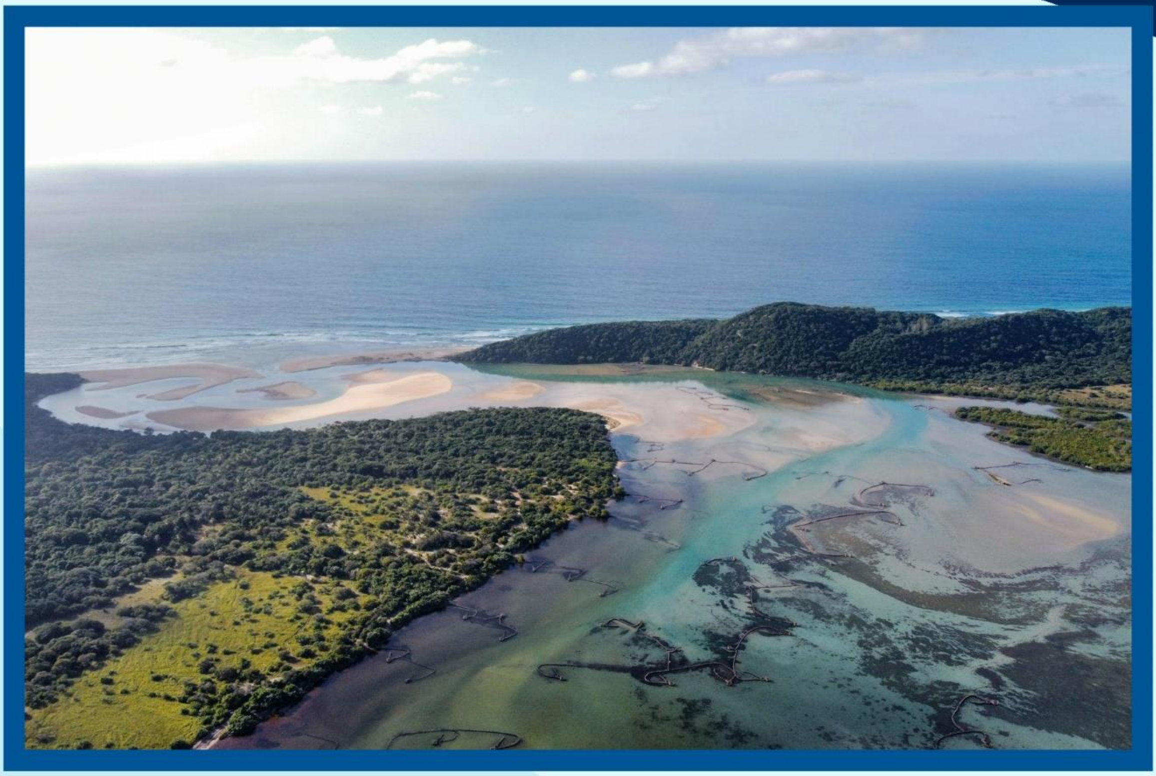
REHABILITATION MANAGEMENT GUIDELINES FOR WATER RESOURCES

VOLUME 3: ESTUARIES



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Water is Life
Sanitation is Dignity

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CARA	Conservation of Agricultural Resources Act
CD: WEM	Chief Directorate: Water Ecosystems Management
CECs	Contaminants of Emerging Concern
CMA	Catchment Management Agency
CMP	Coastal Management Programme
CSIR	Council for Scientific and Industrial Research
DALRRD	Department of Agriculture, Land Reform and Rural Development
DCOGTA	Department of Cooperative Governance and Traditional Affairs
DEA&DP	Department of Environmental Affairs and Development Planning
DFFE	Department of Forestry, Fisheries and Environment
EBVs	Essential Biodiversity Variables
ECA	Environment Conservation Act
EFZ	Estuary Functional Zone
EPA	Estuarine Protected Areas
EMFIS	Estuarine Management Framework and Implementation Strategy
EMPs	Estuarine Management Plans
EWR	Ecological Water Requirements
e-WULAAS	Electronic Water Use Licence Application and Authorisation System
SDS	Directorate: Sources Directed Studies
DEDEAT	Department of Economic Development, Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental impact Assessment
GA	General Authorisation
GBF	Global Biodiversity Framework
GIS	Geographic Information System
HDPE	High-density Polyethylene
HWM	High-Water Mark
IPCC	Intergovernmental Panel on Climate Change
IWQM	Integrated Water Quality Management
IWRM	Integrated Water Resource Management
KZNEDTEA	Kwazulu-Natal Department of Economic Development, Tourism and Environmental Affairs
MAR	Mean Annual Rainfall
MMP	Mouth Management Plan
MaintMP	Maintenance Management Plan
MPRDA	Mineral and Petroleum Resources Development Act
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act
NEM: BA	National Environmental Management: Biodiversity Act
NEM: WA	National Environmental Management: Waste Act
NEM: PAA	National Environmental Management: Protected Areas Act
NFA	National Forests Act
NGOs	Non-Governmental Organisations
NHRA	National Heritage Resources Act
NOAA	National Ocean and Atmospheric Administration
NWA	National Water Act
NWRS	National Water Resource Strategy
NW&SMP	National Water and Sanitation Master Plan
PAHs	Polycyclic Aromatic Hydrocarbons
RQOs	Resource Quality Objectives
RDM	Resource Directed Measures

RWQOs	Resource Water Quality Objectives
SAMSA	South African Maritime Safety Association
SANBI	South African National Biodiversity Institute
SANRAL	South African National Road Agency SOC Ltd
SFR	Stream flow reduction
SDCs	Sources Directed Controls
WARMS	Water use Authorization and Registration Management System
WSA	Water Services Authorities
WCG	Western Cape Government
WCTDP	Wild Coast Tourism Development Policy
WML	Waste Management License
WRC	Water Research Commission
WULA	Water Use License Application
WUL	Water Use License
WWTW	Wastewater Treatment Works

GLOSSARY OF TERMS

Estuaries in terms of the definition from the National Water Act, 1998 (Act 36 of 1998) an estuary means a partially or fully enclosed body of water –

- which is open to the sea permanently or periodically; and
- within which sea water can be diluted, to measurable extent, with fresh water drained from land.

Diffuse pollution - ("non-point source pollution") - pollution that originates from wash-off over a relatively large area. Diffuse pollution sources can be divided into source activities related to either land or water use, including failing septic tanks, agricultural and improper animal-keeping practices, and urban and rural runoff.

Ecological Water Requirements (EWRs) - the flow patterns (magnitude, timing, and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.

Effluent is the municipal sewage or industrial wastewater (untreated, partially treated, or fully treated) that flows out of a wastewater treatment works, septic system, pipe, etc.

The **Estuary Functional Zone (EFZ)** is an area that not only covers the estuary water body but also areas that support physical and biological processes and habitats necessary for estuarine function and condition. The latter includes areas influenced by long-term estuarine sedimentary processes (*i.e.,* sediment stored or eroded during floods), changes in channel configuration, aeolian transport processes, and changes due to coastal storms. The EFZ also encompasses floodplain ecotones and estuarine vegetation (salt marshes, mangroves etc.) that contribute detritus to the base of the estuarine food chain and provides refuge to estuarine biota during high flow events from strong currents.

Eutrophication - (from the Greek *"eutrophos"* meaning *"well-nourished")* Is the process of over-enrichment of waterbodies with minerals and nutrients, which (at the right temperatures, substrate availability, flow velocity and light penetration) increasingly induce primary production, e.g., algal and macrophyte growth. Eutrophication can be regarded as either a natural aging process in waterbodies or an aging process that can be accelerated by anthropogenic activities.

Global Biodiversity Framework (GBF) aims to enable urgent and transformative action by Governments, and subnational and local authorities, with the involvement of all of society, to halt and reverse biodiversity loss, to achieve the outcomes it sets out in its Vision, Mission, Goals and Targets (*i.e.,* GBF Goal A target 2 for restoration of ecosystems). Although the DWS focuses mainly on the reporting on the SDG targets, it is recommended that the relevant authorities should use the outputs of the current RMGs for their reporting at the respective platforms.

Integrated Water Resource Management (IWRM) is a process for co-ordinated planning and management of water, land, and environmental resources. IWRM takes into account the amount of available water (surface and groundwater), water use, water quality, environmental and social issues as an integrated (combined) whole to ensure sustainable, equitable and efficient use.

Mean annual runoff - the average volume of water that flows in a river per year (annum), expressed as cubic meters per annum.

Monitoring - periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

Non-point source pollution - see "Diffuse pollution."

Point source pollution - pollutant loads discharged at a specific location by means of pipes, outfalls, or conveyance channels inter alia delivering wastewater from municipal and industrial Wastewater Treatment Works. Point sources can also include pollutant loads contributed by tributary.

Rehabilitation is the process of promoting the recovery of ecosystem services and values in a transformed/degraded system in order to reclaim part of the system's lost societal value (Hay and McKenzie, 2005). The benefit of ensuring that ecosystems are in good ecological condition secures ecosystem services and maintain resilience against climate change impacts.

Resources Directed Measures (RDM) focus on the quantity and quality of the water resource itself, regarding it as an ecosystem rather than a commodity. RDMs comprise Classes, Reserve and RQOs as components.

Resource Quality Objectives (RQOs) are a numerical or descriptive (narrative) statement of the conditions which should be met in the receiving water resource, in terms of resource quality, in order to ensure that the water resource is protected. They might describe, amongst others, the quantity, pattern, and timing of instream flow; water quality; the character and condition of riparian habitat, and the characteristics and condition of the aquatic biota.

Runoff is the flow of water occurring on the ground surface when excess rainwater, stormwater, meltwater, or other sources, can no longer sufficiently rapidly infiltrate in the soil. Surface runoff replenishes groundwater and surface water resources as it percolates through soil profiles or moves into streams and rivers.

Social-Ecological System (SES) are linked systems of people and nature, emphasising that humans must be seen as a part of, not apart from, nature (Berkes and Folke, 1998).

Source - in water resource management, "source" refers to the source of an impact, usually on a water resource. The relationship between "Source" and "Resource" is similar to the relationships between "Cause" and "Effect" or "Aspect" and "Impact," as per the ISO 14001 definitions. The "Resource" or the "water resource" is part of the receiving environment

Sustainable Development Goals (SDGs) are aimed ensuring the availability and sustainable management of water and sanitation for all by 2030. Every year, an annual SDG Progress Report should be produced based on the global indicator framework and data produced by national statistical systems and information collected at the regional level.

Wastewater is any water used from domestic, industrial, commercial, or agricultural activities, surface runoff or stormwater, which may contain physical, chemical, and biological pollutants.

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EXECUTIVE SUMMARY

Approximately 290 estuaries and 42 micro-estuaries, totally 332 in South Africa are categorized into 22 estuarine ecosystem types, collectively covering an area of 90 000 ha including the open water area and adjacent habitats such as salt marshes and mangroves (Van Niekerk *et al.,* 2019). The estuarine realm is the most threatened of all realms in South Africa, both for the number of ecosystem types (86% threatened) and for the area (99% threatened). Ten percent (10%) of estuary types are Critically Endangered, 45% are Endangered and 32% are Vulnerable. By area, 77% are either Critically Endangered or Endangered (SANBI, 2019). The impacts on estuaries are attributed to both direct and indirect anthropogenic (human) activities. Direct anthropogenic impacts are related to hydrological - flow modification patterns due to weirs, dams, and over abstractions; alteration such as canalisation, riparian infrastructure, infilling; over-exploitation of fish and invertebrates; pollution from Wastewater Treatment Works (WWTWs) and other sources within the catchment; and manipulation of estuary mouths. Indirect pressures largely relate to biological invasions by plants and fish.

To address the impacts on South African estuarine systems, the Directorate Sources Directed Studies (SDS) in the Department of Water and Sanitation (DWS) initiated a project in 2020 for the development of Rehabilitation Management Guidelines for Water Resources, including estuaries. The project responds to one of the objectives of the Chief Directorate Water Ecosystems Management (CD: WEM) to conduct sources-directed studies to ensure water resource protection.

The project aims to address the lack of integration of work across various projects, programmes, and initiatives due to separate mandates and various institutions responsible for the rehabilitation of estuaries. In addition, interventions in these ecosystems need to be reported to Global Biodiversity Framework (GBF) and will require guidance on reporting and integrating these across departments and sectors. It is for this reason that the DWS is developing Estuarine Rehabilitation Management Guidelines (RMGs) to address characteristics of watercourses, namely hydrology, geomorphology, water quality, habitat, and biota through a phased approach, namely; diagnostic, planning and assessment, setting of the rehabilitation objectives, execution, and monitoring phases. The following are key aspects covered to address the shortcomings of each characteristic of watercourses:

- Description of the type and characteristics of watercourses;
- Types of pressures and their impacts for each characteristic of the watercourse – a brief overview and description of the impacts that give rise to the degradation of the watercourses to better understand the problem and subsequently develop effective rehabilitation guidelines;
- Legal considerations - applicable legislation to be considered for undertaking site-specific rehabilitation activities on a particular characteristic of the watercourse; and
- Step-by-step guidelines on rehabilitation measures/interventions for executing rehabilitation - planning, design, implementation, and monitoring.

Human-induced disturbance such as in-stream infrastructure including dams and weirs within and close to estuaries are the main impacts that alters the hydrology of the estuarine ecosystem. Human-induced disturbances such as the abstraction of water from rivers result in flow impediment impact and changes in flow drivers and hydrodynamics, which have a direct impact on the habitat and biota of estuarine systems. Rehabilitation Management Guidelines (RMGs) for hydrology have been developed with a focus on control and management of over-abstraction and artificial mouth breaching activities.

Dredging in estuarine systems causes mechanical damage, results in the smothering of organisms in the sediments; elevated turbidity levels, which reduces light penetration in the water environment, adversely affecting the phytoplankton and aquatic vegetation. Poor catchment land-use practices lead to more sediment, especially finer fractions, entering the system. Sand mining activities also alter the flow in estuaries and their sediment budget to the coast, which causes changes in the habitats upon which biota depend. Rehabilitation Management Guidelines for geomorphology with a focus on rehabilitation relating to sand mining, road construction, and dredging (sand) as well as management of bank erosion have been developed.

Water quality within estuarine systems is affected by sources of pollution emanating mainly from industries and WWTWs. Human-induced climate change alters temperature and salinity regimes and the structure and function of biotic communities in estuaries. Deforestation, and clearing of land activities are other impacts that affect estuaries. Rehabilitation Management Guidelines have been developed to address effluent and discharge from WWTWs and industries.

Estuaries are particularly susceptible to habitat transformation, removal and/or alterations caused by human activities. In addition, the construction of permanent structures on the waterfront, recreational and commercial use which changes bottom habitats due to boat engine props scarring seagrass beds and shellfish dredging of bay bottoms, has consequences. Imported organisms that invade the water body can also have a major impact on the ecosystem *i.e.,* invasive species pose a risk to the stability and biodiversity of an estuarine ecosystem. Therefore, the RMGs have been developed for habitat with a focus on the control and management of Alien Invasive Species; and control of habitat removal/alteration caused by human activities (*i.e.,* protection of mangroves).

In terms of Biota, overfishing, sand mining, and dredging have significant physical, chemical, and biological impacts on estuaries. Estuaries are also degraded through mismanagement and physical interference such as inappropriate artificial breaching and mouth manipulation. Thus, the RMGs have been developed to provide guidance in terms of estuary zonation and estuary mouth breaching.

Most importantly, users of the RMGs should recognise the interaction and interrelationship between cumulative impacts at specific sites also considering site specific existing Estuary Management Plans (EMP) and their recommendations.

1. INTRODUCTION

1.1 BACKGROUND

South Africa has 290 estuaries and 42 micro-estuaries, totally 332 estuaries categorised into 22 estuarine ecosystem types, collectively covering an area of 90 000 ha including the open water area, sand and mudbanks, and blue carbon habitats including salt marshes, seagrasses, and mangroves with supportive freshwater ecosystems along the edges (Van Niekerk *et al.,* 2019). The estuarine realm is the most threatened of all realms in South Africa, both for the number of ecosystem types (86% threatened) and for the area (99% threatened). Ten percent (10%) of estuary types are Critically Endangered, 45% are Endangered and 32% are Vulnerable. By area, 77% are either Critically Endangered or Endangered (SANBI, 2019).

To address the impacts on South African estuarine systems, the Directorate Sources Directed Studies (SDS) in the Department of Water and Sanitation (DWS) initiated a project for the development of Rehabilitation Management Guidelines (RMGs) for Water Resources (*i.e.,* estuaries). The project responds to one of the objectives of the Chief Directorate Water Ecosystems Management (CD: WEM) to conduct sources-directed studies to ensure water resource protection.

In the Situation Assessment Phase of the project, it was found that a great deal of research has been conducted in South Africa to understand the discipline of estuarine management to provide local and site-specific management interventions. Extensive studies have been undertaken by the DWS, Water Research Commission (WRC), Department of Forestry, Fisheries and Environment (DFFE), Cape Nature, and various Provincial Departments of Environmental Affairs. For instance, the Western Cape Government (WCG), the Department of Environmental Affairs and Development Planning (DEA&DP) commissioned the development of the Estuarine Management Framework and Implementation Strategy (EMFIS) that prioritise the development of Estuarine Management Plans (EMPs) as well as the development of other tools, e.g. Mouth Management Plans (MMPs), guidelines dealing with activities within estuaries, and draft by-laws for the effective management of estuaries as per Priority Area 7 of the Western Cape Provincial Coastal Management Programme. To coordinate management actions, the Integrated Coastal Management Act (Act No. 24 of 2008), prescribes that EMPs be compiled for all estuaries in accordance with guidelines found in the National Estuarine Management breaching. Numerous EMPs have been developed and compiled by the relevant environmental departments such as DFFE, WCG DEA&DP, Kwazulu-Natal Department of Economic Development, Tourism and Environmental Affairs (KZNEDTEA) for better management of the whole estuarine functional zone, the adjacent shoreline, and freshwater ecosystems (including rivers and inland wetlands) upstream of the estuaries. Several programmes and initiatives such as the Land and Coast Care Management Programme, Coastal Management Programme (CMP), have been implemented to ensure the mitigation of pressures on estuaries and ensure their resilience.

Although a multitude of the EMPs and programmes have been developed and implemented, the Situation Assessment Phase identified a gap in terms of the lack of Rehabilitation Guidelines for Estuaries and the need for integration of existing EMPs with other related projects, programmes and initiatives.

1.2 PURPOSE OF THE REPORT

The primary objective of the report is to:

- Develop Rehabilitation Management Guidelines for estuaries in terms of their interactions with characteristics of watercourses, namely; hydrology (surface flow and interflow), groundwater flows geomorphology, water quality, habitat, and biota.

1.3 ESTUARY DEFINITION, CATEGORISATION, AND IMPACTS

1.3.1 Definition of Estuaries

In terms of the definition from the National Water Act, 1998 (Act 36 of 1998) an estuary means a partially or fully enclosed body of water –

- which is open to the sea permanently or periodically; and
- within which sea water can be diluted, to measurable extent, with fresh water drained from land.

In terms of the definition from Integrated Coastal Management Act (ICMA), 2008 (Act 24 of 2008) "estuary" means a body of surface water –

- that is part of a water course that is permanently or periodically open to the sea;
- in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the water course is open to the sea; or
- in respect of which the salinity is measurably higher as a result of the influence of the sea.

Van Niekerk *et al.,* (2019) further defined an estuary 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, salinity penetration or back-flooding under closed mouth conditions. During floods, an estuary can become a river mouth with no seawater entering the formerly estuarine area or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become either fresh or even hypersaline*. A defining feature of this definition is that complex estuarine abiotic processes distinguish estuaries from other aquatic ecosystem types *i.e.,* restricted tidal action, mixing of fresh and salt water, increased retention, and/or increased water levels under closed mouth conditions.

1.3.2 Estuarine Categorisation System and Characteristics

Biogeographical regions

South Africa has 290 estuaries EFZs and 42 micro-estuaries, which have been categorized into 22 estuarine ecosystems and 3 micro-estuary types (Van Niekerk *et. al*., 2018). The South African coastline is subdivided into 4 estuarine bio-geographical zones according to the National Biodiversity Assessment (Van Niekerk, 2019) **(Figure 1).** The **Tropical** extends from Kosi Bay Estuary to uMgobezeleni Estuary in the KwaZulu-Natal Province, the **Subtropical** from St. Lucia Estuary to Mbashe Estuary, the **Warm Temperate Zone** is from the Mendwana Estuary to Heuningnes Estuary near Cape Agulhas, and the **Cool Temperate Zone** from Ratel Estuary and ends at the Orange River mouth in the Northern Cape Province.

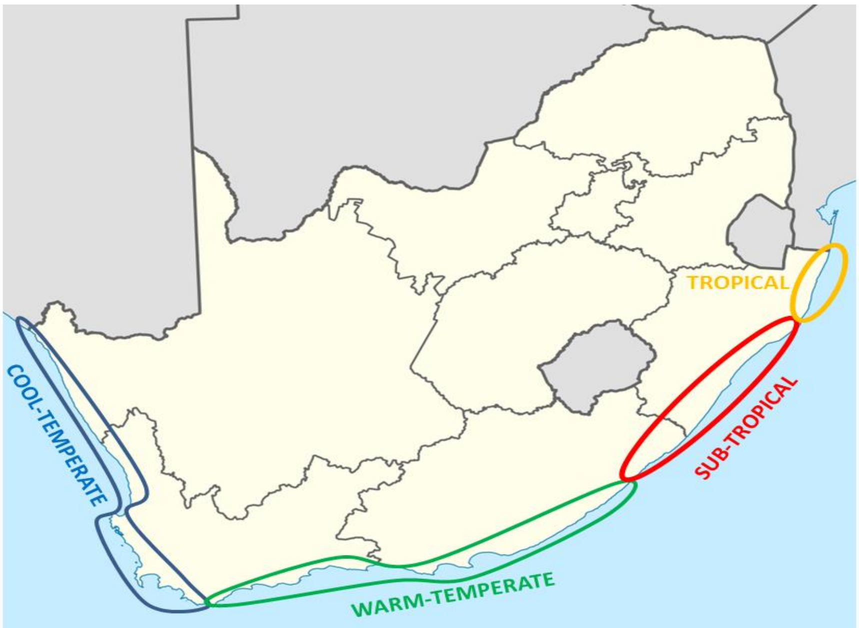


Figure 1: Map of Southern Africa showing the four estuarine biogeographical regions
Source: Van Niekerk *et. al.,* 2019

Estuarine functional types

South African estuaries were previously categorised into five categories (Whitfield, 1992) and have been further refined into nine categories (Van Niekerk, 2019), namely Estuarine Lake, Estuarine Bay, Estuarine Lagoon, Predominantly Open, Large and Small Temporarily Closed, Large and Small Fluvially Dominated, and Arid Predominantly Closed. Individual systems may change from one type to another under the influence of natural events or anthropogenic influences.

Figure 2 below is an illustration of the revised categorisation of South African coastal rivers/streams into estuarine functional types and micro-systems.

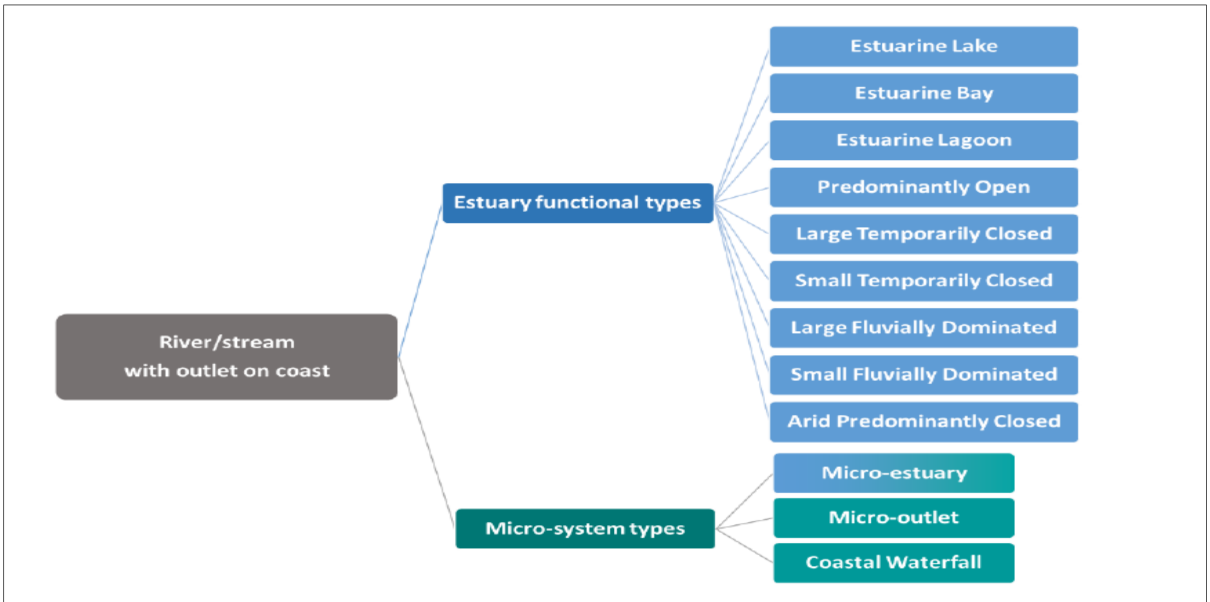


Figure 2: Revised categorisation of South African coastal rivers/streams into estuarine functional types and micro-systems
Source: Van Niekerk *et al.,* 2020

Estuary Functional Zone (EFZ)

The Estuary Functional Zone (EFZ) is defined as *the area that not only covers the estuary water body but also areas that support physical and biological processes and habitats necessary for estuarine function and condition. The latter includes areas influenced by long-term estuarine sedimentary processes (i.e., sediment stored or eroded during floods), changes in channel configuration, aeolian transport processes, and changes due to coastal storms.* The EFZ also encompasses flood plain ecotones and estuarine vegetation that contribute detritus to the base of the estuarine food chain and provide refuge to estuarine biota during high flow events from strong currents (Van Niekerk *et al*., 2020).

1.3.3 Estuarine Key Indicators and Components

DWAF (2008) and Turpie *et al*., (2012) agreed on **four abiotic** and **five biotic** Estuarine Ecosystem Condition Indicators for inclusion in the Estuarine Health Index to evaluate the change in estuary productivity and condition **(Figure 3).** The index includes both **abiotic** and **biotic** condition indicators (also called **components**) as the inter-relationships between these indicators are often not well defined, and also because biotic responses often lag abiotic responses. Abiotic responses can offer an early warning of condition change (Whitfield *et al*., 2008; Van Niekerk *et al.,* 2013).

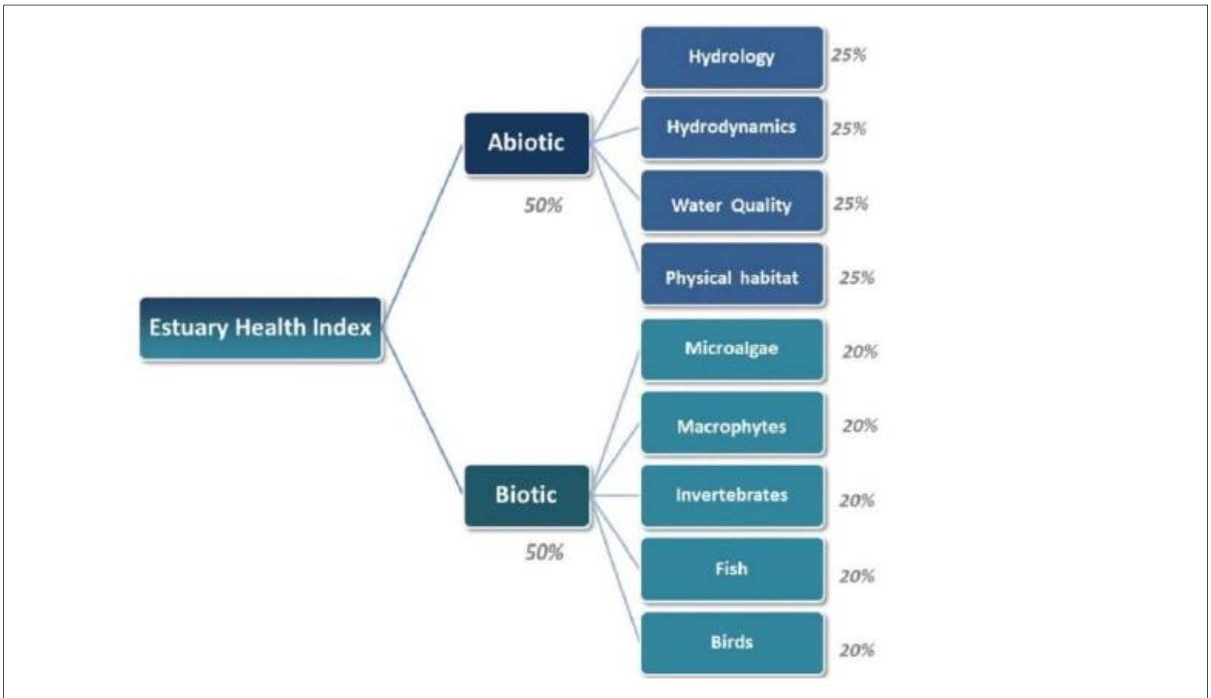


Figure 3: Illustration of the structure of the Estuarine Health Index
Sources: DWAF 2008; Turpie *et al.,*2012

A core set of priority estuaries in need of protection to achieve biodiversity targets has been defined in the National Estuaries Biodiversity Plan and the National Biodiversity Assessment (NBA) 2018.

In the NBA 2011 (Van Niekerk and Turpie, 2012), estuary biodiversity targets are defined in terms of achieving representation of ecosystem types, habitats, and species, as well as meeting population targets that ensure their viability. The overall target was to protect a minimum of 20% of the total estuarine area. Targets for ecosystem types are sometimes used as a surrogate for biodiversity for which data are lacking. In NBA 2011, estuarine ecosystem type was defined based on the associated mouth state, salinity structure, adjacent freshwater type and size, to align with the estuarine ecosystem types used for the assessment of threat status and protection level in the NBA (Van Niekerk and Turpie, 2012). A target of 20% was set for the total area of each type to be protected.

In the recent NBA 2018, estuarine ecosystem protection levels are low, both in terms of number of types and in area. Overall, nearly 82% (19 out of 22 types) of South Africa's estuarine ecosystem types are under-protected. Only 18% of estuarine ecosystem types are Well Protected (four types), while about 36% are Moderately Protected (eight types) and 32% are Poorly Protected (seven types.

In the case of estuaries, protection is not only affected by localised management actions but also through ensuring adequate quantity and quality of freshwater flows into the estuary. In future, flows into an estuary will be decided based on its Water Resource Class (I, II, or III) determined under the National Water Resources Classification System (Dollar *et al*., 2010).

1.3.4 Link between water resources and key components of estuaries

Figure 3 illustrated the key estuarine indicators and components, and it is evident that there is a direct correlation between the estuarine (water resource) and the biotic and abiotic ecosystem components. Furthermore, from **Figure 4** is it evident that the estuarine biotic components are also related to the characteristic of watercourses hydrology (surface flow, surface runoff and interflow), geomorphology, water quality, habitat, and biota) which are the focal points of rehabilitation in this report.

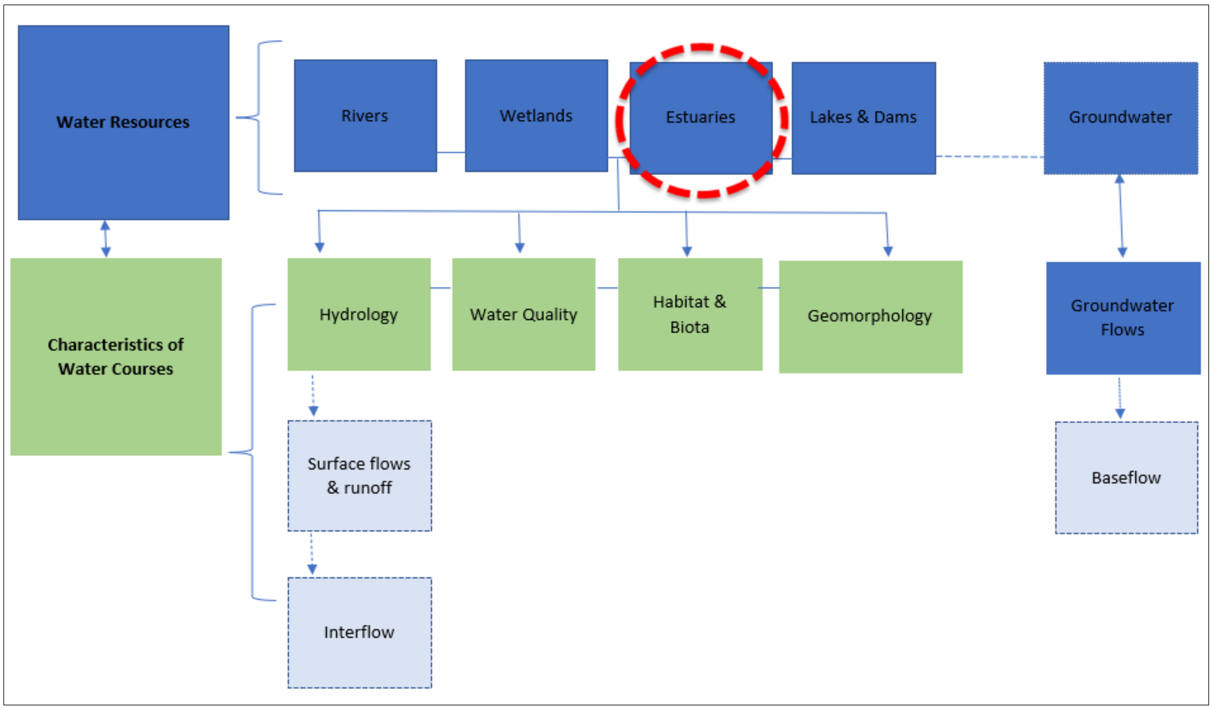


Figure 4: Diagram depicting the link between water resources and key components of estuaries.

Note: *Although* ***Figure 4*** *illustrates the hydrology (relating to river flow whereby water moves in one direction) as the first component of characteristics of watercourses, it should be noted that the component of connectivity i.e., hydraulics hydrodynamics and connectivity mouth state are also considered whereby the flow pattern in estuaries is unsteady, not only because of the tidal rise and fall at the mouth but also because of the water flowing both ways (i.e., not one-way but in both directions) because of the aspect of tidal action.*

1.3.5 Estuarine Ecosystem Services and Impacts

Estuarine Ecosystem Services

Ecosystem services are the benefits that nature provides to people (National Oceanic and Atmospheric Administration [NOAA], 2021). Estuaries are highly productive ecosystems that are culturally, commercially, and recreationally important. Moreover, they support diverse and abundant ecological communities of Fauna and Flora. Additionally, estuaries provide water filtration and habitat protection (NOAA, 2021).

The major concern is that estuarine systems are some of the most heavily used and threatened natural systems globally (Worm *et al.*, 2006). It has been reported that estuaries are intensively and continuously being deteriorated by anthropogenic activities leading to 50% of salt marshes, 35% of mangroves, and 29% of seagrasses being either lost or degraded worldwide (Barbie, 2011). It is for such reasons that the DWS realised the need for the development of rehabilitation management guidelines in order to mitigate against and promote their critical value as well as their benefits to the environment. There are four main types of ecosystem services as per the Common International categorisation of ecosystem services (Young and Potchin, 2018):

- Provisioning Services;
- Regulating Services;
- Supporting Services; and
- Cultural Services.

Table 1 provides some of estuarine ecosystem services and examples.

Table 1: Estuarine Ecosystem Services
Source: Young and Potchin, 2018

Ecosystem Types	Description	Examples
Provisioning Services	Provisioning services are food, raw material, freshwater, and medicinal resources from the ecosystem that benefits people. Many provisioning services are traded in markets. However, in many regions, rural households also directly depend on provisioning services for their livelihoods.	• <u>Fisheries</u>: Estuaries serve as important breeding and nursery grounds for many commercially important fish and shellfish species, contributing to local and global fisheries. • <u>Shellfish Harvesting</u>: Oysters, clams, mussels, and other shellfish are harvested from estuaries, providing a valuable source of seafood.
Regulating Services	Maintaining the quality of air and soil, providing flood and disease control, or pollinating crops are some of the services provided by ecosystems. They are often invisible and therefore mostly taken for granted. When they are damaged, the resulting losses can be substantial and difficult to restore.	• <u>Flood Regulation:</u> Estuaries act as natural buffers against storm surges and flooding by absorbing and dissipating the energy of incoming waves and tides. • <u>Water Purification:</u> Estuaries can filter pollutants from water, improving water quality as it moves from the land into the ocean. • <u>Carbon Sequestration:</u> Salt marshes and seagrass beds within estuaries can sequester carbon dioxide, helping mitigate the impacts of climate change.

Ecosystem Types	Description	Examples
Supporting Services	Providing living spaces for plants or animals and maintaining a diversity of plants and animals, are supporting services and they form the basis of all ecosystems and their services.	• Habitat and Biodiversity: Estuaries provide diverse habitats that support a wide range of plant and animal species, including migratory birds, aquatic organisms, and numerous specialized species adapted to brackish environments. • Nursery Areas: Many marine species use estuaries as nurseries, where juveniles can find food, protection, and suitable environmental conditions for growth. Ecosystem Processes and Functions: ○ Tidal Mixing: The mixing of freshwater and saltwater driven by tides creates a dynamic environment that supports various species and nutrient cycling. ○ Nutrient Cycling: Estuaries are important sites for nutrient cycling, where organic matter and nutrients from land are broken down and recycled, benefiting both estuarine and coastal ecosystems ○ Salt Marsh and Seagrass Ecosystems: These habitats provide valuable services, including shoreline stabilization, water filtration, and habitat for various species. ○ Detritus Food Web: The breakdown of plant and animal material (detritus) supports a food web that sustains many estuarine species
Cultural Services	The non-material benefits people obtain from ecosystems are called cultural service. They include aesthetic inspiration, cultural identity, sense of home, and spiritual experience related to the natural environment. Typically, opportunities for tourism and for recreation are also considered within this group.	• Recreation: Estuaries offer opportunities for recreational activities such as boating, fishing, birdwatching, and photography • Aesthetic and Spiritual Value: People appreciate the natural beauty of estuaries and often have cultural and spiritual connections to these unique landscapes. • Educational Value: Estuaries provide valuable opportunities for research, education, and raising awareness about ecosystem dynamics and conservation.

Estuarine Impacts

Anthropogenic (human) activities are the main causes of estuarine impacts **(Figure 5**). These activities, both **direc**t and **indirect**, are increasingly impacting estuaries and their ability to sustain productivity and associated ecosystem services (Borja *et al*., 2016). Managing, and potentially reducing human impacts on these ecosystems, requires a scientific basis drawing on spatial and temporal trends in ecosystem health (Andersen *et al*., 2015).

Direct anthropogenic (human) pressures can be grouped broadly into five major categories that have been identified namely as follows:

- **Water resource use** *i.e.,* hydrological - flow modification patterns due to weirs, dams, and over-abstractions*;*
- **Land-use** *i.e.,* anthropogenic alteration such as canalisation, riparian infrastructure, infilling;
- **Exploitation of living resources** *i.e.,* Over-exploitation of fish and invertebrates;
- **Pollution** *i.e.,* point (*e.g.,* WWTWs) and diffuse sources (*e.g.,* runoff); and
- **Artificial breaching** *i.e.,* manipulation of estuary mouths.

Indirect pressures largely relate to biological invasions by plants and fish *i.e.*, alien invasive species. Climate change is another impact that cause significant changes on the ecosystem structure and functioning and result in the loss of biodiversity.

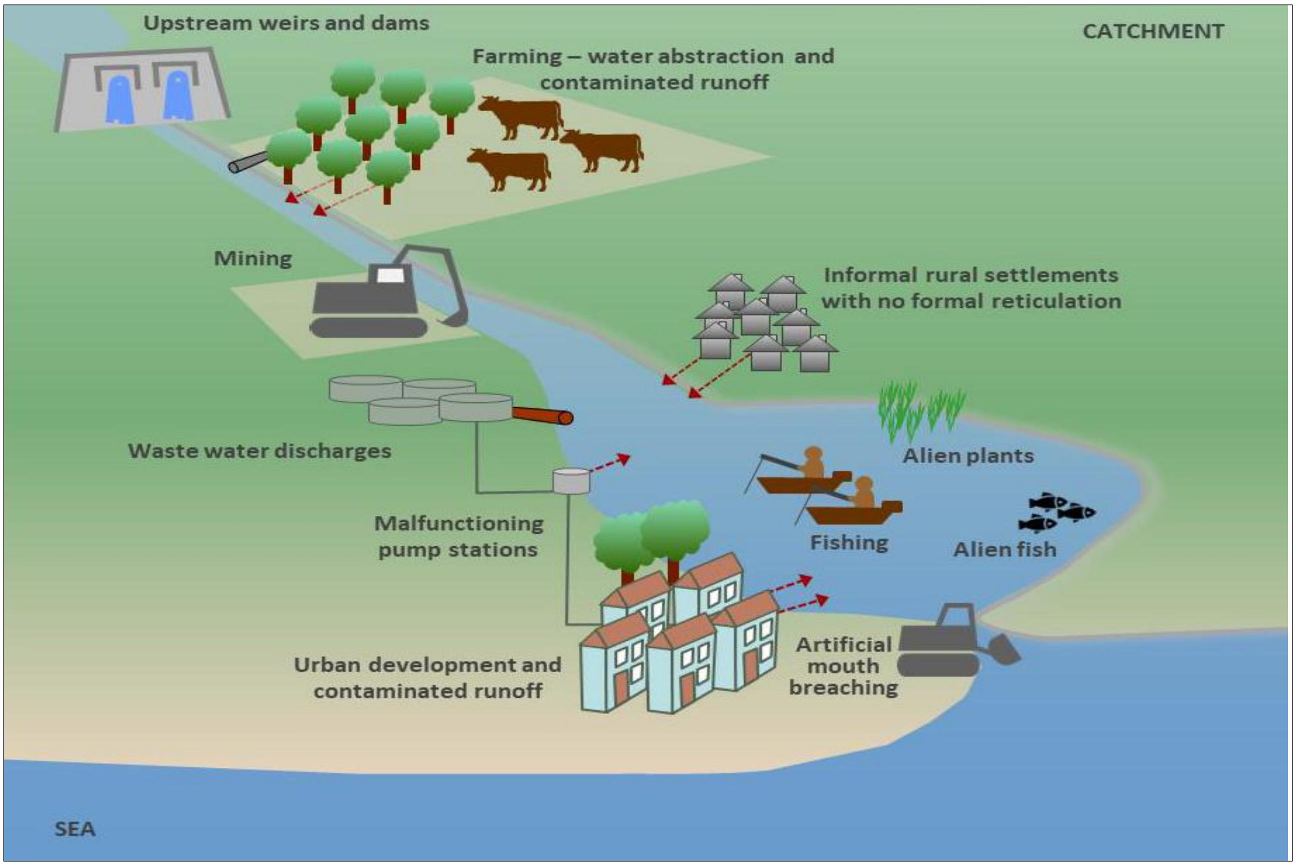


Figure 5: Illustration of some of the key catchment pressures on estuaries
Source: Van Niekerk *et al.,* 2020

1.4 ESTUARINE REHABILITATION DEFINITIONS

Rehabilitation is the process of promoting the recovery of ecosystem services and values in a transformed/degraded system in order to reclaim part of the system's lost societal value (Hay and McKenzie, 2005). The benefit of ensuring that ecosystems are in good ecological condition secures ecosystem services and maintain resilience against climate change impacts.

1.5 GUIDING PRINCIPLES AND APPROACH FOR THE DEVELOPMENT OF THE GUIDELINES

The Estuarine Rehabilitation Management Guidelines are developed to mitigate negative impacts, on **hydrology (surface flow and interflow), groundwater flows, physiochemical (saline mixing ratio), water quality, habitat, and biota**.

The following are aspects to be covered under each characteristic of watercourse:

- Description of the specific **key estuarine components and their natural phases**;
- **Types of impacts** for each characteristic of a watercourse – brief overview and description of the impacts that gives rise to the degradation of the watercourses to better understand the problem and subsequently develop effective rehabilitation guidelines;
- **Legal Considerations** - applicable legislation to be considered for undertaking site-specific rehabilitation activities on a particular characteristic of a watercourse; and
- **Development of Rehabilitation Guidelines** - Step by step guidelines on rehabilitation measures/interventions for executing rehabilitation - planning, design, implementation, and monitoring.

1.5.1 Estuarine Rehabilitation Guiding Principles

Wiseman and Sowman (1992) argued that there are four principles that underlie the approach to estuarine rehabilitation. They include:

- Identification of the symptoms of transformation and degradation;
- Determination of the probable causes of these symptoms
- Choosing the desired "restored state" of the estuary; and
- Evaluation of the alternative strategies to achieve the restored state.

The need for rehabilitation arises due to degradation. Although interventions may not be able to reinstate water resources to a natural state, a functional state must be the aim of ecosystem recovery initiatives. King *et al.,* (2003) and WRC (2016) recommended the following key principles for rehabilitation:

- Defining Rehabilitation Objectives;
- The objectives for rehabilitation should be clear, explicit and be defined by the principles listed above;
- Rehabilitation must direct the system back towards a more natural state, and work in harmony with the major abiotic drivers of ecosystem;
- Undertaking rehabilitation should be seen as an interdisciplinary activity, recognising that rehabilitation may be necessary over a range of spatial and temporal scales;
- Rehabilitation should aim at treating causes rather than symptoms;
- Given that ecosystems are dynamic and can naturally exist in alternative metastable states, it should be remembered that it is easier to cross a degradation threshold than to return over it; and

- Monitoring should be an essential component of rehabilitation.

Below is a list of some key important aspects/approaches and applicability of the above-mentioned principles:

- Ecosystem-based approach;
- Re-instating natural processes;
- Enhancing biodiversity and habitat diversity;
- Improving water quality;
- Flood mitigation and erosion control;
- Stakeholder engagement and community involvement; and
- Long-term sustainability.

1.5.2 Approach

The Estuaries Rehabilitation Guidelines being developed aim to provide guidance to the water users on step-by-step rehabilitation measures/interventions to be followed for executing rehabilitation with specific attention to and consideration of planning, design, implementation, and monitoring for the identified impacts. **Table 2** below presents the approach to be followed for development of the estuarine rehabilitation guidelines.

Table 2: Approach to be followed for the development of Rehabilitation Guidelines for Estuaries

Stakeholder Engagement

Phase	Description
PHASE 1: Diagnostic Phase	• The characteristics will be diagnosed to determine the level of modification and rehabilitation measures that will be recommended to reinstate the conditions of the drivers. • Determine the conditions and the type, size, extent of impacts on characteristics of watercourses.
PHASE 2: Planning & Assessment Phase	• Conduct planning and assessment to ensure the desired rehabilitation outcomes are achieved. • Assess and collate available information from historical and current maps & available datasets on the affected watercourses. • Review and assess legal considerations.
PHASE 3: Define the Rehabilitation Objectives	• Identify and define the objectives of rehabilitation to ensure the impacts on the characteristics of watercourses are addressed.
PHASE 4: Execution	• Recommend techniques and methods to address impacts identified. Consider protection of water resources ecosystem.
PHASE 5: Monitoring and Evaluation (M & E) and Reporting	• Monitor the results of the techniques and methods employed for rehabilitation to determine whether objectives are being achieved and whether there are any additional interventions required. • Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes. • Determine maintenance objectives. • Compilation of Rehabilitation Reports.

1.6 INTENDED USERS OF THE GUIDELINES

The Rehabilitation Management Guidelines for Estuaries is a set of tools developed to ensure that clear and practical steps are provided on a wide range of rehabilitation measures/interventions related to characteristics of watercourses that take cognisance of legal, social, economic, and ecological issues and aspects. The guidelines are intended for all Government Departments (National, Provincial and Local), Proto/Catchment Management Agencies (CMAs), sectoral institutions (*i.e.,* higher education institutions), civil society members, non-governmental entities, private sector (agriculture, industries, mining) and all interested and affected parties involved in the water sector.

These guidelines are developed at a national scale for implementation at a Catchment level.

1.7 STRUCTURE OF THE GUIDELINES

The guideline is divided into four main sections as follows:

- The opening sections contain the document signatories, document index and status, acknowledgements, table of contents, list of figures, tables, acronyms, and executive summary.
- **Section 1** provides the background to the development of the guidelines, estuarine categorisation system and characteristics, estuarine key indicators and components, links between water resources and key components of estuaries, estuarine ecosystem services, estuarine impacts, purpose, approach, intended users and structure of the guidelines.
- **Section 2** provides the overarching legal framework for estuary rehabilitation.
- **Section 3** describes the characteristics of watercourses and their linkage to water resources and the step-by-step Technical Rehabilitation Guidelines for key components of estuaries.
- **Section 4** provides recommendations and a way forward.

2. LEGAL FRAMEWORK

2.1 OVERARCHING LEGAL FRAMEWORK

According to Section 24 of the Constitution of South Africa, *everyone has the right to an environment that is not harmful to their health or 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.*

There is a variety of legal tools (*i.e.,* acts, gazettes) that need to be considered when undertaking estuarine rehabilitation activities. The two main pieces of overarching legislation in South Africa are the National Water Act (NWA) (Act 36 of 1998) and National Environmental Management Act (NEMA) (Act 107 of 1998). These two legislative tools in some instances give provision for some small-scale rehabilitation activities to be undertaken without prior authorization (NEMA) or are eligible for General Authorization (under the NWA). Medium to large scale rehabilitation activities may require different types of approvals prior to commencement, such as licenses, environmental authorizations, permits or rights. The various types of environmental approvals are discussed below. There are other related environmental legislations that can apply to estuarine rehabilitation activities depending on the cause for rehabilitation and different activities of rehabilitation that may need to be carried out. The overarching pieces of legislation applicable to estuarine rehabilitation are as follows:

- Constitution of the Republic of South Africa, Act 108 of 1996;
- National Water Act, 1998 (Act 36 of 1998) (NWA);
- National Environmental Management: Integrated Coastal Management Act, 2008 (Act 24 of 2008);
- National Forests Act ,1998 (Act No 84 of 1998);
- National Ports Act, 2005 (Act 12 of 2005)
- Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947);
- Seashore Act, 1935 (Act 21 of 1935);
- Municipal by-laws; and
- Draft Climate Change Bill (2023).

When setting the objectives for all rehabilitation scenarios, consideration must be given to the (NBA 2018) recommendations on the Ecological Category of estuaries and the DWS RDM outputs~~.~~

2.2 LEGAL CONSIDERATION SPECIFIC TO ESTUARIES REHABILITATION

National Water Act, 1998 (Act 36 of 1998)

Estuary and watercourse are separately defined in the NWA. These definitions imply that estuaries are not seen as watercourses. Therefore Section 21 (c) and (i) activities will not be regulated in estuaries unless there is a freshwater link *i.e,* estuaries with salt marshes form part of the tidal zone, but there may be a strong freshwater inflow on the other side. Therefore, any activity from the 500 m of the freshwater zone would trigger Section 21 (c) and (i) activities.

Integrated Coastal Management (ICM) Act, 2008 (Act 24 of 2008)

Under the Integrated Coastal Management (ICM) Act, the coastal protection zone depicted in **Figure 6** (coastal zone) consists of the following:

- Sensitive coastal areas, as defined by the Environment Conservation Act (Act No. 73 of 1989, section 21 [1]);
- Any part of the littoral active zone that is not coastal public property;
- Any coastal protected area, or part of such an area, which is not coastal public property;
- Any rural land unit that is situated within 1000 metres of the High-Water Mark (HWM) which is zoned as agricultural or undetermined;
- Any urban land unit that is situated completely or partly within 100 metres of the HWM;
- Any coastal wetland, lake, lagoon or dam which is situated completely or partially within a land unit situated within 1000 metres of the HWM that was zoned for agricultural or undetermined use, or is within 100 metres of the HWM in urban areas;
- Any part of the seashore which is not coastal public property (including all privately owned land below the HWM);
- Any admiralty reserve which is not coastal public property; and
- Any land that would be inundated (submerged or covered) by a 1:50 year flood or storm event (this includes flooding caused by both rainstorms and rough seas).

The ICM Act also provides for the establishment of a coastal management line, designed to protect the coastal protection zone. No new development (construction) is permitted within a coastal management line.

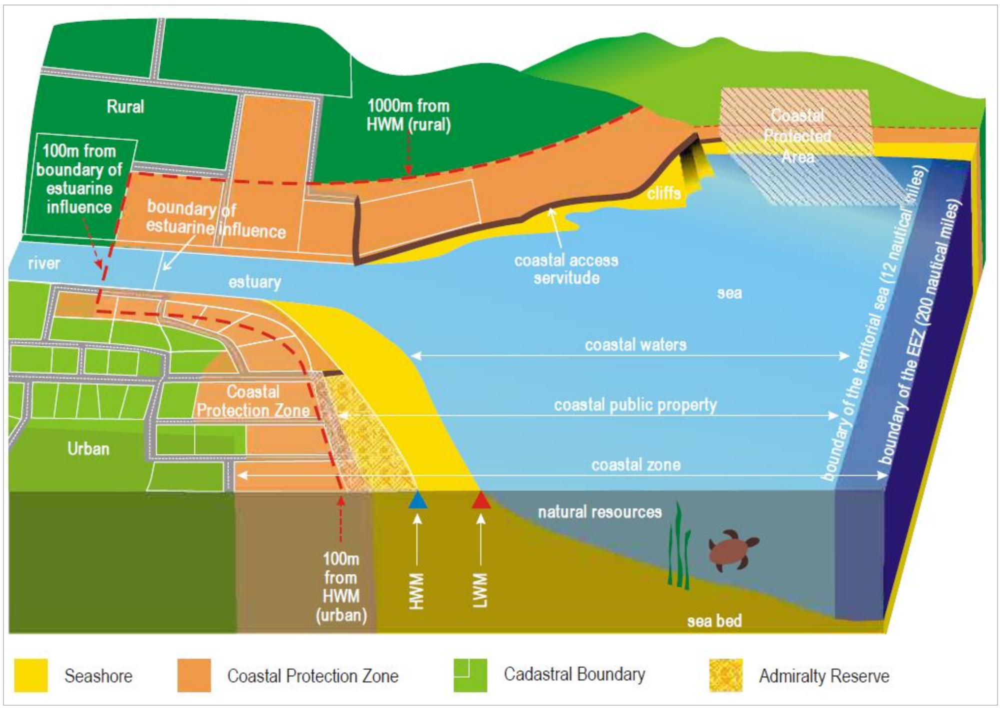


Figure 6: The Coastal Zone of South Africa
Celliers *et al.*, 2009

Several coastal-related activities for which an EIA is required have been defined in relation to a 100 m management line in EIA Regulations 2017. In addition, the coastal buffer zone defined by the ICM Act (Section 16) is 100 m for certain land-uses and the Department of Economic Development, Environmental Affairs and Tourism (DEDEAT). Draft Wild Coast Environmental Management Plan recommends that *estuaries that are still pristine and undeveloped should be retained in that state and all development should have a suitable buffer with estuaries, at least 100 m in most cases.* Thus, in general, a setback line of 100 m is regarded as an acceptable and effective buffer against human interference with the estuary and its sensitive riparian areas, though exceptions may occur.

NEMA EIA Regulations

Any proposed development activities within 32 m of the edge of a river, water course or wetland/salt marsh is regulated by the EIA regulations (2017) of NEMA. Any such development triggers a requirement to obtain environmental authorisation by way of an environmental impact assessment. However, a development setback line of 100 m for estuaries as suggested above would automatically exclude all activities that occur within 32 m of the edge of the estuary.

Listing Notice 3 (GNR 324: 2017) of the National Environmental Management: Environmental Impact Assessment Regulations defines the EFZ as *the area in and around an estuary which includes the open water area, estuarine habitat (such as sand and mudflats, rock and plant communities) and the surrounding floodplain area, as defined by the area below the 5 m topographical contour.*

National Forests Act (NFA), 1998 (Act No 84 of 1998)

The act ensures the effective protection and sustainability of natural forests through proper control over development and land use change affecting forests in South Africa in a cooperative manner in all regions, and according to the mandates stipulated under the NFA.

Natural forests and woodlands form an important part of the environment and need to be conserved and developed according to the principles of sustainable management. Plantation forests play an important role in the economy. They also have an impact on the environment and need to be managed appropriately. Invaders like Eucalyptus or Pinus species encroaching the riparian vegetation from forest plantation must be eradicated since they have impact on indigenous flora and river flows.

By-laws

Municipal by-laws such as Sanitation, Land use Management, Waste Management, Diffuse Water Quality Management, Estuarine and River by-laws [applicable (per coastal area)] need to be considered by every person(s) undertaking rehabilitation.

Other area specific policies and legislations include the following:

1. Wild Coast Tourism Development Policy (WCTDP) gazetted February 2001. The WCTDP is gazetted and is therefore the primary planning document for tourism development within 1 km of the high-water mark on the Wild Coast.
2. Western Cape Biodiversity Act No. 6 of 2021 – the act sets out a best practice model for the governance of public entities in the conservation practice. It integrates administrative provisions and institutions for the conservation, restoration, management and sustainable use of biodiversity and ecosystems in the Western Cape Province.

Table 3 presents a summary of Legislative Tools Applicable to Estuaries Rehabilitation.

Table 3: Legislative Tools Applicable for Estuarine Rehabilitation

Institution	Legislative Tool	Sections	Process/Application
DWS	National Water Act 36 of 1998	19, 20, 21, 39	Water Use License Application (WULA), General Authorization (GA)
	Resource Directed Measures (RDM)	Gazetted RDM outputs	Gazettes
DFFE	National Environmental Management Act, Act 107 of 1998	• Environmental Impact Assessment Regulation (2014) • Listing Notice 1, 2, and 3 (GN R983, R984, R985)	List of activities that have been identified as having the potential to cause harm to the environment that need to be investigated in detail through an Environmental Impact Assessment (EIA) process such that magnitude, extent, and timing of these negative impacts can be fully understood and weighed up again potential positive impacts (social or economic benefits).
		• Section 30	Control of Incidents; 'incident' means an unexpected, sudden, and uncontrolled release of a hazardous substance, including from a major emission, fire or explosion, that causes, has caused or may cause significant harm to the environment, human life or property.

Institution	Legislative Tool	Sections	Process/Application
		• Section 30A	Emergency situation means a situation that has arisen suddenly that poses an imminent and serious threat to the environment, human life, or property, including a 'disaster' as defined in section 1 of the Disaster Management Act, 2002 (Act No. 57 of 2002), but does not include an incident referred to in section 30 of this Act.
	National Environmental Management: Integrated Coastal Management Act, 2008 (Act 24 of 2008) (ICMA)	• Directives	Facilitate the sustainable use and management of South Africa's coastline and coastal and estuarine resources.
		• Section 69 (1)	No person may discharge effluent that originates from a source on land into coastal waters except in terms of a GA contemplated in subsection (2) or a coastal waters discharge permit issued under this section by the Minister after consultation with the Minister responsible for the DWS in instances of discharge of effluent into an estuary.
		• Section 71 (3)	The Minister may not grant a dumping permit that authorises the dumping of any waste or other material, other than— • dredged material; • sewage sludge; • fish waste, or material resulting from industrial fish processing operations; • vessels and platforms or other man-made structures at sea; • inert, inorganic geological material; • organic material of natural origin: or • bulky items primarily comprising iron, steel, concrete and similarly nonharmful materials for which the concern is physical impact and limited to those circumstances where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than dumping at sea.
	Costal Management Programmes (CMPs)	-	The promulgation of the ICMA, for the first time mandated the development of CMP. CMP is a policy directive for the management of the coastal zone, inclusive of strategies and plans for the effective implementation of the ICMA to enable organs of state to plan accordingly, to set a course for the environmental future of a nation by addressing the resolution of current management problems and user-conflicts (due to the wide variety of activities and uses of the coast), as well as the long-term development and management of the coastline. CMP is intended to be used by coastal provinces, coastal municipalities, coastal practitioners and decision-makers, as well as professionals working in non-government organisations and other organisations and institutions that have a bearing on coastal management.
	National Forests Act ,1998 (Act No 84 of 1998)	• Section 1	Promote the sustainable use of forests for environmental, economic, educational, recreational, cultural, health and spiritual purposes.

Institution	Legislative Tool	Sections	Process/Application
		• Section 7 (2)	Mangrove forest[1] is one of the National forests type declared under Section 7 (2) of the NFA as national forests type and was published at a Government gazette No 31232 of 18 July 2008.
		• Section 3(3)(a), Section 12, and Section 15	Application is needed for a licence to destroy the natural forest (*i.e., Barrington racemosa, Brugeria Gymnorrhiza* and *Rhizophora mucronate*, which in terms of Section 3(3)(a) of the Act may only be granted in exceptional circumstances cases. Some mangroves trees species are also protected under Section 12 of the NFA, for which license is needed under Section 15 of the Act.
	National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)	• 52, 53, 56, 57, 65, 66, 67, 69, 70, 71, 73, 75, 76, 88, 89, 90, 91, 92, 93	Environmental Impact Assessment (EIA), Basic Assessment Report (BAR)
	National Environmental Management: Waste Act, 2008 (Act 59 of 2008)	• 45	Water Management License (WML), Licence in terms of section 45
Department of Transport	National Ports Act, 2005 (Act 12 of 2005)	• Section 74 (3a)	The Harbour Master is, in respect of the port for which he or she is appointed, the final authority in respect of all matters relating to pilotage, navigation, navigational aids, dredging and all other matters relating to the movement of vessels within port limits.
DALRRD	Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947)	• Section 3(1)(2)(3), Section 7	The act provides for the registration of fertilisers, farm feeds, agricultural remedies, stock remedies, sterilising plants, and pest control operators with the aim of regulating or prohibiting the importation, sale, acquisition, disposal or use of fertilisers, farm feeds, agricultural remedies, and stock remedies. Furthermore, it governs the use of antimicrobials for growth promotion and prophylaxis/metaphylaxis and the purchase of over-the-counter (OTC) antimicrobials by the lay public (chiefly farmers).
	The Deeds Registries Act, 1937 (Act 47 of 1937)	• Section 19 (1)(a)(b)	The act defines land ownership and registration of deeds. An owner of land is a person in control of land or a person who occupies or uses the land on which: • any activity or process is or was performed or undertaken; or • any other situation exists, which causes or has caused or is likely to cause pollution of a water resource. An owner must take all reasonable measures to prevent any such pollution from occurring, continuing, or recurring. The said owner of the land would have to register their land with the deeds of registries.
Municipalities	By-laws	Sanitation, Land use Management, Waste Management, Diffuse Water Quality	Applicable (per area) municipal by-laws need to be considered by every person(s) undertaking rehabilitation.

[1] *Mangrove rehabilitation has been attempted in various degrees of success and usually require planting or replanting seeds of trees species, with due consideration of the specific environmental requirements of various mangroves species especially tidal depth.*

Institution	Legislative Tool	Sections	Process/Application
		Management, Estuarine and River by-laws	

2.3 ALIGNMENT WITH POLICIES, STRATEGIES AND PRINCIPLES

Various policies, strategies and principles inform Estuarine Rehabilitation Management in South Africa, and these include, but are not limited, to the items:

Policies and Strategies

- National Development Plan;
- The National Water Resource Strategy (NWRS III) (2023);
- The National Water and Sanitation Master Plan (NW&SMP) (2018);
- The Draft Environmental Rehabilitation Policy (2014);
- The Integrated Water Quality Management (IWQM) Policies (2016) and Strategies for South Africa (2017);
- Eutrophication Management Strategy for South Africa – Second Edition (2022);
- The implementation of Gazetted Resource Directed Measures (RDM), particularly the Reserve, Resource Quality Obsessives (RQOs), Water Resource Classification and Sources Directed Controls (SDCs);
- The Catchment Management Strategy is informed by the National Water Policy and promotes the sustainable balance between utilisation and protection of water resources in a catchment; and
- Policy principles and guidelines for control of development affecting natural forests (2010) aimed to ensure the effective protection and sustainability of natural forests through proper control over development and land use change affecting forests in South Africa.

Key Water Resource Management Principles and Concepts

- Integrated Water Resource Management (IWRM) - a process for co-ordinated planning and management of water, land and environmental resources. It takes into account the amount of available water (surface and groundwater), water use, water quality, environmental and social issues as an integrated (combined) whole to ensure sustainable, equitable and efficient use.
- Sustainable Development Goals (SDGs) - are aimed ensuring the availability and sustainable management of water and sanitation for all by 2030. Every year, an annual SDG Progress Report should be produced based on the global indicator framework and data produced by national statistical systems and information collected at the regional level.
- Global Biodiversity Framework (GBF) - aims to enable urgent and transformative action by Governments, and subnational and local authorities, with the involvement of all of society, to halt and reverse biodiversity loss, to achieve the outcomes it sets out in its Vision, Mission, Goals and Targets. Although the DWS focuses mainly on the reporting on the SDG targets, it is recommended that the relevant authorities should use the outputs of the current RMGs for their reporting at the respective platforms.
- Social-Ecological System (SES) – are linked systems of people and nature, emphasising that humans must be seen as a part of, not apart from, nature (Berkes and Folke, 1998).

3. GUIDELINES FOR KEY COMPONENTS OF ESTUARIES

- **In the Diagnostic Phases of all the rehabilitation scenarios in the guidelines, the EMPs and RDM outputs (Reserve, Classification and RQOs) should be consulted to establish estuarine status in terms of any targets that have been set to ensure site-specific rehabilitation measures are put in place per estuary. It should also be noted that the recommended rehabilitation measures under each execution phase are estuary specific and dependent on the site-specific conditions.**

3.1 HYDROLOGY

3.1.1 Description

Hydrology is the science which deals with terrestrial waters. It focuses on the following key components of terrestrial waters:

- Occurrence of terrestrial ecosystems;
- Circulation and distribution on our planet;
- Physical and chemical properties of terrestrial ecosystems; and
- Interaction with the physical and biological environment, including human impact contributions (IHE, 1998).

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

3.1.2 Types of Impact

3.1.2.1 Dam Construction and Weirs

Human-induced disturbance such as instream dams and weirs within and in close proximity to estuaries alters the hydraulics of the estuarine ecosystem which results in impacts on biota. These barriers also alter the flow characteristics which cause changes in the physical habitats upon which biota depend. Moreover, these structures have connectivity impacts on the physical habitat and biota and negative impact on the ecology of the estuaries by preventing the natural migration of biota and sediment.

Other impacts of dams and weirs worth mentioning are:

- Impact on sediment transport (reduces sediment transport into the Estuaries) which causes a negative impact on the ecology of the estuaries *e.g.,* morphological transformation;
- Increases the probability of erosion downstream of the riverbed which can cause turbidity during floods which has an impact on the water quality; and
- Possibility of increasing the water temperature which might affect aquatic life; however, this might be dependent on the quantity of the water being released into the estuary.

Note:
The impacts are dependent on the size and location of the dam/weir structure (this becomes essential during the design stage).

3.1.2.2 Urbanisation and poor land use

The demand for freshwater to meet domestic, industrial, and agricultural demands grows as the population grows. The urbanisation of coastal watersheds also results in greater impervious land cover leading to accelerated freshwater runoff rates and higher river discharges rate *i.e.*, the same volume of run-off takes place over a shorter period. An increase in freshwater flow rates results in a decrease in water residence time in estuaries, which increases their capacity to dilute, transform or get rid of pollutants (Kennish, 2017) (unless sediment-bound). Other changes that can significantly alter water-flow regimes along coasts include channelisation, marsh impoundment, and wetland habitat destruction which affect natural water storage capacity.

3.1.2.3 Over-abstraction

Human-induced disturbances such as over-abstraction of water from rivers result in reduced flow volumes and changes in flow drivers and hydrodynamics (*e.g.,* reduced flow depth can lead to temperature increases; reduced total energy will reduce sediment migration) which have a direct impact on ecological category, habitat, and biota of estuarine systems. Over-abstraction activities also alter the freshwater/saltwater balance. Over-abstraction may result in exposure of organic soils and peat, which may increase the release of greenhouse gasses such as methane, and reduce the nursery function of the estuary, which in turn, negatively impacts fish reserves for local poor communities and the fishery industry.

3.1.2.4 Bridges

Bridges are formal structures that provide safe crossing for one or more modes of transport and/or humans or animals over the course of other transport modes, humans, animals, and watercourses. Bridges have the following impacts (depending on the type):

- Changes flow dynamics;
- Changes in erosion and sedimentation processes and patterns;
- Disturbs benthic habitat; and
- Disrupts migration routes.

The following should be considered when constructing a bridge as it will have implications for potential need for rehabilitation:

- Understand the erosion, deposition and water exchange patterns and foundation conditions before deciding on the location and type of bridge to be constructed;
- The shape and location of the foundation structures must not interrupt flow patterns;
- Bridge foundations and structures should be able to withstand major flood events in accordance with the South African National Road Agency SOC Ltd (SANRAL) Drainage Manual (2015) *i.e.*, different roads have different standards;
- Fully understand the effect of floods, flood levels, and sediment movement; and
- Ensure that a structural engineer with experience in coastal environments registered with a professional body is employed to carry out the planning, design, and construction supervision of a bridge in the EFZ.

The design of a bridge within the EFZ must aim to avoid or minimise the following:

- Size of the footprint and foundations within the water course and floodplain;
- Eddying around bridge pillars (piers) or foundations;

- Undercutting of structures and foundations;
- Approach embankments intruding into watercourses and floodplains and interfering with flow patterns;
- Alteration of flow patterns and backwater effects or impounding of streams;
- Sediment mobilisation;
- Loss of riparian habitat during bridge construction;
- Blocking of riparian wildlife corridors;
- Aesthetically insensitive design for perspectives from above and below the bridge; and
- Pollution of the estuarine environment.

The considerations must also take into account new activities that are planned within estuaries.

3.1.2.5 Jetties & Piers

Piers are large-scale structures of major capital investment, constructed using massive volumes of concrete and steel, and requiring significant foundations. Jetties are simple structures commonly constructed of wood and/or steel. Jetties may be anchored to the river or estuary bed or floating from a secured shore-based point.

Jetties and piers have the following impacts:
- Changes flow dynamics;
- Changes in erosion and sedimentation processes and patterns;
- Disturbs benthic habitat;
- Pollution caused by fuel spillages from boats; and
- Access point for fishing.

Consider the below when rehabilitating or removing jetties and/or piers:
- Ensure that a qualified specialist is employed to carry out the rehabilitation or removal of jetties and/or piers;
- Ensure that local flooding risks and tidal surges are determined by considering the number and jetty or pier types as well as their location;
- Ensure that bank stabilisation is performed according to Scenario 2 of Geomorphology of this guidelines under **Section 3.2.3**;
- Ensure that the foundations of jetties and piers are below the expected erosion level to resist undermining during storm and flood conditions;
- Sediment stabilisation and debris trapping should be taken into consideration in the design and construction of jetties and pier;
- Irreparable jetties and piers must be completely removed;
- Ensure that the number of private jetties is restricted as far as reasonably possible;
- Ensure that Jetties and piers are maintained at all times; and
- A procedure for removal, relocation, or redesign that will lessen the environmental effects should be used to deal with jetties or piers that are improperly situated and are contributing to increasing bank erosion, posing a risk to water users or wildlife, or negatively impacting estuary functioning.

3.1.2.6 Slipways/Launching Ramps

Slipways are used to facilitate the movement of boats into and out of water.

The impacts of slipways are as follows:
- Habitat loss;

- Changes in flow dynamics;
- Erosion; and
- Fuel spillages from boats.

Consider the below when rehabilitating or removing slipways/launching ramps:

- Make sure the slipways are supported by adequate facilities and access, with a focus on preventing negative environmental effects like oil, fuel, and detergent pollution (wash bays) or damage to vegetation due to impromptu staging and parking;
- Slipways should comply with South African Maritime Safety Association (SAMSA) guidelines and safety standards for coastal and inland navigation;
- Ensure that the slipway is placed in a sheltered protected area with short wave action to minimise the need for artificial protection-unless a more environmentally acceptable option exists;
- Ensure that the slipway is built parallel to wave direction *i.e.*, at right angles to predominant waves;
- Ensure that the kind and size of boats that will likely be launched are considered while choosing the slope of the slipway;
- Ensure that the slipway's width is based on the level of wave or swell protection. Typically, a single lane would be 5 m with enough protection and 7 m with inadequate protection. The width should also be informed by the rate at which vessels need to vacate the water body in the event of a storm or similar emergency;
- Ensure that the slipway surface is coarse or wavy (corrugated), especially in tidal estuaries and marine areas, to aid grip when marine vegetation is prominent; and
- Slipways should be clearly marked so that their position is visible to users especially during adverse conditions.

3.1.2.7 Stormwater discharge structures

Stormwater structures are discharge points into rivers, estuaries, floodplains, and wetlands from developed areas.

Stormwater structures impact the following:

- Changes in flow dynamics;
- Changes in erosion and sedimentation processes;
- Habitat transformation/loss; and
- Water quality pollution.

The below should be considered when rehabilitating or removing physical structures:

- The rehabilitation or removal of the structure must not degrade natural processes and should interrupt water flow as little as possible;
- The structures must be aesthetically compatible with the receiving environment;
- The structures may not interfere with legitimate public access to coastal public property or adjacent landowners;
- The structures must accommodate the effects of climate change;
- Physical structures must not facilitate unsustainable impacts on ecological systems or species; and
- If the structure/s leads to unsustainable impacts, they must be removed. This must be done in a manner that will not disturb the natural processes of the environment.

3.1.3 Rehabilitation Management Guidelines for Hydrology (Surface flow, runoff, and baseflow)

Scenario 1: Rehabilitation or removal of physical structures (stormwater structures, weirs) within the water resource

PHASE 1: Diagnostic Phase:

Step 1: Identify the physical structures that need to be rehabilitated or removed.
Step 2: Conduct a desktop assessment of the physical structures that need-to be removed.
Step 3: Consult local, provincial, or national authorities responsible for the physical structures (municipal as well as Provincial DWS and DEA&DP Offices).

PHASE 2: Planning and Assessment

Step 1: Conduct ground truthing of the physical infrastructure that needs to be rehabilitated or removed.
Step 2: If the physical structures are legal, conduct a public participation process for the rehabilitation or removal of these physical structures in accordance with NEMA regulations.
Step 3: If the physical structures are illegal, the responsible person must remove the mentioned structure, or the authority will follow the litigation process.

PHASE 3: Identify and Define the Rehabilitation Objectives

The objectives of rehabilitating or removing physical structures must be defined and be clear from the onset. These objectives must be informed by the information and data collated in **Phases 1** and **2** above. Below is a list of common aims and objectives:

- To remove or rehabilitate any physical structures within the estuary, without inducing other adverse impacts;
- To rehabilitate a more natural flow regime by rehabilitating or removing the physical structures;
- To revitalise the natural regime of the estuary by removing any obstruction in the estuary;
- To improve biodiversity by allowing the revitalisation of the natural regime of the estuary; and
- To prevent habitat degradation.

PHASE 4: Execution

The following are recommended for consideration when rehabilitating stormwater discharge structures:

- Sustainable Urban Drainage Systems must be used where applicable. This is consistent with the ideas of working with nature and sustainable development;
- Ensure that stormwater outlets are built in compliance with local municipal bylaws, and general best practices, and resist erosion and flood events of a size related to expected climate change consequences, such as sea level rise and amplified extreme weather events;
- Ensure that the quantity and quality of stormwater is managed prior to reaching the natural environment, in so far as practical; and
- Ensure that water quality is monitored before it is discharged into floodplains, rivers, or estuaries and pollution control measures must be taken both at the source and before discharge.

PHASE 5: Monitoring, Evaluation and Reporting

Monitoring

- Ensure that the quantity of stormwater is managed prior to reaching the natural environment, in so far as practical;
- Monitor the rehabilitated/removed structures;
- Monitor seasonal flows (low flow and high flow) the flow and habitat conditions at least twice per annum. If there is a negative change, deal with it accordingly;
- Monitoring parameters and frequency depending on the type of estuary in question are as follows:
  - Hydrodynamics and mouth condition;
  - Mouth Closure – Dailly observation when the mouth is nearly closed or open; and
  - A periodic mouth closure for less than 3-months in duration.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objectives.

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas; and
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

Scenario 2 (A): Control and Management of over-abstraction activities in the catchment affecting the freshwater volumes reaching the estuary.

Note:

Human-induced disturbances such as over-abstraction of water from rivers result in flow impediment impacts and changes in flow drivers and hydrodynamics of the estuary, which have a direct impact on ecological category health (including habitat and biota) of estuarine systems.

PHASE 1: Diagnostic Phase:

Step 1: Describe the catchment area including the affected estuary.
Step 2: Identify and describe water users within the area of concern.
Step 3: Review all water users:
- Registered users on the WARMS and eWULAAS
- Identify unregistered/Illegal users through local authorities (DWS, DFFE and municipalities).

PHASE 2: Planning and Assessment

Step 1: Relevant Specialist must conduct a hydrological study of the catchment in question.
Step 2: Use Google Earth Pro, Sentinel, and other available high-resolution images (<10 m spatial resolution) and other related techniques to identify water users abstracting water from the river.
Step 3: Assess the Water use Authorization and Registration Management System (WARMS) and Electronic Water Use Licence Application and Authorisation System (e-WULAAS) on the permits, GAs/WULs given for the abstraction of Water.

Step 4: Conduct ground truthing on Ecological Water Requirements (EWR), to determine whether required quantity and timing of freshwater inflows is reaching the estuaries.

PHASE 3: Identify and Define the Ideal state and Rehabilitation Objectives

The objectives of control and management of over-abstraction activities must be defined and be clear from the onset. These objectives must be informed by the information and data collated in **Phases 1** and **2** above. Some of the common objectives for rehabilitation are to control the abstraction of water from catchments and prevent flow impediment impact and changes in flow drivers and hydrodynamics into the estuary.

PHASE 4.1: Execution (licensed user)

Step 1: Ensure that each water user adheres to the abstraction limits set under the GA/WUL conditions, through continuous monitoring of abstraction volumes
Step 2: The quantity of water to be abstracted must be measured for reporting purposes and to avoid exceedance of the licensed volumes
Step 3: Ensure that EWR adhered to at all times.

PHASE 4.2: Execution (unlicensed user)

Step 1: All water users without a GA/WUL must cease abstraction activities until they are granted a GA/WUL
Step 2: Directives should be issued to users who continue to abstract without a GA/WUL
Step 3: Once GA/WUL is granted, all users must adhere to the abstraction/release volumes stipulated as per the GA/WUL conditions.
Step 4: Users must observe the EWR and Reserve flows, taking into consideration the seasonal flows (wet and dry or winter and summer) in terms of percentages of Mean Annual Rainfall (MAR). Rules and Tables indicating seasonal (wet and summer) volumes to be left in the resource at a different percentile, especially 95th percentile.

PHASE 5: Monitoring, Evaluation and Reporting

Monitoring

Step 1: Regular monitoring will be required depending on the abstraction volumes according to the GA/WUL. Unlawful abstraction observed during monitoring should be reported to the DWS, DFFE and municipalities compliance and enforcement units. This will assist in quantifying the volumes of water loss/gains. This will also aid in Flow Requirement and Water Resource Classification Studies.

Step 2: Monitor the following:

- Volume of abstractions;
- Monitor the flows of the river vs. license abstraction volumes; and
- Changes in the physical habitats upon which biota depends on.

flow characteristics which cause changes in the physical habitats upon which biota depend

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objectives.

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas and the specific stretch of an estuary where flow improvement is visible or further required.
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

Scenario 2 (B): Control and Management of activities in the catchment i.e., baseflow and discharge from WWTWs contributing to increased freshwater flow into the system.

Note:

Baseflow (a natural phenomenon) is that portion of water that is contributed to streams by delayed groundwater. Therefore, this scenario will focus on the discharge of effluent from WWTWs [i.e., Section 21 (f)] contributing to the increase of the freshwater flow into the system i.e., freshwater becoming a driver in the system.

PHASE 1: Diagnostic Phase:

Step 1: Describe the catchment area including the affected estuary.
Step 2: Identify and describe water users within the area of concern.
Step 3: Review all water users:

- o Registered users on the WARMS and eWULAAS
- o Identify unregistered/Illegal users through local authorities (DWS, DFFE)

PHASE 2: Planning and Assessment

Step 1: Use Google Earth Pro, Sentinel, and other available high-resolution images (<10 m spatial resolution) and other related techniques to identify water users discharging waste or water. containing waste into the river.

Step 3: Assess the WARMS and e-WULAAS) on the permits, GAs/WULs given for discharging into the water resource.

Step 4: Conduct ground truthing on Ecological Water Requirements (EWRs), to determine the quantity and quality of the inflows into estuaries.

PHASE 3: Identify and Define the Ideal state and Rehabilitation Objectives

These objectives must be informed by the information and data collated in **Phases 1** and **2** above. Some of the common objectives for rehabilitation are to control the volumes of freshwater into the estuaries and prevent changes to the quality and timing of water into the estuaries.

PHASE 4.1: Execution (licensed user)

Step 1: Ensure that each water user adheres to the discharge quantities and qualities set under the GA/WUL conditions, through continuous monitoring.

Step 2: The quantity and quality of water to be discharged into the resource must be measured for reporting purposes and to avoid exceedance of the licensed volumes and qualities.

Step 3: Ensure that EWR adhered to at all times.

PHASE 4.2: Execution (unlicensed user)

Step 1: All water users without a GA/WUL must cease discharging activities until they are granted a GA/WUL.

Step 2: Directives should be issued to users who continue discharge into the water resource without a GA/WUL.
Step 3: Once GA/WUL is granted, all users must adhere to the discharge quantities and qualities stipulated as per the GA/WUL conditions.
Step 4: Users must observe the EWR and Reserve flows, taking into consideration the seasonal flows (wet and dry or winter and summer) in terms of percentages of Mean Annual Rainfall (MAR). Rules and Tables indicating seasonal (wet and summer) volumes to be left in the resource at a different percentile, especially 95th percentile.

PHASE 5: Monitoring, Evaluation and Reporting

Monitoring

Step 1: Regular monitoring will be required depending on the discharged volumes according to the GA/WUL. Unlawful discharges observed during monitoring should be reported to the compliance and enforcement unit. This will assist in quantifying the volumes of water loss/gains. This will also aid in Flow Requirement and Water Resource Classification Studies.

Step 2: Monitor the following:

- Discharge volumes;
- Quality of the water discharged;
- Monitor the flows of the river vs. license discharge volumes; and
- Changes in the physical habitats upon which biota depends on.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objectives.

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas and the specific stretch of an estuary where flow improvement is visible or further required.
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

3.2 GEOMORPHOLOGY

3.2.1 Description

Geomorphology is a science focused on understanding Earth surface processes and landscape (such as **estuaries**, wetlands, mountains, valleys, river channels) evolution (Keller *et.al.,* 2020). Geomorphological understanding is central to environmental flows because it is the interaction between flow, form, and substrate that influences habitat type, condition, availability, and biotic use across space and time (Meitzen *et. al.,* 2013).

3.2.2 Sources and Types of Impacts

3.2.2.1 Dredging and dredging material disposal

Dredging causes mechanical damage and smothering of organisms in the sediments, which typically leads to mass mortality (Donázar-Aramendía *et al.,* 2020). Dredging results in elevated turbidity levels, which reduces light penetration in the water environment, adversely affecting the phytoplankton aquatic vegetation (Cabrita *et al.,* 2020). The roiling of sediments at the dredged site also releases nutrients and chemical contaminants from the bottom sediments, remobilizing them to other areas of the system. Thus, water quality can be adversely affected as well.

3.2.2.2 Human-induced sedimentation

Poor catchment land-use practices lead to more sediment, especially finer fractions, entering the system (Cooper, 1994). The use and covering of land in coastal watersheds facilitate sediment inputs into estuaries, which contributes to biotic, and habitat impacts. During the construction process, the removal of natural vegetation and other structures increase erosion and the delivery of sediments to estuaries (Kennish, 2017). Sediment delivery to estuaries via these processes typically increases water column turbidity, light attenuation, and shading of the estuarine floor. This results in a decrease in production of seagrass beds and other benthic habitat that supports numerous faunal populations including many commercially and recreationally important finfish and shellfish species (Moore *et al*., 2012). The elevation of turbidity has proven to be responsible for seagrass loss which supports benthic communities (Moore *et al*., 2012). Another impact is the introduction of nutrients and/or organic matter into the estuary via sediment delivery or other means, which influences the bulk density of the sediment or soil from which estuarine plants grow. This influences the occurrence of erosion of soil on the estuary, leading to habitat loss.

3.2.2.3 Sand mining

Sand mining activities on the floodplain *i.e.*, an area of low-lying ground adjacent to a river, formed mainly of river sediments subjected to flooding, tends to remove the medium sand fractions from the system (Cooper, 1994). Mining activities also alter the flow of estuaries which causes changes in the habitats upon which biota depend. This is similar to the impacts associated with the development of dams and weirs in-stream, which result in sediment being trapped upstream of the wall and commensurate higher energy flux of water passing the wall in an apparent sediment-hungry response.

3.2.3 Rehabilitation Management Guidelines for Geomorphology

Scenario 1: Rehabilitation of activities relating to sand mining, road construction and dredging (sand) **(*all of these activities impact on biota, habitat, water quality and hydrology)***

PHASE 1: Diagnostic Phase:

Step 1: Use Google Earth Pro images and desktop research to identify estuaries and their upstream freshwater ecosystems that are affected by sand mining.

Step 2: Undertake ground truthing surveys or use drones to verify information provided by desktop research. Further information can be sourced from the DWS managers responsible for the catchment.

PHASE 2: Planning and Assessment

Step 1: In conjunction with Phase 1, establish the ecosystem status of that estuary (i.e hydrology, water quality, habitat, and biota) linked to different ecosystem services. Establishing the extent and nature of the changes that have occurred.

Step 2: Identifying the main assets of the estuary and the threats to these, identifying why the system or a particular component of the ecosystem has been degraded; for effective rehabilitation.

Step 3: Identifying, screening, and selecting candidate sites for rehabilitation based on the perceived threats to the assets. The aim of this step is to produce a list of sites and their problems, in order of priority for rehabilitation. This should be done when the causes of degradation of an identified asset occur in more than one locality, or where there is more than one reason for degradation, or when the main assets extend over, or occur in more than one locality.

Step 4: Set priorities as to what should be done first considering how much funding is available, stakeholder visions of priorities.

PHASE 3: Identify and Define the Rehabilitation Objectives

Define clear rehabilitation objectives based on information and data gathered in **Phases 1** and **2.** Some of the common objectives are to:

- Improve the flow of estuaries which has been altered prioritising those with severe alterations and where sensitive habitats are degraded.
- Improve habitat upon which biota depends.
  Note: *The extent of degradation should be mapped and reported, and the minimum percentage that should be rehabilitated also listed and the area identified, as well as the remaining area for rehabilitation.*

PHASE 4: Execution

Step 1: Implement a sustainable and reliable approach for addressing impacts relating to mining[2], construction, and dredging activities.

Step 2: Based on best practices, recommend rehabilitation management strategies, which include areas of further research and skill requirements, areas of collaboration as well as aspects of monitoring.

Step 3: Implement best practices in accordance with the applicable legislation *e.g.,* NWA, NEMA, MPRDA.

PHASE 5: Monitoring, Evaluation and Reporting

Monitoring

Appropriate monitoring and evaluation are a critical step in any rehabilitation management of estuaries in South Africa as a formal check on the outcome of a project. Without this, it is difficult to assess whether the objectives of the project are being (or have been) met. The evaluation also allows one to improve the techniques and approaches used.

Monitor the following:

- The rehabilitated areas to ensure they comply with pre-determined critical limits.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objectives.

[2] *The users of the RMGs should also consult the DWS Best Practice Guidelines (BPGs) for mines dealing with pollution prevention and water management strategies and tools.*

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas;
- Before and after photos of rehabilitated area including a significant landmark for comparison purposes, with a brief description including location, and date.

Scenario 2: Bank Erosion and Dune Rehabilitation

It is preferable to leave the banks of rivers and estuaries in their natural state and to set development well back, behind a development set-back line. However, it is crucial to keep in mind that any disturbance to the bank of a natural river or estuary may alter the hydrodynamics of the system, changing the conditions under which the river flows and necessitating further channel alterations. Inadequately built structures may reflect stream flow or wave action, increasing the risk of damage to neighbouring exposed banks.

To correctly identify the cause of the erosion and ensure the selection of appropriate and effective bank stabilisation methods in conjunction with erosion mitigation or where management of the erosion itself is not possible, consultation and a thorough investigation must take place prior to the planning and implementation of erosion measures.

The active intervention measures for a specific scenario depend on the following factors when intervention and erosion protection are deemed appropriate by the competent authority(ies):

- The magnitude of erosive forces;
- The potential cyclical nature of erosive forces;
- The possibility and characteristics of severe events;
- Future weather patterns and climate;
- Types of current and upcoming human activity in the region; and
- How much upkeep is practical for the method that was chosen.

Sand dunes are formed by wind deposits representing a store of sediments in the landward zones of normal high tides. Dunes can either be natural (formed by wind deposits) or artificial (engineered structures created to mimic the functionalities of natural dunes) (French, 2001). Dune rehabilitation refers to rehabilitation of the degraded natural or artificial dunes to optimize coastal protection services (UNEP-DTU, 2017). Importantly, dunes represent natural coastal protection measure such as providing buffers against waves and flooding. Dune rehabilitation could include establishing dune forests as a vegetation target and such rehabilitation may require a forest specialist.

PHASE 1: Diagnostic Phase:

Step 1: Identify estuaries affected by bank erosion and dune de-stabilisation.
Step 2: Identify and determine the causes of movement, weathering and/ or siltation of sand particles.
Step 3: Conduct ground surveying with relevant authorities (municipal, conservation bodies as well as Provincial DWS and DEA&DP Offices) and make use of historic satellite imagery to inform changes and rate of changes. It is important to consider multiple years and natural hydrological cycles and mouth states.

PHASE 2: Planning and Assessment

Planning:

Step 1: Consult relevant authorities (municipal, conservation body as well as Provincial DWS and DEA&DP Offices) in order to obtain buy-in from all stakeholders.
Step 2: Identify areas that should be rehabilitated and the most appropriate method or combination of methods for rehabilitation as well as the related training and capacity needs.
Step 3: Make provision for-the financial costs of rehabilitation.

Assessment:

Step 1: Conduct an Environmental Impact Assessment on the proposed erection of bank stabilisation structures within the EFZ
Step 2: Assess the following:

- Assess the severity of the bank erosion and dune destabilisation;
- Assess present and future human activities in the area that might impact erosion and siltation in the estuary;
- Assess the potential and nature of extreme events; and
- Conduct future climatic conditions and weather patterns.

Step 3: Assess the degree of maintenance that would be practical for the selected method or combination thereof.

PHASE 3: Identify and Define the Rehabilitation Objectives

The objectives of rehabilitating bank erosion and dune stabilisation must be defined and be clear from the onset. These objectives must be informed by the information and data collated in **Phases 1** and **2** above. Below is a list of common aims and objectives:

- To create space in which to address bank erosion by managing eroding banks and sites and reaches where down-cutting or incising occurs;
- To prevent erosion;
- To prevent dune destabilisation; and
- To revitalise the natural regime of the estuary and allow natural erosion of sediments that otherwise accumulate against encroaching alien plants.

PHASE 4: Execution

There are several methods that can be used for bank erosion and dune stabilization such as vegetation, soft or "green" engineering options, geotextiles and/or fences made from tree branches on the seaward side of an existing dune to trap sand and help stabilise any bare sand surfaces. Nature-based systems such as vegetation planting, revegetation with indigenous species and geotextile mats and erosion control blankets are some of the essential examples for creating resilient and sustainable solutions. These methods have been briefly explained below:

a) Vegetation

For low current velocities, the use of vegetation as a stabilisation method is appropriate. The approach uses environmentally friendly and aesthetically pleasing natural materials and processes. Vegetation management is typically regarded as a low-cost method with similar ease of installation. Eventually, if not significantly disturbed or damaged, it will be self-sustaining/reseeding.
The following specific considerations apply to the use of vegetation:

- Riverbank and suitable indigenous species must be used;
- A variety of grasses can be used, but due to fluctuating water levels, it's usually best to use a mix of species planted at various elevations.

- For vegetation to establish, there must be at least one uninterrupted growing season;
- There may be different levels of maintenance and watering needed, depending on the designs, species mix, urgency, etc; and
- Additional geo-textile (such as hessian sheets, honeycomb meshing (geocells) and similar products) may be needed to aid in establishment.

A coastal vegetation specialist and/or dune rehabilitation specialist must be consulted to provide input to the most appropriate, and locally indigenous plant species to be utilised and method of growth establishment, including maintenance such as grass-cutting and fire management.

Figure 7: Examples of vegetation coastal rehabilitation

Western Cape DEA&DP undertook a study in 2021 to investigate the cause of erosion of channel banks in the Berg River Estuary potentially threatening valuable habitat. The study proposed the following three soft or green designs and techniques to be piloted for their effectiveness:

- **Regrading of the bank slope** and **planting** with suitable indigenous vegetation is illustrated in **Figure 8** – it is a low-cost solution that require the laying down of coir or jute matting to temporarily protect the soil from erosion while the plants grow. Suitable species to be planted on the banks and at specific locations up the bank were also recommended.

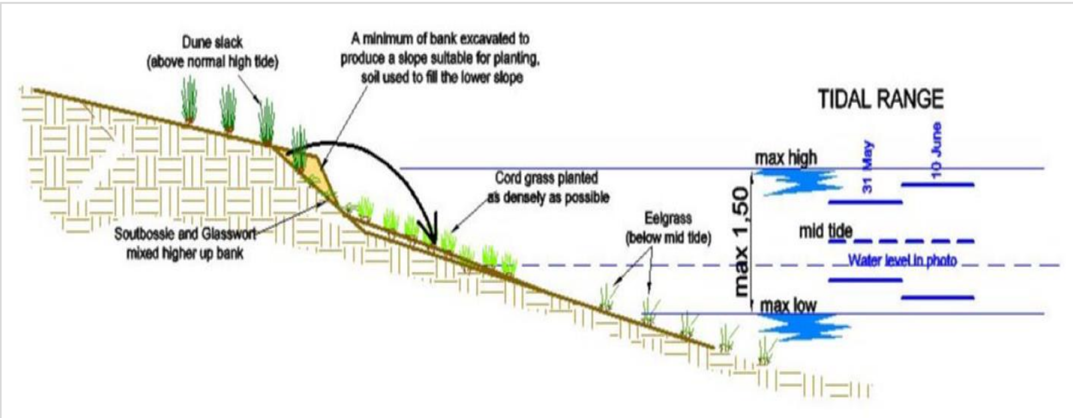


Figure 8: Illustration of regrading of the bank and planting out with suitable indigenous species

Source: DEA&DP, 2021

- **Regrading of the bank slope** and **construction of a toe berm** to prevent wash away of material into the channel and planting with suitable indigenous vegetation is illustrated in **Figure 9** - it involves the regrading of the bank with a low wall at the downslope end located below the mid-tide level. It requires construction of either a small rock berm **(Figure 10)** which could be wrapped in a high-density polyethylene (HDPE) mesh, and geotextile bag designed for shoreline applications.

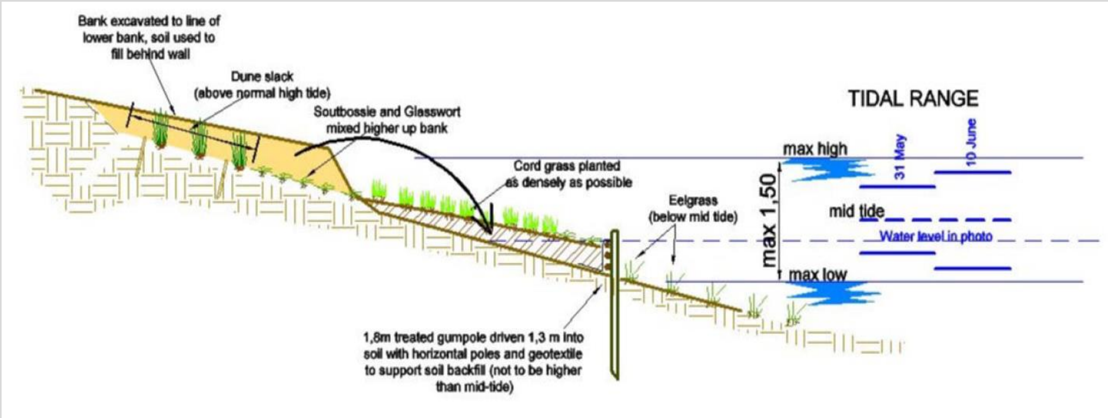


Figure 9: Regrading of the bank with a timber wall at the downslope end
Source: DEA&DP, 2021

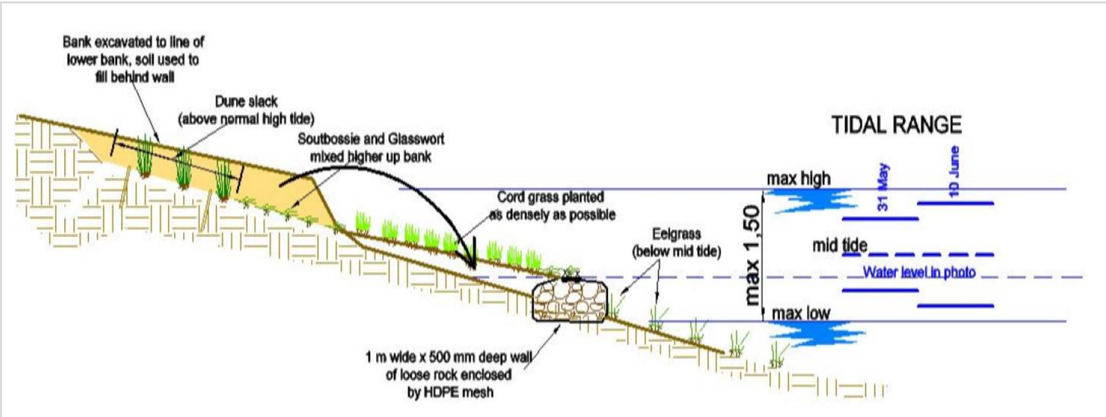


Figure 10: Regrading of the bank with a rock filled mesh sack berm at the downslope end
Source: DEA&DP, 2021

- **Regrading of the bank slope** and **laying down of geo cells** in which soil can be placed and suitable vegetation planted. This technique is illustrated in **Figure 11**.

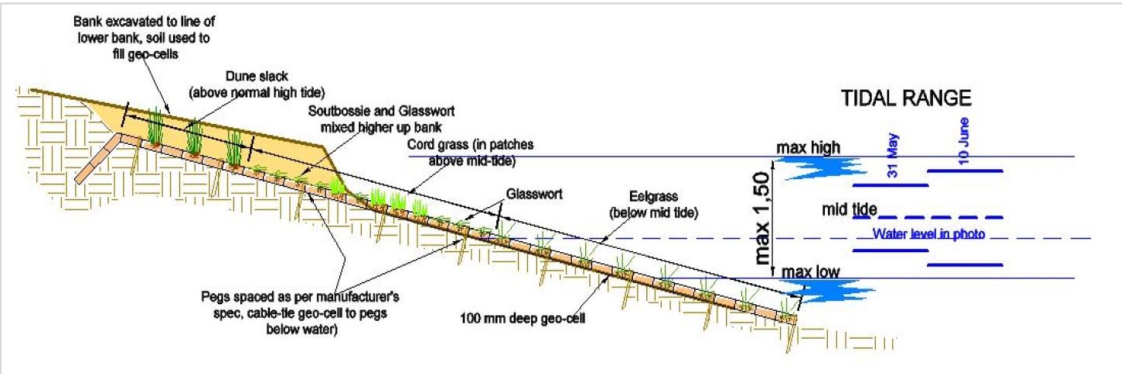


Figure 11: Geo cells vegetated with appropriate indigenous species
Source: DEA&DP, 2021

Other measures recommended by the study to be implemented include prevention of trampling of the salt flats through the construction of board walks, limiting vehicle access, and that boat waves should be limited.

c) Geotextile

A geotextile **(Figure 12)** is a permeable sheet that is used with a foundation, soil, rock, earth, or any other material related to geotechnical engineering as a crucial component of a building or infrastructure project. The geotextile, which serves as a sediment retention layer or structural component, can be made of natural or synthetic fibres. Natural fibre geotextile is made from sisal or coconut fibre, while synthetic geotextile is made from a variety of plastics (polymers). The textiles are also distinguished based on the method of production: woven, needle-punched, or heat-bonded.

Common applications include:

- Layers that act as a sediment retainer or a materials separator and are placed behind or between other structural elements;
- Covering the surface to stop wind or water erosion; sand or silt-filled containers are used as structural elements instead of rock fill;
- Matting in swales or stream channels; and

Figure 12: Example of geotextile.

d) Beach nourishment/replenishment

Beach nourishment, or beach replenishment, is the process of replacing sand lost from a sandy shore due to longshore drift or erosion with material from elsewhere through mechanical means, or a combination of mechanical action and natural forces. It is employed in instances where a wider beach is preferred for safety (enhancing the natural buffer function), to improve a natural habitat (increase the size of natural areas) or aesthetic and economic reasons (to enhance the recreational amenity value) (Western Cape DEA&DP, 2019).

The replacement of sand can be accomplished by directly depositing sand in a location where it is required, or by depositing sand above or below the water for the natural dispersive action by wind, wave, and currents to distribute across the beach area. The sand can be transported in the form of sludge in a pipeline or hauled in vehicles (Western Cape DEA&DP, 2019).

Considerations that should inform beach nourishment include (Western Cape DEA&DP, 2019):

- An understanding of the causes of erosion, as critical input into the design of a long-lasting intervention;
- The capacity and resources available for maintenance of the nourishment scheme;
- The nature of dispersive forces, to determine deposition sites (above or below water, and single or multiple sites) and avoid undesirable outcomes like steep slopes;
- The type of replenishment material required (grain size, silt, or clay content);

- The sources of replenishment material and the impacts of material sourcing on the environment;
- The impacts on the social and natural environments at the replenishment site; and
- Alternatives such as landward retreat, structural intervention, or sand recruitment through entrapment.

PHASE 5: Monitoring and Evaluation and Reporting

Monitoring

Ensure appropriate regular monitoring of the rehabilitated area.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objectives.

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas;
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

3.3 WATER QUALITY

3.3.1 Description

In estuaries, fresh water from rivers, streams and seepage combines with salt water from the ocean. As a result of the constant mixing of fresh and salt water, estuary water quality varies naturally. Furthermore, the physical water quality parameters in an estuary vary depending on the estuary structure and location (Costa *et al*., 2018). The main factors contributing to the degradation in water quality of estuaries are releases of industrial, domestic, and agricultural effluents (Alexakis, 2011; Brockmeyer and Spitzy, 2011), alteration of the chemical, physical and biological properties of water (Karydis and Kitsiou, 2013), and the consequent decrease of dissolved oxygen concentrations (Yin *et al*., 2004; Breitburg *et al*., 2009). Reduced oxygen levels in water negatively impacts the growth, reproduction, distribution, and survival of organisms and thus, accelerates the local pollution of the estuary (Mudge *et al*., 2007; Breitburg *et al*., 2009).

Many water quality variables are diverse and site-specific for estuaries depending on impacting activities. Hence water quality characteristics vary for each estuary, however, water quality health categories can be determined based on monitoring data history and expert knowledge.

Appendix A represents an example of water quality RQOs that were proposed for estuaries on the KZN coast, an example of some of the variables to consider for water quality (DWS, 2015).

3.3.2 Types of Water Quality Impacts

3.3.2.1 WWTW discharges

Inputs of sewage and other organic wastes can exacerbate estuarine eutrophication problems by delivering excess nutrients and organic carbon to estuaries. Water hyacinth (alien invasive aquatic plants) alter distribution of certain species in the estuary like seagrass, resulting in habitat changes or habitat loss. Sewage and organic waste may enter estuarine systems via various sources such as malfunctioning septic systems, stormwater, domestic wastewater discharges, industrial effluents, farmlands, mariculture, wildlife, livestock, and fish processing operations, dredged materials, marinas, and other sources. Hypoxia and anoxia of estuarine and shallow coastal marine environments have increased worldwide over the past 50 years largely due to anthropogenic activities (Diaz, 2015). Pathogens (bacteria, viruses, protozoans, and helminths) increase in estuaries receiving sewage wastes, and in these polluted waters, they pose a health risk to swimmers and humans consuming contaminated shellfish. Emerging pathogens and/or Contaminants of Emerging Concern (CECs) including endocrine disruptors emanating from pharmaceutical industries enter the systems from WWTWs and contribute to accumulative impacts on both human and ecological health. Consumption of raw, viral-tainted shellfish can cause hepatitis and serious gastroenteritis. Pathogenic bacteria in estuaries are particularly threatening to human health. For example, *Vibrio cholerae* causes cholera-like infection (diarrhoea, dehydration, and vomiting), and other pathogenic bacteria (Shigella spp. and Salmonella typhi) are responsible for dysentery and typhoid. *Escherichia coli* causes gastroenteritis and other maladies (Kennish *et al*., 2017).

3.3.2.2 Effluent discharge from industries, surface, and agricultural and stormwater runoff

Chemical pollutants are trapped in the bottom sediments of estuarine and coastal marine habitats, particularly near densely populated metropolitan regions and other urbanized places (Kennish, 2017). Chemical pollutants accumulate in bottom sediments because many of them are particle reactive and settle to the floor of the estuary. Some chemical pollutants gather in high concentrations in estuarine organisms in the estuarine environment. The main delivery systems into estuaries include farming and urban runoff, sewage and industrial waste, river inflow, and air deposition (Kennish, 2015b). The main chemical groups found in estuaries are metals, halogenated hydrocarbons, and polycyclic aromatic hydrocarbons (Kennish, 2017); in addition, CECs are an emerging concern emanating from agricultural runoff. Polycyclic aromatic hydrocarbons (PAHs) are another common pollutant found in estuarine settings around the world and they originate from the combustion of fossil fuel, and oil spills. Other known impacts are as follows:

- Increased temperature in the receiving waters.
- Bio-accumulation in fish, which we then ingest.

The encroachment of sugarcane and banana crops (either planted lawfully or unlawfully) within the floodplains or riparian areas of estuaries causes impacts of pollution, water consumption and increase of nutrient levels. The main fertilizers that are used for used are nitrogen, potassium and phosphorus which add excess nutrients which are be absorbed by the plants, or flow into water resources and promote algae and hyacinth growth and ultimately eutrophication.

3.3.2.3 Climate Change Effects

Increasing global temperatures, ascribed in large part to carbon dioxide emissions, have been linked to greater frequency and severity of damaging storms, coastal flooding, extreme droughts and extreme fires, and other hazards projected by climate forecasting models for the twenty-first century (IPCC, 2007). Extreme climate events and ongoing sea-level rise will be hazardous to coastal communities worldwide. Rising sea levels and coastal inundation will lead to significant loss of some coastal water resources, eliminating buffers and rendering coastal communities more vulnerable to extreme events. Human-induced climate change will also alter temperature and salinity regimes and the structure and function of biotic communities in estuaries (Kennish, 2017). Additionally, configurations of estuarine basins will be modified as they widen and deepen, shifts will occur in nutrient and sediment supply as well as freshwater inputs, tidal prisms, and tidal ranges will change in many systems, and more frequent flooding and inundation of bayshore areas will pose hazards to vulnerable coastal communities worldwide (Kennish *et al*., 2008).

3.3.2.4 Deforestation

Deforestation, clearing of land activities, overgrazing[3] and other poor farming practices[4], as well as roadworks and mining activities, have increased soil erosion and sediment loads in rivers typically by a factor of 10 (Wolanski and Spagnol, 2000). Land clearing activities also increase~~s~~ peak flood flows by up to 30 percent and decrease dry season flows, thus exacerbating flooding in the wet season and droughts in the dry season. The effect of deforestation on estuaries is much more rapid in the tropics than in temperate zones because of intense rainfall.

3.3.3 Rehabilitation Management Guidelines for Water Quality

Scenario 1: Rehabilitation of effluent discharge from Wastewater Treatment Works (WWTWs) and Industries

PHASE 1: Diagnostic Phase

Step 1: Undertake a desktop assessment to identify the WWTWs and industries whose effluent may negatively impact water quality of the estuaries (*i.e.,* facilities situated as far away as 5km-10km away from an estuary).

Step 2: Request historical water quality data and/or incident reports from relevant authorities (for water quality trends and patterns)

Step 3: Initiate communications with the responsible authorities (*i.e.,* WWTWs and industries personnel, municipal as well as Provincial DWS and DFFE Offices)

Step 4: Utilize tools such as Google Earth/ Pro /Google Earth Engine/Sentinel, ensuring the use of high spatial resolution (<10 m) satellite imagery, GIS, and remote sensing to pinpoint changes in land use (land-based catchment pollution that could be associated with changes in the quality of water)

Step 5: Conduct ground truthing to identify visible signs of water quality changes such as extremely foul odour, dead fish, algal blooms and loss of biodiversity in the estuary

Step 6: In undertaking the diagnostic assessment of the facility, consideration must be given to the below factors that tend to exacerbate the poor water quality:

- The overall integrity and functioning of the WWTWs and industrial facilities;
- Challenges associated with power cuts and failures; and
- Land-based activities and the overall management of the catchment.

  Note: *Malfunctioning pump stations may form part of direct pollutants to the watercourse and should be addressed as part of overall catchment management of pollution.*

PHASE 2: Planning and Assessment

Planning Phase

Step 1: Request local government officials (municipal as well as Provincial DWS/CMAs and DEA&DP Offices) and local NGOs community forums responsible to assist with identifying point sources of pollution to provide guidance on available regulatory processes.

[3] Mass removal of crabs of all species in the system has resulted in the destruction of many pioneer trees.

[4] Incorrect veld management, cultivation of steep areas and lack of contour furrows cause degradation and affect estuaries adversely.

Step 2: Investigate other sources of pollution and water quality *e.g.,* non-point sources of pollution.

Assessment Phase

Step 1: Undertake the following:

- Analysis of the historical data (water quality) to see the trend and reference point.
- Collect the actual final effluent water samples from the sources *i.e.,* WWTW and industrial facility.
- Collect monthly water quality samples from the resource *i.e.,* Estuary:
  - 1 upstream of the WWTW and industrial facility discharge points.
  - 1 downstream of the WWTW & industrial facility discharge points.
- Have samples analysed at an accredited laboratory to determine the water quality at the sources and resource, respectively.
- The source and resource should be continuously monitored until the observed results from the analysis show improvement of water quality.

Step 2: Undertake the following:

- Compare laboratory-generated water quality data to the expected state for the identification of areas of concern.
- Data analysis should be compared against the RQOs/RWQOs, or Aquatic Ecosystem Water Quality Standards if they have not yet been established for that catchment.

PHASE 3: **Identify & Define the Rehabilitation Objectives**

Define clear rehabilitation objectives based on information and data gathered in **Phases 1** and **2.** Common objectives are to manage and prevent poor effluent from WWTWs and industrial facilities from discharging into water resources *i.e.,* estuaries.

PHASE 4: Execution

The following steps must be followed by practitioners for the rehabilitation of water quality activities:

Step 1: Implement environmentally sustainable solutions through stakeholder engagements, communication within the water sector and between government departments sector, and between DFFE and other relevant government departments.

Step 2: Undertake the following:

- Ensure treatment of effluent from point sources prior to discharge;
- Effluent which does not meet the discharge standards should be temporarily stored for further intervention and/or treatment; and
- Monitor the effluent before discharge to ensure that it is of acceptable quality standard.

Step 3: Undertake the following:

- Implement surface water management around the WWTWs and industrial facilities;
- Install cut-off trenches around the facilities to separate clean and dirty water and direct clean water back into natural drainage lines and the natural environment; and
- The dirty water channels should be drained to an emergency holding dam for treatment.

Step 4: Construct temporary berms along the estuary to prevent further offsite migration/discharge of effluent ending into the estuary.

Step 5: Directives/notices should be issued to users who continue to operate non-compliant WWTW facilities.

The primary response however should be to improve the efficacy and capacity of the WWTW, to avoid future substandard discharges.

PHASE 5: Monitoring, Evaluation and Reporting

Monitoring

Step 1:

- Undertake monthly water quality monitoring in the estuary depending on the volume discharge, local municipal by-laws, and the type of permit allowed;
- Salinity intrusion – measured as TPCs for biota (fish, invertebrates, and microalgae) – Measurement should be done upstream of the estuary on a quarterly basis;
- Continuously assess WWTWs and industrial facilities to assist with defining the quality of the water and extend to which treatment is required (records of up to a year are desirable to characterise the state of the of the facilities).

Step 2:

Monitoring parameters for WWTWs:

- Nutrients, bacteria (*E.coli* or *coliforms*), pH, conductivity, suspended solids (SS), COD, NH3, NO3, Ortho phosphate (as P).

Monitoring parameters for industries:

- Metal (*i.e.,* Chromium - Cr, Cadmium - Cd and Copper -Cu) concentrations and distributions at least once every 3-5 years for industrial facility;
- Metal concentrations in tissues of fish/mussels (bio-accumulation) at least once every 3-5 years.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objectives.

Note: *The expected outcomes of monitoring and evaluation can be achieved through the use of available knowledge hubs on emerging pathogens and/or CECs emanating from pharmaceutical industries, agricultural runoff, WWTWs etc. Pesticide residues, transformation products and endocrine disruptors in estuaries should be considered for monitoring, where applicable. The outputs of monitoring should be reported to the relevant international frameworks i.e., SDGs, GBF.*

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas; and the specific stretch of an estuary where water quality improvement is visible or further required.
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

3.4 HABITAT

3.4.1 Description

Estuarine habitats are transitional tidal zones between the sea and land which are inhabited by macrophytes, and algae, that can withstand sporadic flooding (Lubke and Van Wijk, 1988; Adams *et al*., 2016). Habitat type is generally determined by salinity characteristics, topography, geomorphology, and ecosystem energetics (Nichols and Biggs 1985; Kennish 1986; Van Niekerk *et al*., 2020). In South Africa, estuarine habitat types are recorded as the blue carbon habitats, being salt marshes, seagrasses and mangroves, the adjacent hydromorphic units (seeps and floodplains) sand, and mud banks, macroalgae, open surface water area, and adjacent freshwater habitats (Coetzee *et al*., 1997; Colloty *et al*., 1998; Adams *et al*., 1999; Fernandes and Adams, 2016).

3.4.2 Types of Habitat Impact

3.4.2.1 Habitat removal and alteration

Estuaries are particularly susceptible to habitat transformation, removal, degradation, and alteration caused by human activities. The construction of permanent structures on the waterfront for recreational and commercial use alters the habitat. Additionally, boat engine propellers and dredging activities have consequences on the habitat (Kennish *et al.,* 2008; Kennish, 2017). Dredged material disposal at selected sites in estuarine basins causes longer-term alteration of habitat, albeit in restricted areas. The development of coastal watersheds has converted extensive natural habitats to compacted soils and impervious cover that decrease the infiltration of rainwater while increasing runoff, erosion, and nonpoint source pollution to estuarine water bodies. Changes in land use and land cover in these developed areas frequently result in higher nutrient and sediment loads, which have an impact on the water and sediment quality of estuaries (Arnold and Gibbons, 1996). Furthermore, habitat alteration can also be attributed to change in baseflows (more freshwater input into the system as a result of WWTW) - change in the ecosystem from marine dominated to freshwater - leading to a loss of critical habitats, where they had been previously found e.g. seagrass habitat loss in upper to middle reaches.

3.4.2.2 Alien Invasive Species

Introduced organisms that invade the water body can have a major impact and negative on the ecosystem. Introduced and/or invasive species can be a danger to the stability and biodiversity of an estuarine ecosystem. In cases where native controls are lacking, these species can have a significant competitive advantage, often rapidly dominating plant, or animal communities. Invasive species can be a danger to the stability and biodiversity of an estuarine ecosystem. The food web structure is commonly disrupted, and native species may be displaced or greatly reduced in abundance. The introduction or invasion of exotic species is expected to increase in the future due to an expanding world population, the effects of climate change, and greater shipping and other human activities at sea and in estuaries. These changes will likely promote additional ecological disruption.

3.4.2.3 Sand mining

Both sand mining and dredging have significant negative physical, chemical, and biological impacts on estuaries. These impacts result in habitat destruction, and elevated turbidity levels, which reduces light penetration in the water environment, adversely affecting the phytoplankton aquatic vegetation (Cabrita *et al*., 2020).

3.4.2.4 Dredging activities

Many estuaries experience active erosion of banks due to dredging activities, which threaten infrastructure and endanger~~s~~ the lives of people and animals. Response actions should target not only the site where the erosion is taking place but also consider possible interventions that can reduce or mitigate the drivers of erosion. Erosion protection measures and bank stabilisation can include hard techniques, soft techniques, or a combination of both.

3.4.2.5 Climate change

Floods are extreme events that can rapidly alter water and habitat quality in receiving estuaries. Major floods transport significantly more sediment and nutrients than regular freshwater flows and can have substantially different effects on fish communities in estuaries and coastal bays (Montagna *et al*., 2012). Heavy rainfall and rapid drainage of large volumes of water and sediment from catchments into rivers and estuaries can quickly change estuarine water quality. As such, fish, prawns, and other organisms in receiving estuaries and bays can be positively or negatively affected by floods. Immediate and short-term effects (occurring hours to days after flood initiation) include the mortality of sessile organisms, such as bivalves, from sediment smothering or low salinity and mortality of mobile organisms by stranding (Anderson *et al*., 2004, Duggan *et al*., 2014).

3.4.3 Rehabilitation Management Guidelines for Habitat

Scenario 1: Control and Management of Alien and Invasive Vegetation

PHASE 1: Diagnostic Phase

Step 1: Identify the areas infested by alien and invasive vegetation.

Step 2: Initiate communications with the responsible authorities (*i.e.,* local and district municipality as well as DWS Regional Office) responsible for the catchment in which the resource affected is located.

Step 3: Utilize tools such as Google Earth/ Pro /Google Earth Engine/Sentinel, ensuring the use of high spatial resolution (<10 m) satellite imagery, GIS, and remote sensing to identify the areas affected.

Step 4: Using information obtained from Google Earth satellite images and Remote Sensing, describe in detail areas identified that are affected by alien invasive vegetation. Consider including the following in the description:

- **Step 4.1:** Visual description of the areas affected and a ground assessment of the areas affected.
- **Step 4.2:** Is the affected area at a catchment, sub-catchment, or quaternary scale?
- **Step 4.3:** Is the area affected at a localized non-localized scale?
- **Step 4.4:** Describe the extent of the infestation of the affected area.
- **Step 4.5:** Describe the conditions upstream or downstream of the affected area including the CEC’s.

Step 4: Based on all the above information acquired, make an informed decision in terms of the type of habitat types of alien invasive species vegetation affecting your area of concern. Two habitat types of alien vegetation are dealt with, namely:

- Riparian and/or aquatic; and
- Landscape/terrestrial.

Other examples of known aquatic species include floating macrophytes such as *Pontederia crassipes* (water hyacinth), *Pistia stratoites* (water Lettuce), and the new emerging species, *Salvinia minima* (common salvinia) amongst others, and submerged species such as *Myriophyllum spicatum* (spiked water milfoil), *Egeria densa* (dense water weed) and Vallisneria spiralis (tapeweed) amongst others.

Landscape/Terrestrial invasive plants can further be categorized into the following growth forms, namely:

- Sprouting trees
- Non-sprouting trees

- Shrubs
- Cacti
- Herbaceous
- Grass
- Creepers
- Aquatic weeds

PHASE 2: Planning and Assessment

The below is a summarised list of steps to be followed during the planning and assessment phase of alien and invasive vegetation clearing[5,6]:

- Identify priority alien and invasive plant species for control.
- Identify sensitive indigenous vegetation that should be protected during alien and invasive plant clearing operations.
- Mark individual trees or stands of vegetation to guide workers on site during alien and invasive alien plant clearing and prevent accidental environmental contamination. Danger tape or paint markings can be used for marking or utilise mapping tools such as ArcGIS mapping and monitoring.
- Identify areas that should be protected from disturbance activities– in some areas (*e.g.,* fynbos renosterveld and biocontrol reserves)
- Identify the most appropriate clearing method or combination of methods, that take account of the species requiring control, the specific conditions of the site, ecotoxicity, environmental fate, and human health impacts of the herbicide, and the circumstances of the landowner. Consult the DFFE: Environmental Programme (EP) Pesticide Policy and toolkit.
- Identify and obtain the necessary field and personal protective equipment (PPE) for the selected clearing method(s) according to the mode of action of the herbicide and exposure risk utilising the appropriate PPE matrix, including the most appropriate herbicides. (DFFE, 2022),
- Identify training needs for clearing workers and supervisors (e.g., herbicide application, use of chain saws, etc.)
- Identify approaches and areas for the disposal of cleared plant material, dependent on the hazardous waste classification of the material.
- Consult the DFFE EP Pesticide Policy and Pesticide Toolkit for the decision support tool to ensure environmental contamination and chronic human health exposure and risks are mitigated or as the least lessened.
- Prepare an accurate estimate of the financial costs of clearing and ensure that there are sufficient funds to achieve a successful outcome.

PHASE 3: Identify & Define the Rehabilitation Objectives

The objectives of rehabilitation of alien and invasive vegetation must be defined and be clear at the start. These objectives must be informed by the information and data collated in **Phase 1 and 2** above. Below is a list of common aims and objectives[7]:

- To create space in which to address bank erosion by managing eroding banks and sites and reaches where down-cutting or incising occurs in compliance with 11(1)(n)(ii) of NEM: BA.

[5] *Water Research Commission (WRC). 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa.*
[6] *DFFE: EP.2021. Environmental Programmes Pesticide Policy and Pesticides Toolkit.*
[7] *WRC. 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa.*

- To increase space for flood alleviation by clearing alien and invasive vegetation to increase the conveyance or the natural flow of water, noting restricted activities compliance with Section (65)(1) and environmental authorisations under Section (24) of NEMA.
- To rehabilitate a more natural river flow regime by releasing trapped sediments and allowing erosion processes to restore natural river levels.
- To prevent erosion as a result of channel confinement and bank undercutting.
- To improve biodiversity by allowing the establishment / generation of natural indigenous riverine flora.
- To revitalise the natural disturbance regime of a river and allow natural erosion of sediments that otherwise accumulate against encroaching alien and invasive plants.

PHASE 4 – Execution:

Alien and invasive vegetation control methods are divided into three main categories, control options, namely manual (or mechanical) control, chemical control, and biocontrol as illustrate in **Figure 12.** Integrated control methods or integrated plant species management (IPM) is the most effective method in various combinations, depending on the alien and invasive species, landscape and bioregion. The DFFE Pesticide Policy and associated EP species and pesticide list, 2021[8], with the pesticide toolkit and decision support tool provides all the information needed, from the species, control methods and herbicides to ecotoxicity, environmental fate, human health exposure and risks, hazard criteria and acute and chronic toxicities. These three methods have been prescribed and comprehensively covered in the River Rehabilitation Guidelines/Manual developed by WRC[9] and adapted to align to the methods under NEM:BA and the EP Pesticides Policy. These methods must be supported by a Plant Species Plan developed by a landscape architect or botanist.

Note: *The chemical control method which entails the application of herbicides should be carried out in accordance with the stipulations of the Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947).*

PHASE 5 – Monitoring, Evaluation and Reporting

Monitoring

Monitoring of rehabilitated areas must be undertaken to:

- Ensure that treatment methods employed are adequate and effective to ensure that no additional measures are required.
- Allow learning from past practices, so that ongoing alien and invasive plant clearing initiatives are constantly improving and are in accordance with seasonal changes.

The following monitoring suggestions are recommended by WRC[10]:

- A fixed-point photographic record should be compiled, showing the river in its affected reaches before, during and at regular time periods after initial alien and invasive clearing has taken place. The internals will depend on the herbicides mode of action, time taken to control the alien and invasive species and time taken for regrowth to appear.
- Historical Google Earth images should be used over time, to provide a spatial record of alien and invasive clearing extent and effects.

[8] DFFE: EP, 2021. Environmental Programmes Pesticide Policy for the Control of Alien and Invasive Species and associated documents.
[9] WRC. 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa.
[10] WRC. 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa.

- Records should be kept of the time and costs required for each alien and invasive clearing intervention, and the approximate volume and life stage (*e.g.,* seedling or mature plant) of the bulk of material removed on each occasion. Restricted activities as defined by NEM:BA include 'The conveying, moving/removing or otherwise translocating any specimen of a listed invasive species' as PROHIBITED for category 1a and 1b species. This information will allow quantification of the costs of alien and invasive control to show landscape changes resulting from alien and invasive removal and potentially inform decisions that are required around changes in clearing frequency, area, or approach.
- Remote sensing and GIS.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes.
- Determine maintenance objectives.

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas; and
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

Scenario 2: Rehabilitation of excessive habitat removal/alteration

PHASE 1: Diagnostic Phase:

Step 1: Acquire habitat and zonation maps from the relevant authority to identify the extent of habitat alteration.

Step 2: Measure impacts using the essential biodiversity variables (EBVs), quantifying changes in extent and quality.

Step 3: Identify the most impacted habitat(s) for example overutilisation of raw material (*e.g.,* salt marshes, seagrasses, and mangroves in that particular estuary.

Step 4: Undertake a desktop analysis to evaluate impacts (as a result of human activities such as historic agriculture activities, illegal recreational and tourism developments, mangrove harvesting/cutting and current sand mining operations).

PHASE 2: Planning and Assessment

Step 1: Assess to understand the conservation value of the estuary. An Estuary Protected Zone (as demarcated in the zonation map) would incorporate a variety of habitats (*e.g.,* inter- and supra-tidal salt marsh, sandbanks, and mudbanks) and any species would be closed to all forms of human disturbance – specific to each estuary.

Step 2: It is vitally important that a rehabilitation plan is developed which will articulate clear goal(s) and vision. It also needs to take into consideration the monitoring programme. Such plan should be used to set rehabilitation priorities with an estuary, using scientific criteria and socio-economic factors.

PHASE 3: Identify and Define the Rehabilitation Objectives

Define clear rehabilitation objectives based on information gathered in **Phases 1** and **2**. Common objectives for habitat rehabilitation are to:

- Protection of Indigenous estuarine vegetation;

- Implement mitigation measures such as bank stabilisation; and
- Rehabilitation of topographical sequences.

PHASE 4: Execution

Step 1: Consult all relevant authorities and ensure that you have acquired all the necessary information pertaining to the requirements and all the legal mandates are complied with.
Step 2: Identifying funding sources and securing funding, including considering linking ecosystem service outcomes to beneficiaries and targeting funding opportunities linked to the ecosystem service outcomes.
Step 3: Establishing project management systems and the technical approaches.
Step 4: Undertaking rehabilitation, including the services of community volunteers, citizen science officials and Contractors.
Step 5: Nature-based systems, geotextile mats and erosion control blankets are some of the essential examples of resilient and sustainable rehabilitation options that can be implemented.

PHASE 5: Monitoring, Evaluation and Report

<u>**Monitoring**</u>

- Rehabilitation of estuarine habitats requires time and vigilance to allow the cumulative effects of smaller projects to emerge and larger-scale natural processes to re-establish themselves.
- Once objectives for rehabilitation have been set, having a monitoring programme in place will assist with assessing the changes taking place in the estuary in response to measures undertaken to transform that particular estuary.
- It is, therefore, important that monitoring be started as soon as this phase/task commences. The monitoring programme should be developed during the assessment phase.
- Monitoring parameters and frequency for Habitat~~s~~ and Geomorphology are as follows:
  - Suspended sediment concentration – Monthly
  - Sediment Quality – Annually
  - Riparian Vegetation/Habitat – Annually
- Monitoring parameter and frequency for Instream Habitat/ Hydrology is as follows:
  - The water column habitat not to be severely reduced for longer than 3 months at a time.

<u>**Evaluation**</u>

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objective.

<u>**Reporting**</u>

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas; and
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

<u>*Scenario 3: Estuary Mouth Breaching*</u>

Estuary mouth breaching is estuary specific. Natural breaching will always remain the preferred option for breaching. There are two types of artificial beaching, **Planned artificial breaching** and **Emergency breaching** (*e.g.,* for ecological benefits and to avoid the danger of flooding). Artificial breaching is not the solution to water quality problems (*e.g.,* low oxygen levels). Thus, water quality problems should be fixed at the source.

Box 1	Box 2
<u>Planned Breaching</u> • Planned breaching is undertaken when the estuary experiences high water levels or at the frequency that is necessary for the protection of infrastructure and ecosystem functioning. • Requires the approval of a Maintenance Management Plan with the input of a specialist Estuarine Scientist. • Conducted periodically i.e., every two years or less.	**<u>Emergency Breaching</u>** • Emergency breaching is undertaken due to conditions that develop when an estuary mouth is closed/constricted and severe rainfall occurs in the catchment causing a large flood. • Triggers NEMA: S30A Regulations. • Conducted once-off.

PHASE 1: Diagnostic Phase:

Step 1: Describe the catchment area or estuary of concern. Consider the ecosystem type and natural phases of the estuarine mouth state.
Step 2: Use tools such as Google Earth/Engine/Sentinel, satellite imagery, GIS, and Remote Sensing to identify estuaries that are affected by sand berms depriving freshwater flow.
Step 3: Identify and describe water obstruction on the watercourse that might hinder the natural breaching of the mouth.
Step 4: Develop an understanding of sediment dynamics using relevant tools.
Step 5: Determine whether a **planned** or **emergency** breaching is required.

PHASE 2.1: Planning and Assessment (Planned Breaching)

Step 1: Consult relevant authorities (municipal, conservation body as well as Provincial DWS and DEA&DP Offices.
Step 2: At desktop level, employ remote sensing to assess the extent of the problem as well as estuarine field surveys. This activity needs to be done in conjunction with information from **Step 1** of **Phase 1** to avoid duplication of efforts.
Step 3: Assess whether impacts are due to natural or anthropogenic factors using estuarine indices.
Step 4: Determine estuarine conditions, which will provide an indication of the extent and type of rehabilitation that is needed for the estuary. There are different indices that are employed at various levels of aggregation, that is, estuary ecosystem condition indicators, estuary health index and national estuarine ecosystems condition index (Van Niekerk *et. al*, 2020).

<u>PHASE 2.2: Planning and Assessment (Emergency Breaching)</u>

<u>Note:</u>
While breaching should be conducted according to a Mouth Management Plan (MMP) in support of an Estuarine Management Plan (EMP), some of the general breaching principles may be waivered under emergency conditions to ensure practical breaching.

Step 1: A written request to breach, in terms of NEMA Section 30A should be directed to the Provincial Departments (DEA&DP) Environmental Impact Assessment units. The request should be accompanied by photographs of the status quo of the estuary.

Step 2: Where reasonably possible, a site inspection must be undertaken by the Provincial Departments (DEA&DP) to verify the information received. The inspection may consist of a team coordinated by the Provincial Departments (DEA&DP) which involves all the affected authorities and relevant specialists.

Step 3: Once the status quo of the estuary has been confirmed by the Provincial Departments (DEA&DP) a decision/written directive regarding the commencement of the requested activity *(i.e.,* emergency breaching) should be issued.

PHASE 3: Identify and Define the Rehabilitation Objectives

Clearly define the objectives for estuary mouth breaching, which must be clear from the start. These objectives must be informed by the information and data collated in **Phases 1 and 2** above. Below is a list of common aims and objectives:

- Maintain the estuarine biodiversity;
- Prevent further causes ecological degradation;
- Improve the overall functions of estuaries in line with the desired state in terms of extent and condition; and
- Flood prevention.

PHASE 4: Execution

Note:

Steps 1-4 below are applicable to Planned Estuary Breaching, while Step 3-4 below are applicable to Emergency Breaching.

Step 1:

- Develop a Mouth Management Plan (MMP) in support of the Estuarine Management Plan (EMP)[11] to provide information of the methods and mechanisms of breaching suitable to a specific estuary.
- Consult the EMP if readily available for the estuary of concern.

Step 2: Breaching should be conducted under the following conditions:

- When the water level in the estuary is at the highest to ensure that maximum outflow on the falling tide can be achieved.
- During periods of low waves to prevent estuary mouth closure.
- At low tide to maximise outflow on the falling tide.
  Note: *One should avoid breaching during times of storm or huge wave events specifically to prevent estuary mouth closure. Storm or huge wave events tend to push the sand up and close the estuary mouth approximately after 2 hours of breaching. Breaching should be undertaken at maximum water levels and just after high tide so that maximum outflow on the falling tide can be achieved.*

Step 3: The following steps needs to be followed:

- Select the appropriate location for breaching, using historic images which can be accessed from local libraries. Consult relevant estuarine ecologists/coastal engineers if needed.

[11] *EMPs should be consulted in order to ensure that any activity is in alignment with the Management objectives contained within that particular estuary. If an Estuary Advisory Forum is in place, they should be consulted during planning phases.*

- Consider public safety, crowd control and animal mobility during breaching. Breaching should ideally be done in the late afternoon or early morning for safety reasons.
- Excavated trenches should be reasonable in size depending on the size of the sand berm. The aim is to lose all the excess water in the estuary.
- Excavated sand must be sent back to the ocean and not be left on the sides of the breached mouth.

  Note: *The branch Oceans and Coasts of the DFFE is mandated with the responsibility for regulating the disposal of materials in the marine environment. Therefore, the relevant officials of the department should be consulted.*

Step 4:

- Excavate a deep trench (about 2m in depth and 3-4m in width) before breaching to maximise outflow – unless site specific conditions dictate otherwise.
- Sediment taken out would have to be moved to the ocean.

PHASE 5: Monitoring and Evaluation

Monitoring

- Monitoring needs to focus on **water levels** and **mouth observations.**
- Monitoring should be an ongoing activity that must be undertaken pre, during and post the breaching.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objective.

3.5 BIOTA

3.5.1 Description

Biota/aquatic biota is described as the community of plants and animals with a biotic integrity, which reflects the health, community structure and distribution which is dependent on habitat (DWAF, 1999). Estuaries are important for fish reproduction by providing a nursery function for several juvenile fish species. Fishing is a crucial socio-economic activity for local communities as it plays a key role in tourism, livelihood activities and sustenance.

3.5.2 Types of Biota Impacts

3.5.2.1 Over-exploitation / Overfishing

Overfishing is catching fish at a higher rate than which the fish can reproduce to replace what has been caught. The overfishing of fish populations leads to decreased supplies as well as changes in supplies in the food-web structure of estuaries. For example, the decrease in major fish populations may lead to an increase its prey species, which creates an imbalance in the ecosystem (Briggs, 2012).

3.5.2.2 Plastic Waste

In estuarine and marine ecosystems, marine waste, particularly plastics, has become a global problem. The pervasive use of plastics together with the lack of degradation results in the pollution problem. Many organisms, particularly fish, turtles, birds, and mammals that consume some of the pollutants or are exposed to them, are at risk. Some organisms mistake the floating material for prey (Verster and Hindrik, 2020). The ingestion of plastics and other marine debris can suffocate the animals or obstruct their digestive systems, causing death (Verster and Hindrik, 2020; Kennish, 2017).

3.5.2.3 Artificial Breaching / Mouth manipulations

Estuaries provide valuable ecological, environmental, and economic services but severely degraded ecosystems cannot offer such services. Estuaries are also manipulated through releases from dams upstream, resulting in loss of natural timing, and volume of system flows. Frequent artificial breaching has serious implications and results in persistently low water levels that reduce the amount of aquatic habitat available for benthic macroalgae, invertebrates, fish and birds, and encourage the encroachment of reed beds into the open estuary (DEDEAT, 2020).

3.5.2.4 Sand mining

Sand mining and dredging have significant physical, chemical, and biological impacts on estuaries. The impacts include the loss of plants and animals in the mined sand including the loss of habitat in the channel and on the banks and floodplain. These impacts also affect organisms (habitat diversity/type), resulting in elevated turbidity levels, which reduces light penetration in the water environment, adversely affecting the phytoplankton aquatic vegetation (Cabrita *et al*., 2020).

3.5.2.5 Pollution Impacts

Artificial breaching can increase the impact of pollution as breaching allows fish or invertebrates near the mouth to escape to sea. The subsequent reduction in estuary water level can expose the remaining fauna to often even poorer water quality conditions post-breaching. This is especially the case in fish kills linked to WWTWs that also discharge/spill significant organic matter with a high oxygen demand. If the estuary water depth is reduced, the buffer between oxygen-depleting organic bottom material and the surface layer that can be oxygenated by wind is also reduced. A similar response can occur in eutrophic estuaries where low oxygen events are linked to high loads of decaying plant material (DEDEAT, 2020).

3.5.3 Rehabilitation Management Guidelines for Biota

<u>Scenario 1: Re-establishment of biota migratory routes</u>

Identified Impacts

- **Sand mining, dredging & dredging material disposal, in-stream infrastructure creating barriers and preventing biota migration**
- Over-exploitation / Overfishing
- Water Quality

Sand mining, dredging & dredging material disposal, in-stream infrastructure and sedimentation processes & patterns have the following impacts on biota:

- Disrupts biota migration routes
- Disturbs the spawning, feeding, dispersion and colonisation of biota
- Changes the flow dynamics of the estuary

IMPACTS

INTERVENTIONS

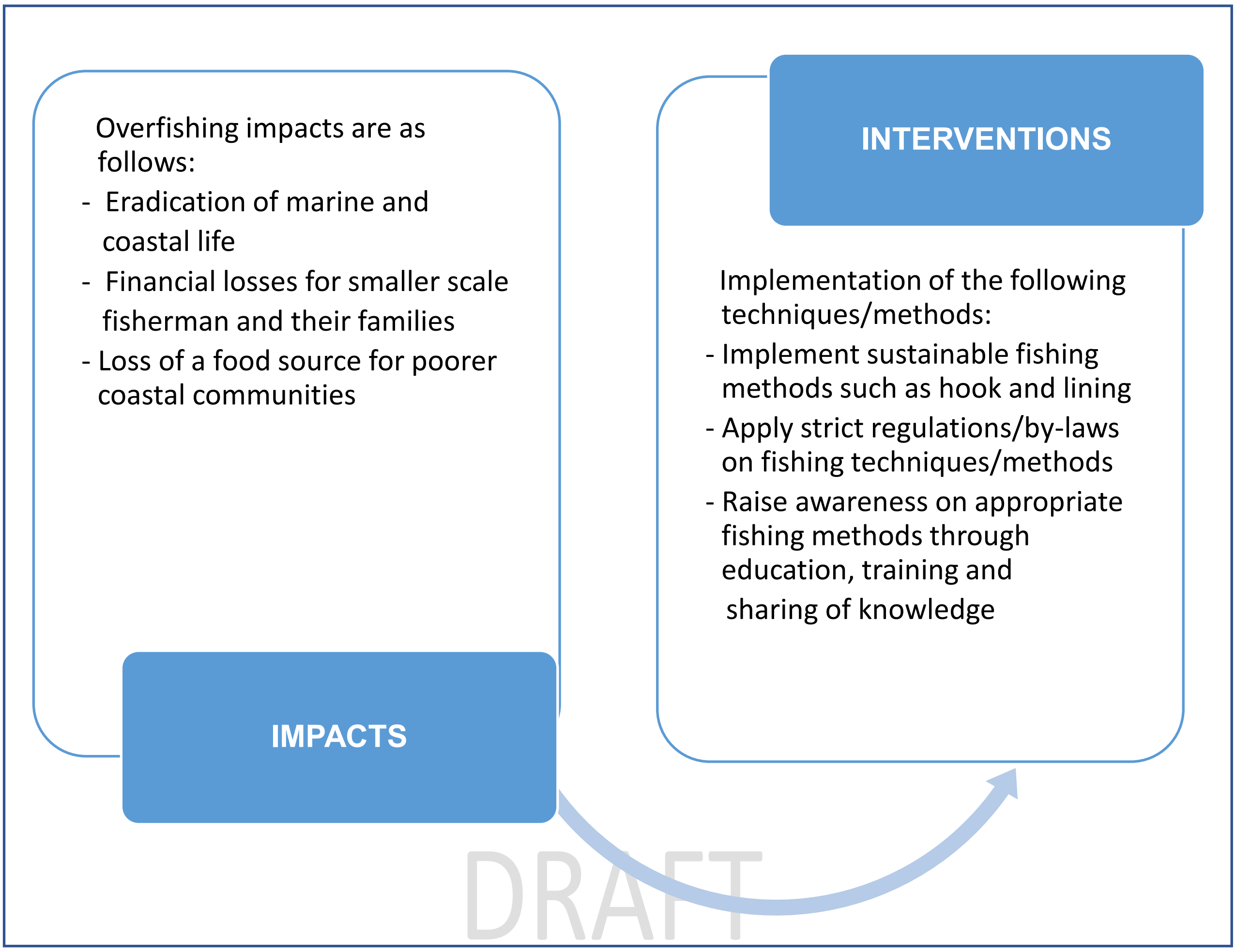
Implementation of the following techniques/methods:

- Estuary Mouth Breaching outlined under Scenario 3 for Habitat
- Removal/rehabilitation of physical structures outlined under Scenario 1 for hydrology
- Rehabilitation of activities relating to sand mining & dredging outlined under Scenario 1 for Geomorphology

Scenario 2: Control and Management measures to prevent overfishing.

Identified Impacts

- **Sand mining, dredging & dredging material disposal, in-stream infrastructure creating barriers and preventing biota migration**
- Over-exploitation / Overfishing
- Water Quality



PHASE 1: Diagnostic Phase:

Step 1: Describe the catchment area or estuary of concern.
Step 2: Identify and describe fishing activities in the estuarine area.
Step 3: Understand the community dynamics using relevant tools.

PHASE 2: Planning and Assessment

Step 1: Consult relevant authorities (conservation body as well as Provincial DWS and DEA&DP Offices)in order to obtain buy-in from all stakeholders on develop a zonation map to clearly define the restrict areas and access points. Examples of areas to be included in the zonation maps are:

- **Restricted Areas -** areas are commonly known as 'No-Take' areas, where the extraction and harvesting of any marine or plant life is not allowed;
- **Controlled Areas** - areas are also known as 'Open' areas. In these areas you are allowed to fish, go diving, spear fish, scuba dive and whale watch given that you have a valid permit.

Step 2: Identify potential Estuarine Protected Areas (EPA) for the conservation of overexploited linefish species. These areas must include the mouth regions and adjacent marine environment.
Step 3: Establish sanctuary areas where threatened invertebrate and floral species occur.
Step 4: Reduce fishing effort by controlled access or increased access costs.

PHASE 3: Identify and Define the Rehabilitation Objectives

Clearly define the objectives to prevent overfishing, which must be clear from the start. These objectives must be informed by the information and data collated in **Phases 1 and 2** above. Below is a list of common aims and objectives:

- Prevent over exploitation of fish;
- Reduce fishing pressure on the estuarine system;
- Maintain the estuarine biodiversity;
- Prevent causes of ecological degradation; and
- Improve the overall functions of estuaries.

PHASE 4: Execution

Step 1: Implement sustainable fishing methods and promote alternatives to consumptive exploitation. This can include by is not limited to the following:
- Catch and release fisheries;
- Control access to bait collecting areas; and
- Rotate bait collection areas to be on an annual basis to allow for recovery.

Step 2: Implement strict regulations/by-laws on fishing techniques/methods to reduce overfishing. This can include by is not limited to regulations/by-laws prohibiting the following:
- Capture of linefish species (e.g., grunter) using cast nets, seine nets, gill nets and traps;
- Collection of mud prawn, sand prawn, bloodworm, pencil bait and tapeworm during night hours;
- Harvesting of juvenile fish;
- Collection ornamental fish; and
- Capture of fish (irrespective of methods) during mouth breaching events in temporarily open/closed systems.

Step 3: Apply and implement zonation, through consultation with all Interested and Affected Parties (IAPs), of estuaries for recreational and subsistence fishing activities and non-consumptive activities to reduce user conflict.

Step 4: Implement holistic approach to estuarine management (*i.e.,* incorporate issues related to the catchment and adjacent terrestrial and marine environments).

Step 5: Promote estuarine awareness and instil a feeling of social responsibility towards estuaries through advertising and marketing and education of managers, user groups and the general public.

PHASE 5: Monitoring, Evaluation and Reporting

Monitoring

- Monitor key indicators and implement effective monitoring programmes dedicated to individual species. Undertake directed research aimed at stock status and sustainable yields.
- Monitoring parameters and their frequencies are as follows:
  - Fish – FRAI – Annually
  - Birds, benthic invertebrates and mammals - Annually
  - Microalgae (phytoplankton and microphyto-benthos)/ Diatoms– Quarterly after every 3-months)
- Enforce, through compliance monitoring, existing legislation under the Marine Living Resources Act (MLRA) e.g., permits, catch restrictions, and use of cast nets. Penalties and convictions need to be severe and be implemented.

Evaluation

- Evaluate the effectiveness of interventions against the achievement of rehabilitation objectives and outcomes; and
- Determine maintenance objective.

Reporting

A Rehabilitation Report should be compiled and be accompanied by supporting information such as:

- A map of disturbed and rehabilitated areas;
- Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

4. RECOMMENDATIONS AND WAY FORWARD

The Estuarine Rehabilitation Management Guidelines have been developed to address characteristics of watercourses, namely hydrology, hydrodynamics, geomorphology, water quality, habitat, and biota through a phased approach. Below is a summarised list of recommendations for users to consider when implementing the guidelines:

- In the Diagnostic Phases of all the rehabilitation scenarios in the guidelines, the EMPs and RDM outputs (Reserve, Classification, and RQOs) should be consulted to establish estuary status in terms of any targets that have been set to ensure site-specific rehabilitation measures are put in place per estuary.
- When setting the objectives of all rehabilitation scenarios one should consider the National Biodiversity Assessment (2018) recommendations on the Ecological Category of estuaries. Stakeholders may have an improvement vision for the estuary specified in the Estuary EMP, and as a result, to align with the Vision, the desired classification of the resource may be a higher Ecological Category towards which the Estuary would be managed.
- Estuary Management Plans should be put in place, if not already available, to ensure estuary-specific management targets as each estuary has unique characteristics. The EMP should be consulted, and any rehabilitation management plans should align with targets and priorities to enhance the EMP. Such an EMP should detail information relating to rehabilitation zones and priority rehabilitation activities.
- The activities undertaken within estuaries that are demarcated as conservation zones may be controlled either via local by-laws or in certain instances by national legislation, the Integrated Coastal Management Act, the Sea Shore Act, NEMA and its associated EIA regulations, and CARA"
- There are currently no by-laws in local authorities that addresses the quality of storm water that goes into the estuaries. Contaminated urban runoff is one of the biggest sources to pollution of estuaries. Therefore, Water Services Authorities (WSAs) should consider developing such by-laws.
- For all characteristics of watercourses, rehabilitation monitoring activities specific to each estuary should be included in the EMP and authorities are to ensure that they are prioritised and included in annual operational plans.
- Compliance, monitoring and enforcement must be strengthened in terms of human resources and capacity for all rehabilitation work to be undertaken. The regulatory mechanisms should be implemented at both estuary and catchment level and be sufficiently variable to cater to the uniqueness of each estuary in terms of its combination of biodiversity, use value, threats, and socio-economic context.
- Regulation at the catchment level, regarding water quantity and quality and overall catchment management should be supported. Thus, a combination of regulatory mechanisms is advisable.
- An integrated alien plant management program should be developed – this should align with the control plans already developed for the estuaries.
  - Follow up treatment should be done repeatedly; this is because some alien species are difficult to eradicate;

- If chemical eradication method is to be applied for eradication of alien trees, it is recommended that environmentally friendly chemicals or other suitable control methodologies are applied;
- Working for Water Programme could assist by prescribing specific methods that can be used to eradicate infested areas for rehabilitation, where possible.

REFERENCE LIST

Adams, J. B., Veldkornet, D., & Tabot, P. 2016. Distribution of macrophyte species and habitats in South African estuaries. South African Journal of Botany. 107: 5–11.

Alexakis, D. 2011. Assessment of water quality in the Messolonghi–Etoliko and Neochorio region (West Greece) using hydrochemical and statistical analysis methods. Environ. Monit. Assess. 182: 397–413.

Arnold, C.L. and Gibbons, C.J. 1996. Impervious surface coverage: the emergence of a key environmental indicator. J Am Plan Assoc. 62:243–258.

Andersen, J.H., Halpern, J.H., Korpinen, B.S., Murray, S., Reker, C.J. 2015. Baltic Sea biodiversity status vs. cumulative human pressures. Estuarine Coastal and Shelf Science 161: 88-92.

Barbie, E.D. Hacker, S.D. Kennedy, C. Koch, E.W. Stier, A. Silliman, B.R. 2011. The Value of Estuarine and Coastal Ecosystem Services. Ecological Monographs. 81(2): 169-193.

Berkes, F., and C. Folke. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK.

Borja, A., M. Elliott, M., Snelgrove, P., Austen, M., Berg, T., Cochrane, S., Carstensen, S., Roberto, D., Greenstreet, S., Heiskanen, A.-S., Lynam, C., Mea, M., Newton, A., Patrício, J., Uusitalo, L., Uyarra, M., Wilson, C. 2016b. Bridging the gap between policy and science in assessing the health status of marine ecosystems. Frontiers in Marine Science 3:175.

Breitburg, D. L., Hondorp, D. W., Davias, L. A. and Diaz, R. J. 2009. Hypoxia, nitrogen, and fisheries: integrating effects across local and global landscapes. Ann. Rev. Mar. Sci. 1: 329–349.

Brockmeyer, B. and Spitzy, A. 2011. Effects of sugar cane monocultures on origin and characteristics of dissolved organic matter in the Manguaba lagoon in northeast Brazil. Org. Geochem. 42: 74–83.

Cabrita, M.T., Brito, P., Caçador, I. and Duarte, B. 2020. Impacts of phytoplankton blooms on trace metal recycling and bioavailability during dredging events in the Sado estuary (Portugal). Marine environmental research, 153, p.104837

Celliers, L., Breetzke, T., Moore, L. and Malan, D. 2009. A User-friendly Guide to South Africa's Integrated Coastal Management Act. The Department of Environmental Affairs and SSI Engineers and Environmental Consultants. Cape Town, South Africa.

Coetzee, J.C., Adams, J.B. & Bate, G.C., 1997. A botanical importance rating of selected Cape estuaries. Water SA. 23: 81–93.

Colloty, B.M., Adams, J.B. & Bate, G.C. 1998. The use of a botanical importance rating system to assess changes in the flora of the Swartkops estuary. Water SA. 26: 171–180.

Costa, C.R., Costa, M.F., Dantas, D.V. and Barletta, M. 2018. Interannual and Seasonal Variations in Estuarine Water Quality. Frontiers in Marine Science. 5:301

Council for Scientific and Industrial Research (CSIR). 1990. Great Brak River: Estuary Environmental Study concerning a management plan for the Wolwedans Dam and Great Brak River Mouth. CSIR Report EMA-C9036. Stellenbosch: CSIR

Department of Economic Development, Environmental Affairs and Tourism. DEDEAT. 2020. Protocol for requests to breach estuary mouths in Kwazulu-Natal. Mouth Maintenance Management Plans.

Diaz, R.J. 2015. Anoxia, hypoxia, and dead zones. In: Kennish MJ (ed) Encyclopedia of estuaries. Springer, Dordrecht. pp 19–29.

Donázar-Aramendía, I., Sánchez-Moyano, J.E., García-Asencio, I., Miró, J.M., Megina, C. and García-Gómez, J.C. 2020. Environmental consequences of dredged-material disposal in a recurrent marine dumping area near to Guadalquivir estuary, Spain. Marine Pollution Bulletin. 161: 111736.

Department of Water Affairs and Forestry (DWAF). 2008. Water resource protection and assessment policy implementation process. Resource Directed Measures for protection of water resource: Methodology for the determination of the ecological water requirements for estuaries. Version 2.1 Pretoria: Department of Water Affairs.

Department of Water Affairs and Forestry (DWAF). 2008. Resource Directed Measures for Protection of Water Resources: Methodologies for the determination of ecological water requirements for estuaries. Version 2. Pretoria.

Department of Water and Sanitation (DWS). 2015. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 4: Estuary Resource Quality Objectives. Prepared by: Van Niekerk, Adams, Taljaard, Weerts. DWS Report: RDM/WMA11/00/CON/CLA/0615.

Elliot, M. and McLusky, D.S. 2002. The need for definition in Understanding Estuaries. Estuarine, Coastal and Shelf Science. 55: 815-827.

Fernandes, M. and Adams, J.B. 2016. Quantifying the loss and changes in estuary habitats in the Umkomazi and Mvoti estuaries, South Africa. South African Journal of Botany 107: 179-187

French, P.W. 2001. Coastal defences: Processes, Problems and Solutions. London: Routledge.

Intergovernmental Panel on Climate Change (IPCC). 2007. Fourth Assessment Report: Climate Change 2007. Cambridge: Cambridge University Press

Karydis, M. and Kitsiou, D. 2013. Marine water quality monitoring: a review. Mar. Pollut. Bull. 77: 23–36.

Kennish MJ. 1986. Estuarine ecology. Boca Raton, Florida, United States: CRC Press.

Kennish, M.J., Livingston, R.J., Raffaelli, D. and Reise, K. 2008. Environmental future of estuaries. In: Polunin N (ed) Aquatic ecosystems: trends and global prospects. Cambridge University Press, Cambridge, pp 188–208.

Lubke, R.A. & Van Wijk, Y. 1988. Estuarine plants. A Field Guide to the Eastern Cape Coast. The Grahamstown Centre of the Wildlife Society of Southern Africa, Grahamstown. pp.133-145.

Meitzen, K.M., Doyle, M.W., Thoms, M.C., and Burns, C.E. 2013. Geomorphology within the interdisciplinary science of environmental flows. Geomorphology. https://doi.org/10.1016/j.geomorph.2013.03.013

Moore, K.A., Shields, E.C., Parish, D.B. and Orth, R.J. 2012. Eelgrass survival in two contrasting systems: role of turbidity and summer water temperatures. Mar Ecol Prog Ser. 448:247–258.

Morant, P and Quinn, N. 1999. Estuaries of South Africa: *Influence of Man and Management of South African Estuaries*. PP 289-320.

Mudge, S. M., Icely, J. D., and Newton, A. 2007. Oxygen depletion in relation to water residence times. J. Environ. Monit. 9: 1194–1198.

National Biodiversity Assessment 2018: The status of South Africa’s ecosystems and biodiversity. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria.

Skowno, A.L.; Poole, C.J.; Raimondo, D.C.; Sink, K.J.; Van Deventer, H.; Van Niekerk, L.; Harris, L.R.; Smith-Adao, L.B.; Tolley, K.A.; Zengeya, T.A.; Foden, W.B.; Midgley, G.F. & Driver, A. 2019. National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria. http://hdl.handle.net/20.500.12143/6362.

National Environmental Management Act (NEMA), (Act No. 107 of 1998). 1998. Republic of South Africa. Government Gazette 19519. Government Printer, Cape Town.

National Ocean and Atmospheric Administration (NOAA), 2021. Why Are Estuaries Important: Ecosystem Services. https://coast.noaa.gov/digitalcoast/training/econ-120-ecosystem-services.html

National Water Act (NWA) (Act No. 36 of 1998). 1998. Republic of South Africa. Government Gazette 39299. Government Printer, Cape Town.

National Water Resource Strategy (NWRS), Second Edition, 2013. Department of Water Affairs (DWA), Private Bag x 313, Pretoria, 0001. Republic of South Africa.

National Water and Sanitation Master Plan (NW&SMP), 2018. Ready for the Future and Ahead of the Curve. Volume 1: Call to Action, Version 10.1. Department of Water and Sanitation, Private Bag x 313, Pretoria, 0001. Republic of South Africa

Nichols, MM, Biggs, RB. 1985. Estuaries. p 77–186. In: Coastal Sedimentary Environments, 2nd edn. Davis RA. (Ed.) New York, United States: Springer-Verlag.

Pritchard, D. W. (1967). What is an estuary: a physical viewpoint. American Association for the Advancement of Science 83: 3–5.

South African National Biodiversity Institute (SANBI). 2014. South Africa's Fifth National Report to the Convention on Biological Diversity.

SANBI. 2019. The status of South Africa's ecosystems and biodiversity. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries.

Thayer, G. W., T. A. McTigue, R. J. Bellmer, F. M. Burrows, D. H. Merkey, A. D. Nickens, S. J. Lozano, P. F. Gayaldo, P. J. Polmateer, and P. T. Pinit. 2003. Science-based restoration monitoring of coastal habitats, volume one: A framework for monitoring plans under the Estuaries and Clean Waters Act of 2000 (Public Law 160-457). NOAA Coastal Ocean Program Decision Analysis Series. https://coastalscience.noaa.gov/data_reports/science-basedrestoration-monitoring-of-coastal-habitats-volume-one-aframework-for-monitoring-plans-under-the-estuaries-and-cleanwaters-act-of-2000-public-law-160-457/. Accessed 12 Dec 2023

Turpie, J.K., Taljaard, S., Adams, J.B., Van Niekerk, L., Forbes, N., Weston, B., Huizinga, P., Whitfield, A. 2012. Methods for the determination of the Ecological Reserve for estuaries. Version 3. Water Research Commission and Department of Water Affairs, Pretoria.

Turpie, J.K., Taljaard, S., Van Niekerk, L., Adams, J., Wooldrige, T., Cyrus, D., Clark, B. and Forbes, N. 2013. The Estuary Health Index: a standardised metric for use in estuary management and the determination of ecological water requirements. WRC Report No. 1930/1/12. 90pp.

UNEP-DTU 2017. Climate Change Adaptation Technologies for Water: Dune construction and rehabilitation.

Van Niekerk, L. and Turpie, J.K. (eds). 2012. 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. Available at: http://bgis.sanbi.org/nba/project.asp.

Van Niekerk, L., Adams, J.B., Bate, G.C., Forbes, N., Forbes, A., Huizinga, P., Lamberth, S.J., MacKay, F., Petersen, C., Taljaard, S., Weerts, S., Whitfield, A.K. and Wooldridge, T.H. 2013. Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment. Estuarine, Coastal and Shelf Science 130: 239-251.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, F., Taljaard, S., Turpie, J.K., Weerts, S., Raimondo, D.C. (eds). 2019. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. CSIR report number CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: http://hdl.handle.net/20.500.12143/6373.

Van Niekerk, L., Adams, J.B., James, N.C., Lamberth, S.J., MacKay, C.F., Turpie, J.K., Rajkaran, A., Weerts S.P. & Whitfield A.K. 2020. An Estuary Ecosystem Classification that encompasses biogeography and a high diversity of types in support of protection and management, African Journal of Aquatic Science, 45 (1-2): 199-216.

Verster, C. and Bouwman, H. 2020. Land-based sources and pathways of marine plastics in a South African context. South African Journal of Science. 116: 1-9

Western Cape, the Department of Environmental Affairs and Development Planning (DEA&DP). 2019. Western Cape Estuarine Management Framework and Implementation Strategy (EMFIS): Best Practice Activity Guidelines V.1 (October 2019).

Western Cape, the Department of Environmental Affairs and Development Planning (DEA&DP). 2021. Bank Erosion in the Berg River Estuary: Causes and Concerns. Report prepared for DEA&DP Prepared by: Anchor Research & Monitoring (Pty) Ltd in association with Zutari.

Whitfield, A.K. and Kok, H.M. 1992. Recruitment of juvenile marine fishes into permanently open and seasonally open estuarine systems on the southern coast of South Africa. Ichthyological Bulletin of the J.L.B. Smith Institute of Ichthyology 57, 1-39.

Whitfield, A.K., Adams, J.B., Bate, G.C., Bezuidenhout, K., Bornman, T.G., Cowley, P.D., Froneman, P.W., Gama, P.T., James, N., Mackenzie, B., Riddin, T., Snow, G.C., Strydom, N.A., Taljaard S., Terörde, A.I., Theron, A.K., Turpie, J.K., Van Niekerk, L., Vorwerk, P.D. and Wooldridge, T.H. 2008. 'A multidisciplinary study of a small, temporarily open/closed South African estuary, with particular emphasis of the influence of mouth state on the ecology of the system', African Journal of Marine Science 30: 453-473.

Worm, B., *et al*. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314:787–790.

Yin, K., Lin, Z. and Ke, Z. 2004. Temporal and spatial distribution of dissolved oxygen in the Pearl River Estuary and adjacent coastal waters. Cont. Shelf Res. 24: 1935–1948.

APPENDICES

Appendix A

Table 2.1 Proposed RQOs for water quality associated with ecosystem health for the estuaries in WMA 11

<table>
<tr><th rowspan="2">Variable</th><th colspan="6">Health Category</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>Dissolved oxygen (DO)</td><td colspan="2">Average in estuary
$\geq$ 6 mg/l</td><td>Average in estuary
$\geq$ 4 mg/l</td><td colspan="3">Average in lower estuary
$\geq$ 4 mg/l</td></tr>
<tr><td>Turbidity</td><td colspan="3">Estuary: Clear (< 10 NTU) accept during high flows</td><td colspan="3">Estuary: Mostly clear (< 15 NTU) accept during high flows</td></tr>
<tr><td>Dissolved inorganic nitrogen (DIN) in river inflow</td><td>50%ile < 0.1 mg/l</td><td>50%ile < 0.2 mg/l</td><td>50%ile < 0.3 mg/l</td><td colspan="3">50%ile < 0.5 mg/l</td></tr>
<tr><td>Dissolved inorganic phosphate (DIP) in river inflow</td><td>50%ile < 0.01 mg/l</td><td>50%ile < 0.015 mg/l</td><td>50%ile < 0.025 mg/l</td><td colspan="3">50%ile < 0.125 mg/l</td></tr>
<tr><td>Toxic substances</td><td colspan="6">▪ Substance concentrations in estuarine sediment not to exceed targets as per Western Indian Ocean (WIO) Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters Department of Water Affairs and Forestry (DWAF,1995).</td></tr>
</table>