**REHABILITATION MANAGEMENT GUIDELINES FOR WATER RESOURCES**

**VOLUME 3: ESTUARIES**

**November 2023**

**Version 1.9**

Graphical user interface, text, application

Description automatically generated

**Published by**

The Department of Water and Sanitation   
Private Bag X313  
Pretoria, 0001  
Republic of South Africa

Tel: (012) 336 7500/ +27 12 336 7500  
Fax: (012) 336 6731/ +27 12 336 6731

**Copyright Reserved**

**No part of this publication may be reproduced in any manner   
without full acknowledgment of the source.**

|  |
| --- |
| **This report should be cited as:**  Department of Water and Sanitation. 2022. Rehabilitation Management Guidelines. *Rehabilitation Management Guidelines for Estuaries*. Report 2.3. Sources Directed Studies. Report No: RDM/RMG/00/IHP/SDS/0322. Pretoria, South Africa |

##### Document Index

|  |  |  |
| --- | --- | --- |
| **REHABILITATION MANAGEMENT GUIDELINES FOR WATER RESOURCES** | | |
| **REPORT SERIES** | **REPORT TITLE** | **DWS REPORT NUMBER** |
| 1. **Project Planning Reports** | | |
| 1.1 | Project Plan | RDM/RMG/00/IHP/SDS/0120 |
| 1.2 | Gap Analysis Report | RDM/RMG/00/IHP/SDS/0220 |
| 1.3 | Framework Document | RDM/RMG/00/IHP/SDC/0121 |
| 1.4 | ToR for PSC members | RDM/RMG/00/IHP/SDS/0221 |
| 1.5 | Inception Report | RDM/RMG/00/IHP/SDS/0321 |
| **1.6** | Situation Assessment Report | RDM/RMG/00/IHP/SDS/0422 |
| 1. **Development of Rehabilitation Management Guidelines** | | |
| 2.1 | Rehabilitation Management Guidelines for Rivers | RDM/RMG/00/IHP/SDS/0122 |
| 2.2 | Rehabilitation Management Guidelines for Wetlands | RDM/RMG/00/IHP/SDS/0222 |
| 2.3 | Rehabilitation Management Guidelines for Estuaries | RDM/RMG/00/IHP/SDS/0322 |
| 2.4 | Rehabilitation Management Guidelines for Groundwater Resources | RDM/RMG/00/IHP/SDS/0422 |
| 2.5 | Rehabilitation Management Guidelines for Lakes and Dams | RDM/RMG/00/IHP/SDS/0123 |
| 1. **Implementation Report** | | |
| 3.1 | Guidelines into Practice | RDM/RMG/00/IHP/SDS/0423 |
| 1. **Project Administration Reports** | | |
| 4.1 | Capacity Building Report | RDM/RMG/00/IHP/SDS/0523 |
| 4.2 | Stakeholder Engagement: Issues and Response Register | RDM/RMG/00/IHP/SDS/0623 |
| 4.3 | Technical Close-Out Report | RDM/RMG/00/IHP/SDS/0723 |

##### Departmental Approval

***Authors****: Mr Kgotso Mahlahlane, Dr Mampolelo Photolo, Ms Mmaphefo Thwala,*

*Mr Samkele Mnyango, Mr Sibusiso Majola, Ms Tovhowani Nyamande*

***Project******Name****:* ***Rehabilitation Management Guidelines for Estuaries***

***Report******No****: RDM/RMG/00/IHP/SDS/0322*

***Status******of******Report****: Draft 2*

***Report version:*** *Version 1.9*

***Date:*** *November 2023*

***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***

***Department of Water and Sanitation***

*Chief Directorate: Water Ecosystems Management*

***Recommended for Approval by:***

*……………………………………………..*

***Scientific Manager: Sources Directed Studies***

*Ms Mmaphefo Thwala (Project Manager)*

***Approved for DWS by:***

*…………………………………………….*

***Director: Sources Directed Studies***

*Ms Tovhowani Nyamande (Project Leader)*

*…………………………………………….*

***Chief Director: Water Ecosystems Management***

*Ms Ndileka Mohapi*

##### Acknowledgments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DWS Project Administration Committee (PAC)** | | | | |
|  | | | | |
| Ms | Tovhowani Nyamande | Director: Sources Directed Studies | Project Leader | |
| Ms | Mmaphefo Thwala | Scientific Manager: Sources Directed Studies | Project Manager | |
| Mr | Kgotso Mahlahlane | Production Scientist: Source Directed Studies | Project Coordinator | |
| |  |  |  |  | | --- | --- | --- | --- | | **DWS Sub-Technical Task Team (Sub-TT)** | | | | |  | | | | | Ms | Tovhowani Nyamande | Director: Sources Directed Studies | Project Leader | | Ms | Mmaphefo Thwala | Scientific Manager: Sources Directed Studies | Project Manager | | Mr | Kgotso Mahlahlane | Production Scientist: Source Directed Studies | Project Coordinator | | Mr | Musawenkosi Kunene | Production Scientist: Strategy – Disaster Management | Member | | Ms | Rachel Mpe | Production Scientist: Northwest Regional Office | Member | | Mr | Samkele Mnyango | Production Scientist: Source Directed Studies | Member | | Mr | Sazi Mthembu | Production Scientist: Resource Quality Information Services | Member | | Mr | Stanley Nzama | Production Scientist: Reserve Determination - Groundwater | Member | | Ms | Shaddai Daniel | Water Resource Management – Western Cape Regional Office | Member | | Ms | Dikeledi Baloyi | Environmental Officer Specialised Production: Resource Protection and Waste | Member | | Ms | Adaora Okonkwo | Scientific Manager: Water Resource Classification | Member | | Ms | Joyce Machaba | Production Scientist: Reserve Determination-Surface Water | Member | | Mr | Pieter Ackerman | Landscape Architect: Water Abstraction and In-Stream Use | Member | | Ms | Nombuyiselo Mgca | Institutional Establishment – Eastern Cape | Member | | Mr | Lindelani Lalumbe | Production Scientist: Surface and Groundwater Information | Member | | Dr | Mampolelo Photolo | Resource Quality Information Services | Member | | Mr | Sibusiso Majola | Resource Quality Information Services | Member |   **DWS Technical Task Team (TTT)**   |  |  |  |  | | --- | --- | --- | --- | | Ms | Tovhowani Nyamande | Director: Sources Directed Studies | Project Leader | | Ms | Mmaphefo Thwala | Scientific Manager: Sources Directed Studies | Project Manager | | Mr | Kgotso Mahlahlane | Production Scientist: Source Directed Studies | Project Coordinator | | Mr | Elijah Mogakabe | Scientific Manager: Resource Quality Information Services | Member | | Mr | Washington Tunha | Chief Engineer: Implementation Support – Micro Planning | Member | | Ms | Thivhafuni Nemataheni | Scientific Manager: Water Use Efficiency | Member | | Mr | Musawenkosi Kunene | Production Scientist: Strategy – Disaster Management | Member | | Ms | Rachel Mpe | Production Scientist: Northwest Regional Office | Member | | Mr | Samkele Mnyango | Production Scientist: Source Directed Studies | Member | | Mr | Sazi Mthembu | Production Scientist: Resource Quality Information Services | Member | | Mr | Stanley Nzama | Production Scientist: Reserve Determination - Groundwater | Member | | Ms | Shaddai Daniel | Water Resource Management – Western Cape Regional Office | Member | | Ms | Dikeledi Baloyi | Environmental Officer Specialised Production: Water Resource Regulation | Member | | Mr | Rendani Ndou | Control Environmental Officer: Resource Protection and Waste | Member | | Ms | Adaora Okonkwo | Scientific Manager: Water Resource Classification | Member | | Ms | Esther Lekalake | Production Scientist: Water Resource Classification | Member | | Ms | Dephney Kabini | Planning and Information – Free State Regional Office | Member | | Mr | Stanford Macevele | Institutional Establishment – Mpumalanga Regional Office | Member | | Ms | Jeanette Nyama | Institutional Establishment – Gauteng Regional Office | Member | | Ms | Mahadi Mofokeng | Deputy Director: Strategy Coordination | Member | | Dr | Wietsche Roets | Specialist Scientist: Water Abstraction and In-Stream Use | Member | | Ms | Abashoni Nefale | Deputy Director: Compliance Monitoring - Irrigation | Member | | Mr | Tendamudzimu Rasikhanya | Director: Institutional Establishment | Member | | Ms | Lumka Kuse | Production Scientist: Water Abstraction and In-Stream Use | Member | | Ms | Morongwa Seko | Deputy Director: Compliance Monitoring & Enforcement | Member | | Ms | Joyce Machaba | Production Scientist: Reserve Determination-Surface Water | Member | | Mr | Pieter Ackerman | Landscape Architect: Water Abstraction and In-Stream Use | Member | | Ms | Nombuyiselo Mgca | Institutional Establishment – Eastern Cape | Member | | Mr | Lindelani Lalumbe | Production Scientist: Surface and Groundwater Information | Member | | Dr | Mampolelo Photolo | Resource Quality Information Services | Member | | Mr | Joseph Phasha | Control Engineering Technician | Member | | Mr | Sibusiso Majola | Resource Quality Information Services | Member |   **DWS Project Management Committee (PMC)** | | | | |
|  | | | | |
| Ms | Tovhowani Nyamande | Director: Source Directed Studies | | Project Leader (Chairperson) |
| Ms | Mmaphefo Thwala | Scientific Manager: Source Directed Studies | | Project Manager |
| Mr | Kgotso Mahlahlane | Production Scientist: Sources Directed Studies | | Project Coordinator |
| Mr | Samkele Mnyango | Production Scientist: Source Directed Studies | | Member |
| Ms | Abashoni Nefale | Deputy Director: Compliance Monitoring - Irrigation | | Member |
| Ms | Dephney Kabini | Planning and Information – Free State Regional Office | | Member |
| Ms | Rachel Mpe | Production Scientist: Northwest Regional Office | | Member |
| Mr | Stanford Macevele | Institutional Establishment – Mpumalanga Regional Office | | Member |
| Ms | Jeanette Nyama | Institutional Establishment – Gauteng Regional Office | | Member |
| Ms | Nombuyiselo Mgca | Institutional Establishment – Eastern Cape | | Member |
| Ms | Khumbuzile Moyo | Scientific Manager: Water Use Efficiency | | Member |
| Ms | Thivhafuni Nemataheni | Scientific Manager: Water Use Efficiency | | Member |
| Mr | Kwazikwakhe Majola | Scientific Manager: Reserve Determination | | Member |
| Mr | Lindelani Lalumbe | Production Scientist: Surface and Groundwater Information | | Member |
| Ms | Lusanda Agbasi | Deputy Director: Sanitation Services Support | | Member |
| Mr | Molefi Mazibuko | Production Scientist: Reserve Determination | | Member |
| Ms | Mahadi Mofokeng | Deputy Director: Strategy Coordination | | Member |
| Mr | Musawenkosi Kunene | Production Scientist: Strategy – Disaster Management | | Member |
| Mr | Elijah Mogakabe | Scientific Manager: Resource Quality Information Services | | Member |
| Mr | Sazi Mthembu | Production Scientist: Resource Quality Information Services | | Member |
| Mr | Washington Tunha | Chief Engineer: Implementation Support – Micro Planning | | Member |
| Mr | William Mosefowa | Deputy Director: Resource Protection and Waste | | Member |
| Mr | Stanley Nzama | Production Scientist: Reserve Determination - Groundwater | | Member |
| Ms | Joyce Machaba | Production Scientist: Reserve Determination-Surface Water | | Member |
| Ms | Adaora Okonkwo | Scientific Manager: Water Resource Classification | | Member |
| Ms | Shaddai Daniel | Water Resource Management – Western Cape Regional Office | | Member |
| Ms | Esther Lekalake | Production Scientist: Water Resource Classification | | Member |
| Mr | Tendamudzimu Rasikhanya | Director: Institutional Establishment | | Member |
| Mr | Pieter Viljoen | Scientist Manager: Water Resource Planning Systems | | Member |
| Dr | Wietsche Roets | Specialist Scientist: Water Abstraction and In-Stream Use | | Member |
| Mr | Pieter Ackerman | Landscape Architect: Water Abstraction and In-Stream Use | | Member |
| Ms | Dikeledi Baloyi | Environmental Officer Specialised Production: Resource Protection and Waste | | Member |
| Mr | Rendani Ndou | Control Environmental Officer: Resource Protection and Waste | | Member |
| Ms | Lumka Kuse | Production Scientist: Water Abstraction and In-Stream Use | | Member |
| Ms | Morongwa Seko | Deputy Director: Compliance Monitoring & Enforcement | | Member |
| Mr | Siyabonga Buthelezi | Scientific Manager – Kwazulu Natal Regional Office | | Member |
| Ms | Nolusindiso Jafta | Deputy Director: Integrated Water Resource Management | | Member |
| Mr | Isaac Ramukhuba | Environmental Officer Specialised Production: Water Use Licensing | | Member |
| Mr | Michael Munzhelele | Environmental Officer Specialised Production: Water Use Licensing | | Member |
| Mr | Bashan Govender | Mine Water Management | | Member |
| Dr | Christa Thirion | Resource Quality Information Services | | Member |
| Ms | Lerato Mokhoantle | Northern Cape Provincial Office | | Member |
| Mr | Jaco Roelofse | Northern Cape Provincial Office | | Member |
| Dr | Mampolelo Photolo | Resource Quality Information Services | | Member |
| Mr | Joseph Phasha | Control Engineering Technician | | Member |
| Mr | Sibusiso Majola | Resource Quality Information Services | | Member |
| **Project Steering Committee Members (PSC)** | | | | |
| DWS Representatives | | | | |
| Ms | Mohapi Ndileka | Chief Director: Water Ecosystems Management | | Chairperson |
| Ms | Tovhowani Nyamande | Director: Source Directed Studies | | Project Leader |
| Ms | Mmaphefo Thwala | Scientific Manager: Source Directed Studies | | Project Manager |
| Mr | Kgotso Mahlahlane | Production Scientist: Sources Directed Studies | | Project Coordinator |
| Mr | Samkele Mnyango | Production Scientist: Source Directed Studies | | Member |
| Ms | Abashoni Nefale | Deputy Director: Compliance Monitoring - Irrigation | | Member |
| Ms | Dephney Kabini | Planning and Information – Free State Regional Office | | Member |
| Ms | Rachel Mpe | Production Scientist: Northwest Regional Office | | Member |
| Mr | Stanford Macevele | Institutional Establishment – Mpumalanga Regional Office | | Member |
| Ms | Jeanette Nyama | Institutional Establishment – Gauteng Regional Office | | Member |
| Ms | Nombuyiselo Mgca | Institutional Establishment – Eastern Cape | | Member |
| Ms | Khumbuzile Moyo | Scientific Manager: Water Use Efficiency | | Member |
| Ms | Thivhafuni Nemataheni | Scientific Manager: Water Use Efficiency | | Member |
| Mr | Kwazikwakhe Majola | Scientific Manager: Reserve Determination | | Member |
| Mr | Lindelani Lalumbe | Production Scientist: Surface and Groundwater Information | | Member |
| Ms | Lusanda Agbasi | Deputy Director: Sanitation Services Support | | Member |
| Mr | Molefi Mazibuko | Production Scientist: Reserve Determination | | Member |
| Ms | Mahadi Mofokeng | Deputy Director: Strategy Coordination | | Member |
| Mr | Musawenkosi Kunene | Production Scientist: Strategy – Disaster Management | | Member |
| Mr | Elijah Mogakabe | Scientific Manager: Resource Quality Information Services | | Member |
| Mr | Sazi Mthembu | Production Scientist: Resource Quality Information Services | | Member |
| Mr | Washington Tunha | Chief Engineer: Implementation Support – Micro Planning | | Member |
| Mr | William Mosefowa | Deputy Director: Resource Protection and Waste | | Member |
| Mr | Stanley Nzama | Production Scientist: Reserve Determination - Groundwater | | Member |
| Ms | Joyce Machaba | Production Scientist: Reserve Determination-Surface Water | | Member |
| Ms | Adaora Okonkwo | Scientific Manager: Water Resource Classification | | Member |
| Mr | Fanus Fourie | Scientific Manager: Water Resource Planning Systems | | Member |
| Ms | Shaddai Daniel | Water Resource Management – Western Cape Regional Office | | Member |
| Ms | Esther Lekalake | Production Scientist: Water Resource Classification | | Member |
| Mr | Tendamudzimu Rasikhanya | Director: Institutional Establishment | | Member |
| Mr | Pieter Viljoen | Scientist Manager: Water Resource Planning Systems | | Member |
| Dr | Wietsche Roets | Specialist Scientist: Water Abstraction and In-Stream Use | | Member |
| Mr | Pieter Ackerman | Landscape Architect: Water Abstraction and In-Stream Use | | Member |
| Ms | Dikeledi Baloyi | Environmental Officer Specialised Production: Resource Protection and Waste | | Member |
| Mr | Rendani Ndou | Control Environmental Officer: Resource Protection and Waste | | Member |
| Ms | Lumka Kuse | Production Scientist: Water Abstraction and In-Stream Use | | Member |
| Ms | Morongwa Seko | Deputy Director: Compliance Monitoring & Enforcement | | Member |
| Mr | Siyabonga Buthelezi | Scientific Manager – Kwazulu Natal Regional Office | | Member |
| Ms | Nolusindiso Jafta | Deputy Director: Integrated Water Resource Management | | Member |
| Mr | Isaac Ramukhuba | Environmental Officer Specialised Production: Water Use Licensing | | Member |
| Mr | Michael Munzhelele | Environmental Officer Specialised Production: Water Use Licensing | | Member |
| Mr | Bashan Govender | Mine Water Management | | Member |
| Dr | Christa Thirion | Resource Quality Information Services | | Member |
| Ms | Lerato Mokhoantle | Northern Cape Provincial Office | | Member |
| Mr | Jaco Roelofse | Northern Cape Provincial Office | | Member |
| Dr | Mampolelo Photolo | Resource Quality Information Services | | Member |
| Mr | Joseph Phasha | Control Engineering Technician | | Member |
| Mr | Sibusiso Majola | Resource Quality Information Services | | Member |
| Ms | Thembisa Torch | Assistant Director: DWS: Berg-Olifants Proto-CMA | | Member |
| Ms | Lebogang Matlala | Director: DWS Water Resource Classification | | Member |
| Ms | Anet Muir | Chief Director: Water Use Compliance & Enforcement | | Member |
| Ms | Barbara Weston | Scientific Manager: Reserve Determination | | Member |
| Mr | Yakeen Atwaru | Director: Reserve Determination | | Member |
| Ms | Thembela Bushula | Freshwater Ecologist: Breede-Olifants Catchment Management Agency | | Member |
| Ms | Thembela Bushula | Freshwater Ecologist: Breede-Olifants Catchment Management Agency | | Member |
| Ms | Elkerine Rossouw | Water Use Specialist: Breede-Olifants Catchment Management Agency | | Member |
| Water Sector Representatives | | | | |
| Dr | Andrew Wood | Principal Scientist: SRK Consulting SA (Pty) Ltd | | Member |
| Mr | Lehlohonolo Phadima | General Manager: Scientific Services: Ezemvelo KZN Wildlife | | Member |
| Dr | Eddie Riddell | Water Resources Manager: South African National Parks | | Member |
| Mr | Ntsikelelo Wiseman Dlulane | Acting Chief Executive Officer: Ezemvelo KZN Wildlife | | Member |
| Mr | Phil McLean | Task Manager: Western Cape Department of Environmental Affairs and Development  Planning, Pollution and Chemicals Directorate | | Member |
| Mr | Stanley Tshitwamulomoni | Director: Water Sources and Wetlands Conservation: DFFE | | Member |
| Dr | Dhiraj Rama | Executive Director: Association of Cementitious Material Producers (ACMP) | | Member |
| Mr | Kobus Fell | Advisor: National Water Monitor Non-Profit Company | | Member |
| Mr | Donovan Gillman | President: Institute for Landscape Architecture in South Africa | | Member |
| Mr | Reginald Mabalane | Policy Analyst: Mineral Council of South Africa | | Member |
| Ms | Busisiwe Mahlangu | Control Environmental Officer: Inkomati-Usuthu Catchment Management Agency | | Member |
| Mr | Sihle Ximba | Acting Water Care Manager: Ezemvelo KZN Wildlife | | Member |
| Mr | Bonani Madikizela | Research Manager: Water Research Commission | | Member |
| Ms | Elkerine Rossouw | Water Use Specialist: Breede-Gouritz Catchment Management Agency | | Member |
| Ms | Hermien Oberholzer | Senior Principal Engineer: Anglo American Platinum | | Member |
| Ms | Stephinah Mudau | Head Environment: Minerals Council of South Africa | | Member |
| Mr | Matome Makwela | Senior Policy Analyst: Minerals Council of South Africa | | Member |
| Ms | Jenifer Zungu | Project Leader: South African National Biodiversity Institute | | Member |
| Mr | Douglas Macfarlane | Chief Scientist: Eco-Pulse Environmental Consulting Services | | Member |
| Mr | Andre Beegte | Implementation Manager – Wetlands: Department of Forestry, Fisheries, and the Environment | | Member |
| Ms | Debbie Muir | Biodiversity Officer Control: Department of Forestry, Fisheries, and the Environment | | Member |
| Ms | Kate Snaddon | Senior Consultant: Freshwater Consulting | | Member |
| Dr | Yolandi Schoeman | Postdoctoral Scientist and Ecological Engineer: University of the Free State | | Member |
| Dr | Chantel Petersen | Senior Professional Officer: City of Cape Town | | Member |
| Dr | Vhahangwele Masindi | Research and Development Manager: Magalies Water | | Member |
| Ms | Kim Hodgson | Scientist – Water Quality Management: Umgeni Water | | Member |
| Ms | Lilian Siwelane | Control Environmental Officer: DWS: North West, Institutional Management | | Member |
| Mr | Mashudu Rafundisani | Senior Specialist - Catchment Management: City of Johannesburg Municipality | | Member |
| Ms | Mpho Zwane | Senior Specialist - Water Quality Management: City of Johannesburg Municipality | | Member |
| Ms | Esmeralda Ramburran | Deputy Director - Operational Support and Planning: Department of Forestry Fisheries and the Environment | | Member |
| Mr | Norman Nokeri | Manager - Strategy and Planning: Lepelle Northern Water | | Member |
| Mr | Pule Makena | Specialist - Catchment Management: City of Ekurhuleni Metropolitan Municipality | | Member |
| Mr | Reveck Hariram | Senior Water Quality Advisor: Rand Water | | Member |
| Mr | Theolin Naidoo | Senior Scientist: Institute of Natural Resources NPC | | Member |
| Mr | Wiseman Ndlala | Senior Specialist - Water Quality and Catchment Management: City of Johannesburg | | Member |
| Mr | Roger Bills | Senior Curator: South African Institute for Aquatic Biodiversity (SAIAB) | | Member |
| Mr | Fazel Sheriff | Chief Engineer: Municipal Infrastructure Support Agent | | Member |
| Mr | Themba Dladla | Provincial Programme Manager: Municipal Infrastructure Support Agent | | Member |
| Dr | Kobus Du Plessis | Managing Director: Envirokonsult Scientific Services (Pty) Ltd | | Member |
| Ms | Mulala Sundani | Environmental Impact Management: Department of Forestry, Fisheries, and the Environment (DFFE) | | Member |
| Dr | Elizabeth Day | Director: Liz Day Consulting (Pty) Ltd | | Member |
| Dr | Heidi van Deventer | Principal Researcher: Council for Scientific and Industrial Research | | Member |
| Mr | Lubabalo Luyaba | Specialist – Water and Sanitation: South African Local Government Association | | Member |
| Mr | Vhangani Silima | Coordinator Environmental Rehabilitation: Rand Water | | Member |
| Ms | Phumelele Sokhulu | Environmental Officer: Umgeni | | Member |
| Mr | Robert Siebritz | Senior Professional Officer: City of Cape Town | | Member |
| Mr | Eddy Tshabalala | Control Environmental Officer: Sedibeng District Municipality | | Member |
| Mr | Rodney February | MEL Coordinator: World Wide Fund for Nature | | Member |
| Mr | Ruwen Pillay | Control Environmental Officer: Estuaries Management: DFFE | | Member |
| Ms | Yolokazi Galada | Control Environmental Officer: DFFE | | Member |
| Mr | Stephen Midzi | Manager: Biodiversity Conservation SANParks | | Member |
| Dr | Thakane Ntholi | Manager: Water and Environment: Council for Geoscience | | Member |
| **DWS One-on-one workshop on Estuaries Bank Stabilization** | | | | |
| DWS Engineering Team from Directorate: Environmental Impact Monitoring under the Chief Directorate: Engineering Services.  Mr Karl Bester  Mr Kelvin Legge  Mr Miyelani Maluleke | | | | |
| **DWS and DFFE One-on-one workshop on Estuaries** | | | | |
| DFFE Directorate Coastal Biodiversity Conservation (Estuaries and MPA Management)  Mr Mbulelo Dopolo  Ms Yolokazi Galada  Mr Ruwen Pillay  Ms Yvonne Mokadi | | | | |

##### List of Acronyms

|  |  |
| --- | --- |
| **CARA**  **CD: WEM**  **C.A.P.E**  **CMA**  **CMP**  **CSIR**  **DALRRD**  **DCOGTA**  **DEA**  **DEA&DP**  **DEDTEA**  **DFFE**  **ECA**  **EFZ**  **EMFIS**  **EMPs**  **EWR**  **e-WULAAS**  **SDS**  **DEDEAT**  **DWAF**  **DWS**  **EIA**  **GA**  **GIS**  **IPCC**  **IWQM**  **IWRM**  **MMP**  **MaintMP** | Conservation of Agricultural Resources Act  Chief Directorate: Water Ecosystems Management  Cape Action Plan for the People and the Environment  Catchment Management Agency  Coastal Management Programme  Council for Scientific and Industrial Research  Department of Agriculture, Land Reform and Rural Development  Department of Cooperative Governance and Traditional Affairs  Department of Environmental Affairs  Department of Environmental Affairs and Development Planning  Department of Economic Development, Tourism and Environmental Affairs  Department of Forestry, Fisheries and Environment  Environment Conservation Act  Estuary Functional Zone  Estuarine Management Framework and Implementation Strategy  Estuarine Management Plans  Ecological Water Requirements  Electronic Water Use Licence Application and Authorisation System  Directorate: Sources Directed Studies  Department of Economic Development, Environmental Affairs and Tourism  Department of Water Affairs and Forestry  Department of Water and Sanitation  Environmental impact Assessment  General Authorization  Geographic Information System  Intergovernmental Panel on Climate Change  Integrated Water Quality Management  Integrated Water Resource Management  Mouth Management Plan  Maintenance Management Plan |
| **MPRDA**  **NBA** | Mineral and Petroleum Resources Development Act  National Biodiversity Assessment |
| **NEMA**  **NEM: BA**  **NEM: WA**  **NEM: PAA**  **NFA** | National Environmental Management Act  National Environmental Management: Biodiversity Act  National Environmental Management: Waste Act  National Environmental Management: Protected Areas Act  National Forests Act |
| **NHRA**  **NOAA** | National Heritage Resources Act  National Ocean and Atmospheric Administration |
| **NWA** | National Water Act |
| **NWRS** | National Water Resource Strategy |
| **NW&SMP**  **PAHs**  **RQOs** | National Water and Sanitation Master Plan  Polycyclic Aromatic Hydrocarbons  Resource Quality Objectives |
| **RDM**  **SANBI**  **SFR** | Resource Directed Measures  South African National Biodiversity Institute  Stream flow reduction |
| **SDCs**  **(WCTDP)**  **WML**  **WRC**  **WULA**  **WUL** | Sources Directed Controls  Wild Coast Tourism Development Policy  Waste Management License  Water Research Commission  Water Use License Application  Water Use License |
| **WWTW** | Wastewater Treatment Works |

##### Contents

[Document Index iii](#_Toc152070752)

[Departmental Approval iv](#_Toc152070753)

[Acknowledgments v](#_Toc152070754)

[List of Acronyms xii](#_Toc152070755)

[Contents xiv](#_Toc152070756)

[List of Figures xv](#_Toc152070757)

[List of Tables xv](#_Toc152070758)

[executive summary xvi](#_Toc152070759)

[1. INTRODUCTION 1](#_Toc152070760)

[1.1 Background 1](#_Toc152070761)

[**1.2** **Purpose of the report** 1](#_Toc152070762)

[1.3 ESTUARY DEFINITION, CategoriSation, AND IMPACTS 2](#_Toc152070763)

[1.3.1 Definition of Estuaries 2](#_Toc152070764)

[1.3.2 Estuarine Categorisation System and Characteristics 2](#_Toc152070765)

[1.3.3 Estuarine Key Indicators and Components 4](#_Toc152070766)

[1.3.4 Link between water resources and key components of estuaries 5](#_Toc152070767)

[1.3.5 Estuarine Ecosystem Services and Impacts 6](#_Toc152070768)

[**Estuarine Impacts** 8](#_Toc152070769)

[1.4 estuarine Rehabilitation Definitions 9](#_Toc152070770)

[1.5 GUIDING PRINCIPLES and approach FOR the DEVELOPMENT OF THE 9](#_Toc152070771)

[GUIDELINES 9](#_Toc152070772)

[1.5.1 Estuarine Rehabilitation Guiding Principles 10](#_Toc152070773)

[1.5.2 Approach 10](#_Toc152070774)

[1.6 INTENDED USERS of the guidelines 11](#_Toc152070775)

[1.7 STRUCTURE OF THE GUIDELINES 11](#_Toc152070776)

[2. LEGAL FRAMEWORK 12](#_Toc152070777)

[2.1 OVERArCHING LEGAL FRAMEWORK 12](#_Toc152070779)

[2.2 Legal COnsideration Specific to Estuaries Rehabilitation 13](#_Toc152070780)

[2.3 ALIGNMENT WITH POLICIES, STRATEGIES AND PRINCIPLES 16](#_Toc152070781)

[3. GUIDELINES FOR key components of estuaries 17](#_Toc152070782)

[3.1 hydrology 17](#_Toc152070783)

[3.1.1 Description 17](#_Toc152070784)

[3.1.2 Types of Impact 17](#_Toc152070785)

[*3.1.2.1* *Dam Construction and Weirs* 17](#_Toc152070786)

[*3.1.2.2* *Urbanisation and poor land use* 18](#_Toc152070787)

[*3.1.2.3* *Over-abstraction* 18](#_Toc152070788)

[*3.1.2.4* *Bridges* 18](#_Toc152070789)

[*3.1.2.5* *Jetties & Piers* 19](#_Toc152070790)

[*3.1.2.6* *Slipways/Launching Ramps* 20](#_Toc152070791)

[3.1.3 Rehabilitation Management Guidelines for Hydrology (Surface flow, runoff, and baseflow) 20](#_Toc152070792)

[3.2 gEOMORPHOLOGY 25](#_Toc152070793)

[3.2.1 **Description** 25](#_Toc152070794)

[3.2.2 Types of Impacts 26](#_Toc152070795)

[*3.2.2.1* *Dredging and dredging material disposal* 26](#_Toc152070796)

[*3.2.2.2* *Human-induced sedimentation* 26](#_Toc152070797)

[*3.2.2.3* *Sand mining* 26](#_Toc152070798)

[3.2.3 Rehabilitation Management Guidelines for Geomorphology 26](#_Toc152070799)

[3.3 WATER QUALITY 34](#_Toc152070800)

[3.3.1 Description 34](#_Toc152070801)

[3.3.2 Types of Water Quality Impacts 34](#_Toc152070802)

[*3.3.2.1* *WWTW discharges* 34](#_Toc152070803)

[*3.3.2.2* *Effluent discharge from industries, surface, and agricultural and stormwater runoff* 34](#_Toc152070804)

[*3.3.2.3* *Encroachment of sugarcane and banana plantation* 35](#_Toc152070805)

[*3.3.2.4* *Climate Change Effects* 35](#_Toc152070806)

[*3.3.2.5* *Deforestation* 35](#_Toc152070807)

[3.3.3 Rehabilitation Management Guidelines for Water Quality 35](#_Toc152070808)

[3.4 HABITAT 38](#_Toc152070809)

[3.4.1 Description 38](#_Toc152070810)

[3.4.2 Types of Habitat Impact 38](#_Toc152070811)

[*3.4.2.1* *Habitat removal and alteration* 38](#_Toc152070812)

[*3.4.2.2* *Alien Invasive Species* 39](#_Toc152070813)

[*3.4.2.3* *Sand mining* 39](#_Toc152070814)

[*3.4.2.4* *Dredging activities* 39](#_Toc152070815)

[*3.4.2.5* *Climate change* 39](#_Toc152070816)

[3.4.3 Rehabilitation Management Guidelines for Habitat 39](#_Toc152070817)

[3.5 BIOTA 46](#_Toc152070818)

[3.5.1 Description 46](#_Toc152070819)

[3.5.2 Types of Biota Impacts 46](#_Toc152070820)

[*3.5.2.1* *Over-exploitation / Overfishing* 46](#_Toc152070821)

[*3.5.2.2* *Plastic Waste* 46](#_Toc152070822)

[*3.5.2.3* *Artificial Breaching / Mouth manipulations* 46](#_Toc152070823)

[*3.5.2.4* *Sand mining* 46](#_Toc152070824)

[3.5.3 Rehabilitation Management Guidelines for Biota 46](#_Toc152070825)

[4. recommendations and way forward 51](#_Toc152070826)

[Reference List 52](#_Toc152070827)

[Appendices 56](#_Toc152070828)

##### List of Figures

[Figure 1: Map of Southern Africa showing the four estuarine biogeographical regions (Van Niekerk et al., 2019). 3](#_Toc152070829)

[Figure 2: Revised categorisation of South African coastal rivers/streams into estuarine functional types and micro-systems (Van Niekerk et al., 2020) 4](#_Toc152070830)

[Figure 3: Illustration of the structure of the Estuarine Health Index (DWAF 2008; Turpie et al.,2012) 5](#_Toc152070831)

[Figure 4: Diagram depicting the link between water resources and key components of estuaries. 6](#_Toc152070832)

[*Figure 5: Illustration of some of the key catchment pressures on estuaries (Van Niekerk et al., 2020)* 9](#_Toc152070833)

[Figure 6: Examples of vegetation coastal rehabilitation 30](file:///C:\Users\MahlahlaneK\Desktop\SDS%20Website%202023\Draft%20Reports\RMG_Draft%20Estuaries%20Guidelines%20Report_16Nov2023_V1.9..docx#_Toc152070834)

[Figure 7: Examples of Rip-rap revetments 30](file:///C:\Users\MahlahlaneK\Desktop\SDS%20Website%202023\Draft%20Reports\RMG_Draft%20Estuaries%20Guidelines%20Report_16Nov2023_V1.9..docx#_Toc152070835)

[Figure 8: Example of geotextile. 31](#_Toc152070836)

[Figure 9: Examples of Seawalls and Bulkheads. 32](file:///C:\Users\MahlahlaneK\Desktop\SDS%20Website%202023\Draft%20Reports\RMG_Draft%20Estuaries%20Guidelines%20Report_16Nov2023_V1.9..docx#_Toc152070837)

[Figure 10: Example of Gabion Erosion Control (Source: https://www.gabion1.co.uk/river-bank-protection/) 33](#_Toc152070838)

##### List of Tables

[Table 1: Estuarine Ecosystem Services. 7](#_Toc152070842)

[Table 2: Approach to be followed for the development of Rehabilitation Guidelines for Estuaries 11](#_Toc152070843)

[*Table 3: Legislative Tools Applicable for Estuarine Rehabilitation* 14](#_Toc152070844)

##### executive summary

Approximately 290 Estuarine Functional Zones (EFZs) and 42 micro-estuaries, totally 332 in South Africa are categorized into 46 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 existing Estuarine Management Plans, different 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 Goal A of the post-2020 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
* Development of Rehabilitation Guidelines – 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 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 (RMGs) 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 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.

# INTRODUCTION

## Background

South Africa has 290 Estuarine Functional Zones (EFZs) and 42 micro-estuaries, totally 332 estuaries categorised into 46 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. 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 (DEA). For instance, in Western Cape, 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 per Priority Area 7, which seeks an effective national information system and research framework to support integrated coastal management. 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 Protocol. Numerous EMPs have been compiled by DFFE 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), and Cape Action Plan for the People and the Environment (C.A.P.E) Regional Estuarine Management Programme 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 & initiatives.

* 1. **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.

## ESTUARY DEFINITION, CategoriSation, AND IMPACTS

* + 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.

***Note:*** *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.*

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. 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 four 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.

Map

Description automatically generated

Figure : Map of Southern Africa showing the four estuarine biogeographical regions (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.

Diagram

Description automatically generated

Figure : Revised categorisation of South African coastal rivers/streams into estuarine functional types and micro-systems (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. 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).

Diagram

Description automatically generated

Figure : Illustration of the structure of the Estuarine Health Index (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 (~~see~~ 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. Link between water resources and key components of estuaries

**Figure 3** above 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** below, 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.

A diagram of a company

Description automatically generated

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

* + 1. Estuarine Ecosystem Services and Impacts

**Estuarine Ecosystem Services**

Ecosystem services are the benefits that nature provides to people (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, 30% of coral reefs, 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 ofrehabilitation 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 : Estuarine Ecosystem Services.

|  |  |  |
| --- | --- | --- |
| **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. | * Fisheries: Estuaries serve as important breeding and nursery grounds for many commercially important fish and shellfish species, contributing to local and global fisheries. * Shellfish Harvesting: Oysters, clams, mussels, and other shellfish are harvested from estuaries, providing a valuable source of seafood. * Aquaculture: Estuaries are often used for aquaculture activities, such as cultivating fish, shrimp, and oysters for commercial purposes. |
| **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. | * Flood Regulation: Estuaries act as natural buffers against storm surges and flooding by absorbing and dissipating the energy of incoming waves and tides. * Water Purification: Estuaries can filter pollutants from water, improving water quality as it moves from the land into the ocean. * Carbon Sequestration: Salt marshes and seagrass beds within estuaries can sequester carbon dioxide, helping mitigate the impacts of climate change. |
| **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. |
| **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. * 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. |

**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.



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

## 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.

## 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. 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 importance 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. 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 : 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. |

## 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.

## STRUCTURE OF THE GUIDELINES

The guideline is divided into six main sections as follows:

* The opening sections contain the document signatories, document index and status, acknowledg~~e~~ments, 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 introduction characteristics of watercourses and their linkage to water resources and thestep-by-step Technical Rehabilitation Guidelines for key components of estuaries.
* **Section 4** provides recommendations and a way forward.

# 2. LEGAL FRAMEWORK



## 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); and
* 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~~.~~

## Legal COnsideration Specific to Estuaries Rehabilitation

Under the Integrated Coastal Management (ICM) Act the coastal protection zone extends 1 km from the coastal and estuarine high tide mark for all areas outside established townships, settlements, and urban areas (*i.e.,* for almost the entire Wild Coast). The ICM Act also provides for the establishment of a coastal setback line, designed to protect the coastal protection zone. No new development (construction) is permitted within a coastal setback line.

Several coastal-related activities for which an EIA is required have been defined in relation to a 100 m set-back line in EIA Regulations 2010; Listing Notice 1. 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 (2010) 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, Stormwater Management and Diffuse Water Quality Management 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. |
| * 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. |
| 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. |
| * Section 7 (2) | Mangrove forest[[1]](#footnote-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, Stormwater Management, Diffuse Water Quality Management by-laws | Applicable (per area) municipal by-laws need to be considered by every person(s) undertaking rehabilitation. |

## 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 II) (2013);
* 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).

# 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.**

## hydrology

* + 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).

* + 1. Types of Impact
       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).*

* + - 1. *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.

* + - 1. *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 alterthe 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.

* + - 1. *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.

Consider the below when constructing a bridge:

* Understand the erosion, deposition and water exchange~~s~~ 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.

* + - 1. *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;
* 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.
  + - 1. *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 protectionunless 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.
  + 1. 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 needto be removed.

**Step 3:** Consult local, provincial, or national authorities responsible for the physical structures

(municipal as well as Provincial DWS & DFFE 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**

Consider the below 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.

**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.

Consider the below 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 are 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 are as follows:
* Hydrodynamics and mouth condition;
* Mouth Closure – Dailly observation when the mouth is nearly closed or open; and
* Allowance (*e.g.,* 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 & eWULAAS; and
  + Identify unregistered/Illegal users through local authorities (DWS, DFFE).

**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 & Registration Management System (WARMS) & 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 issue 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 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:

* Volume of abstractions;
* Monitor the flows of the river vs. license abstraction volumes; and
* Impacts of pressures on habitats.

**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.

***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:

* + Registered users on the WARMS & eWULAAS
  + 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
* Impacts of pressures on habitats and biota.

**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.

## gEOMORPHOLOGY

* + 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).

* + 1. Types of Impacts
       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.

* + - 1. *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.

* + - 1. *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.

* + 1. Rehabilitation Management Guidelines for Geomorphology

***Scenario 1: Rehabilitation of activities relating to sand mining, road construction & 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.
* Improve habitat degradation 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,

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; and
* 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.

**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.

***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 & DFFE 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 & DFFE

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 forthe financial costs of rehabilitation.

**Assessment:**

**Step 1:** Conduct an Environmental Impact Assessment on the proposed erection of 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 is a number of methods that can be used for bank erosion and dune stabilization such as vegetation, rip-rap revetments, 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:

1. **Vegetation**

For low current velocities, the use of vegetation as a stabili~~s~~ation 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.

A picture containing text, grass, outdoor, nature

Description automatically generated A picture containing outdoor, water, nature, shore

Description automatically generated A picture containing grass, tree, outdoor, nature

Description automatically generated

Figure : Examples of vegetation coastal rehabilitation

1. **Rip-rap revetment**
2. **Rip-rap revetment**

Naturalised revetment consisting of loose rocks positioned on a bank slope is referred to as "rip-rap." The advantage of rip-rap is that the loose rocks can absorb bank deformation without necessarily reducing the level of protection provided (depending on filter compatibility between rip-rap and base soil, and protection against undercutting). Similar to vegetation, it is a straightforward, inexpensive method that is simple to install. It is suitable for low current velocities and small waves. It is frequently employed to treat erosion at the base of more official protection works.

The following specific considerations apply to the use of rip-rap:

* The thickness must be at least 1.5 times the size of an average rock, which is typically taken to be twice the size of an average stone;
* The toe must extend beyond the foot of the protection works by at least 1.7-2 times the estimated scour/erosive depth;
* The rock at the foot must be positioned in a layer that is 1.5 times as thick as that on the bank; and
* Filters (gravel of different sizes or geotextiles) are needed as an underlayer of protection against erosion of the underlying bed because they prevent piping (loss) of the fines through the protection layer.

**A picture containing grass, outdoor, rock, stone

Description automatically generated**

Figure : Examples of Rip-rap revetments

1. **Geotextile**

A geotextile 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
* The backing material for seawalls and bulkheads, as well as the lining for gabions or riprap, serve as stabilising elements in foundations.

**A picture containing tree, outdoor, water, river

Description automatically generated**

Figure : Example of geotextile.

1. **Seawalls and Bulkheads**

Bulkheads are typically used along estuaries and riverbanks to prevent slumping of the embankment and to protect against light to moderate wave action, whereas seawalls are large structures used along the seashore to resist intense wave action (USACE, 1995). In essence, bulkheads are solid vertical walls of concrete, metal, wooden poles, gabion baskets, interlocking brickwork, concrete blocks or similar such as dolosse that serve as retaining walls. Where deep water for boating is the main requirement, seawalls and bulkheads are most appropriate and gentle slopes are not required. Such protection is costly initially, but over time, cost-effectiveness and sustainability increase because a properly designed structure can withstand damage and require less upkeep. These structures may not be appropriate for sandy shores and may fail over time if improperly designed and built. This is because they tend to increase erosion due to reflective waves.

The following specific considerations apply to the design and use of seawalls and bulkheads:

* Sloped or curved walls can be used on open stretches of seawalls to reduce reflective energy;
* Weep holes prevent hydraulic pressure from building up behind the structure; the toe of the structure is to be adequately protected; overtopping is to be avoided; and the material should be strong enough to withstand wave action and scouring and other environmental exposure conditions such as vandalism, effects of UV light, effects of wildfires, etc;
* Seawall/bulkhead structures made of wood, metal sheeting, or interlocking bricks have a limited success rate due to South Africa's high-energy coastline;
* It is crucial to check that the piling is deep enough, and the anchoring is strong enough to keep the structure stable during storm events when extensive erosion may occur. These kinds of structures ought to be created by specialists who are appropriately qualified in exposed beach areas;
* The design of seawalls and bulkheads should:
  + Allow the most efficient wave energy dissipation;
  + Prevent scour, undermining, and collapse, and provide adequate toe protection;
  + Minimise negative impacts, particularly increased erosion, on the nearby coastline;
  + Prevent interference with longshore sediment movement (littoral drift) and accelerated erosion; make sure that the erosion recovery following a storm-event is not hampered.
  + Reduce negative impacts on beach amenities and where possible aesthetically enhance the environment.
  + Make sure the structures can withstand extreme events without catastrophic failure.
  + Tolerating more erosion at the structures' ends; make sure costs are recouped in the long run.
* In order to prevent erosion behind the erosion protection materials, protection should always be anchored into the bank on the flanks and extend far beyond either side of the problematic area (to prevent outflanking).

A picture containing outdoor, water

Description automatically generated A picture containing outdoor, row, wooden, lined

Description automatically generated

Figure : Examples of Seawalls and Bulkheads.

1. **Gabions and Retaining Walls**

Retaining walls are used for steep to nearly vertical slopes, wave/current attack that is quite severe due to wave action, natural river or stream flows, stormwater outlets, excavation that results in "critical" steep slopes, and requirements for jetties, walkways, roads, parking areas, and building sites. There are many different types of rocks and interlocking concrete block designs that may be used, and many of them can be covered with flora to fit in with the natural bank and enhance the aesthetic appeal. These are however just skin treatments, and the bank stability needs to be considered as a whole with particular attention to filtration and drainage.

The use of wire mesh baskets packed with stones is another technique that is widely used for strengthening banks. This technique is well suited for use in natural areas since they are more flexible than stiff interlocking blocks and more tolerant of plant formation, however, the wire of the basket has a limited life and is not suitable for super-critical flow exposure conditions where metal fatigue through vibration is induced.

The nature of the erosive forces present should guide the choice of the type of reinforcement. In saltwater conditions where rust speeds up degradation or where structural flex action is feasible, wire mesh baskets are particularly susceptible to scour and impact damage. Although wire mesh with a plastic coating is available, it is not advised for coastal areas owing to the plastic waste it generates when the coating breaks, depending on the operational life required. However, all structures are susceptible to erosion at their edges and are particularly vulnerable to rapid progressive collapse when erosive forces may take advantage of any damage or weak points. Hydraulic activity must also be taken into account during design, especially during floods.

A picture containing stone

Description automatically generated

Figure : Example of Gabion Erosion Control (Source: https://www.gabion1.co.uk/river-bank-protection/)

**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.

## WATER QUALITY

* + 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).

* + 1. Types of Water Quality Impacts
       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 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).

* + - 1. *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.
  + - 1. *Encroachment of sugarcane and banana plantation*

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.

* + - 1. *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).

* + - 1. *Deforestation*

Deforestation, clearing of land activities, overgrazing[[2]](#footnote-2) and other poor farming practices[[3]](#footnote-3), 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.

* + 1. 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 & 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 & industries

personnel, municipal as well as Provincial DWS & 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, loss of biodiversity in the estuary

**Step 5:** 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 & 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 & DFFE Offices)

and local NGOs community forums responsible to assist with identifying point sources of

pollution to provide guidance on available regulatory processes.

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

***Assessment Phase***

**Step1:** 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 & industrial facility.
* Collect monthly water quality samples from the resource *i.e.,* Estuary:
* 1 upstream of the WWTW & 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.

**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 & 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 & 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.

**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 & 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*).

**Monitoring parameters for industries:**

* Metal 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
* Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

## HABITAT

* + 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).

* + 1. Types of Habitat Impact
       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.

* + - 1. *Alien Invasive Species*

Imported 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.

* + - 1. *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).

* + - 1. *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.

* + - 1. *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).

* + 1. Rehabilitation Management Guidelines for Habitat

***Scenario 1:*** *Control and Management of Alien Invasive Species*

**PHASE 1: Diagnostic Phase**

**Step 1:** Identify the areas invaded by alien vegetation.

**Step 2:** At a desktop level, employ available tools such as Google Earth Pro or Sentinel or Google Earth

Engine, using high spatial resolution (<10 m), satellite images and remote sensing to identify

the areas affected.

**Step 3:** Using information obtained from Google Earth satellite images and Remote Sensing, describe

in detail areas identified that produce~~s~~ less runoff/inflow (or outflow). Consider including the following in the description:

* **Step 3.1:** Visual description of the areas affected;
* **Step 3.2:** Is the affected area at a catchment, sub-catchment, or quaternary scale?
* **Step 3.3:** Is the area affected at a localized non-localised scale?
* **Step 3.4:** Describe the extent of the infestation of the affected area;
* **Step 3.5:** Describe the conditions upstream or downstream of the affected area.

**Step 4:** Based on all the above information acquired, categorise the type of alien vegetation affecting your area of concern. Two types of alien vegetation are dealt with, namely:

* Riparian and
* Non-riparian or terrestrial.

Alien vegetation can further be categorised into one of three groups, namely:

* Short trees (1.5 – 2m);
* Tall trees (>2m);
* Tall shrubs (<2.5m); and
* Climbers, creepers, grasses, and reeds

**PHASE 2: Planning and Assessment**

The below is a summarised list of steps to be followed during the planning and assessment phase of alien vegetation clearing[[4]](#footnote-4):

* Identify priority invasive plant species for control;
* Identify sensitive indigenous vegetation that should be protected during invasive plant-clearing operations;
* Mark individual trees or stands of vegetation to guide workers on-site during invasive alien plant clearing and prevent accidental damage. Danger tape or paint markings can be used for marking;
* Identify areas that should be protected from mechanical disturbance;
* Identify the most appropriate clearing method or combination of methods, that take account of the species requiring control, the specific conditions of the site, and the circumstances of the landowner;
* Identify and obtain the necessary field and personal protective equipment for the selected clearing method(s), including herbicides;
* Identify training needs for clearing workers and supervisors (*e.g.,* herbicide application, use of chain saws as well as identifying the species to be removed);
* Identify approaches and areas for the disposal of cleared plant material; and
* 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 vegetation must be defined and be clear at 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[[5]](#footnote-5):

* To increase space for flood alleviation by clearing vegetation to increase the conveyance capacity or the natural flow of water;
* To rehabilitate a more natural flow regime by releasing trapped sediments and allowing erosion processes to restore natural river flows;
* To improve biodiversity by allowing the establishment/generation of natural indigenous riverine flora; 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:**

Alien vegetation clearing and control methods are divided into three main categories, namely physical (or mechanical) control, chemical control, and biocontrol. A combination of approaches may however be recommended in the case of some invasive plant species. These three methods have been prescribed by WRC[[6]](#footnote-6). Eradication and clearing should be implemented on an ongoing basis, targeting invasive alien plant infestations.

***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 invasive alien plant-clearing initiatives are constantly improving and are in accordance with seasonal changes.

The following monitoring suggestions are recommended by WRC[[7]](#footnote-7):

* A fixed-point photographic record should be maintained, showing the estuary in its affected reaches before, during, and at regular time periods after initial alien clearing has taken place.
* Historical Google Earth images should be used over time, to provide a spatial record of clearing extent and effects.
* Records should be kept of the time and costs required for each clearing intervention, and the approximate volume and life stage (*e.g.,* seedling or mature plant) of the bulk of material removed on each occasion. This information will allow quantification of the costs of invasive alien vegetation removal, show landscape changes resulting from invasive alien removal and potentially inform decisions that are required around changes in clearing frequency, area, or approach.
* Utilse tools such as Google Earth Pro, Sentinel or Google Earth Engine, using high spatial resolution (<10 m), satellite images and remote sensing.

The following are further considerations for the control and management of invasive plant species:

* Authorities such as DFFE to Implement an ad hoc programme to contain the further spread of alien invasive plant species; and
* On an annual basis update the maps of the types and extent of invasive alien vegetation in and around the estuary.

**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:*** *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 & 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 with community volunteers, citizen science officials and

Contractors.

**PHASE 5: Monitoring, Evaluation and Report**

**Monitoring**

* 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.

**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; and
* Before and after photos of rehabilitation including a significant landmark for comparison purposes, with a brief description including location, and date.

***Scenario 3: Estuary Mouth Breaching***

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 2**

**Emergency Breaching**

* 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.

**Box 1**

**Planned Breaching**

* 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.
* Triggers NEMA: EIA S30 Regulations.
* Conducted periodically i.e., every two years or less.

**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:** Understand 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 & DFFE

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).

**PHASE 2.2: Planning and Assessment (Emergency Breaching)**

***Note:***

*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

DFFE Office. 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 DFFE Office

to verify the information received. The inspection may consist of a team coordinated by the

Provincial DFFE Office which involves all the affected authorities.

**Step 3:** Once the status quo of the estuary has been confirmed by the Provincial DFFE Office, 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 3-2 below are applicable to Emergency Breaching.***

**Step 1:**

* Develop a Mouth Management Plan (MMP) in support of the Estuarine Management Plan (EMP) 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 is at the highest which increases the flushing rates of sediments;
* During periods of their high waves which promote an influx of sediments, depending on site specific climate.
* At high tide to maximise outflow.

**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.
* Consider public safety 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 & 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.

## BIOTA

* + 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 the local communities as it plays a key role in livelihood activities and sustenance.

* + 1. Types of Biota Impacts
       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).

* + - 1. *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).

* + - 1. *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.

* + - 1. *Sand mining*

Sand mining and dredging have significant physical, chemical, and biological impacts on estuaries. These impacts 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).

* + 1. Rehabilitation Management Guidelines for Biota

***Scenario 1: Re-establishment of biota migratory routes***

***Scenario 2: Control and Management measures to prevent overfishing.***

**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 & DFFE 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 & 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
* Microalgae (phytoplankton & 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 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.
* Some estuaries have been demarcated as conservation zones “activities within these 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”.
* For all characteristics of watercourses, 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.
* Regulation should take place at both an estuary level and catchment level. At an estuary level, regulation mechanisms should 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 & 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

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

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.

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

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

Description automatically generated

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. [↑](#footnote-ref-1)
2. Mass removal of crabs of all species in the system has resulted in the destruction of many pioneer trees. [↑](#footnote-ref-2)
3. Incorrect veld management, cultivation of steep areas and lack of contour furrows cause degradation and affect estuaries adversely. [↑](#footnote-ref-3)
4. Water Research Commission (WRC). 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa. [↑](#footnote-ref-4)
5. WRC. 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa. [↑](#footnote-ref-5)
6. WRC. 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa. [↑](#footnote-ref-6)
7. WRC. 2016. The Development of a Comprehensive Manual for River Rehabilitation in South Africa. [↑](#footnote-ref-7)