barren areas or salt marsh.	70	Medium
Score min (a to c)		**30**	**Medium**

14.7 GROEN ESTUARY

14.7.1 Previous studies

The ECRU studies in the 1980s described *Sarcocornia natalensis* on the northern bank of the estuary near the mouth. *Sarcocornia pillansii* and *Juncus acutus* fringed the banks of the upper reaches of the estuary (Bickerton, 1981). Dense concentrations of algae and phytoplankton, indicative of eutrophic conditions, were present during these early surveys. Filamentous algae and *Stuckenia pectinata* (previously *Potamogeton pectinatus*) was present in the estuary, approximately 2.5 km from the mouth. *Stuckenia pectinata* is intolerant of high salinity and grows best at salinity less than 20 psu. Bickerton (1981b) described its presence in the estuary due to the moderating influences of the springs at the head of the estuary. Terrestrial vegetation recorded in the vicinity of the estuary included *Drosanthemum* sp., *Eragrostis cyperoides*, *Limonium equisternium, Othonna* sp., *Rushia* sp. and *Zygophyllum morgsana.* A few Eucalyptus trees occur around farm buildings in the upper reaches of the estuary. These trees are still present around the Namaqua National Park reception buildings and housing units. Extensive sand dunes occur on the northern side of the mouth.

The areal extent of the estuary was reported in Bickerton (1981) to be around 28 ha, and at the time of the survey, in October 1980, the approximate area of open water in the lagoon was 13 ha. The area contained within the estuarine functional zone of the Groen Estuary is 52.4 ha and open water area covered an area of 8 ha in 2011 and 2014. In 1943 the approximate area of open water was 13 ha. In 1985 open water occupied an area of roughly 11 ha. The open water surface area in the lower reaches of the estuary has therefore decreased over time whereas the surrounding estuarine vegetation has remained stable (Wooldridge et al. 2016).

14.7.2 Field survey (2016)

The Groen Estuary was mapped in February 2015 (Figure 14.12, Adams *et al*., 2015). The dominant habitat was supratidal salt marsh with the dominant species *Sarcocornia pillansii* that covered 8 ha. Intertidal salt marsh represented by *Sarcocornia natalensis* and *Salicornia meyeriana* occurred along the banks of the estuary mostly along the lower reaches of the northern bank. Terrestrial species including *Lampranthus* sp., *Lycium strandveldense* and *Mesembryanthemum guerichianum* that were present in the ecotone between the supratidal zone and terrestrial habitat (Namaqualand Coastal Duneveld). The reed and sedge habitat, represented by common reed (*Phragmites australis*), fringed the steeper channel in the upper reaches. This habitat is important as it indicates freshwater seepage in the upper reaches of the estuary. Salt pans were present in the lower and middle reaches of the estuary. These waterlogged areas were devoid of vegetation. Much of the vegetation surrounding the estuary was dead at the time of sampling in February 2015. Although not included as estuarine habitat the following species were identified in the dune vegetation at the mouth of the estuary: *Aloe arenicola, Asparagus* spp.*, Ballota africana, Calobota spinescens,Chrysanthemoides incana, Cotyledon orbiculata, Mesembryanthemum guerichianum, Salvia africana-lutea* and *Tapinanthus oleifolius.* The elevation of the north bank in the lower reaches is unsuitable for establishment of estuarine vegetation. Algae occurred throughout the estuary and were represented by *Rhizoclonium riparium* (Cladophoraceae, Chlorophyta). The filamentous cyanobacteria *Lyngbya* sp. were abundant in the water column. These species formed free floating mats and also attached to the substrate. No submerged macrophytes were observed in 2015 or in 2016.

On 8 October 2016 the estuary was visited to see if any major changes had occurred. New seedling growth of *Sarcocornia* spp. were observed in the middle reaches possibly in response to the lower salinity in 2016 compared to 2015 (Figure 14.13). In both years' salinity was measured in the reed beds where there was no longer open water surface area. Holes were augured and allowed to fill with water. In 2015 the salinity at both reed sites was 9 psu whereas in 2016 this dropped to 6 psu just below the causeway in line with the first SANParks houses. At this site water occurred at 30 cm depth. These sites in the upper reaches had high nutrient concentrations which could indicate input from the houses and offices.

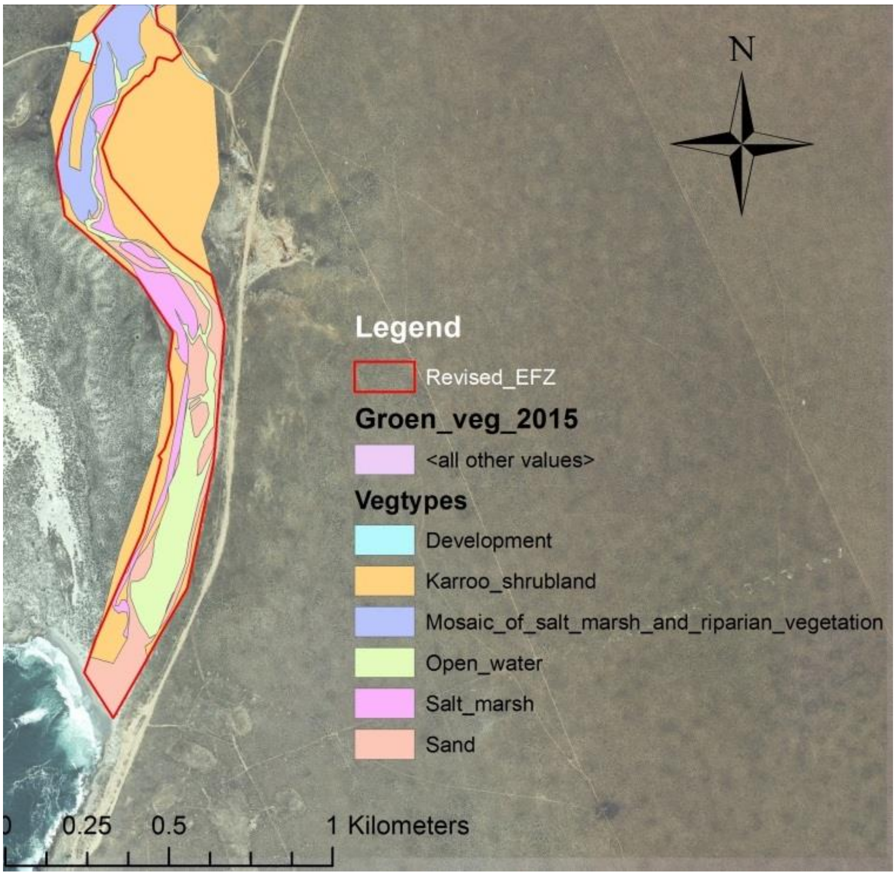

Figure 14.12 Present vegetation map of the Groen Estuary

Figure 14.13 Left) New seedling growth of *Sarcocornia* spp. in the middle reaches of the Groen Estuary and Right) freshwater seepage area with *Phragmites australis, Juncus kraussii* and *Isolepis* sp.

14.7.3 Present state

The low-level road crossing, fences, agriculture and development in the floodplain has decreased the health of the Groen Estuary. In the 1942 images there was a large unvegetated area to the north of the mouth. In 1967 the area was still unvegetated and many access roads to the estuary were visible on either side of the river. The SANParks offices were also being constructed. By 1997 some of these roads have become overgrown and the large dune area partly vegetated. Groundwater abstraction and increases in salinity have had the greatest effect on the macrophytes potentially decreasing the abundance of reeds and sedges.

Table 14.9 Description of changes in macrophyte habitats for the Groen Estuary

Present estuary habitats
Floodplain: (10% change): Namaqualand Coastal Duneveld - 8 ha of which 1 ha is occupied by the Namaqua National Park offices. Salt marsh: Arid Estuarine Salt Marsh – 12 ha Reeds – 1 ha Sand banks – 10 ha Open water – 8 ha

Table 14.10 Assessment of present state for the macrophytes in the Groen Estuary

Variable	Present State	Score	Confidence
a. Species richness	Disturbance in the upper reaches due to road and buildings may have resulted in some loss of species.	85	Medium
b Abundance	Groundwater abstraction and increases in salinity will have decreased reed, sedge and salt marsh abundance.	85	Medium
c. Community composition	Groundwater abstraction and an increase in salinity could change reed habitat to dry barren areas or salt marsh.	85	Medium
Score min (a to c)		**85**	**Medium**

14.8 SOUT ESTUARY

14.8.1 Field survey (2016)

No prior information exists on the vegetation of the Sout Estuary. The system was mapped on 9 October 2016 and checked to approximately 1.2 km upstream. Mapping of the upper reaches was done based on changes in vegetation colour from the aerial images and confidence is low. Around the mouth of the Sout Estuary Namaqualand Seashore Vegetation occurs. Adjacent to this and along sections of the estuary there is Namaqualand Coastal Duneveld (Section 14.9). Arid Estuarine Salt Marsh is the predominant vegetation type in the EFZ, often with pure stands of *Limonium*, *Sporobolus virginicus* and *Sarcocornia pillansii* (Figure 14.11). *Sarcocornia pillansii* forms bands in places along the edges of the water channel. In the middle reaches of the estuary large open sand flats devoid of vegetation are common due to the hypersaline conditions. Most of the original Arid Estuarine Salt Marsh has been replaced by the works. The water channel splits into two channels and approximately 3.3 km from the mouth it appears to be dammed (Figure 14.12).

14.8.2 Present state

At the coast the system has been largely altered and is characterised by three water bodies separated by road causeways. The saltworks is situated in the middle reaches of the system. An analysis of available past aerial photographs indicated that the water area seems to have increased with causeways and possible upstream damming. Open water surface area has changed over time but was difficult to map and distinguish water from sand (1942 – 9.79 ha, 2003 – 26.03 ha, 2010 – 18.92 ha, 2013 – 74.13 ha).

Table 14.11 Description of changes in macrophyte habitats for the Sout Estuary

Habitat	2013 (ha)	Change
Namaqualand Seashore Vegetation	27.09	Relatively unchanged
Namaqualand Coastal	117.031	Largely modified with the construction of the salt works,

Duneveld		many access roads and damming of water.
Arid Estuarine Salt Marsh	140.178	Largely modified with the construction of the salt works, many access roads and damming of water.
Sand banks	54.62	Difficult to distinguish on old aerial photos.
Disturbed floodplain	85.28	Was once either Arid Estuarine Salt Marsh or Namaqualand Duneveld, it is difficult to distinguish the 5 m contour mark and the lateral boundary of the estuary.
Open water	74.265	Increased due to what seems like damming
TOTAL	**498.464**	

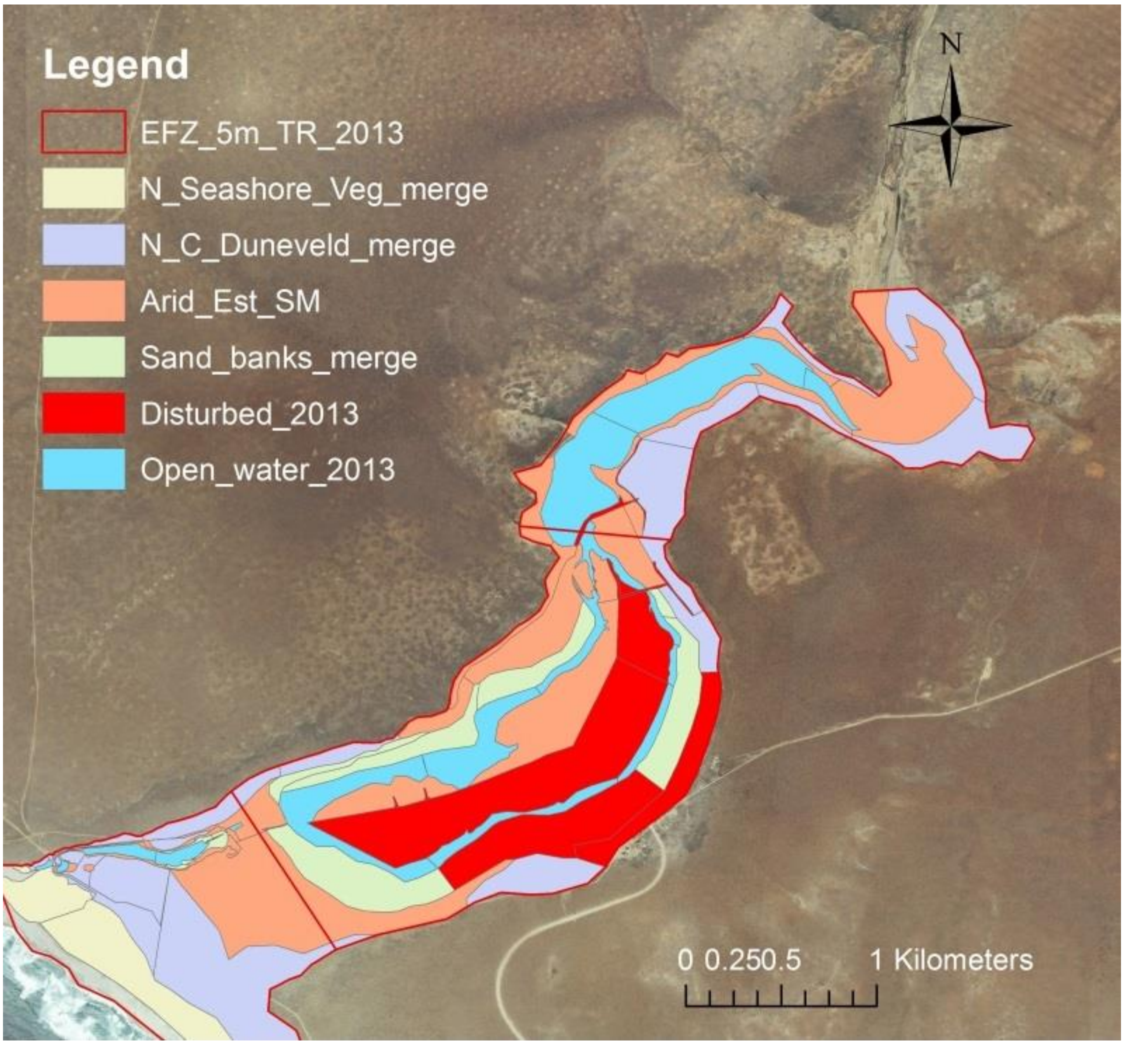

Figure 14.14 Vegetation map of the Sout Estuary for the estuarine functional zone based on the 2013 aerial images

Table 14.12 Assessment of present state for the macrophytes in the Sout Estuary

Variable	Present State	Score	Confidence
a. Species richness	The estuary bears little resemblance to its natural state, it is now mostly a salt pan and loss of habitat would have decreased species richness.	30	Low
b Abundance	Floodplain and arid estuarine salt marsh has been removed by the salt works and access roads. Windblown salt and saline sediment conditions cause die-back of the surrounding vegetation.	20	Low
c. Community composition	Unnatural ponds in the lower reaches and salt pans in the upper reaches have transformed the community	20	Low

	composition.		
Score min (a to c)		**20**	**Low**

View of the lower reaches showing the two ponds

Pond closest to the mouth.

Saline pond with flamingos (Site 3).

Arid estuarine with large bare areas in the middle reaches.

Disturbed upper reaches.

Access roads through the estuary.

Figure 14.15 Macrophyte habitats and current status of the Sout Estuary

14.9 MACROPHYTE SPECIES LIST OF SMALL WEST COAST ESTUARIES

Species	Family	Buffels	Swartlintjies	Spoeg	Groen	Sout
Acacia cyclops A. Cunn. ex G. Don.	Fabaceae	X				

Species	Family	Buffels	Swartlintjies	Spoeg	Groen	Sout
Aloe arenicola Reynolds	Asphodelaceae				X	
Amphibolia laevis (Aiton) H.E.K.Hartmann	Aizoaceae	X			X	
Arctotis decurrens Jacq.	Asteraceae		X			X
Arctotis hirsuta (Harv.) Beauverd	Asteraceae					X
Asparagus capensis L.	Asparagaceae	X				
Asparagus lignosus Burm.f.	Asparagaceae				X	
Asparagus rubicundus P.J.Bergius	Asparagaceae				X	
Babiana hirsuta (Lam.) Goldblatt & J.C.Manning GBIF	Iridaceae		X			
Ballota africana (L.) Benth.	Lamiaceae				X	
Berkheya spinosissima (Thunb.) Willd.	Asteraceae		X			
Calobota spinescens (Harv.) Boatwr. & B.-E.van Wyk	Fabaceae				X	
Carpobrotus quadrifidus L. Bolus	Mesembryanthemaceae	X		X		
Chaetobromus involucratus (Schrad.) Nees ssp. *dregeanus* (Nees) Verboom	Poaceae		X			
Chrysanthemoides incana (Burm.f.) Norl.	Asteraceae				X	
Cladoraphis cyperoides (Thunb.) S.M.Phillips (*Eragrostis cyperoides*)	Poaceae	X	X			X
Cotula leptalea DC.	Asteraceae	X				
Cotyledon orbiculata L. var. *orbiculata*	Crassulaceae				X	
Crassula atropurpurea (Haw.) D.Dietr	Crassulaceae	X	X			X
Crassula plegmatoides Friedrich	Crassulaceae		X			
Didelta carnosa (L.f.) Aiton	Asteraceae	X	X	X		
Dimorphotheca sinuata DC.	Asteraceae		X			
Dorotheanthus bellidiformis (Burman) N.E.Br	Mesembryanthemaceae		X			
Drosanthemum hispidum (L.) Schwantes	Mesembryanthemaceae		X	X		
Drosanthemum luederitzii (Engl.) Schwantes	Mesembryanthemaceae	X				
Drosanthemum salicola L.Bolus	Mesembryanthemaceae				X	
Eragrostis sabulosa (Steud.) Schweick.	Poaceae		X			
Eriocephalus africanus L.	Asteraceae	X	X			
Euphorbia mauritanica L.	Euphorbiaceae			X		
Felicia australis (Alston) E.Phillips	Asteraceae		X	X		X
Gazania lichtensteinii Less.	Asteraceae		X			
Hypertelis salsoloides (Burch.) Adamson	Aizoaceae	X		X		
Jordaaniella cuprea (L.Bolus) H.E.K.Hartmann	Mesembryanthemaceae				X	
Jordaaniella spongiosa (L.Bolus) H.E.K.Hartmann	Mesembryanthemaceae			X		

Species	Family	Buffels	Swartlintjies	Spoeg	Groen	Sout
Juncus kraussii Hoscht.	Juncaceae	X	X	X		
Juncus dregeanus Kunth.	Juncaceae	X	X	X		X
Lampranthus stipulaceus (L.) N.E.Br.	Mesembryanthemaceae				X	
Lessertia frutescens (L.) Goldblatt & J.C. Manning	Fabaceae					X
Limonium equisetinum	Plumbaginaceae		X			X
Lycium strandveldense A.M.Venter	Solanaceae				X	
Lycium tetrandrum Thunb.	Solanaceae	X	X	X		X
Mesembryanthemum crystallinum L. (*Cryophytum crystallinum*)	Mesembryanthemaceae	X	X			X
Mesembryanthemum guerichianum Dinter	Mesembryanthemaceae	X	X		X	
Othonna sp.	Asteraceae			X		
Othonna cylindrica (Lam.) DC.	Asteraceae				X	
Osteospermum oppositifolium (Aiton) Norl.	Asteraceae	X	X			
Osteospermum sinuatum (Thunb.) Hutch.	Asteraceae	X	X			
Pennisetum clandestinum Chiov.	Poaecae	X				
Pentzia grandiflora	Asteraceae	X				X
Phragmites australis (Cav.) Steud.	Poaeceae	X		X		
Potamogeton pectinatus L.	Potamogetonaceae	X				
Psilocaulon dinteri (Engl.) Schwantes	Aizoaceae		X			
Ruppia cirrhosa (Pentag.) Grande	Ruppiaceae			X		
Ruschia bina L. (Bolus).	Aizoaceae	X	X	X		X
Salsola zeyheri (Moq.) Bunge	Chenopodiaceae	X		X	X	
Salicornia meyeriana Moss LC	Chenopodiaceae				X	
Salvia africana-lutea L.	Lamiaceae				X	
Sarcocornia natalensis (Bunge ex Ung.-Sternb.) A.J.Scott subsp. affinis (Moss) S.Steffen, Mucina & G.Kadereit	Chenopodiaceae	X	X	X	X	X
Sarcocornia pillansii (Moss) A.J. Scott	Chenopodiaceae	X	X	X	X	X
Sporobolus virginicus (L.) Kunth	Poaceae	X	X	X	X	X
Stipagrostis ciliata (Desf.) De Winter var. *capensis* (Trin. & Rupr.) De Winter	Poaceae				X	
Sutherlandia frutescens (L.) Goldblatt & J.C.Manning (Lessertia frutescens)	Fabaceae	X				
Tapinanthus oleifolius (J.C.Wendl.) Danser	Loranthaceae				X	
Tetragonia decumbens Miller	Aizoaceae	X				
Tripteris sp	Asteraceae	X				
Typha capensis (Rohrb.) N.E.Br.	Typhaceae	X				
Zaluzianskya villosa F.W.Schmidt	Schrophulariaceae		X			

Species	Family	Buffels	Swartlintjies	Spoeg	Groen	Sout
Zygophyllum morgsana L.	Zygophyllaceae	X	X			

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15 APPENDIX G: REPORT COMMENTS

Page and / or section	Report statement	Comments	Changes made to report	Author Comment