Situation Assessment Report:
Seekoei Estuary
March 2018

Situation Assessment of the Seekoei Estuary

Prepared for

KOUGA local municipality

Good Governance through Service Excellence

By

Prof Tris H Wooldridge
Prof Janine B Adams
Dr Denise M Schael
Dr Taryn Riddin

Institute for Coastal and Marine Research
Nelson Mandela University
PO Box 77000
Summerstrand
Port Elizabeth

Coastal and Marine Research

6031

Tel: +27 (0) 41 504 2852
Fax: +27 (0) 41 583 2317
Email: Tris.Wooldridge@mandela.ac.za

http://cmr.mandela.ac.za/Consulting/Seekoei-Estuary-Project

Executive Summary

In a broad sense, estuaries represent the meeting place of rivers and the sea. Salinity along the length of an estuary therefore ranges from freshwater at the river end (salt content of the water is near-zero), to full seawater at the other (salt content is around 35). Between these two extremes, mixing processes lead to a gradient in salinity that is continually changing. Salinity distribution and the degree of mixing are in turn driven by the quantity of freshwater entering the estuary and tidal ebb and flow through the inlet. Because of the ever-changing salt content of the water, estuaries support a unique assemblage of plants and animals. Productivity is naturally high and estuaries rank among the most productive systems on the planet.

Whitfield (1992) described five broad categories of estuaries in South Africa. These estuarine types range from those that remain permanently open to the sea, to those whose tidal inlets temporarily close owing to sandbar development across the mouth. Estuaries in the latter category are termed Temporary Open/Closed Estuaries (or TOCE's) and are the most common type (>72%) of about 300 estuaries around the South African coastline.

Temporarily open/closed estuaries display characteristics very differently from permanently open systems. TOCE's should open and close naturally and the timing of these events is important. Under natural conditions, most would open with the onset of seasonal rains. This ensures that the estuary plays an optimal role with respect to important estuarine functions. The seasonal utilization of the estuary as a nursery for juvenile fish is an example. However, anthropogenic activities in the surrounding environs can impact negatively on mouth state and hence biotic exchange.

Floods are a key component in the natural functioning of TOCE's. Accumulated sediments are scoured from the estuary basin, but the degree of scouring is dependent on the magnitude of the flood. These sediments accumulate naturally and are derived from the catchment and from the marine nearshore. The latter tend to be coarser sediments (sand) and are transported into the estuary by wave and tidal action. It is thus marine sediments that block tidal inlets of TOCE's and the mouth will only open naturally when the water level in the estuary builds up to a level that breaches the bar. The higher the water level, the more effective the breach event in scouring the estuary basin. Natural breaching of an estuary mouth also maximizes the probability of the mouth remaining open for longer compared to a premature artificial breaching event and usually at a lower water level. After breaching and flushing of sediment from the inlet, the cycle of marine sand accumulation in the lower estuary begins again.

Fine cohesive sediments from the catchment tend to accumulate in estuarine basins and can consolidate over time. Once such sediments have consolidated, a flood of greater magnitude is required to remove them compared to unconsolidated material. Besides the role of floods in the natural cycle, freshwater baseflow (river inflow between flood events) performs the vital function of regulating salinity gradients in the estuary. In extreme cases of freshwater deprivation, salinity levels in TOCE's can exceed 35, becoming hypersaline and potential die-off of the biota in the estuary is possible. Two hypersaline events occurred in 2017 in the Seekoei Estuary (salinity reached >45 on each occasion) and many organisms died as a result.

Sufficient river baseflow also increases the water level in the estuary and may eventually overtop the bar and lead to a breaching event. Water volume in the estuary will obviously only increase if the volume of river inflow exceeds the natural evaporation rate from the waterbody. A reduction in baseflow (river inflow between floods) affects inlet dynamics, as the tidal inlet will close more frequently and remain closed for longer periods compared to the natural state. This also leads to changes in the structure and composition of estuarine biotic communities compared to the natural state. Natural breaching of a TOCE provides the natural variation and timing of the open phase and river inflow is a critical issue in terms of regulating mouth condition.

Clearly, the natural functioning of TOCE's is highly dependent on the inflow of freshwater. Because of their relatively small size, TOCE's are also extremely sensitive to anthropogenic impacts in the catchment. A series of dams (even small ones) impact freshwater supply to estuaries and this leads to a range of negative impacts that reduce estuarine function to undesirable levels. It is therefore imperative that artificial changes in freshwater supply to an estuary are carefully considered and managed.

Examples of goods and services provided by the Seekoei Estuary include the following:

- Ecological benefits such as biodiversity enrichment, high levels of productivity that provide rich feeding grounds for a range of predators, obligatory nursery habitats for numerous species of fish sought after by recreational anglers, as well as migratory corridors between rivers and the sea.
- Provision of living resources for food and building materials.
- Recreational and tourist activities that cover a range of interests.
- Aesthetic benefits that enhance the value of property.

Unless actively managed in a sustainable way, ecosystem services provided by estuaries (including their associated monetary and social values), are compromised. Historically, effective management of our estuaries were not adequately addressed by marine, freshwater and biodiversity conservation legislation. This led to *The Integrated Coastal Management Act (Act 24 of 2008, ICMA)* which recognized the importance of estuaries together with their effective management. Estuary Management Plans (EMP's) for all South African estuaries became mandatory in terms of the Act and this Act outlines a National Estuarine Management Protocol (NEMP) to support this.

The protocol identifies the need and minimum requirements for the development of EMPs. Responsibility is also delegated to relevant authorities and agencies to help align and coordinate estuaries management at a local level. Three phases (summarized in Figure 1) are identified in the NEMP for the development of an Estuary Management Plan. The phases are:

- **The Scoping Phase.** Focus is primarily on an assessment of the current situation (status and management) of a specific estuary. A Situation Assessment Report is generated, providing key information that informs management decisions within the estuary. Included is an assessment of the ecological condition of an estuary, its socio-economic context, ecosystem services provided by the estuary, major threats and pressures, existing legal instruments and management initiatives.

- **The Objective Setting Phase.** This involves the preparation of the EMP in accordance with national guidelines. Stakeholder participation is critical during the process and involves ecological, economic, social and cultural objectives. The Vision for the estuary is created and reflects these objectives, recognizing limits the estuary may place on development. Objectives focus on measurable outcomes that assess progress towards meeting the vision.

The aim is therefore to provide a blue-print for the desired condition (maintain or improve current state) of the estuary that has been agreed upon. This is addressed through the development of management objectives (conservation, living and non-living resource management, social issues, land use, infrastructure planning and development, water quantity and quality, climate change, education and awareness, compliance and enforcement etc.). Selection of performance indicators and development of a monitoring plan are fundamental to the final Estuary Management Plan, as are Institutional capacity and arrangements required to effectively execute the EMP.

- **The Implementation Phase.** The third phase focuses on the execution and continuous monitoring of the EMP developed in the Objective setting phase. Monitoring must gauge progress towards achieving the objectives set and must be reviewed every five years. An adaptive management approach should be followed, and if necessary, implementation plans reviewed and adapted to improve the EMP.

The current report fulfils the requirements for the Scoping phase of the Management Plan for the Seekoei Estuary as outlined. This small TOCE is located between the resort towns of Aston Bay and Paradise Beach. These two townships fall under the Kouga Municipality which has approximately 113 000 residents in the municipal area. Of these, about 950 live in Aston Bay and 500 in Paradise Beach (2011 census). Over 70% of the residents living in Paradise Beach are formally retired (Riaan Kolesky; Paradise Beach Neighbourhood Watch), but many remain active in the workplace. The Kouga municipal area also has the fastest annual growth rate in the district (Sarah Baartman district), increasing by 14.6% between 2011 and 2017. The town of Humansdorp 18 km north of the Seekoei is close to the catchment and has a population of about 29 000 people (2011 census).

The estuary is accessible via a 5 km tar road from Jeffreys Bay Township and an 18 km route to the town of Humansdorp to the north. There is a gravel loop road (approximately 8 km in length) around the northern border of the estuary, although the road is often dangerous to drive, especially in wet weather. The landscape between the estuary and Humansdorp is largely transformed, with extensive farming activities.

The Seekoei Estuary is an example of a South African TOCE that has been extensively modified because of anthropogenic activities along the river-estuary-nearshore continuum. In 2006, an Ecological Reserve Study (EWR) concluded that the Estuary Health Index (EHI) score allocated to the Seekoei Estuary was a score of 42 (Category D – moderately modified). However, this score is on a continuum between a Category D and Category E, a highly degraded system between 21 and 40. Urgent management intervention is required to prevent further deterioration to the health of the estuary. Because the estuary is linked to a Provincial Nature Reserve, conservation requirements dictate that the Estuary should be at Category A (near pristine) or highest attainable health status.

A summary of the issues impacting negatively on the structure and functioning of the Seekoei Estuary are provided below:

- The Seekoei no longer functions as a healthy temporarily open/closed estuary. The ecological health score indicates a highly modified system and it is now classified as a Category D estuary.
- Excessive abstraction of freshwater from the catchment has resulted in reduced and at times, zero freshwater baseflows reaching the estuary.

- Reduced baseflow leads to elevated or even hypersaline conditions in the estuary. Most of the estuarine biodiversity is at risk of a die-off if salinity values rise to high (>50) e.g. fish kills.
- When compared to historical records, fewer water birds use the estuary with respect to both diversity and numbers. This has a negative effect on the monetary value of surrounding properties, as well as the spiritual and recreational function offered by birding to residents and visitors.
- The presence of the causeway reduces the effectiveness of tidal action throughout the estuary (important functions of tidal action include maintaining open mouth conditions, the mixing of different bodies of water, redistribution of nutrients, and regulation of salinity levels).
- Excessive damming of the two inflowing rivers reduces the size and amplitude of small to medium floods and therefore reduced scouring of accumulated sediments from the estuary. The presence of the causeway exacerbates the reduction in floods and the associated reduced scouring benefits.
- Excessive sediment accumulation (the dam wall effect) and aggravating the consolidation of these fine sediments above the causeway.
- Excessive alien vegetation growth in the catchment and along the Seekoei and Swart Rivers. These alien plants use larger amounts of water compared to natural vegetation.
- The presence of the carpark and communal centre (formerly part of the Swimming pool complex) in the former outflow mouth channel. This prevents the mouth from migrating to its natural location which during periods of low flow can constrain the low tide thereby maintain high water levels in the system.
- There is the possibility that the artificial location of the present mouth leads to increased sediment loading by marine sand in to the lower estuary by tidal action and marine overwash of the berm during storm events.
- Freshwater wetlands in Paradise Beach have lost connectivity with the estuary due to poor road design and causeway construction. In one instance at least, a barrier wall was built across the wetland and must therefore be considered as an 'illegal dam'. The natural ephemeral nature of the wetland has therefore been altered artificially.
- Housing development has taken place below the 5 m estuary contour line and this increases the risk of flooding of these properties.
- The estuary is currently opened artificially on occasions (water level in the estuary usually around +0.9 m Mean Sea Level (MSL)) to reduce over-wash of the causeway and damage to vehicles. These artificial opening events lead to ineffective scouring of sediments from the estuary and are below the natural mouth breaching level of +2.0 to +2.5 m MSL for the Seekoei. The recommended water level for South African estuaries in general is +2.5 to +3.5 m MSL. Scouring benefits to TOCE's increase exponentially as water level behind the berm increase.
- Lack of scientific data that would inform more effective management of the estuary and catchment.

Potentially, ongoing climate change will alter the composition and behaviour of estuarine biotic communities and impose greater risks to human society. Of note is the current rise in sea level of 1.48 mm per year along the south coast of South Africa. Coupled with the predicted increase in the frequency of storms, it is likely that wave overwash of berms associated with TOCE's will also increase. Increased storminess and the ongoing rise in sea level also has implications for the causeway; overwash is likely to become more frequent and this situation underlines the importance of the Estuary and Wetlands Management Committee having an adaptive management approach as the situation changes in the future. By 2030, sea level will increase by about 1.5 cm; by 2050 sea level will increase by 45 cm compared to present. Management strategies will need to adaptive to these ongoing changes in climate.

Table of Contents

List of Figures

List of Tables

List of Plates

List of Abbreviations

CSIR	Council for Scientific and Industrial Research
CWAC	Coordinated Water Bird Count
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEDEAT	Department of Economic Development and Environmental Affairs and Tourism
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation (current)
EFZ	Estuary Functional Zone
EMP	Estuary Management Plan
EWR	Ecological Reserve Study
ICMA	The Integrated Coastal Management Act
MSL	Mean Sea Level
NEMA	National Environmental Management Act
NEMP	National Estuarine Management Protocol
NH_4^+	Ammonia
SRP	Soluble Reactive Phosphorus
TOCE	Temporary Open/Closed Estuary
TOxN	Total Oxidised Nitrogen

Terminology

Berm in this document refers to the sand strip that separates the Seekoei Estuary and the surfzone on the seaward side. The berm is dynamic, increasing or decreasing in height relative to Mean Sea Level according to the interactive influence of dominant driving forces**.**

Biota refers to living organisms, plant and animal.

CWAC counts - Coordinated Water Bird Counts done at least twice a year (winter and summer) by local volunteers on identified wetlands. Programme initiated by the Animal Demography Unit (ADU) at the University of Cape Town.

Ecological Reserve refers to the quality, quantity and timing of freshwater inflows reserved to support ecosystem function.

Estuarine classification is the determination of an ecological class by taking ecological, social and economic factors into account, in a transparent, participatory process.

Estuarine classification system of Whitfield (1992) separates estuaries into permanently open estuaries, temporarily open/closed estuaries, estuarine lake systems, estuarine bays and river mouths.

Estuarine Functional Zone (EFZ) correlates with the 5 m topographical contour as delineated in the National Biodiversity Assessment: Estuary Technical Report (2012). This includes any open water areas, estuarine habitat (sand and mudflats, rock and plant communities) and floodplain areas.

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

EFZ – Estuary Functional Zone refers to the zone below the 5 m contour line.

EMP – Estuary Management Plan.

Hypersalinity occurs when the salt content of the water exceeds 35 parts per thousand. If salinity exceeds 50 - 55, the medium becomes lethal to the biota and mass mortality occurs. For many species, breeding will cease at lower levels.

Present Ecological State is a measure of the present quality (water quantity, water quality, habitat and biota) of the resource – assessed in terms of the degree of similarity to the reference condition.

Productivity the rate of biomass generation by living organisms.

Reference condition refers to the natural, unimpacted characteristics of a water resource, and represents a stable baseline.

River baseflow refers to the volume of freshwater flowing in to an estuary under normal conditions, i.e. floods excluded.

TOCE – Temporarily Open or Closed Estuary; connection with the sea is intermittent.

1 Introduction

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

Clearly, our estuaries are extremely variable in character leading to five broad categories described by Whitfield (1992). Originally, the list of South African estuaries stood at about 250 functional systems, but a recent revision expanded the list to nearly 300 (Van Niekerk and Turpie 2012). The five estuarine types and their typical attributes are listed in Table 1.

Table 1 Classification scheme of South African Estuaries with typical examples – modified from Whitfield (2005). The salt content or salinity of freshwater is around zero and that of seawater, 35. Hypersaline conditions refer to salinity values that exceed 35.

Estuarine type and example	Marine or freshwater balance	Tidal prism	Mean salinity
Estuarine Bay (Knysna Lagoon)	Marine dominance	Large	25 – 35
Permanently open (Kromme)	Marine dominance	Large	15 – 40
River mouth (Storms River)	Freshwater dominance	Small	1 – 15
Estuarine lake (Swartvlei)	Variable	Small	1 – >35
Temporary open/closed (Seekoei)	Variable	Sometimes absent	1 – >35

Temporary open/closed estuaries (TOCE's) such as the Seekoei constitute more than 72% of our estuarine types in South Africa (Whitfield 1992, Perissinotto *et al.* 2010). Characteristically, river catchments are small and salinity values in the estuary switch from freshwater after strong floods, to values that may exceed the concentration of seawater during dry periods. These occasional floods also lead to the volume of freshwater in the estuary increasing behind the berm when the mouth is closed. If the water level inside the estuary is sufficiently high, the berm is naturally breached and sediment scouring and draining of the estuary occurs. The mouth may close again relatively quickly, linked to the residual water volume stored in the estuary, weak tidal exchange after breaching and redevelopment of the sandbar as sand is redistributed along- and up-shore driven by surfzone wave action (Perissinotto *et al.* 2010). During the closed phase, marine over-wash may occur during high spring tides or during storm events when wave surges lead to overtopping of the sandbar if the berm is low enough.

Associated with variability in estuarine salinity (that may range from near-zero to >35) is the state of the mouth, varying from wide open to fully closed with the development of a berm (Plate 1). Occasionally, the mouth may remain closed for extended periods (years) if river runoff remains low. Under closed mouth conditions, water movement driven by tidal action obviously ceases and wind becomes the main driver of water mixing. Under conditions of mouth closure, salinity in the estuary may decrease progressively if low freshwater baseflows persist. If evaporation rates from the estuary exceed the volume of freshwater inflow from the catchment over time, then salt concentration in the estuary increases progressively. Under such conditions, salt concentration in the estuary may attain levels that result in major mortality crashes of the biota (>50).

Both estuarine salinity and state of the mouth are significantly impacted by the artificial reduction in freshwater discharge (Reddering 1988, Whitfield and Bruton 1989). In the case of the Seekoei, the mouth remains closed for longer between major floods and salinity variability increases. These aspects are covered in more detail in Section 6.

The physico-chemical attributes of Temporary open/closed estuaries are recognizably very different when compared to the other four broad estuarine types, supporting their own unique floral and faunal assemblages. Changes in biotic structures and ecological functioning between individual TOCE's also exist, linked to physico-chemical conditions at any time. Changes in the physico-chemical environment and the concomitant biotic response may be further modified by anthropogenic impacts that include:

- River flow modification (e.g. water abstraction, alien plants, forestation, increased urban runoff).
- Changes in land-use patterns in the catchment.
- Pollution (e.g. agriculture, waste water treatment works, industrial, sediment).
- Exploitation of living resources (e.g. Fish, invertebrates, mangroves).
- Habitat destruction (e.g. low-lying developments, bridges, jetties, and other structures in and around estuaries such as mining).
- Climate change (e.g. modification in rainfall, changes in temperature, increase in storm events and their magnitude, increase in drought events and their magnitude, sea level rise).

Plate 1 **The Temporarily open/closed Mngazi Estuary (a short distance south of Port St Johns) a few days before final winter mouth closure. Typically, water levels in the estuary would slowly build up and with the onset of summer rains or a flood, breach the sandbar at the mouth and remove much of the accumulated marine sand. Natural breaching of an estuary mouth maximizes the probability of the mouth remaining open for longer compared to a premature artificial breaching event at a lower water level.**

The anthropogenic influences outlined above impact negatively on Ecosystem Services provided by estuaries (including their associated monetary value). Historically, effective management of our estuaries were not adequately addressed by marine, freshwater and biodiversity conservation legislation. This led to *The Integrated Coastal Management Act (Act 24 of 2008, ICMA)* which recognized the importance of estuaries together with their effective management. Estuary Management Plans (EMP's) for all South African estuaries became mandatory in terms of the Act and this Act outlines a National Estuarine Management Protocol (NEMP) to support this.

The protocol identifies the need and minimum requirements for the development of EMPs. Responsibility is also delegated to relevant authorities and agencies to help align and coordinate estuaries management at a local level. Three phases (summarized in Figure 1) are identified in the NEMP for the development of an Estuary Management Plan. The phases are:

- **The Scoping Phase.** Focus is primarily on an assessment of the current situation (status and management) of a specific estuary. A Situation Assessment Report is generated, providing key information that informs management decisions within the estuary. Included is an assessment of the ecological condition of an estuary, its socio-economic context, and ecosystem services provided by the estuary, major threats and pressures, existing legal instruments and management initiatives.

- **The Objective Setting Phase.** This involves the preparation of the EMP in accordance with national guidelines. Stakeholder participation is critical during the process and involves ecological, economic, social and cultural objectives. The Vision for the estuary is created and reflects these objectives, recognizing limits the estuary may place on development. Objectives focus on measurable outcomes that assess progress towards meeting the vision. The aim is therefore to provide a blue-print for the desired condition (maintain or improve current state) of the estuary that has been agreed upon. This is addressed through the Development of Management Objectives (Conservation, living and non-living resource management, social issues, land use, infrastructure planning and development, water quantity and quality, climate change, education and awareness, compliance and enforcement etc.). Selection of performance indicators and development of a monitoring plan are fundamental to the final Estuary Management Plan, as are Institutional capacity and arrangements required to effectively execute the EMP.

- **The Implementation Phase.** The third phase focuses on the execution and continuous monitoring of the EMP developed in the Objective setting phase. Monitoring must gauge progress towards achieving the objectives set and must be reviewed every five years. An adaptive management approach should be followed, and if necessary, implementation plans reviewed and adapted to improve the EMP.

The current report fulfils the requirements for the Scoping phase of the Management Plan for the Seekoei Estuary as outlined above

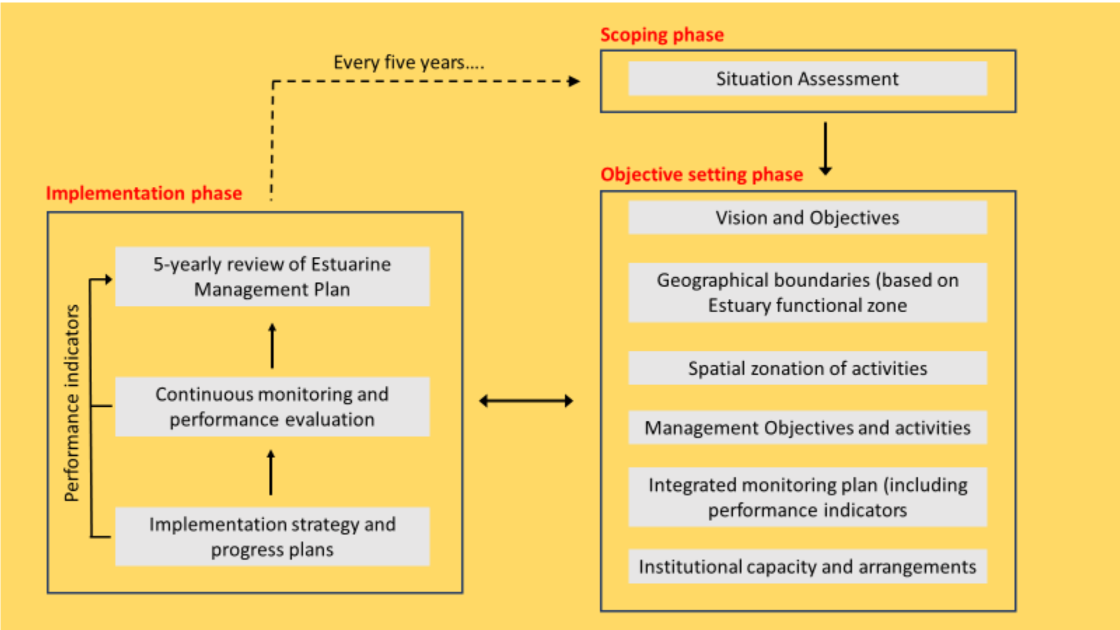

Figure 1 The framework for integrated estuarine management in South Africa.

2 Purpose of the Situation Assessment

The purpose of the Situation Assessment is to provide relevant information that would inform and/or influence the management decisions within the estuary. The document therefore provides a framework that enables the decision process to attain the desired state that has been agreed upon.

The following components are included in the Situation Assessment Report:

- The legislative instruments currently applicable to the effective management of the Seekoei Estuary – including existing and planned management strategies or plans (catchment management strategies, Integrated Development Plans, Spatial Development Frameworks, Coastal Management Programmes, Disaster Management Plans, Contingency Plans and Mouth Management Plans are examples).
- The biogeographical status of the Seekoei Estuary.
- A comprehensive assessment of the structure (abiotic and biotic), functioning and state of the estuary. Current management challenges are also highlighted.
- In the case of the Seekoei Estuary, the Ecological Water Reserve Requirements are available (Desktop Level). Key conclusions pertaining to the reserve are summarized in Sections 6.7.
- The Geographical and socio-economic context of the Seekoei, including dependence of local communities on the estuary. Opportunities and Constraints provided by the estuary for local communities.
- Identification of information gaps pertaining to the estuary.

3 Legislative Framework

This section provides a general overview of legislation and policy applicable to management of estuaries in South Africa and specifically to the Seekoei Estuary. More detailed discussion on legislative framework for estuary management, including international and regional treaties and obligations, national policies and laws, provincial and local policies and legislation is provided in Taljaard (2007).

It is important to keep in mind the overarching law of the land is the South African Constitution which provides the legal framework for regulating environmental management in a general sense. Section 24 of the Constitution states that:

"Everyone has the right:

- To an environment that is not harmful to their health of well-being; and
- To have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that –
    - Prevent pollution and ecological degradation;
    - Promote conservation; and
    - Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

South African environmental law is underpinned by these principles (Breen and McKenzie 2001) and is the justification for the wise use of estuarine biodiversity.

The transitional nature of an estuary as an interface between freshwater, marine and terrestrial habitats have made legislating and managing, for estuaries specifically, difficult and hence neglected. The very fact that they are at this interface makes them very heavily influenced by all the activities that feed into them and therefore are subject to numerous guidelines, policies and laws from all those spheres.

The various National, Provincial and local policies as they pertain to the Seekoei Estuary are outlined in Table 2 below. Estuary management falls under two national government departments: Department of Water and Sanitation (DWS) which is responsible for water resources, and the Department of Environmental Affairs (DEA) which is responsible for all other environmental matters e.g. land use, living resources. The management of the environment is devolved to provincial departments, in this case in the Eastern Cape, Department of Economic Development and Environmental Affairs (DEDEA). The management and conservation of marine living resources, however, is retained at the national level, with the primary responsibility residing with the Department of Agriculture, Forestry and Fisheries Marine and Coastal Management of DEA. When there is conflict between provincial and/or local legislation, national legislation takes precedence. At a local or municipality level, municipal councils pass municipal by-laws that cannot conflict with provincial and national laws (McKenzie 2011).

The Seekoei Estuary lies within the Eastern Cape, within the Sarah Baartman District Municipality and the Kouga Local Municipality.

Table 2 Summary of national, provincial and local policies which affect water quality and quantity in estuaries in general, land use, development and resource use in the estuarine environment.

	Relevant Legislation and policy	Lead Agent	Implications/Relevance
National Legislation	The South African Constitution		Provides for overall environmental protection.
	National Water Act 36 of 1998	DWS	Defines the environmental reserve in terms of quantity and quality of water; provides for national, catchment and local management of water.
	Water Services Act 108 of 1997	DWS	
	National Environmental Management Act 107 of 1998 as amended	DEA	NEMA provides environmental and sustainability principles relevant to the EMP and EIA requirements.
	National Environmental Management: Integrated **Coastal Management** Act 24 of 2008 **(NEM: ICMA)**	DEA	Provides for integrated coastal and estuarine management in South Africa and sustainable development of the coastal zone, defines rights and duties in relation to coastal areas; includes a National Estuarine Management Protocol for South Africa and requires that estuarine management plans be developed and implemented for all estuaries.
	National Environmental Management: **Protected Areas** Act 57 of 2003 **(NEM: PAA)**	DEA	Provides for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes; and for establishment of a national register of national, provincial and local protected areas, describes the different types of protected areas that can be declared which may also apply to estuaries.
	National Environmental Management: **Biodiversity Areas** Act 10 of 2004 **(NEM: BA)**	DEA	Provides for the conservation of biological diversity and regulates sustainable use of biological resources.
	National Environmental Management: **Air Quality** Act 39 of 2004 **(NEM: AQA)** National Environmental Management: **Waste** Act 59 of 2008 **(NEM: WA)**	DEA	Provides for the control of air emissions and air quality.
	Marine Living Resources Act 18 of 1998 **(MLRA)**	DAFF (Fisheries)/ DEA (MPA's)	Regulates living resource use within marine and estuarine areas, mainly through licensing; provides for establishment of Marine Protected Areas.
	Marine Pollution (Control and Civil Liability) Act 1981	DEA	Provides for the protection of the marine environment from pollution by oil and other harmful substances, the prevention and combating of such pollution and the determination of liability in certain respects for the loss or damaged caused by the discharge of oil from ships, tankers and offshore installations.

	Relevant Legislation and policy	Lead Agent	Implications/Relevance
National Legislation	**Environmental Conservation** Act 1989	DEA	Most of the provisions of this Act have been repealed by NEMA, apart from the regulation on Sensitive Coastal Areas.
	National Forest Act 84 of 1998	DAFF	Provides for the protection of any forest located within the estuarine environment.
	Conservation of Agricultural Resources Act 43 of 1983 (CARA)	DWS	Provides for the control of alien plant species located within aquatic habitats such as estuaries.
	Local Government: **Municipal Systems Act** 32 of 2000 as amended	DPLG	Requires each local authority to adopt a single, inclusive plan for the development of the municipality intended to encompass and harmonise planning over a range of sectors such as water, transport, land use and environmental management.
	Mineral and Petroleum Resources Development Act 2002	DME	Deals with environmental protection and management of mining impacts including sand and coastal mining.
	World Heritage Convention Act 1999	DEA	Provides for the incorporation of the World Heritage Convention into South African Law and for the recognition and establishment of World Heritage Sites in South Africa.
	National Heritage Resources Act 1999	DEA	Provides for management of national heritage resources (including landscapes and natural features of cultural significance and for participation of communities in the identification, conservation and management of cultural resources.
National Policy	National Climate Change Response White Paper 2012		
	White Paper for Sustainable Coastal Development 2000		
	Department of Water Affairs River Health Programme		
Provincial Policy	Eastern Cape State of the Environment Report 2010	DEDEAT	
	Eastern Cape Climate Change Response Strategy 2011	DEDEAT	
	Eastern Cape Biodiversity Conservation Plan (ECBCP, 2007)	DEDEAT	
	Eastern Cape Coastal Management Programme; 2013 Update	DEDEAT	

	Relevant Legislation and policy	Lead Agent	Implications/Relevance
	DEDEAT Coastal Environmental Management Framework	EDEAT	
	Eastern Cape Air Quality Management Plan	DEDEAT	
	Eastern Cape Provincial Integrated Waste Management Plan (PIWMP, 2010)	DEDEAT	
	EC Parks and Tourism Conserved Areas Expansion Programme 2012	DEDEAT	
Local	Kouga Integrated Development Plan Resolution No. 17/05/AME&SP3		Fulfils the requirements of the Municipality Systems Act 32 of 2000 to layout specific plans and management needs of the municipality within a 5 yr plan. Within that plan is the management of water supply, infrastructure and healthy environment for people. The estuary must be managed in these terms. KPA Basic Service provision, coastal and estuary management with the objective to ensure well managed coastal areas and estuaries.
	Kouga Heritage Plan 2015-18		
	Kouga Spatial Development Framework (SDF) EC03/2014/7 2015		

4 Ecosystem Services Provided by Estuaries

The South African coast of about 3000 km is an extremely dynamic environment with relatively few sheltered inlets protected from oceanic turbulence. Estuaries therefore, represent relatively calm areas that offer some protection from an otherwise open coastline. Besides providing important and unique ecological benefits, estuaries have become sought-after localities for socio-economic development. Consequently, their economic value is significant. Ecosystem goods and services provided by estuaries are numerous, examples of which are summarized in Table 3.

Table 3 Examples of goods and services provided by estuaries

Category	Goods and Services	Examples of opportunities and activities
Ecological	Biodiversity enrichment	Estuaries provide habitats at the landscape level inhabited by unique biotic assemblages
	Trophic interactions	Biotic biomass is high in estuaries and they are among the most productive ecosystems on the planet
	Nursery habitats	Important recreational fish and invertebrate species utilize estuaries as nursery areas. For some, estuaries represent an obligatory habitat during their respective life cycles. Stocks may be negatively compromised if estuaries are in poor condition.
	Migratory corridors	Numerous fish and invertebrate species migrate through estuaries into freshwater or marine habitats.
	Erosion control	Sediments are trapped in estuaries by vegetation.
Subsistence	Collection of living resources for food	Line-fishing, seine netting and intertidal bait collecting.
	Building materials	Reeds, mangrove poles and other materials.
Recreation and Tourism	Nature appreciation	Bird watching and walking.
	Scenic opportunities	Residential development, property investment and housing for rental purposes.
	Recreational fishing	Recreational angling e.g. Fly fishing .

	Water sports	Boating, sailing, canoeing and swimming.
	Culture activities	Education, research, spiritual and aesthetic values.
	Aesthetic and scenic experiences	Residents and holiday makers gain much pleasure from the estuary and environs.
Commercial and Industrial	Mariculture	Production of living resources for human consumption and other uses.
	Transport services	Marinas, ports and ski-boat launching sites.
	Protection from extreme natural hazards	Estuaries can mitigate the impact of coastal hazards such as winter storms.

5 Geographical, demographic and climatic considerations

5.1 Location and demographic patterns

The Seekoei Estuary (Figure 2) is located between the resort townships of Aston Bay on the eastern side and Paradise Beach on its western side. These two townships fall under the Kouga Municipality (one of seven in the Sarah Baartman District) which has approximately 113 000 residents in the municipal area Kouga Integrated Development Plan 2017 – 2022 (Kouga Municipality 2017). Kouga is the second smallest region in the district, covering only 4.1% of the land area. Despite its relative small size, it is the most populous region representing approximately 24% of the total population in the district.

Two tributaries (the Swart and the Seekoei) discharge into the Seekoei Estuary about 1.3 km from the beach (Figure 2). The two rivers originate northwest of the town of Humansdorp and are each approximately 35 km in length. At its widest point, the estuary is 580 m wide, with a variable depth profile. Tidal reach extended 4.2 km upstream and the original tidal prism was 0.82 x 10^6 m^3 of water per cycle (Esterhuysen 1982). The total area of the Seekoei Estuary is 276 ha (refer also to Table 9). The landscape between the estuary and Humansdorp is largely transformed, with extensive farming activity undertaken (see Section 5.2). The Seekoei Estuary and environs experience a warm temperate climate, receiving rainfall throughout the year although most falls during the cooler months. The river drainage area is small and available reports are inconsistent with regards to the total area. However, DWAF (2006b) suggest that the area is probably close to 250 – 260 km^2. (Whitfield and Bruton 1989) indicate that the average annual rainfall is 585 mm and the average annual runoff is 17 x 10^6 m^3. Other records (www.saexplorer.co.za/south-africa/climate/humansdorp_climate .asp) suggest that rainfall is about 474 mm on average in the catchment area.

The geological substrate is composed of Table Mountain Group quartzite in the upper catchment, changing to Bokkeveld Group slates at lower elevations (Esterhuysen 1982). Slate outcrops occur along the eastern shore of the estuary and these outcrops continue to extend into the nearshore. To the west, the coastal strip is composed of unconsolidated sands extending 12 km to the township of St Francis Bay on the southern bank of the Kromme Estuary.

The Kouga Municipality has the fastest annual growth rate in the district. Between 2011 and 2016, the population increased by 14.6%, compared to a rate of 6.5% for the Sarah Baartman District as a unit. The second fastest growth rate was shown for the Kou Kamma region, which registered a growth rate of 7.4% for the same period (2011 – 2016). The growth rate for the Eastern Cape Province was 0.3% (Kouga Integrated Development Plan 2017 – 2022). Of these, about 950 live in Aston Bay and 500 in Paradise Beach (2011 census). Over 70% of the residents now living in Paradise Beach are formally retired (Riaan Kolesky; Paradise Beach Neighbourhood Watch), but many remain active in the workplace. The town of Humansdorp 18 km north of the Seekoei is close to the catchment and has a population of about 20 123 people (Kouga Integrated Development Plan 2017 – 2022).

Paradise Beach is a relatively young township, first marketed in the early 1970's. By March 1973, 40 houses had been built (Billy Ives, personal communication). The Paradise Beach Neighbourhood Watch now documents a total of 540 - 550 houses in the resort, not considering flats and small units in the Caravan Park (approximately 90 units). In November 2017, a further 27 houses were under construction.

There are no major business enterprises employing medium to large work-forces in Paradise Beach. Most business opportunities in the resort centre on tourism, with 20 B & B units providing about 100 – 120 beds. (Jeffreys Bay tourism). However, several residents active in the formal work sector travel to work in other centres during the week. Visitors and residents particularly enjoy the 10 km of pristine beach, stretching all the way to the mouth of the Kromme River to the west. Walking, swimming and fishing are very popular activities, with beach lifeguards patrolling during busy times of the year. Job opportunities for gardeners and household helpers number about 100 to 120 persons (Neighbourhood Watch, Paradise Beach).

Paradise Beach is directly linked to the business centre of Jeffreys Bay via a 5 km tar road and an 18 km road (much of which is gravel) to the town of Humansdorp to the north. Jeffreys Bay is also accessible via a 20 km loop road (of which 9 km is gravel) around the northern border of the estuary. The gravel section of this loop is considered dangerous to drive (particularly for older folk and in wet weather) especially at night. Safety is a large concern voiced by many residents. The causeway is the preferred and most travelled route in and out of the area (Table 4) most likely because it's the direct and safest route in and out of Paradise Beach for residents.

Besides the ongoing residential development in Paradise Beach, there are many houses and plots on the market. Many residents are said to be frustrated with problems associated with the causeway and state of alternate roads to Humansdorp or Jeffreys Bay. Residents need to access essential amenities (shops, banks, schools etc.) or a formal workplace in other centres on a regular basis. More specifically:

- At times, high water levels in the estuary flood the causeway. Estuary water is usually salty (becoming hypersaline on occasions) and this leads to serious damage (rust, malfunctioning electrical systems etc.) and associated repair cost to vehicles crossing. The situation is exacerbated under windy conditions. An idea of the number of vehicles and pedestrians crossing the causeway daily is shown in Table 4.

- On occasions, the causeway is also very dangerous to drive when water levels overtop the causeway. Pedestrians crossing the causeway are also at serious risk when water levels are high. The causeway is then closed to traffic, sometimes indefinitely. Closure of the causeway compels residents to use one of the alternate roads when they need to access business centres.
- Due to the above, visits to a doctor, hospitals and clinics are not only abnormally difficult for older folk, but for Paradise Beach residents in general. Domestic helpers including gardeners are also compromised when moving between their homes and workplace.
- There are currently about 30 – 40 school children resident in Paradise Beach. These learners cross the causeway most weekdays to meet the school transport bus at the collection point at the shopping centre in Aston Bay. The number of persons crossing the causeway daily during the week averages over 60 (Table 4).
- It has been suggested by some that the problem with reasonable and equitable access to Paradise Beach has put a damper on development and investments over the years.

Table 4 Vehicle and pedestrian counts conducted on two occasions in 2017 by the Paradise Beach Neighbourhood Watch. Two stations were monitored: those vehicles/pedestrians crossing the causeway and those using the alternate gravel loop road. Counts were done for 12 hrs from 6 am to 6 pm on Wednesday 24 October and Thursday 15 November 2017. Note that these were mid-week counts and not during any holiday period. On the first occasion (24 October) rain fell for the entire 12-hr monitoring period.

	24 October			15 November			Daily Average		
Causeway	**In**	**Out**	**Total**	**In**	**Out**	**Total**	**In**	**Out**	**Total**
Cars	656	686	**1342**	780	728	**1508**	718	707	**1425**
Contractors	159	132	**291**	108	110	**218**	134	121	**255**
Trucks	8	14	**22**	24	26	**50**	16	20	**36**
Pedestrians	51	39	**90**	18	18	**36**	35	29	**63**
Cars & Contractors	815	818	**1633**	888	838	**1726**	852	828	**1680**
All Vehicles	823	832	**1655**	912	864	**1776**	868	848	**1716**
Gravel Road									
Cars	162	172	**334**	126	119	**245**	144	146	**290**
Contractors	16	15	**31**	34	37	**71**	25	26	**51**
Trucks	8	8	**16**	26	26	**52**	17	17	**34**
Pedestrians	15	12	**27**	1	2	**3**	8	7	**15**
Cars & Contractors	178	187	**365**	160	156	**316**	169	172	**341**
All Vehicles	186	195	**381**	186	182	**368**	186	189	**375**
Total Vehicle Traffic In and Out of Paradise Beach	1009	1027	**2036**	1098	1046	**2144**	1054	1037	**2090**

Closure of the causeway will seriously impact Paradise Beach Residents in a negative way, but there are also wider implications for the region. Included are:

- Pedestrians, particularly those coming to Paradise Beach to obtain work, will be seriously compromised in terms of access. Table 4 above indicates that the number of pedestrians crossing the causeway for the two mid-week surveys averaged 35 (in) and 29 (out) of Paradise beach. An additional survey using a brief questionnaire (see Appendix) and circulated to workers indicated the following broad results:
    - Number of respondents who submitted returns – twenty-six persons.
    - Of the twenty-six persons, seven were Gardeners and eleven were Domestic Helpers. Four of the other eight persons were Tradesmen.
    - Of the twenty-six persons, ten walked across the causeway and two crossed the causeway on bicycle. Four persons used a taxi and ten persons used private transport (lift club included).
    - The number of dependents at home who were also supported by the income generated from working in Paradise Beach numbered eighty – 3-4 dependents per household on average.
    - Twenty-five of the respondents to the questionnaire indicated that income was only generated if work was carried out – no work, no pay principle.

- The residents of Aston Bay, Marina Martinique and others will have no alternate exit route should the road to Jeffreys Bay be temporarily blocked and/or damaged. Community protests in the township for example, could theoretically disrupt the route indefinitely. Included will be emergency services and others wanting to access Aston Bay environs.

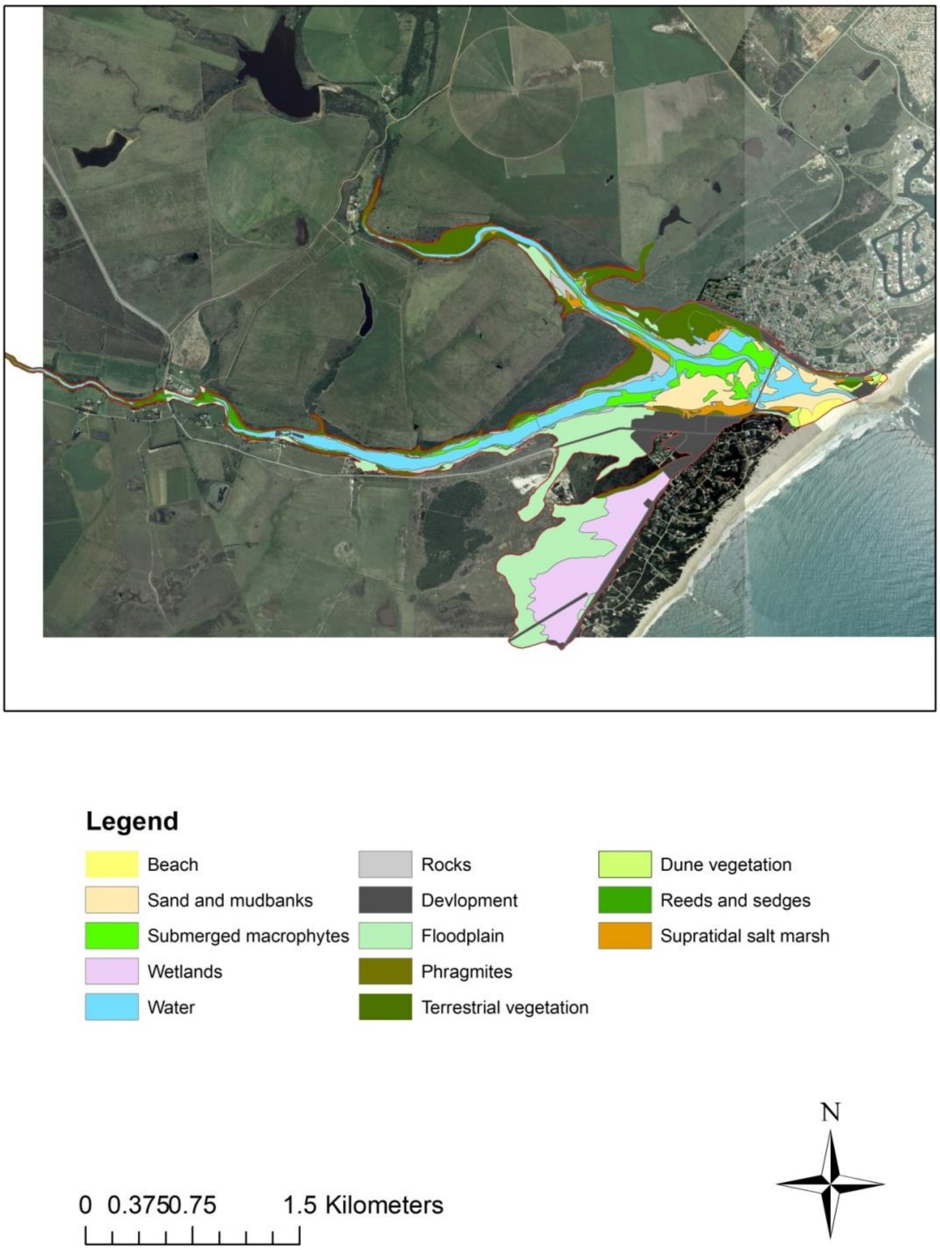

Figure 2 **Map of the Seekoei Estuary showing the resort towns of Paradise Beach (south of the estuary) and Aston Bay on the northern side. The Seekoei tributary to the south and the Swart to the north flow in to the estuary basin. Also shown are the habitat types below the 5 m contour line around the estuary (outlined by the red line). The area below the 5 m contour line is referred to as the Estuary Functional Zone (EFZ). Note the extensive area of wetland to the west of Aston Bay.**

5.2 Landuse around the Seekoei Estuary

From the earliest Topographical Survey images obtained (1942, Figure 3) the catchment of the Seekoei Estuary has mostly been under privately owned farmland (sheep, grazing and wheat) and remains so at present (Figure 4). The seasonal wetlands present within the 5 m estuarine functional zone (EFZ) (outlined by the red contour line and calculated to be 33.8 ha in extent, Figures 2 and 4) are partly transformed through housing development. On occasion, some homes are flooded by high water levels in the wetlands (Plate 2).

Plate 2 Housing development in low-lying areas are occasionally flooded after local rainfall flood the wetlands

There are 46 existing lawful use dams within Seekoei/Swart River catchment, DWS quaternary catchment K90F with a total of 74 storage water bodies. Of those, 24 registered dams are in the immediate vicinity of the main stem rivers, 10 of which are on-stream dams (Figure 5). The capacity of just these 24 dams is estimated to be approximately 4.6 x 10^6 m^3. Water is used primarily for livestock and/or irrigation purposes. One dam is also listed as a water supply dam.

Illegal damming of the wetlands is also apparent. The link road across the wetland immediately west of the small shopping centre has raised the height of the original crossing by about 0.5 – 1.0 m. A barrier wall has also dammed the wetland adjacent to the road crossing on the west side. Small flow-through pipes allow for some throughflow of water under the road.

Along with agricultural practices shown in Figures 2 and 4, other pressures on the estuary include many small farm dams (25 to 30 dams), causeways, roads, a car park-swimming facility at the mouth and residential development. Table 5 provides a summary of land use changes/impacts on the Seekoei Estuary and were obtained from the Land Survey maps available.

6 Activities impacting goods and services provided by the Seekoei Estuary

Estuarine structure and function is mainly regulated by the interactive effects of river inflow (both baseflow and floods) and the tidal influence of the sea (DWAF 2006b). Although these two key drivers fluctuate naturally, anthropogenic induced changes artificially alter the functioning of an estuary. For example, anthropogenic impacts can alter salinity patterns in an estuary (Sections 6.1 and 6.8), sedimentary processes and mouth dynamics. These are classified as abiotic aspects of estuarine functioning and they in turn, lead to unnatural shifts in the biotic assembly, e.g. changes in the fish community.

6.1 Freshwater supply and salinity effects

River impoundments and freshwater abstraction are major factors impacting negatively on the natural functioning of both rivers and downstream estuaries throughout South Africa. The severity of these actions is exemplified in the following statement by Davies *et al.* (1993): "*There are few rivers in southern Africa that have not been over-exploited, degraded, polluted, or regulated by impoundments, and we know of many that were once perennial, but which now flow only seasonally or intermittently*".

The natural runoff for the Seekoei was estimated at 20.27 Million m^3/year which have been reduced by 44% to 11.36 Million m^3/year in 2005 (DWS 2006b). Most of this significant flow reduction was in the baseflow component as there is no large dams in the catchment, manifesting as a zero or near zero inflow for months at a time to the estuary.

The effects of the abstraction of freshwater are clearly demonstrated along the estuary-river continuum of the Seekoei and the natural functioning of both the rivers and estuary are now critically compromised. With respect to dam construction, the Seekoei and Swart Rivers have numerous small farm dams along their combined length (refer also to (Bickerton and Pierce 1988, Whitfield and Bruton 1989). Because the catchment is relatively small, even small but many storage dams can greatly reduce run-off to the estuary. Major river floods for example, flush large quantities of accumulated sediment from an estuary, while river baseflow is the main factor keeping the mouth open in small estuaries (DWAF 2006b).

Figure 3 Aerial survey images of the Seekoei catchment in 1942, the 5 m contour line around the estuary is outlined in red.

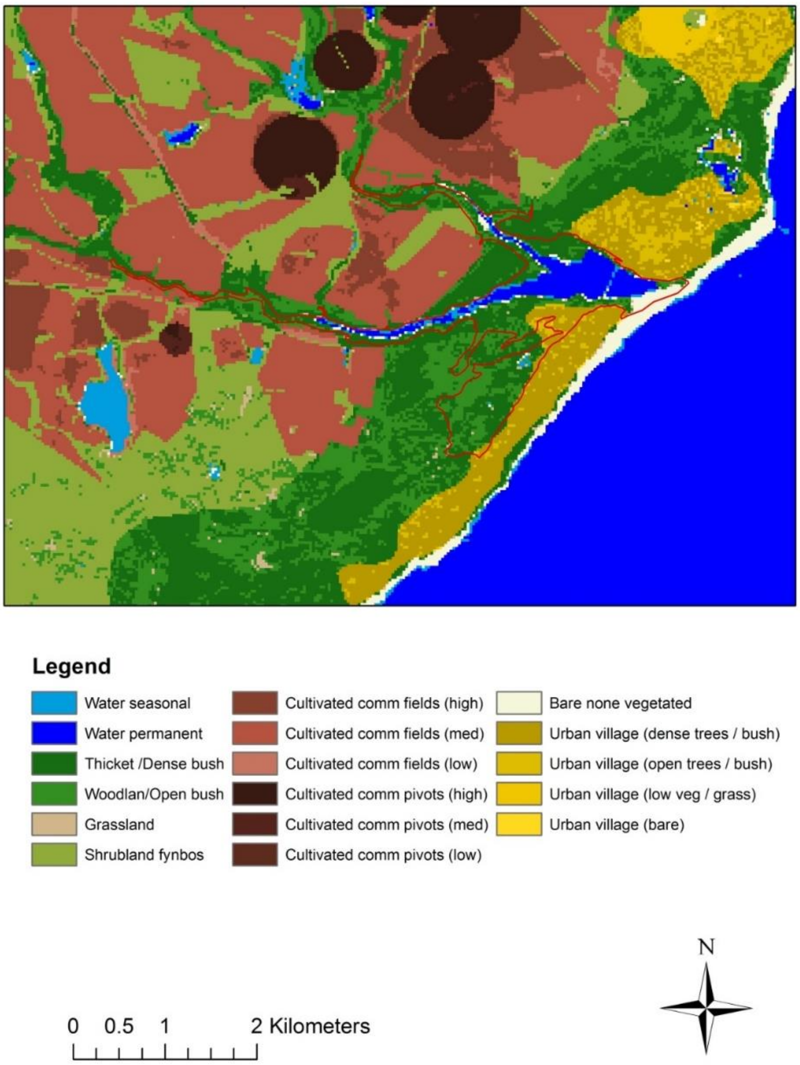

Figure 4 Land use patterns around the Seekoei Estuary. Note the water storage reservoirs associated with the two tributaries.

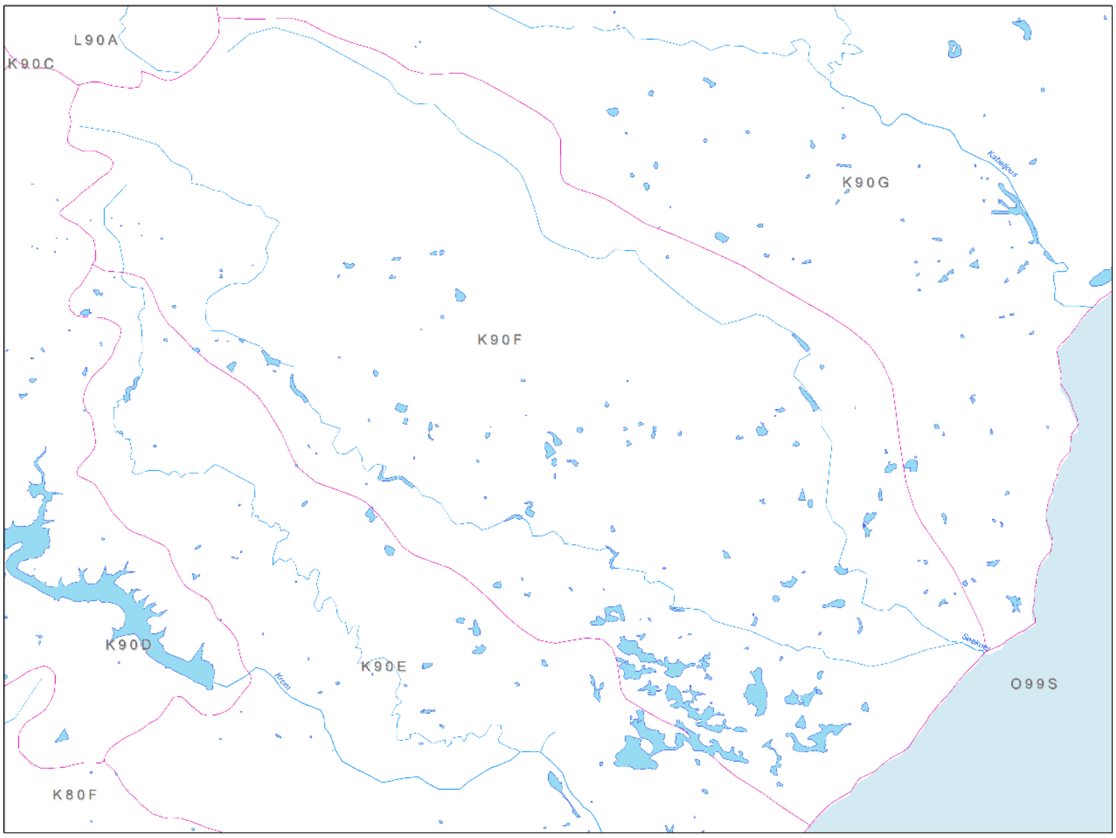

Figure 5 **DWS map of quaternary catchments in Kouga Municipality area, K90F is the catchment for the Seekoei Estuary. Registered dams shown in blue.**

The Seekoei Estuary and environs have a long history of man-induced changes, some of which have impacted the structure and functioning of the system in a severe way. Historical observations by Whitfield and Bruton (1989) focus on principle effects of freshwater deprivation on estuaries in general, but also discuss the Seekoei Estuary as an example of a freshwater deprived estuary. Reddering (1988) also specifically refers to the Seekoei as a freshwater starved estuary. Along with dams (large and small, Figure 5) in the catchment, there is water abstraction for irrigation and non-irrigation uses.

The Reserve Determination study (DWAF 2006b) recommended that no new storage reservoirs be built in the catchment because of the high level of freshwater abstraction. At the time, it was estimated that approximately 56% of the natural MAR still reached the estuary (Table 9). Based on DWS (DWS pers. comm. 2017) reporting and model estimates, there is now approximately 20.27 x 10^6 m^3 water abstracted/stored from the catchment from non-irrigation (0.8%), irrigation (57%) and current storage (42%, dams). Given that the average annual runoff for the catchment is estimated to be 20.27 x 10^6 m^3, abstraction now equals and may even exceed runoff, demonstrating the impact of the lack of freshwater inflow to the estuary.

This information suggests that water abstraction from the Seekoei catchment has continued to increase and that the Reserve Study recommendation that no new dams be constructed appears to have been ignored. Support for this statement is also reflected on the Google image of 2012. At least three of the dams shown in Plate 3 were not present on the Google image of 2004.

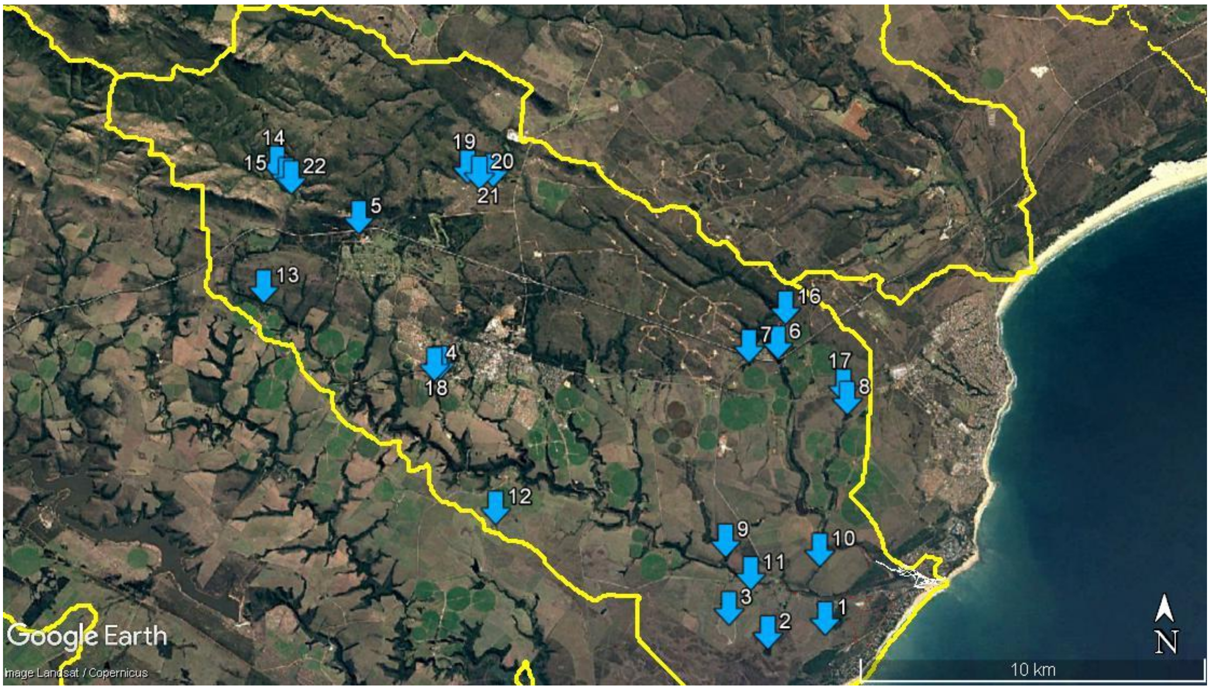

Plate 3 **Most of the dams reflected on the Google image of 2012 (above) were present on the Google image of 2004.**

Critical to the current discussion is the cyclical nature of wet and dry phases in South Africa, with the country experiencing severe and prolonged droughts than are often terminated by severe floods. We live in a country generally described as water-stressed and typical of such climates, rainfall is highly variable within and between years. Figure 6 below reflects this high variability over the past 10 years near the Gamtoos River Mouth, 30 km east of the Seekoei Estuary and from Cape St. Francis, 15 km south-west of the estuary. Despite high variability in rainfall and from the perspective of the estuary, dry phases have increased because of increasing retention of freshwater in catchments.

Table 5 Chronology of changes/impacts on the Seekoei Estuary. Data gleaned from Survey maps.

DATE	CHANGE
1942 image	 • No evidence of residential development near the mouth area constraining the mouth position. • Mouth open with a narrow channel leading to sea. • Well scoured channels and wetted perimeter in lower reaches may indicate a recent breaching. • Dark areas in inlet channel may be bedrock showing through, but could also be shadows from a deep channel. • Water level very low with exposed sand banks up side of present causeway visible indicating that even with a breaching over rocky sill the estuary still drained significantly (i.e. rocky sill to not obstruct outflow as much previously assumed) • Farmland visible between Swart and Seekoei tributaries, as well as upper reaches of both tributaries • Algoa Dune Strandveld cordon along coast mostly vegetated (80%) • Crossings upstream of the Seekoei tributary (1.8 kms)

1961 image	 • Mouth closed. • Water level very low and relatively large areas of saltmarsh visible Large area at mouth appears to be salt marsh (currently sand banks). • Sand banks near house on bend also salt marsh (now under water). • No residential development. • Algoa Dune and Strandveld dune cordon not developed. • Farmlands in catchment.
1968	• Weir built on top of the rocky sill at the original mouth position
1969	• Construction of a protective embankment and car park at the mouth
1973	• Construction of the swimming pool at the mouth • Construction of the causeway 700 m from the mouth. This was done privately by residents. This was built to prevent complete drainage of the estuary that occurred due to a shift in the mouth southwards because of the car park/swimming pool complex construction
1975 image	• Mouth closed • Residential development in the lower reaches either side of the estuary • Dune cordon on Paradise Beach side developed
1981	• Causeway repaired and raised after flood damage in 1976 and 1979
1986 image	• Mouth closed
2000	• Back-flooding resulted in artificial breaching to allow connectivity between Aston Bay and Paradise Beach

2014	• Strong winds and high water level in the estuary damaged the causeway and collapsed culverts • Flash floods breach the estuary in December 2015 and stays open until March/April 2015 when it closed naturally
2015	• April 2015 residents began breaching the mouth artificially due to high water level in the estuary • Upgrading of the causeway. The estuary was breached prior to upgrading and reduce water level in the estuary to assist with construction work.
2017	• High water level in the estuary and residents breach the mouth artificially

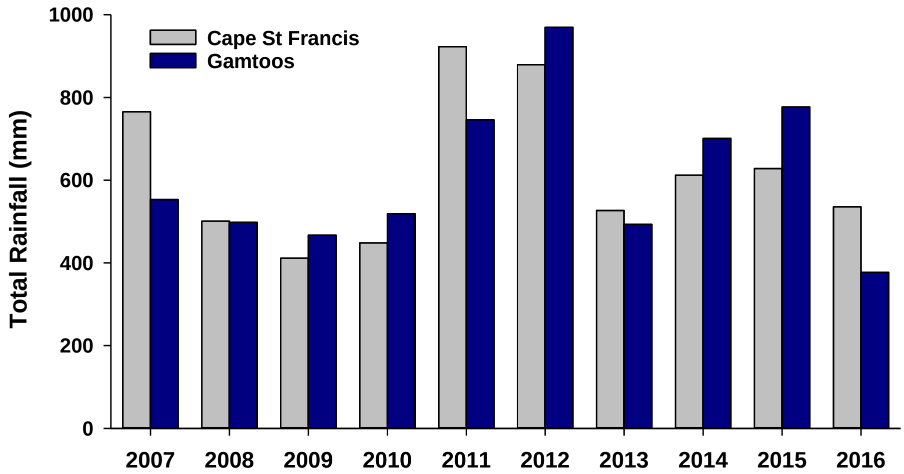

Figure 6 **Rainfall (mm) recorded at the Gamtoos River Mouth Resort and Cape St. Francis weather station, 2007 – 2016. The data show high variability between years, following the pattern typical of dry climates in general. Although the total rainfall per year differs from that recorded at Seekoei, variability will be similar. Gamtoos data from Wooldridge, unpublished; Cape St. Francis data from SA Weather Service.**

Because of the high variability between years (refer to Figure 6), damming/freshwater abstraction can have a critical influence on the structure, natural functioning and evolutionary pathway of the estuary, particularly during dry phases (Whitfield and Bruton 1989). Abstraction schemes impact an estuary in different ways, including:

- Dams reduce the scouring ability of river floods on the estuary (DWAF 2006b, Reddering 1988). This usually takes the form of increased shoaling in the lower estuary. Tidal exchange between the estuary and sea then gradually reduces and sediment buildup occurs since it is not effectively scoured from the estuary basin compared to similar floods under the natural state. Overall, water volume in the estuary reduces as the system becomes shallower.
- A second major and negative impact of freshwater abstraction from rivers is the reduction in base flows (normal river flow volumes between floods) (DWAF 2006b). The mouth of an estuary will therefore close more frequently and for longer. If evaporation from the estuary

water body exceeds freshwater inflow from the rivers, hypersaline conditions can develop (salinity exceeds 35 which is the salinity of seawater). The net effect on the broad mix of biotic organisms (Freshwater associated species, typical estuarine species and seawater associated species) is that biodiversity is reduced since some of them will not survive in seawater. Hypersalinity can be particularly severe in TOCEs and salinity can quickly rise to critical levels. This was well-demonstrated by Whitfield and Bruton (1989) when salinity in the Seekoei Estuary value exceeded 90. Approximately 6000 individual fish of 11 species were killed. Although Whitfield and Bruton (1989) only reported on fish mortality, many of the other species present in the estuary would have been impacted in the same way. For example, a major die-back of *Ruppia cirrhosa* occurred during the 1989 drought after salinity attained a level of 90 (DWAF 2006b). Mobile species such as birds probably moved away from the estuary if prevailing conditions and food supply was wiped out. The incidence of biotic die-backs due to hypersaline events continues to impact the estuary, the most recent occasion being at the end of summer 2016/17 when a fish and invertebrate kill occurred. Salinity on this occasion exceeded 50 – refer to Table 10.

- A reduction in base flow will affect inlet dynamics, as the tidal inlet will close more frequently and remain closed for longer periods compared to the natural state. This will further exacerbate salinity shifts towards hypersalinity and potential die-off of the biota in the estuary. Whitfield and Bruton (1989) also state that marine species trapped in TOCE's will decline in abundance during periods of prolonged mouth closure.
- Estuarine water flowing out to sea on an ebb tide forms a plume off the estuary mouth (Figure 7). This provides a cue for migrating fish that move into estuarine environments (Whitfield and Bruton 1989). Many of these fish are juveniles and require an obligatory estuarine phase during their respective life cycles. Thus, a reduction in plume size will reduce migratory success and ultimately, fewer fish reaching adulthood.

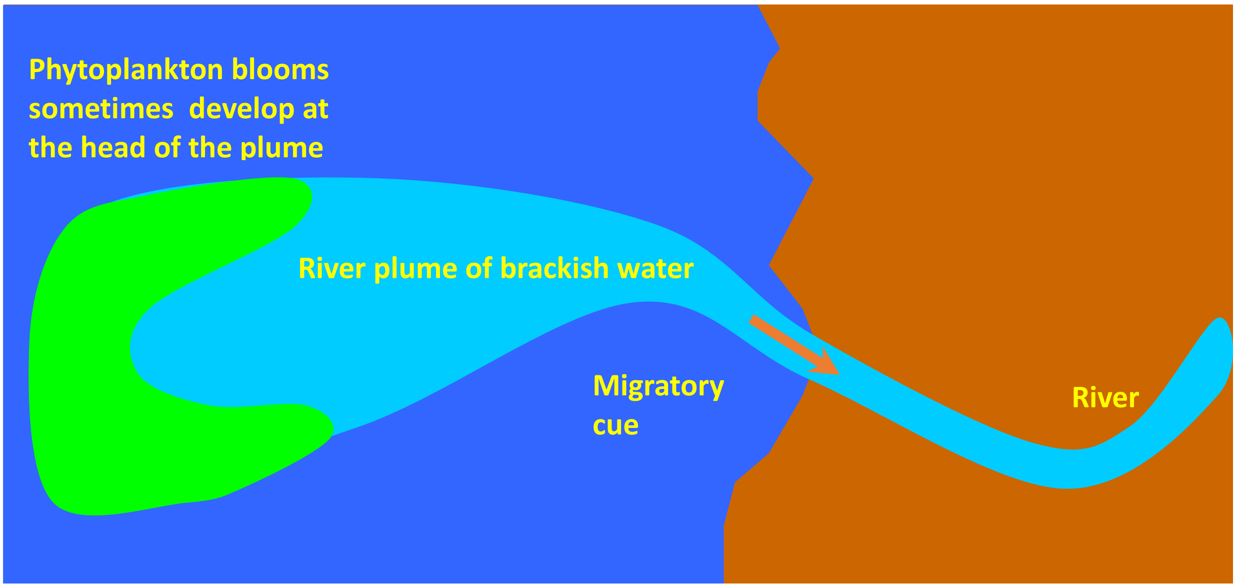

Figure 7 **Diagrammatic representation of a plume of estuary water having lowered salinity compared to seawater. The plume provides a cue to aid migration for fish utilizing estuaries.**

Invasive alien plants such as *Acacia mearnsii* (Black Wattle), *Acacia cyclops* (Rooiikrans) or species of *Eucalyptus* among others use much more water than indigenous trees and plants. Water consumption by these invaders can lead to reduction in river flow, or even the drying up of springs and streams. In the case of the Seekoei, invasive plants (particularly the *Acacia* species) in the relatively small catchment will impact downstream water flow in a meaningful way, further leading to negative impacts on the estuary. The original prediction that invasive plants would have a negative effect on the water yield from catchments formed the basis for the establishment of the very successful Working for Water Programme (Görgens and Van Wilgen 2004).

6.2 Construction of the carpark and swimming pool in the former mouth of the estuary

The original mouth area of the Seekoei Estuary is privately owned (Bickerton & Pierce 1988), and because the land was alienated prior to the proclamation of the Seashore Act of 1935, is exempt from specific provisions in the Act. This allowed for the construction of the swimming pool complex to go ahead.

While during large floods the estuary would have scoured a straight channel (present location) to the sea, it tends to migrate to a more protected, perched position under the low flow condition (WNNR 1990). Thus, the tidal inlet of the Seekoei Estuary was originally predominantly located on the eastern side approximately 350 m to the east of the current stabilized mouth (Plate 4). In its former position, the depth of the inlet was controlled by the underlying slate substrate (Esterhuysen 1982). WNNR (1990) estimates this to be +0.3 m. Bickerton and Pierce (1988) noted some important functions of the rocky sill with respect to its influence on the estuary. Their statements were largely based on the work of (Fromme and Badenhorst 1987):

- The sill acted as a natural barrier with respect to the northward migration of the mouth. Mouth position on the eastern side of the estuary is maintained by longshore currents and sand that predominantly move northwards, stabilizing the position of the mouth channel over the rocky sill. The sill controlled the depth of the mouth channel and the estuary retained a residual volume of water and never drained completely at low tide.
- The original position of the relatively shallow mouth over the sill also limited the influx of sand by tidal transport and the mouth remained open for longer after breaching.
- The presence of the swimming pool complex (Plate 4) forced the mouth southwards away from the shallower section of the sill. This prevented the mouth from migrating to the more constraint position resulting in an increase in the tidal transport of sediment in the estuary

Plate 4 **At the time of this photograph (mid 1980's), the original rubble causeway had been breached and floodwaters eroded a relatively deep and wide channel. The photograph also shows a plume of discoloured estuarine water radiating from the mouth – refer to Figure 7 (Photograph from T Wooldridge).**

Fluctuations in water level and salinity impacted negatively on waterfowl in the estuary whose numbers began to decline significantly. This led to the establishment of the Seekoei River Nature Reserve in 1969 (under Provincial Management), encompassing the northern part of the estuary and triangular piece of land between the Seekoei and Swart Rivers (see Plate 5). The reserve was primarily proclaimed as a sanctuary for waterfowl but was also an attempt to re-establish the once prolific birdlife in the area (Esterhuysen 1982).

Construction of the carpark and then the swimming pool started in 1969. A stone embankment was also constructed on the western side of the carpark to stabilize the position of the estuary mouth. Consequently, the mouth channel was forced westwards and away from the shallower bedrock to the east. Breaking waves and the underlying slate beds can be clearly seen opposite the swimming pool.

In 1991, a decision was taken to build a concrete canal from the north-western corner of the carpark. The canal extended behind the former swimming pool complex to the beach on the eastern side (DWAF 2006b). The purpose was to direct the inlet through the canal stabilize maximum water level in the estuary. However, the canal limited tidal exchange and quickly sanded up after the water level in the estuary had dropped sufficiently. The floor level of the canal was at the average height of spring tide and sanding up of the canal occurred on a regular basis. Attempts to clear the canal were then stopped.

6.3 The construction of the causeway

The construction of the causeway started in 1973 (Bickerton and Pierce 1988) and was originally constructed to trap water behind the barrier to prevent complete drainage of the estuary at low tide. This was an attempt to counter the negative effects caused by the swimming pool complex at the estuary mouth. Building of the causeway was also considered necessary to improve the aesthetic value of the estuary and the development of Aston Bay and Paradise Beach as townships (Esterhuysen 1982). Management issues linked to the causeway and mouth of the estuary have since arisen, and these were acknowledged in the Integrated Development Plan 2017 – 2022, summary of priority development needs in Ward 12.

After the construction of the causeway, the Seekoei Estuary was split in to two separate units that essentially blocked tidal flow to the upper estuary (Plate 4). This significantly reduced tidal flows through the estuary inlet, resulting in premature closure. More recently, alterations were done to improve the connectivity between the two water bodies. While it was originally predicted that the upper estuary would become fresh (Esterhuysen 1982), extensive freshwater abstraction has negated this.

The original causeway was poorly designed using rock and rubble (Esterhuysen 1982) and needed to be repaired on numerous occasions. Unfortunately, repair work and design proved inadequate with respect to the connectivity between the north and south water bodies. Culverts and pipes had a relatively small diameter and only permitted minimum water exchange. A report by Grindley (1976) (unpublished report quoted in Bickerton and Pierce (1988)) identified the isolation of the two water bodies, with a salinity of 27 below the causeway and 7 immediately above the causeway.

Plate 5 View of the Seekoei from mouth to catchment area, demonstrating the separate channel basins at the mouth area. Photograph from T Wooldridge.

The causeway was severely damaged by floods in 1976 and 1979, but local authorities under pressure from residents repaired the causeway to permit a short road link between the two townships. In the 1979 flood, the causeway breached and a 15 metre gap was scoured through the rock and rubble. Tidal exchange was restored with the upper section and the system began to function as an estuary. The water depth through causeway gap was 5.5 m at low tide (Esterhuysen 1982). The causeway was repaired and raised by November 1981, but tidal influence above the causeway was again minimal due to design constraints.

Within a year, the lower estuary was poorly drained and the causeway became the effective tidal head. Thus, the volume of water entering and leaving the estuary was greatly reduced. The system moved along a trajectory of a dysfunctional system as net sand accumulation in the lower basin exceeded sand export. Sediment accumulation through fluvial origin also occurred in the upper basin and in effect, the whole system became progressively shallower. The upper estuary also acted as a sediment trap, with the deposition of fine-grained clay particles and organic material that would consolidate over time and become more difficult to remove by floods (Esterhuysen 1982). Currently, the sediment-trap effect caused by the causeway has resulted in the upper estuary becoming shallower. Water damming up against the causeway because of too small culverts, also caused damage to adjacent lands roads and property. WNNR (1990) indicate a +.8 m increase in flood level in a 1:50 year event because of the causeway obstructing outflows.

The causeway effectively acts as a barrier to floods, thus reducing scouring potential and cause upstream sediment deposition Similarly, during breaching the causeway reduces scouring potential, thus compounding the effects of artificial breaching. The causeway also restricts the movement of marine sediment into the middle and upper reaches, thus overtime the system will have a very sharp break in sediment types, i.e. sandy marine sediment in the lower reaches and fine clays in the middle and upper reaches.

Since construction, the causeway has been damaged by floods or seawater overwashing the berm numerous times (reports collated by Hennie Swanevelder of the Department of Environmental Affairs and Forestry). The most recent damage was caused by flooding in 2012, leading to closure of the causeway in early 2013 for 3-months when extensive structural repair work to the causeway was undertaken. Throughout its history, repair-work to the causeway and/or raising the height of the roadway resulted in temporary solutions only and problems continually recur. Traffic using the causeway is relatively heavy and, on the increase (Our Times, 17 June 2005). Heavy transport vehicles delivering building materials also cross the causeway on a regular basis. However, frequent highwater levels and strong winds result in vehicles receiving a good spray of salt water (refer to Plate 10) if the road is not closed to traffic. This situation has led to illegal mouth breachings to artificially lower water levels behind the berm.

Numerous reports aimed at finding solutions to ongoing management problems in the Seekoei Estuary are available. These reports span nearly fifty years, highlighting ongoing issues that remain unresolved. Earlier reports are cited in the Situation Assessment document, but the following more recent reports are briefly summarized and are appended at the end of this document.

A report by Consulting Engineers Ninham Shand (Ninham Shand 1991) submitted to Algoa Regional Services Council focused on the concrete outflow canal. The report suggested that the water level in the estuary be maintained at +0.9 m MSL and that this level should also be applied to the floor level of the concrete drainage canal constructed immediately north of the carpark and swimming pool complex. Although the drainage canal provided an outlet for smaller floods (without breaching the mouth sandbar), it did not cater for natural estuary-marine water exchange. Natural salinity patterns could therefore not develop in the estuary. However, the report suggested that seawater could be pumped in to the estuary to raise salinity levels, but this would require a large pumping system. When necessary, the canal could also be artificially blocked and the water level in the estuary increased before a more natural breaching event took place. This would result in better scour and water exchange with the sea. However, water levels in the estuary would then probably impact the causeway and lead to problems currently experienced, particularly under windy conditions.

Undesirable low water levels in the estuary could also be managed, either through the pumping of seawater in to the estuary or through river inflow. However, low water levels in the estuary are often linked to reduced or no freshwater inflow from the catchment (freshwater also retained by dams etc. – refer to Section 6.1). Evaporation rates in the estuary are high and salinity threshold levels in the estuary could rapidly become lethal to the biota. The addition of more seawater would mean that salinity levels would continue to remain at high levels.

In July 2013, Environmental Assessment Practitioner Francis Silberbauer of Jeffreys Bay prepared a report outlining the necessary procedure to artificially breach the estuary mouth. The plan was to drop the water level in the estuary by 600 mm to effect repair work to existing culverts under the causeway. The outcome improved water exchange between north and south water bodies, although on the scale of the estuary, they would probably be insufficient to effect healthy water exchange, especially under conditions of strong water flow.

A report in August 2017 by Civil and Structural Engineer A le Roux, first documents a brief history of the causeway, including numerous problems linked to freshwater supply to the estuary and sand deposition in the lower estuary. When Paradise Beach joined the Jeffreys Bay Municipality (following disbanding of the Algoa Regional Services Council), one of the conditions was that the causeway be up-graded and solutions be found regarding high water levels in the estuary. The report mentions that the problem of high water levels affecting the causeway was caused by the changed position of the mouth following construction of the swimming pool complex and carpark. This led to the suggestion that the mouth be allowed to follow its natural course over the rocky sill to the east (refer to Section 6.2). Unfortunately, the solution is not as simple as suggested from an ecological point of view. Temporary open/closed estuaries function differently when compared to permanent open systems. TOCE's are driven by the complex interaction of floods, freshwater baseflow (including temporal flow patterns), freshwater abstraction in the river catchment, berm development because of wave action and longshore sand movement, wind direction and strength, and water levels in the estuary prior to a breaching event. Effectively, scouring efficiency is significantly reduced when the estuary is artificially breached at a lower level compared to natural. Sediment build-up also increases over time when artificial breaching is implemented, contributing to other negative issues. The report also suggests that there is no evidence that the ecology of the Seekoei estuary is compromised by the causeway – this is incorrect (refer to salinity issues etc. in this report). However, the report does make a very important statement in that the ideal outcome would centre on the removal of the causeway, parking area and community hall and that new bridges be built over the Seekoei and Swart tributaries.

6.4 Artificial breaching of the estuary mouth

Any breaching of an estuary mouth should occur naturally, although circumstances sometimes prescribe that a mouth needs to be breached artificially (CSIR 2017). Advantages for a natural breaching are numerous and the following section is a broad summary of key issues relevant to the Seekoei (CSIR 2017):

- Natural breaching of a Temporarily Open/Closed Estuary (TOCE) provides the natural variation and timing of the open phase that enables the estuary to play an optimal role with respect to important estuarine functions. The seasonal utilization of the estuary as a nursery for juvenile fish is an example.
- Natural breaching of TOCE enables the water level in the estuary to reach the highest level possible before the mouth opens. The higher the water level, the greater the amount of accumulated sediment flushed from the system. The potential flushing of sediments increases exponentially with the increase in outflow velocity and duration. Along the South African coastline, breaching of an estuary mouth usually occurs when water level in the estuary reaches +2.5 to +3.5 m MSL. When breaching persistently occurs at lower levels, less sediment is removed on each occasion and likely to result in increased sedimentation over time. Ultimately, the mouth closes prematurely and flood risks increase.

- Salinity levels in a TOCE will naturally respond to variable inputs of river and marine water. If the estuary mouth is opened artificially and outside its natural cycle, the salinity shift in the estuary may have negative biotic consequences.
- From a fish perspective, breaching events should occur between October and April (warmer months). This enables the estuary to fulfil a major ecological role as a nursery area for numerous marine fish species that require an obligatory estuarine phase of development during their respective life cycles in summer. Migration of juvenile fish into the estuary is only possible if an estuary mouth is open.
- Along the South African coastline high waves generally occur in winter. Under high wave conditions, mouth closure occurs more rapidly. These high waves also lead to an excessive influx of sediment in to the estuary if the mouth is open at the time.
- Salt marsh vegetation in TOCE's should not be inundated by water for too long, especially during the warmer months. Germination of seeds for example, will be compromised by high water levels.
- Water quality problems are more likely to occur under closed mouth conditions. If the mouth is closed in summer when water temperatures are relatively high, pollution becomes more of an issue especially if the estuary is used for recreational purposes.

6.5 Supplementary information on the current state of the Seekoei mouth

Anecdotal reflections suggest that the Seekoei Estuary mouth remained open for long periods under natural conditions. However, historical aerials photographs and the low natural runoff into this system indicate that is was not likely to be permanently open mouth. Thus, it is not possible to state with certainty that the estuary remained mostly open or even permanently open (DWAF 2006b). It should also be noted that while artificial breaching and manipulation of the inlet position have contributed to ongoing siltation and a reduction in open mouth periods, the major causes of estuary degradation are the bisecting of the estuary by the causeway and severe baseflow reduction.

In more recent times, mouth observations by Mr G Ferreira of the Eastern Cape Nature Conservation Department indicated that the mouth breached six times between June 1995 and January 1996, but only remained open for 3 – 16 days at a time. Of the six counts the mouth opened between June 1995 and January 1996, four events were due to artificial breaching events (Department of Economic Affairs, Environment and Tourism. Directorate Environmental Affairs. Letter dated 21 February 2000 and submitted by Mr Ferreira to Marius Rossouw, CSIR, Stellenbosch). Between 1996 and January 2005, observations show that the estuary sometimes remained open for months at a time (up to 17 months on one occasion). Although heavy rains and runoff were mainly responsible for mouth opening, observations indicate than occasionally, the mouth remained open under low or no river inflow conditions.

Data from a continuous water level recorder (DWS K9h009) in the Seekoei Estuary from 2003 to 2013 (Figure 8 and Figure) show tidal variations at times for more than a year, such as from Jan 2003 to May 2004 and June 2011 to April 2014. In contrast there is the period from Jan 2009 till June 2011 when you don't see any tidal action. This is likely due to the severe drought experienced in the region during that period. The spikes on the graphs in this period is likely caused by wave and wind effects. Increases in water levels may be caused by river inflow, but can also be caused by overwash of the berm by waves. Dropping of water levels could be by outflows and/or by evaporation.

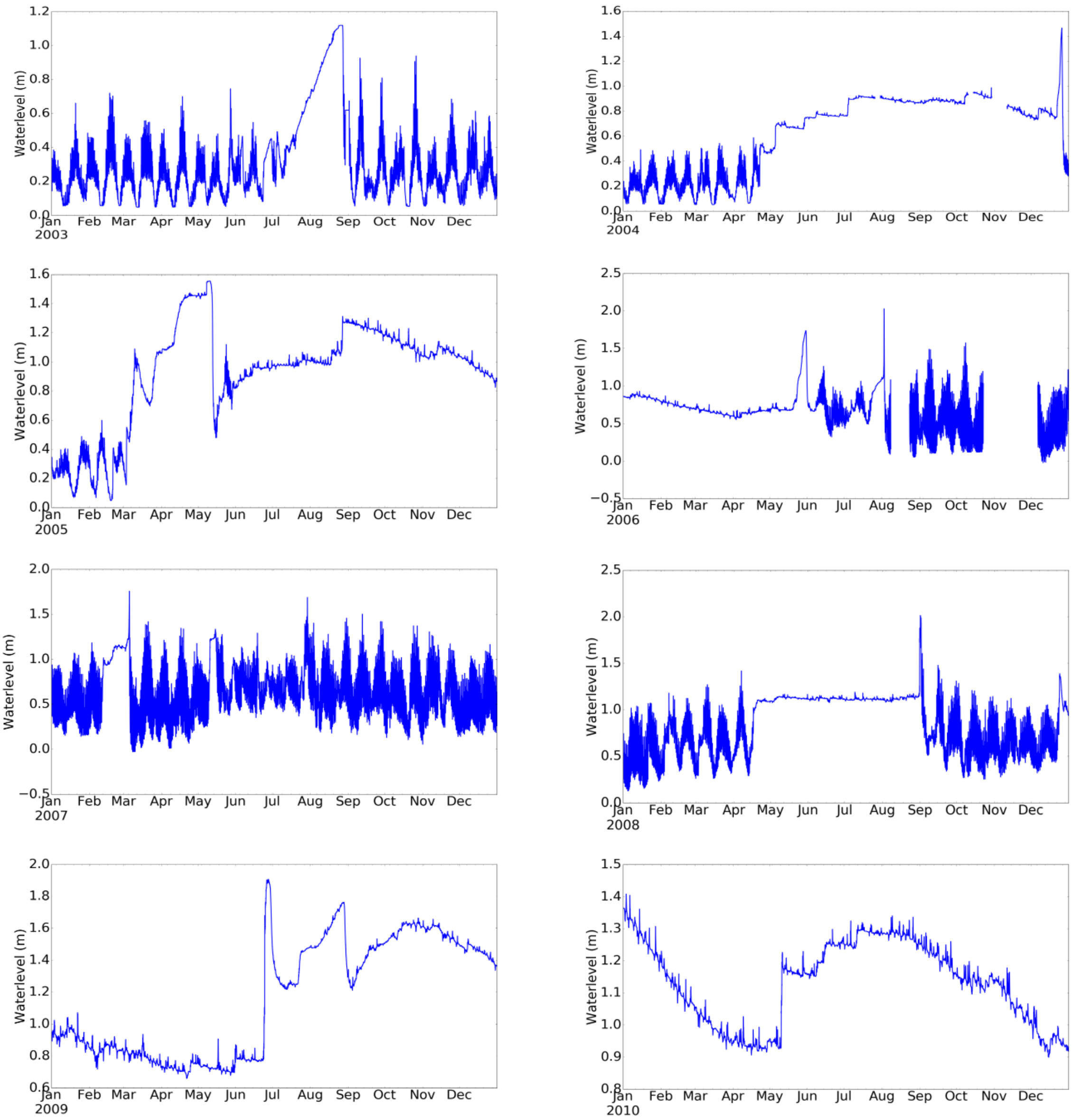

Figure 8 Seekoei Estuary water level recordings for DWS gauge K9h009 from 2003 to 2010.

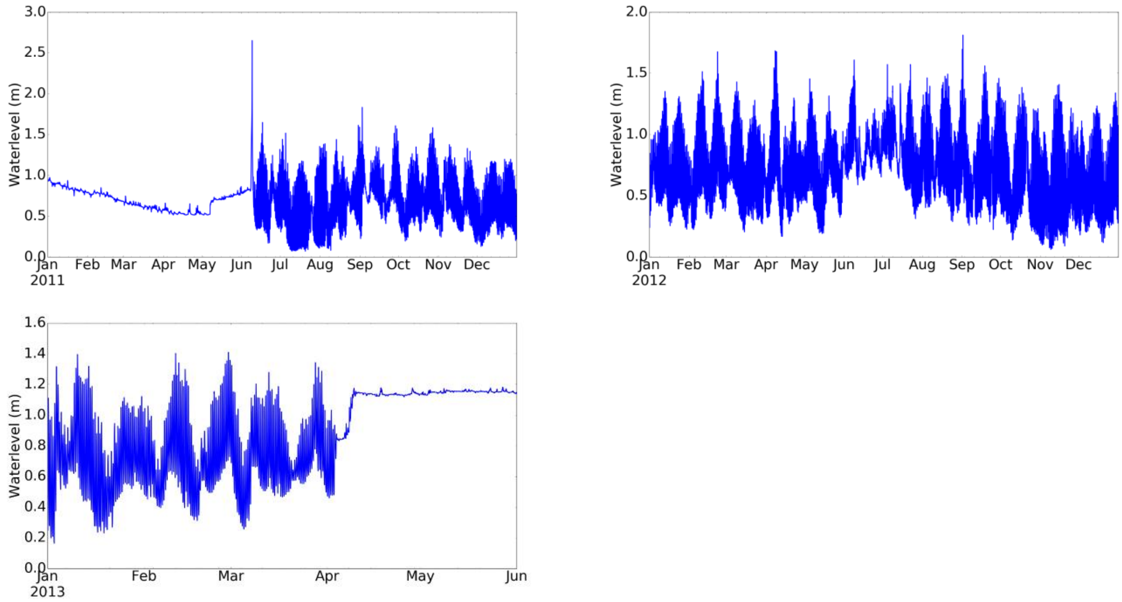

Figure 9 Seekoei Estuary water level recordings for DWS gauge K9h009 from 2011 to 2013.

DWAF (2006b) after studying the few water level recordings available concluded that the estuary filled up over spring tides and emptied over neaps. This was a dynamic process, but generally effective in keeping the mouth open. However, obstruction to tidal flows such as the presence of the concrete canal and the causeway across the estuary probably had a negative influence on mouth dynamics, contributing to mouth closure.

In summary, DWAF (2006b) describe mouth dynamics of the Seekoei Estuary over time as follows:

Although the mouth remained open for long periods, the estuary moved along a trajectory of more frequent closure events. At present the mouth remains open for short period only, unless a strong river flow was maintained. After improvements to the causeway in 2012-2013, the mouth again remained open for longer when connectivity between the upper and lower estuary was improved allowing for the backup of water behind the causeway on the high tide and therefore increasing the outflow on the low tide.

Four possible reasons may be responsible for the reduction in open mouth conditions in recent years:

- Progressive reduction in river runoff to the estuary because of farm dam developments and irrigation in the catchment. In February 2002, Mr G Ferreira (Chief Nature Conservator, Department of Economic Affairs, Environment and Tourism. Directorate Environmental Affairs. Letter dated 21 February 2000 and submitted to Marius Rossouw, CSIR, Stellenbosch,) estimated at the time of this report that there were at least 25 dams at the time of various sizes in the catchment.
- Obstruction to tidal flows because of the construction of the causeway before connectivity between the north and south sides improved.
- Obstructions to tidal flows caused by the concrete canal.

- Artificial mouth breaching at levels too low for effective scouring of sediments – usually at about +0.9 m MSL rather than +2.0 to +2.5 m MSL. The height of +0.9 m MSL was necessary to avoid damage to low-lying properties and overtopping of the causeway.

6.6 Recent surveys on the height of the berm

Since 2010, a series of field surveys undertaken by Maarschalk & Partners Inc. recorded berm-height at 10 fixed points along a transect between two base stations on either side of the berm (Table 6). These surveys were undertaken monthly on behalf of the Kouga Municipality. The data show that the average height of the berm separating the estuary and nearshore has flatted out to a much lower level compared to 2010 and at the time of the final survey in 2015, berm height averaged +1.59 m MSL (Figure 10). Sample size was not identical each year and no surveys were undertaken in 2012, but a sequential trend of a diminishing height of the berm emerges.

Table 6 The number of readings to determine average berm height (Sample size) done each year between 2010 and 2015 inclusive. Maximum number of readings would be 120 if a survey of the 10 fixed points across the berm (East – West) was done every month.

Year	Sample Size
2010	20
2011	20
2012	Nil
2013	50
2014	120
2015	80

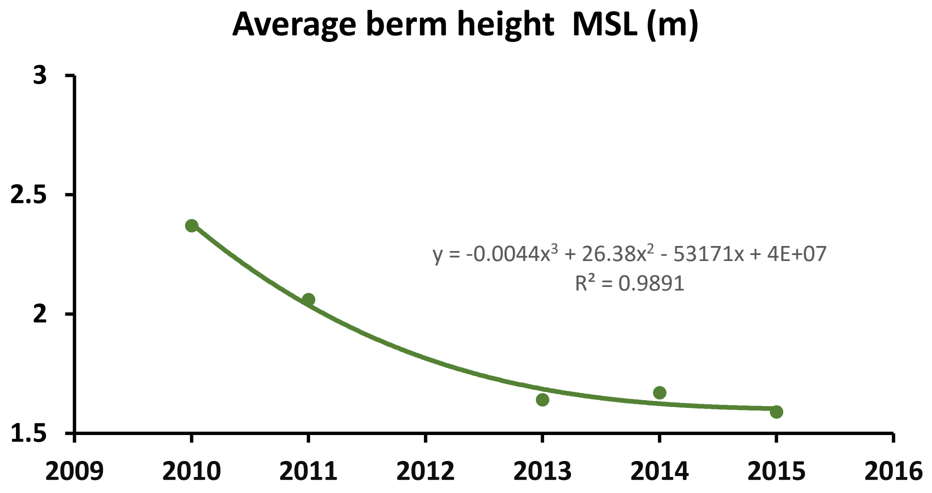

Figure 10 Average berm height (m) above MSL across the mouth of the Seekoei Estuary between 2010 and 2015 inclusive. Fixed points were measured monthly between two base stations as set out in Table 6.

The low berm height was still evident in June to August 2017 (Plates 6 and 7). Information suggests that overtopping of the berm by wave action occurs under storm conditions, particularly if they coincide with spring tides. Numerous records are available indicating flattening of the berm by wave action is intermittent, linked to storm events. The photograph below (Plate 6) was taken on the 24rd June at approximately 1 pm and two days after New Moon. At the time, no riverine input to the estuary was evident. Water volume in the estuary was probably maintained at the observed high level by berm over-wash of seawater.

Salinity at the time was 46 immediately above the causeway. Hypersalinity has persisted throughout 2017. In March 2017, another fish kill was reported (Renzo Perissinotto of the Nelson Mandela University, pers. com.), with many dead fish and invertebrates washed up around the edge of the estuary.

A further overtopping of the berm occurred on the 24th August 2017. The event happened shortly after spring tides. A major storm swept across the south coast at the time (Plates 6 – 10). Plate 11 further illustrates the danger of crossing the causeway when covered, even when water depth is just a few centimetres.

Plate 6 The flattened berm is clear in the photograph above. The photo was taken during the spring tide cycle and three hours before the peak of high tide on 24th June 2017.

Plate 7 Large volumes of sand were transported on the high tide into the estuary on the 24 and 25th August 2017. Photo by Hennie Swanevelder – Department of Economic Development and Environmental Affairs.

Plate 8 **Berm overwash occurred around high tide on 24 August 2017. The estuary was rapidly filled, with the tide also overwashing the causeway. Depth of the water across the berm peaked at about 40 – 50 cms. During such events, large quantities of marine sand are deposited in the estuary. Photograph from Hennie Swanevelder – Department of Economic Development and Environmental Affairs.**

Plate 9 **Berm overwash shown in Plate 8 deposited large quantities of flotsam on the Aston Bay road running parallel to the estuary. Photograph from Hennie Swanevelder – Department of Economic Development and Environmental Affairs.**

Plate 10 **Berm overwash shown in Plate 8 resulted in the causeway overtopping with seawater. Zero freshwater inflow to the estuary occurred around this time, so that salinity levels in the estuary would remain at 35 or higher. High rates of evaporation would rapidly result in hypersaline conditions developing in the estuary as the estuary closed again within 48 hrs. Photograph from Hennie Swanevelder – Department of Economic Development and Environmental Affairs.**

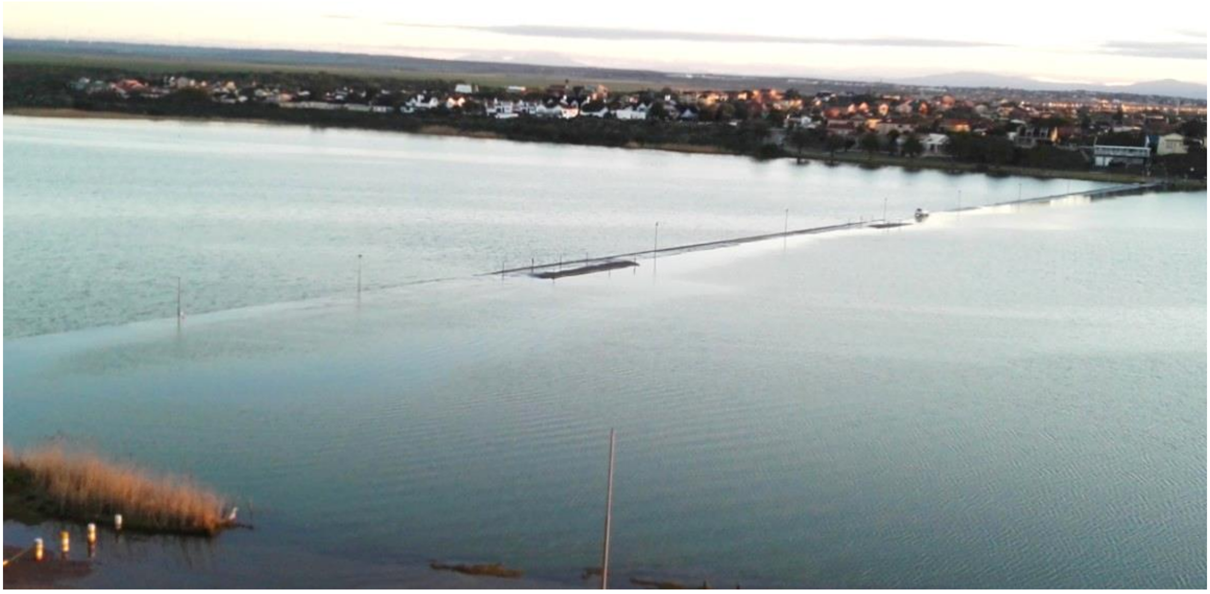

Plate 11 Overtopping of the berm causes significant damage to vehicles (electrical issues included) and puts life at risk (vehicles sliding off the causeway, pedestrians crossing on foot), particularly under windy conditions. Both photos demonstrate the undulatory nature of the roadway.

6.7 Present Ecological Status

In 2006, an Ecological Water Reserve Study (EWR) was prepared by Coastal and Environmental Services on the Seekoei Estuary for the DWAF (2006a). Ecological Reserve Studies follow set national protocols and are now a legal requirement under the new Water Act of 2008. In the case of Estuarine Reserve Studies, the following identified categories are scored - hydrology, hydrodynamics, mouth condition, water quality, physical habitat alteration and five biotic components (microalgae, macroalgae, invertebrates, fish and birds). The evaluation of these components is undertaken by a team of specialists who allocate scores to each component after thorough evaluation of available knowledge.

The results from this study concluded that the Estuary Health Index (EHI) score allocated to the Seekoei Estuary was an overall score of 42 (Table 7). It is important to note that the score determined for the Habitat Health was 50, whereas the biological health score was 35. This suggests that the Seekoei Estuary is on a trajectory of change to Category E (refer to Table 7). The overall EIH score of 42 equates to a Category D or a largely modified system (Table 8). This puts the Seekoei Estuary in a critical situation and urgent management intervention is required to prevent further deterioration in the health of the estuary. There are approximately 157 estuaries in the Temperate Biogeographical region of South Africa (Orange River to Mbashe Estuary), but only 22 of them are rated lower than a 'C' Category (Van Niekerk et al. 2015). Seekoei is rated as an 'Important' estuary (Category 4 system), and this underlines the need for improved management practice.

Table 7 The Estuarine Health Index scores allocated to different components of the Seekoei Estuary under present-day conditions. Note that a Habitat Health Score and Biotic Health Score are determined separately. The average of the two provides the overall Health score and category shown in Table 7.

	Weight	Score	Weighted Score
Hydrology	25	58	14
Hydrodynamics and mouth condition	25	40	10
Water Quality	25	40	12
Physical Habitat Alteration	25	61	15
Habitat Health Score			**50**
Microalgae	20	35	7
Macrophytes	20	35	7
Invertebrates	20	30	6
Fish	20	35	7
Birds	20	40	8
Biotic Health Score			**35**
Estuarine Health Score			**42**

Table 8 Estuarine Health Index Scores define the Ecological Management category. The lower the EHI Score, the more degraded the estuary. In the case of the Seekoei, modifications largely responsible for the Category D status are noted in Section 6.8.

EHI Score	Present Ecological Status	General Description
91 – 100	A	Unmodified, natural
76 – 90	B	Largely natural with few modifications
61 – 75	C	Moderately Modified
41 – 60	**D**	**Largely Modified**
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

The Present Ecological Status of the Seekoei Estuary with respect to the non-biological attributes are summarized above (Table 9). Data extracted from the Rapid Reserve Study determined for the estuary in 2006 (DWAF 2006b).

Table 9 Summarized information on key abiotic variables that impact the structure and functioning of the Seekoei Estuary. Note that the data presented relates to information available in 2006, although data suggests further deterioration in recent years (refer to Section 6.1). The hydrological information is fundamental to our understanding of how the estuary functioned under the Natural State. Present state can then be compared to our understanding of the Natural State and allows scientists to gauge how other variables (e.g. changes in mouth behaviour, saltmarsh plant response etc.) are likely to change. Hydrological information is generated from simulated runoff data over 73 years (DWA 2010)

Variable	Comment
Mean Annual Runoff from the catchment (MAR)	The natural MAR from the Seekoei catchment is estimated to be 20.27 x 10^6 m^3. Under the present state, this is now reduced to 11.36 x 10^6 m^3. Thus, 56% of the natural MAR still reaches the estuary. Major floods (flow rates exceed 10 x 10^6 m^3 sec) still reach the estuary, but their frequency is now reduced to about 16 times over the 73-year period. The natural frequency of floods was estimated to be about 26 times over the same period – a reduction of 40%. Small to medium floods reduced in amplitude because of dam retention in the catchment. Note that a recent assessment of river runoff to the estuary has probably declined further and currently it is estimated that storage capacity of dams in the catchment equals or exceeds Mean Annual Runoff (Section 6.1).
Freshwater inflow and Mouth State	Annual river flows above 3 x 10^6 m^3 of water will result in the mouth remaining mostly open. During years when river flow falls below 3 x10^6 m^3 of water, the estuary will remain mainly closed. The dams present in the Seekoei and Swart catchments mostly reduce pulses of freshwater following local rainfall. The extent of the reduction is dependent on the size of the farm dams.
Mouth Breaching	The mouth of the Seekoei Estuary will naturally breach at water levels between +2.0 and +2.5 m MSL.

Variable	Comment
Volumes required	The minimum annual volume of water required is 3.0 million m^3 of water. This is because the estuary requires 2.0 – 2.5 million m3 of freshwater water to reach its breaching level and 0.892 million m3 of water to counter annual evaporative loss from the estuary water body
Tidal amplitude	Tidal range in the estuary could typically range between 0 m around neaps, to 0.5 m around spring tide. Because the estuary tends to fill around spring tides and empty around neaps, water levels can vary up to 0.3 m.
Water retention times	Water retention times will be greater above the causeway, especially around neaps. Retention time of the water mass below the causeway will be much shorter - typically 1 – 2 tidal cycles around springs.
Salinity distribution in the estuary	During years when the mouth remains mostly open, salinity in the estuary will range between saline (35) and hypersaline (>35) to a state where a strong salinity gradient to fresh exists (0 – 35). This equates to a median monthly freshwater inflow rate of >0.5 million m^3 of water when the salinity gradient in the estuary ranges from a strong salinity gradient to fresh. Below a median monthly freshwater flowrate of 0.5 million m^3, conditions in the estuary will be saline to hypersaline (>35).
Flood plain inundation	If water levels behind the berm approach+ 2 to + 2.5 m MSL, extensive flooding of the surrounding floodplain will occur.
Present flood regime	Farm dams present in the Seekoei and Swart catchments mostly retain freshwater pulses and small to medium floods. Major floods still pass through the system (>10 x 10^6 m^3), although their effect might be reduced.
Siltation	Because of present land use in the catchment, siltation of the estuary occurs, especially above the causeway (fine sediments). The causeway has also fixed and reduced the dynamic nature of channel configuration in the lower estuary. Because of low breaching levels (+0.9 m MSL) and reduced scouring effects at these breaching levels, ongoing sediment build-up in the lower estuary has probably occurred.

6.8 Freshwater baseflow levels

Confidence in the hydrological data applied to the Seekoei Estuary Reserve Study was at a relatively low level because of limited runoff information available. However, the Reserve Study determined that about 56% of the Mean Annual Runoff of the natural is estimated to reach the estuary (DWAF 2006b). Major floods (flow rates exceed 10 x 10^6 m^3 sec) still reach the estuary, although their frequency is estimated to be reduced to 60% compared to the natural state. This equates to about 16 major floods over a 73- year period, compared to 26 major floods under natural conditions.

Information on base-flows (and related salinity levels in the estuary) was not historically captured (DWAF 2006b). However, scattered information over recent decades on salinity levels ae available. These are captured in Table 10. In recent years water abstraction has reduced base-flow levels further, to the extent that these flows cease for months on end, especially during drought periods (see Section 6.1). Evidence supporting this conclusion is summarized below.

Table 10 Little abiotic data are available on the Seekoei Estuary, but the following information suggests that salinity fluctuates widely, depending on river runoff.

Date	Salinity	Remarks	Reference
August 1976	7 above causeway 27 below causeway	Mouth closed. Also refer to Section 6	Grindley (1976).
November 1984	26 – 27 throughout	Mouth closed. Four sites sampled of which three above the causeway.	Bickerton & Pierce (1988).
April 1989	98 above causeway 47 – 50 below causeway	No freshwater entering the estuary. Drought conditions and mouth closed. Any flow retained by dams Seepage through the bar - tidal fluctuations observed below causeway.	Whitfield & Bruton (1989) J.S.V. Reddering – quoted in Whitfield & Bruton (1989)
Winter 1995	8 at surface, 10 measured near-bottom	Estuary Water Quality Survey	CSIR catchment and Coastal Environmental programme. No specific date provided, but survey started in June 1995. Water temperature of 15^{O}C suggests a winter reading.
February 2004	34.9 at the mouth 36 at the causeway 39 – 42 in the Swart & Seekoei tributaries respectively	Mouth open Mouth open Mouth open	Van Niekerk & Huizinga – reported in: DWAF (2006b)
July 2004	35 - 39	Mouth closed	Bezuidenhout (2011)
October 2014	35 - 36	?	Bezuidenhout (2011)
January 2015	7 - 23	Flood – mouth open	Bezuidenhout (2011)
March 2017	Average 52.3	Major fish kill observed	R. Perissinotto pers communication
July 2017 – August 2017	40 - 46 above the causeway	Overtopping of the sandbar – refer to Plates 6 - 8.	Field observations (T. H. Wooldridge) and data supplied by H. Swanevelder
January 2018	55 immediately above the causeway and 43 below causeway	Mouth closed, water level relatively low.	Field observations (T.H. Wooldridge)

6.9 Sedimentation from the catchment

Sedimentation from the catchment is an issue in the Seekoei estuary (refer to Plate 5). Fine sediments brought down by the two tributaries becomes trapped behind the causeway because of the damming effect (WNNR 1990). Over time, these sediments consolidate and they become more difficult to remove during floods. General observations suggest that the floor-level above the causeway is higher on the northern side compared to the south side. This situation will be exacerbated by:

- Farming activities in the catchment, including crop growing and animal husbandry.
- Clearing of natural vegetation from the riparian zone.
- Increased frequency and duration of mouth closure.
- Inability for tidal flows to remove turbid water and unconsolidated sediments above the causeway.

6.10 Water Quality

With respect to water quality, the main threat to the estuary is likely to centre on agricultural return flows. Much of the catchment is modified with different forms of agricultural practices, potentially leading to elevated nutrient levels and other chemicals that enter the estuary when river flows are sufficient. However, little data are available to assess the potential threat from negative water quality issues. A new and on-going study by a student from Nelson Mandela University has recently collected nutrient data. Thus far in 2017, the measured levels of soluble reactive phosphorus (SRP, 0.27 – 0.62 µg L^-), ammonium (NH_4^+, 0.0 – 3.3 µg L^-) and total oxidised nitrogen (TOxN, 0.0 – 0.15 µg L^-) (unpublished data, R. Perissinotto) are typical of most estuaries in the South-eastern Cape region and are at levels that indicate that the system is oligotrophic. As the Seekoei is a very shallow, wind-driven system most of the nutrient cycling is benthic (coming from the sediments), with very little coming directly from the catchment during low flow periods, especially with most of the freshwater runoff captured by upstream dams and weirs.

Another possible impact on water quality, coming from catchment activities, is heavy metal inputs. A trace metal survey undertaken by Watling and Watling (1983) of St Francis Bay revealed no evidence of trace metals near the Seekoei Estuary.

There are very few studies, other than the estuarine reserve determination (DWAF 2006b) for the Seekoei Estuary that specifically consider water quality variables.

6.11 Macrophyte vegetation

Available literature on the vegetation of the Seekoei Estuary was sourced from Bickerton and Pierce (1988), Bezuidenhout (2011)and DWAF (2006b). This together with present day ground truthing formed the basis of the vegetation status and changes over time for the Seekoei Estuary. Catchment information was obtained from the 2015 South African Land Cover database (http://bgisbeta.sanbi.org/Projects/Detail/44).

During the 1988 mapping (Figure 11) the mouth of the estuary was closed and the water level was high. Bickerton and Pierce (1988) report that there was a winter dieback of seasonal macrophytes, especially under high water and flooded conditions, which resulted in the decay of submerged vegetation and release of nutrients. This in turn promoted the growth of the green macroalga *Entermorpha* sp. These authors reported dense beds of *Zostera capensis* in the shallow creeks. No *Potamogeton pectinatus* was found due to increased salinity since the construction of the causeway. It is assumed that this species was present prior to the causeway construction. *Potamogeton pectinatus* prefers 2 to 15 salinity, whereas *Zostera capensis* prefers 15 to 35 (Whitfield and Bate 2007). As salinity increases *Potamogeton* is replaced by *Zostera*. Although not found growing, the authors did find evidence of *Ruppia spiralis* (*cirrhosa*) washed up on the shoreline as wrack. Bickerton and Pierce (1988) mapped isolated patches of *Phragmites australis* occur at freshwater seepage areas. This species can be found where estuarine water salinity can reach 30 as long as the roots are in freshwater (Whitfield and Bate 2007). This species also shows a natural seasonal winter die back and if water level increases during the autumn period when nutrients are remobilised for spring growth then it can have a negative impact (Whitfield and Bate 2007). *Paspalidium obtusifolium* was also found on the floodplain. This is an introduced aquatic/semi-aquatic plant. Other floodplain species that were found were *Stenotaphrum secundatum, Cynodon dactylon, Sporobolus virginicus*, *Sarcocornia natalensis* and *Juncus krausii*. According to Bickerton and Pierce (1988) the causeway permanently raised the water level in the upper estuary and destroyed the natural intertidal and supratidal environment resulting in a large reduction in the area covered by salt marsh vegetation.

During the time of the 1988 survey, salinity was 26 to 27. In 1976 (Grindley 1976) found that salinity below the causeway was 27 compared to 7 above the causeway (Table 10) with a sharp difference because of causeway effects.

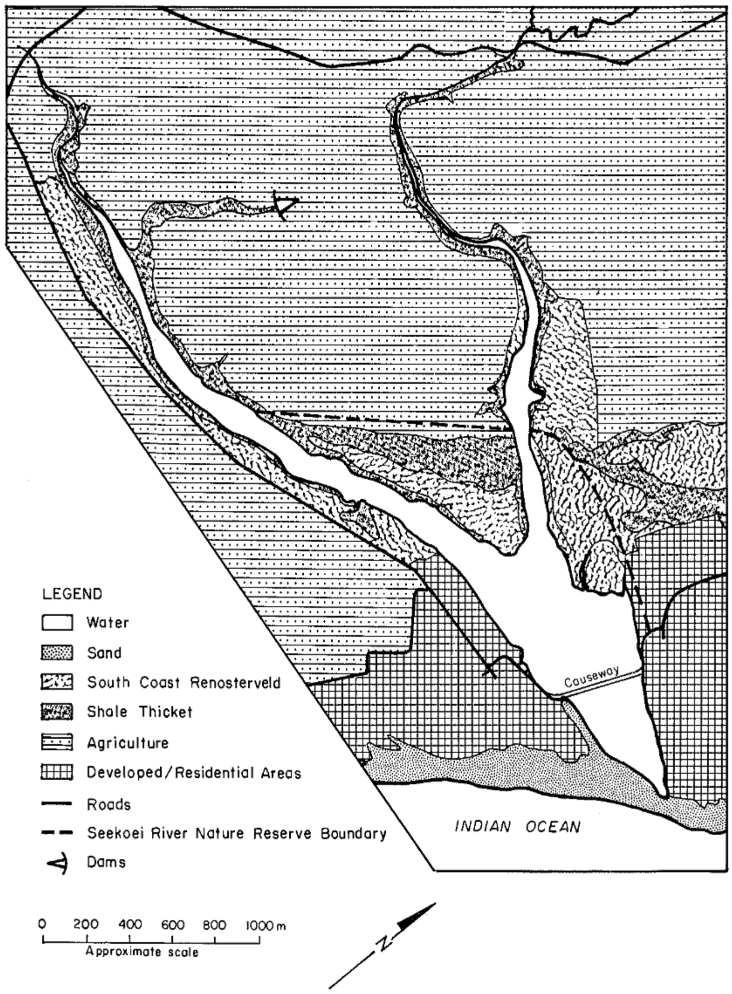

Figure 11 Vegetation of the Seekoei Estuary as mapped in 1988 by Bickerton and Pierce (1988).

In 2004 and 2005 Bezuidenhout (2011) established three transects; one in the lower reaches, one in the upper reaches of the Swart and one in the Seekoei tributary to determine the relationship between macrophytes and environmental variables (Figure 11). She also tried to map changes over time, but poor image quality made this difficult. The present vegetation analysis was done once during an open mouth phase (January 2005) and twice during closed mouth phases (July and October 2004). The Seekoei Estuary was predominantly in a closed mouth state during the period of 2004-2005 and it seldom opened for extended periods of time. After the heavy flash floods of 24 December 2004, the mouth stayed open for approximately three months. During the July trip salinity ranged from 35 to 38.8 and from 35 to 36 in October 2014. However, salinity in January 2015 had dropped to 7 to 23 after a flood. The mapped vegetation showed 12.9 ha salt marsh mostly confined to the lower reaches of the Seekoei Estuary. The upgrading of the causeway with larger culverts increased the tidal action above the causeway resulting in the formation of a small functional intertidal area being established in areas where these were previously absent (Coastal and Environmental Services, 2006). The dominant species within the salt marsh areas consisted of *Sporobolus virginicus* and *Sarcocornia perennis*.

Submerged macrophytes (*Zostera capensis* and *Ruppia cirrhosa*) covered 16.7 ha (Figure 12). *Zostera capensis* was dominant in areas close to the mouth, west of the causeway, where the estuary channel is shallow and there is limited scouring and sedimentary disturbances (Adams and Talbot 1992). These conditions were created by the construction of the causeway that impedes flow. For this reason, the author suggested that it would be expected that prior to the construction of the causeway lower density beds of *Zostera capensis* would have been present. Further upstream where the water channel was deeper, and less saline *Zostera capensis* was found in conjunction with *Ruppia cirrhosa*.

Reeds covered 2.02 ha, the dominant species being *Phragmites australis* and *Juncus kraussii*. These species were found sporadically throughout the estuary and characterize areas of freshwater seepage. The author suggested that *Phragmites australis* might have increased over time due to the extensive residential development around the estuary and the subsequent inflow of freshwater and nutrients from septic tanks. Sand banks extended over 13.6 ha during the 2004/5 vegetation assessment.

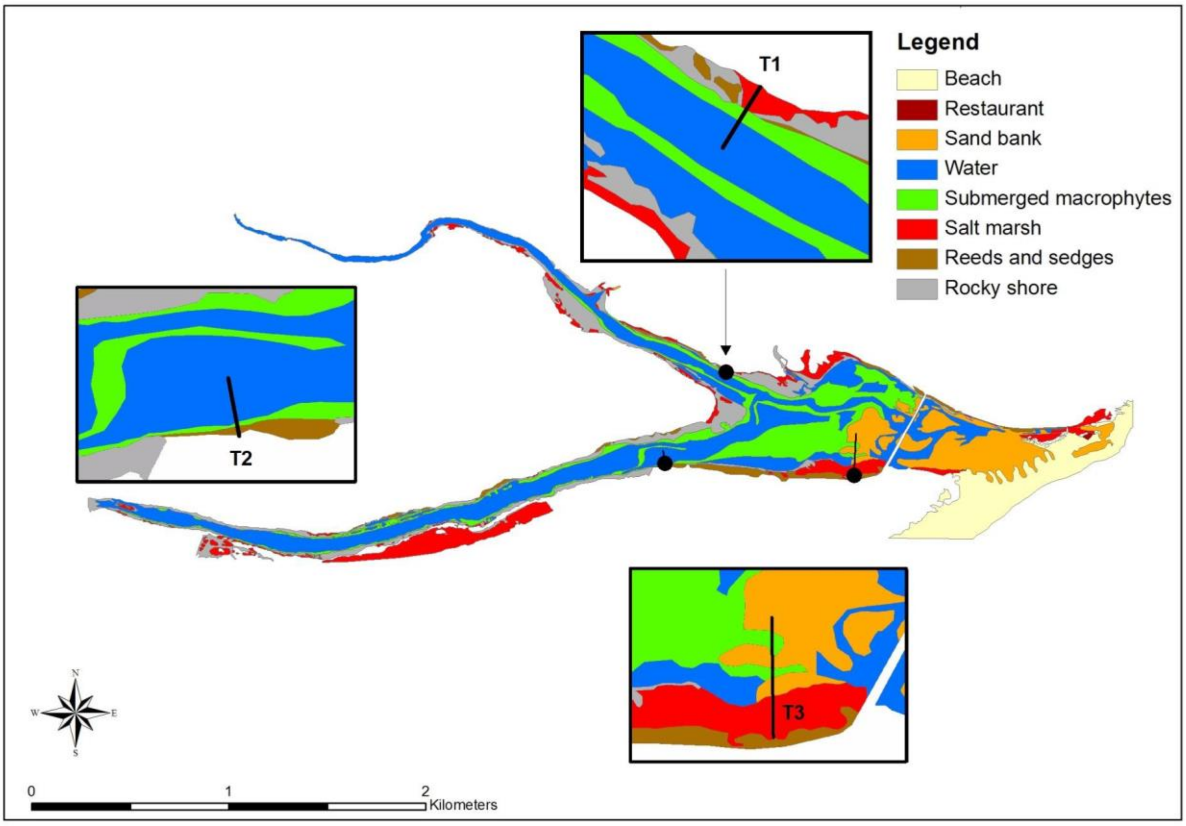

Figure 9 Vegetation of the Seekoei Estuary in 2005 (Bezuidenhout 2011). The three transect lines are also shown.

Bezuidenhout also performed statistical analysis on the interaction of vegetation habitats to environmental drivers. Habitat was separated into terrestrial, salt marsh and submerged types. *Juncus* and *Phragmites* were outliers. Depth to groundwater, sediment EC and % sand fraction were found to be the drivers.

For the present 2017 vegetation assessment ground truthing and geotagged images were taken in July and August 2017 (Figure 11). Avenza PDF maps was used to take geotagged notes on a Samsung tablet. This data assisted GIS spatial mapping in ArcMap 10.3 for Desktop (ESRI ®) from 2015 orthorectified images obtained from National Geo-spatial Information in Cape Town (NGI, ex Surveys and Mapping). The projected coordinate system used for mapping is AEA_WGS84, Projection Albers, with central meridian 25. The geographic coordinate system was GCS_WGS_1984, with D_WGS_1984 datum. Google Earth was also used but water level for the latest images was still low and similar to the 2015 NGI images. At the time of the site visits the water level was high. This clearly represents the variability in habitats of the Seekoei Estuary where the causeway had led to damming of the water and flooding habitat on a more rapid scale than under "normal" conditions. Historical images were also obtained from NGI for the years 1942, 1961, 1975, 1986, 1999 and 2000.

Where possible vegetation was mapped for these images but poor black and white quality made this difficult and mapping confidence for these years is low. Where mapping could not be done a percentage of the total EFZ (estuarine functional zone) was estimated. Table 11 and Figure 13 show the present vegetation area for the Seekoei Estuary and where possible, historical area within the 5 m EFZ. Sand banks and submerged macrophytes are included in the open water area. Floodplain includes disturbed areas like grassed and disturbed areas and farming. Roads, causeways, air strip and residential areas were mapped under "development".

In broad summary, Table 11 suggests that vegetation cover for most of the plant types in the Estuarine Functional Zone (EFZ and below the 5m contour line) has not changed significantly. Variations that exist are probably linked to the degree of submergence between dates. Salt marsh area cover reflects high variation between dates and is probably linked to changing abiotic conditions particularly water level.

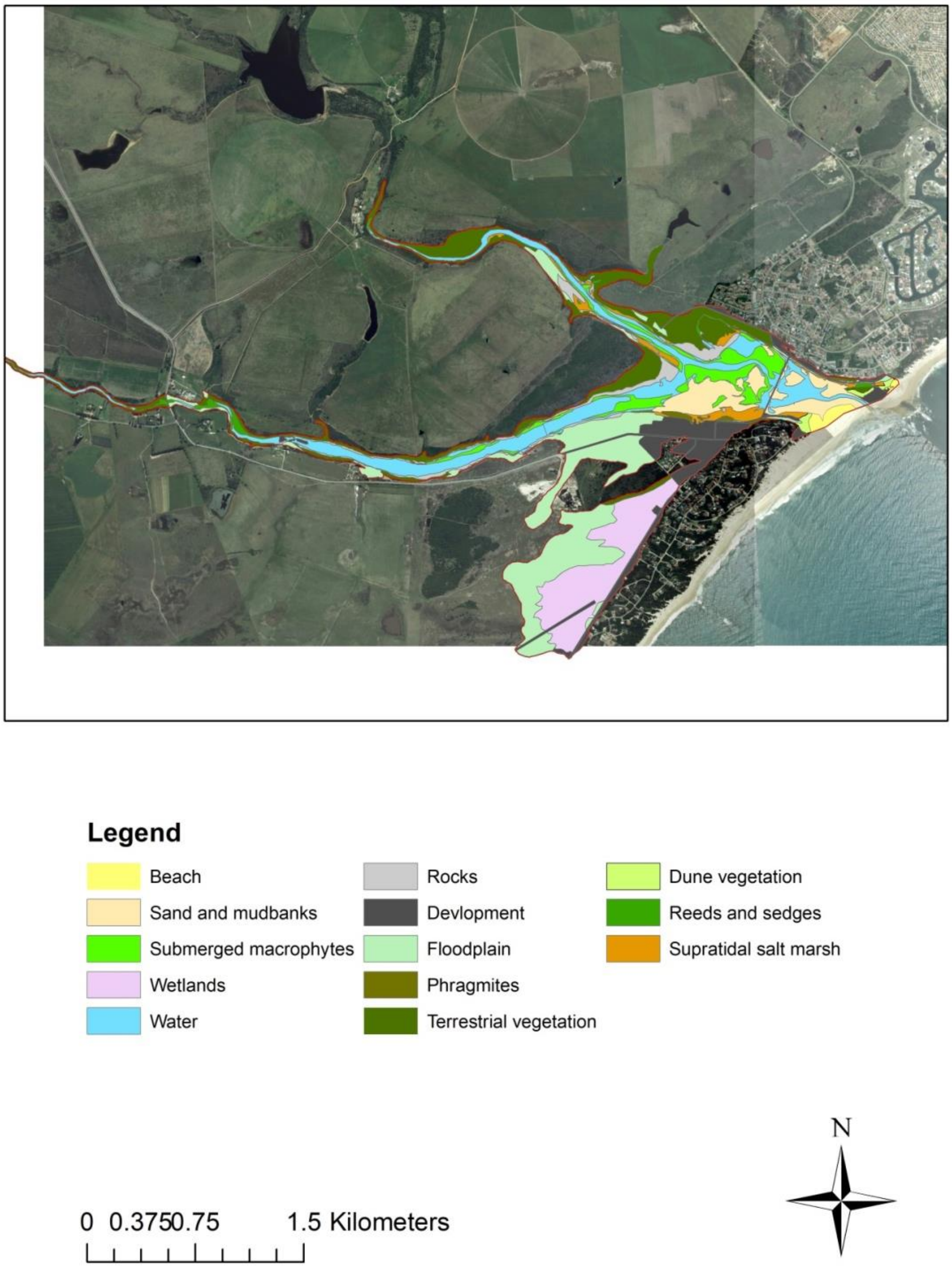

Figure 10 Present habitat distribution (2017) in the Seekoei Estuary.

Table 11 Present and past habitat area for the Seekoei Estuary within the 5 m EFZ. * indicates that these habitats were included in the open water as they were submerged at the time of sampling.

Habitat	1942		1961		2017	
	Area (ha)	% of total	Area (ha)	% of total	Area (ha)	% of total
Wetlands					33.8	12.0
Beach					2.8	1.0
Open water	85.1	30.0			77.9	28.0
Sand/Mud banks	3.0	1.0			22.8	8.0*
Rocks	12.6				12.6	5.0
Development	0.0	0.0			28.2	10.0
Floodplain	110.0	40.0			59.4	22.0
Reeds and sedges	Not visible		Not visible		5.2	2.0
Salt marsh	Not visible		20.0	7	8.5	3.0
Submerged macrophytes	Not visible		Not visible		18.5*	7.0*
Terrestrial vegetation	55.0	20.0			47.0	18.0
Total					276.0	

6.12 Invertebrates

Information on invertebrates in the Seekoei Estuary is limited, with no information available on zooplankton. Bickerton and Pierce (1988) reported the presence of the carid shrimp *Palaemon perengueyi* and the crown-crab *Hymenosoma orbiculare* above the causeway, but no other invertebrates were taken in the beam trawl used during sampling. In a separate survey, Gaigher (reported in Bickerton & Pierce 1988) recorded the presence of the sandprawn *Callichirus kraussi* in sandy substrata below the causeway, while the mudprawn *Upogebia africana* occurred in muddy areas further upstream. Occasional mixed populations of the two species were also present and both were present in low to moderate numbers. Occasional dead shells of the pencil bait *Solen cylindraecus* were also collected.

The recording of *Upogebia africana* in the estuary is noteworthy, since this species requires a marine phase of larval development after larvae are released into the zooplankton. First stage larvae are exported from the estuary on an ebb tide, while late stage larvae return on the flood to recolonize estuarine mudbanks. The presence of mudprawns in the estuary around 1988 therefore, supports earlier statements that the estuary remained open for much of the time prior to present.

6.13 Fishes

Fishes of marine and estuarine origin occur in the Seekoei Estuary. Marine species rely on opening of the estuary mouth for access to move into the estuary to use it as a nursery area. This typically occurs after peak spawning in spring and summer months. Estuary-resident species were dominant during all four seasons in 2016 – 2017 and included the important fodder fish, the estuary round herring *Gilchristella aestuaria* as well as important goby species such as river goby *Glossogobius callidus*, the mud loving *Caffrogobius gilchristi* and Knysna sand goby *Psammogobius knysnaensis*.

Marine species using the estuary as a nursery area are in the important families Sparidae and Marine Mugilidae. The sparids *Rhabdosargus holubi* (Cape stumpnose); *Diplodus capensis* (Blacktail) and *Sarpa salpa* (Strepie) all come into the estuary on a regular basis when the estuary opens in summer. Other common marine species using the estuary as a nursery and feeding area are the mullets, namely the Southern mullet, *Liza richardsonii* and freshwater mullet, *Myxus capensis* as well as the Cape Mooney, *Monodactylus falciformis*. One of the most significant findings in the current fish study is the prevalence of young White Steenbras, *Lithognathus lithognathus*. The numbers in the Seekoei are unusually high for such a small estuary. The evidence of growing fish observed by increasing sizes over the course of the year show that fish are thriving on the abundant sand prawns in the system and the estuary is a valuable nursery for this species. This heightens the conservation status of the estuary as this species is now red-listed due to major stock declines from overfishing in the marine environment.

Despite the loss of hundreds of young fishes in the Seekoei during high salt levels where salinities rose above 55 in summer, White Steenbras were able to move to areas in the upper estuary to find lower salt content. This highlights the importance of migration routes staying open to fishes to move upstream during unfavourable conditions – this however is impeded by weirs, causeways and dams. Fishes then accumulate below such obstacles *en masse* and increased competition results. The proper management of the mouth for the estuary to prevent hypersalinity and the removal of unnecessary dams to improve baseflow will provide a reliable refuge and nursery area for this species.

The Seekoei Estuary is an important nursery area for the threatened White steenbras, *Lithognathus lithognathus*, where numbers are unusually high prior to recent fish kills from salt content rising more than 20 units above sea salt levels (Plate 12).

Plate 12 White Steenbras collected from Seekoei estuary. Photograph from Nadine Strydom.

6.14 Birds

The Seekoei River Nature Reserve was proclaimed in 1969 as a sanctuary for the prolific birdlife that occurred in the area. The reserve was renowned for its waterfowl populations and was located between the confluence of the Seekoei and Swart tributaries and part of the estuarine area. After the swimming pool complex was constructed, the estuary drained at low tide, negating the purpose of the reserve. This led to the construction of the causeway barrier designed to retain a permanent body of water above the causeway. Recurring changes to the causeway followed, including repair operations after floods and upgrading of the causeway to accommodate increasing traffic using the road across the estuary. In August 1976, Grindley (1976) noted that the salinity above the causeway was relatively fresh (salinity of 7), with aquatic plants such as *Potamogeton, Chaetomorpha* and *Enteromorpha* flourishing. Birdlife was also notable, with Red-knobbed Coots (*Fulica cristata*), Little Grebes (*Tachybaptus ruficollis*) and Reed Cormorants (*Microcarbo africanus*) prominent.

Following the establishment of the Bird Sanctuary, waterfowl counts were undertaken by C.W. Heyl (Cape Department of Nature and Environmental Conservation) between 1965 and 1985. Although seasonal fluctuations were apparent, Heyl noted the absence of Southern Pochard and Cape Teal for the period August 1979 to April 1985. Low numbers of Cape Shoveler and Maccoa Duck over the period as well as lower numbers of waterfowl in general compared to pre-1970 data (quoted in Bickerton and Badenhorst 1987). This suggested that bird numbers declined progressively over the years and is supported by recent CWAC data (Figure 14).

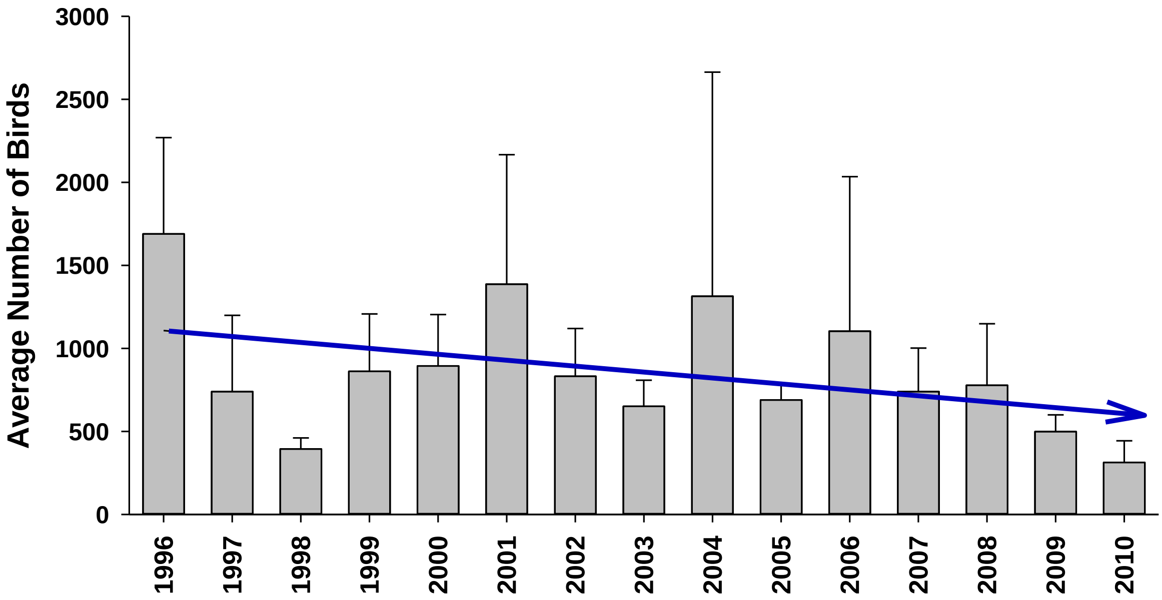

Figure 11 **Average number of birds counted during summer and winter CWAC counts between 1996 and 2010. Data from UCT ADU accessed September 2017. Blue arrow denotes the downward trend in overall counts over time.**

These changes in bird assemblages over time are well summarized in the water Reserve study undertaken (DWAF 2006b). From the point of view of the number of bird species present on the estuary at any one time, species richness has declined. Over time, species richness has probably undergone little change. This is because of significant fluctuations in available food resources that respond to shifting physico-chemical states in the estuary (e.g. water level, salt concentration of the water). In terms of overall bird abundance, fluctuations are far more variable compared to the natural state of the estuary.

Table 12 Average number of birds identified and counted during Summer and Winter CWAC counts between 1995 and 2013, and maximum from that period. Winter bird counts from 2013 are in bold.

Common name	Taxonomic name	Average	Maximum	2013
Common Sandpiper	*Actitis hypoleucos*	2.3	5	
Malachite Kingfisher	*Alcedo cristata*	1.2	2	
Egyptian Goose	***Alopochen aegyptiacus***	**35.1**	**179**	**20**
Cape Teal	*Anas capensis*	18.0	48	
Red-billed Teal	***Anas erythrorhyncha***	**9.9**	**22**	**6**
Hottentot Teal	*Anas hottentota*	3.0	3	
Cape Shoveler	***Anas smithii***	**21.2**	**74**	**14**
African Black Duck	*Anas sparsa*	2.0	2	
Yellow-billed Duck	***Anas undulata***	**21.6**	**70**	**44**
Duck, Unidentified		9.3	14	
African Darter	***Anhinga rufa***	**3.0**	**9**	**5**
Grey Heron	***Ardea cinerea***	**8.2**	**19**	**7**
Goliath Heron	*Ardea goliath*	1.5	2	
Black-headed Heron	***Ardea melanocephala***	**2.7**	**7**	**4**
Purple Heron	***Ardea purpurea***	**2.4**	**7**	**7**
Ruddy Turnstone	*Arenaria interpres*	3.0	8	
Hadeda Ibis	***Bostrychia hagedash***	**6.2**	**25**	**25**
Cattle Egret	***Bubulcus ibis***	**27.2**	**112**	**112**
Water Thick-knee	***Burhinus vermiculatus***	**10.3**	**20**	**12**
Sanderling	*Calidris alba*	4.0	9	
Red Knot	*Calidris canutus*	11.0	17	
Curlew Sandpiper	*Calidris ferruginea*	185.9	857	
Little Stint	*Calidris minuta*	70.1	214	
Pied Kingfisher	***Ceryle rudis***	**6.6**	**18**	**6**
Common Ringed Plover	*Charadrius hiaticula*	38.9	92	
White-fronted Plover	*Charadrius marginatus*	9.8	36	
Chestnut-banded Plover	*Charadrius pallidus*	8.0	8	
Kittlitz's Plover	*Charadrius pecuarius*	35.5	111	
Three-banded Plover	*Charadrius tricollaris*	5.1	18	
African Marsh-harrier	*Circus ranivorus*	1.0	1	
Great Egret	***Egretta alba***	**6.7**	**50**	**1**
Little Egret	***Egretta garzetta***	**10.1**	**28**	**8**
Yellow-billed Egret	*Egretta intermedia*	1.0	1	
Red-knobbed Coot	***Fulica cristata***	**370.6**	**1592**	**546**
Common Moorhen	***Gallinula chloropus***	**4.8**	**8**	**4**
African Black Oystercatcher	*Haematopus moquini*	2.9	9	
African Fish-eagle	*Haliaeetus vocifer*	1.2	2	
Black-winged Stilt	***Himantopus himantopus***	**9.5**	**28**	**24**
Grey-headed Gull	*Larus cirrocephalus*	2.5	4	
Kelp Gull	***Larus dominicanus***	**47.0**	**95**	**38**
Bar-tailed Godwit	*Limosa lapponica*	1.0	1	

Common name	Taxonomic name	Average	Maximum	2013
Giant Kingfisher	*Megaceryle maximus*	1.4	3	
African Pied Wagtail	*Motacilla aguimp*	4.0	4	
Cape Wagtail	***Motacilla capensis***	**17.3**	**51**	**19**
Southern Pochard	*Netta erythrophthalma*	2.0	3	
Eurasian Curlew	*Numenius arquata*	3.5	5	
Common Whimbrel	*Numenius phaeopus*	3.2	1	
Black-crowned Night-Heron	*Nycticorax nycticorax*	3.0	6	
Osprey	***Pandion haliaetus***	**1.2**	**2**	**1**
Reed Cormorant	***Phalacrocorax africanus***	**55.6**	**226**	**226**
Cape Cormorant	***Phalacrocorax capensis***	**1.9**	**3**	**1**
White-breasted Cormorant	***Phalacrocorax carbo***	**43.5**	**252**	**114**
Ruff	*Philomachus pugnax*	28.5	35	
Lesser Flamingo	*Phoenicopterus minor*	5.0	5	
Greater Flamingo	***Phoenicopterus ruber***	**53.5**	**206**	**20**
African Spoonbill	***Platalea alba***	**8.8**	**23**	**17**
Spur-winged Goose	***Plectropterus gambensis***	**11.0**	**33**	**3**
Glossy Ibis	***Plegadis falcinellus***	**1.0**	**1**	**1**
Grey Plover	*Pluvialis squatarola*	20.4	71	
Great Crested Grebe	*Podiceps cristatus*	1.0	1	
Allen's Gallinule	*Porphyrio alleni*	1.0	1	
African Purple Swamphen	***Porphyrio madagascariensis***	**1.0**	**1**	**1**
Brown-throated Martin	*Riparia paludicola*	1.0	1	
Little Tern	*Sterna albifrons*	33.9	127	
Lesser Crested Tern	*Sterna bengalensis*	27.0	27	
Swift Tern	***Sterna bergii***	**10.9**	**84**	**31**
Caspian Tern	***Sterna caspia***	**6.5**	**30**	**7**
Roseate Tern	*Sterna dougallii*	1.0	1	
Common Tern	*Sterna hirundo*	144.6	1224	
Arctic Tern	*Sterna paradisaea*	7.0	20	
Sandwich Tern	*Sterna sandvicensis*	37.5	119	
Antarctic Tern	*Sterna vittata*	38.0	46	
Tern, Unidentified		32.0	85	
Little Grebe	***Tachybaptus ruficollis***	**13.0**	**58**	**3**
South African Shelduck	*Tadorna cana*	28.9	128	
White-backed Duck	*Thalassornis leuconotus*	2.0	2	
African Sacred Ibis	***Threskiornis aethiopicus***	**45.1**	**281**	**25**
Common Greenshank	***Tringa nebularia***	**8.3**	**27**	**1**
Marsh Sandpiper	*Tringa stagnatilis*	9.0	19	
Blacksmith Lapwing	***Vanellus armatus***	**10.0**	**38**	**2**
Terek Sandpiper	*Xenus cinereus*	2.0	2	
Wader, Unidentified		43.5	134	

6.15 Potential climate change impacts

In a broad sense, estuaries are described as the meeting place of rivers and the sea. Consequently, changes in climate that impact both the terrestrial environment and the sea will influence estuaries in some way (James *et al.* 2013). These changes include rising sea level, wind dynamics, an increase in the frequency and magnitude of storm events, increasing air and water temperatures, altered rainfall patterns that in turn impact the quality and quantity of river flow rates, flood dynamics and timing of freshwater supply to estuaries.

Because of the continuing rise in average air temperature, coastal winds will also adjust. Surf zone dynamics will respond to altered wind strengths and patterns, leading to different sediment characteristics and longshore transport of beach sand. Consequently, the combined effects of all these changes affecting terrestrial and marine environments will alter the frequency and duration of opening/closing of TOCE inlets in a way different to present.

From a biotic point of view, estuary response to climate change will change the composition and behaviour of estuarine biotic communities. Unfortunately, our knowledge of the impacts of climate change on estuaries are currently poorly understood and predictions remain approximate. Of note however, is the current rise in sea level of 1.48 mm yr^{-1} along the south coast of South Africa (quoted in James et al. (2013)). Coupled with the predicted increase in the frequency of storms, it is likely that wave overwash of berms associated with TOCE's will also increase.

Increased storminess and the ongoing rise in sea level also has implications for the causeway; overwash is likely to become more frequent and this situation underlines the importance of the Estuary and Wetlands Management Committee having an adaptive management approach as the situation changes in the future. By 2030, sea level will increase by about 1.5 cm; by 2050 sea level will increase by 45 cm compared to present. Management strategies will need to adapt to ongoing changes driven by climate change.

7 Recreational activities

Recreational activities on the estuary include boating, board-sailing and recreational angling, although these activities have probably become less popular in recent times as the estuary becomes overgrown with macrophytes and shallow at times. However, birding remains popular, particularly with day-trippers.

With significant modification to freshwater supply (Van Niekerk and Turpie 2012), the Seekoei Estuary is now functionally degraded. Much of the aquatic birdlife has disappeared, although populations return when conditions in the estuary become temporarily suitable.

8 SWOT analysis

Evaluation of the Situation Assessment and after discussion with Stakeholders, the following SWOT analysis table of the estuary and catchment provides a useful overview of current and future management practices.

8.1 Strengths

- Commitment of the Local authority and residents to optimally manage the estuary and environs to ensure its sustainability.
- Commitment of the local Authority to correct historical decisions that have impacted the estuary in a negative way.
- The protected status and value of the Bird sanctuary for residents and visitors.
- A well-developed infrastructure attractive to tourists. Proximity to beaches and numerous accommodation facilities are examples.
-
- Lack of high density and pollution by commercial enterprises in the catchment area and townships surrounding the estuary.

8.2 Weaknesses

- The Seekoei no longer functions as a temporarily open/closed estuary compared to its natural state. The ecological health score indicates a highly modified system and it is now classified as a Category D system. This assessment was done in 2006 and it is probable that the health of the estuary has declined further.
- Excessive abstraction of freshwater from the catchment has resulted in reduced or zero baseflows reaching the estuary.
- Reduced or zero baseflow volumes lead to elevated or even hypersaline conditions in the estuary.
- When compared to historical records, water birds no longer use the estuary with respect to both diversity and numbers.
- Presence of the causeway across the estuary.
- Excessive damming of the two rivers reduces the amplitude of small to medium floods and therefore reduced scouring of accumulated sediments from the estuary. The presence of the causeway exacerbates reduced scouring benefits by these floods.
- Excessive sediment accumulation (the dam wall effect) and consolidation of these fine sediments above the causeway.
- Excessive alien vegetation in the catchment and along the Seekoei and Swart Rivers.
- The presence of the carpark and communal centre (formerly part of the Swimming pool complex) in the former outflow mouth channel. This prevents the mouth from migrating to its historical location.
- The artificial location of the present mouth results in the erosion of a deeper channel and draining of the estuary.
- There is the possibility that the artificial location of the present mouth leads to increased sediment loading by marine sand into the lower estuary by tidal action and marine overwash of the berm during storm events.

- Freshwater wetlands in Paradise Beach have lost connectivity with the estuary due to poor road design and causeway construction. In one instance at least, a barrier wall was built across the wetland and must therefore be considered as an 'illegal dam'. The natural ephemeral nature of the wetland has therefore been altered artificially.
- Housing development has taken place below the 5 m estuary contour line in the EFZ and this increases the risk of flooding of these properties.
- The estuary is currently opened artificially on occasions (water level in the estuary, usually around +0.9 m Mean Sea Level (MSL)) to reduce over-wash of the causeway and damage to vehicles. These artificial opening events lead to ineffective scouring of sediments from the estuary and are well below the natural mouth breaching level of +2.0 to +2.5 m MSL for the Seekoei. The recommended water level for South African estuaries in general is +2.5 to +3.5 m MSL. Scouring benefits to TOCE's increase exponentially as water level behind the berm increase.
- The gravel loop-road around the estuary is dangerous to travel, especially in wet weather.
- Lack of scientific data that would inform more effective management of the estuary and catchment.
-

8.3 Opportunities

- Current conditions impacting the Seekoei Estuary in a negative way can be partly reversed, improving the Ecological Health of the system. This is in line with recommendations outlined in the Ecological Water Requirement Study. Because of the proclaimed Provincial Bird Sanctuary on the Seekoei, the status of the estuary should be improved to Level B (currently the estuary is classified as Level D). Level B probably represents the best attainable level under present circumstances.
- Less extreme salinity maxima will enable the estuarine biota to survive conditions in the estuary.
- Enable water bird populations to increase in diversity and become more permanent residents on the estuary.
- To restore the estuary as a functional system supporting a rich biotic community. This will attract visitors to the area and promote tourism and business opportunities for the local community.
- Further development of the tourism industry.
- Send local people on training courses to become bird guides. They could then earn an income from guiding birders visiting the area.
- Minimize potential threats of climate change through informed decision making around infra-structure development and management strategies.
- Establishment of a co-operative estuarine management forum including residents, municipal management, and other relevant authorities.

8.4 Threats

- Because of intermittent incidents of reduced or zero baseflows (zero baseflows may persist for months), salinity levels may rise to excessive levels (a salinity of 98 is on record) and no estuarine biota survives such levels. Such events may become more common in future.
- Over- and possible illegal abstraction of freshwater upstream.
- Alien vegetation increasing in extent in the catchment.

-
- Increased pollution from river runoff or agricultural return flow from farming activities in the catchment.
- Injury or loss of human life in the event of an accident on the causeway during inclement weather conditions and/or water levels overtopping the crossing.
- Freshwater and seawater flooding leading to erosion and removal of causeway.
- Socio-economic issues that lead to higher crime rates.
-

9 Information Gaps

Numerous information gaps on the Seekoei Estuary became apparent during the Ecological Water Requirements (EWR) Study undertaken by the Department of Water Affairs Forestry (2006). These are listed below;

- Runoff and river inflow data is poor therefore the levels of freshwater input into the estuary cannot be accurately determined. Included is accurate information on water storage and water abstraction from the catchment.
- Only limited information on water quality is available. This includes historical records on nutrients, toxic substances and salinity distribution in the estuary.
- Sediment characteristics in the estuary.
- Frequency and duration of mouth opening events.
- Information on invertebrates.
- Quantitative information on the fish fauna.
- Details on the socio-economic opportunities and constraints.

10 References

Adams, J. B., and M. M. B. Talbot. 1992. The influence of river impoundment on the estuarine seagrass *Zostera capensis* Setchell. Botanica Marina **35**:69-75.

Bezuidenhout, C. 2011. Macrophytes as indicators of physico-chemical factors in South African Estuaries.

Bickerton, I. B., and S. M. Pierce. 1988. Estuaries of the Cape. (eds. Heydorn, A.E.F. & Morant, P.D.) Part II. Synopsis of available information on individual systems, Report No. 33: Krom (CMS 45), Seekoei (CMS 46) and Kabeljous (CMS 47). CSIR Research Report 432, Stellenbosch. 109 pp.

Breen, C. M., and M. McKenzie, editors. 2001. Managing estuaries in South Africa: an introduction. Institute of Natural Resources, Pietermaritzburg.

CSIR. 2017. Artificial Breaching Protocol for the Western Cape Estuaries. CSIR, Stellenbosch.

Davies, B. R., J. O'Keeffe, and C. D. Snaddon. 1993. A synthesis of the ecological functioning, conservation and management of South African river ecosystems. Water Research Commission, Pretoria.

DWAF. 2006a. A draft position paper on the development of a water resource classification system (WRCS): Draft discussion document. Department of Water Affairs and Forestry (DWAF), Pretoria.

DWAF. 2006b. Kromme/Seekoei Catchments Reserve Determination Study - Technical Component. Report No. RDM/K90/04/CON/0705, Department of Water Affairs, Pretoria.

Esterhuysen, K. 1982. The Seekoei Estuary: Example of Disrupted Sedimentary Ecology. University of Port Elizabeth.

Fromme, G. A. W., and P. Badenhorst. 1987. The dynamics of the estuaries of St. Francis Bay (Kromme, Seekoei and Kabeljous). CSIR Report T/SEA 8707:39

Görgens, A. H. M., and B. W. Van Wilgen. 2004. Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges: Working for Water. South African Journal of Science **100**:27-33.

Grindley, J. R. 1976. Causeway across Seekoei Estuary. Die Zeekoeirivier-monding: 'n verslag aan die Munisipaliteit van Jeffreysbaai, Jeffreys Bay.

James, N. C., L. van Niekerk, A. K. Whitfield, W. M. Potts, A. Götz, and A. W. Paterson. 2013. Effects of climate change on South African estuaries and associated fish species. Climate Research **57**:233-248.

Kouga Municipality, K. L. 2017. Integrated Development Plan 2017 - 2022. Resolution No. 17/05/AME&SP3, Kouga Local Municipality, Jeffreys Bay.

Ninham Shand. 1991. Seekoeiriviermond: Moontlike oplossings vir bestaande probleme Verslag Nr. 1832/5632. Ninham Shand, Port Elizabeth, South Africa.

Perissinotto, R., D. D. Stretch, A. K. Whitfield, J. B. Adams, A. T. Forbes, and N. T. Demetriades. 2010. Ecosystem functioning of temporarily open/closed estuaries in South Africa. Pages 1-69 *in* J. R. Crane and A. E. Solomons, editors. Estuaries: types, movement patterns and climatical impacts. Nova Science Publishers, New York.

Reddering, J. S. V. 1988. Prediction of the effects of reduced river discharge on the estuaries of the south-eastern Cape Province, South Africa. South African Journal of Science **84**:726-730.

Taljaard, S. 2007. C.A.P.E. Estuaries Guideline 1: Interpretation of Legislation pertaining to Management of Environmental Threats within Estuaries., CSIR, Stellenbosch.

Van Niekerk, L., S. Taljaard, J. B. Adams, D. Fundisi, P. Huizinga, S. J. Lamberth, S. Mallory, G. C. Snow, J. K. Turpie, A. K. Whitfield, and T. H. Wooldridge. 2015. Desktop provisional EcoClassification of the temperate estuaries of South Africa. 2187/1/15, Water Research Commission, Pretoria.

Van Niekerk, L., and J. K. Turpie. 2012. South African national biodiversity assessment 2011: Technical report. Volume 3: Estuary component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch.

Watling, R. J., and H. R. Watling. 1983. Trace metal surveys in Mossel Bay, St. Francis Bay and Algoa Bay, South Africa. Water S. A. **9**:57-65.

Whitfield, A. 1992. A characterization of southern African estuarine systems. Southern African Journal of Aquatic Science **18**:89-103.

Whitfield, A. K. 2005. Fishes and freshwater in southern African estuaries - A review. Aquatic Living Resources **18**:275-289.

Whitfield, A. K., and G. C. Bate. 2007. A review of information on temporarily open/closed estuaries in the warm and cool temperate biogeographic regions of South Africa, with particular emphasis on the influence of river flow on these systems. Page 232. Water Research Commission Report No 1581/1/07.

Whitfield, A. K., and M. N. Bruton. 1989. Some biological implications of reduced fresh water inflow into eastern Cape estuaries: a preliminary assessment. South African Journal of Science **85**:691-695.

WNNR. 1990. Seekoeirivier mond: ondersoek na problem. Voorgele aan Algoa Streeksdiensteraad. Report no. WNNR EMA-C 9039.

11 Appendix- Questionnaire

CROSSING THE CAUSEWAY BETWEEN ASTON BAY AND PARADISE BEACH

Crossing the causeway between Aston Bay and Paradise Beach can be discouraging or even life-threatening at times when water levels in the estuary overtop the road surface. We would appreciate a few minutes of your time expressing your opinion of how high water levels affect you when regularly crossing the causeway on your way to work in Paradise Beach. Please note that we already have opinions of persons travelling out of Paradise beach and who cross the causeway on a regular basis.

Please fill in the information or tick the appropriate boxes below:

Your name:

Approximate distance from home to Paradise Beach where I work:

My job description: Domestic Helper [ ] A Gardener [ ] Tradesman [ ]

Other [ ]

How do you get to work? Private transport [ ] Taxi [ ] Bicycle [ ] Pedestrian [ ]

If you are not able to cross the causeway because of flooding, are you in a position to use the alternative gravel road from the Humansdorp side?

Yes [ ] No [ ]

How many dependents rely on your income at home?

If you are not able to get to work in Paradise Beach, is it a question of:

No work, no pay? Yes [ ] No [ ]

Thank you for your time. The information will be used for statistical purposes only and will contribute to the Management Plan being developed for the estuary.

Kind regards

Prof TH Wooldridge