STRATEGIC ENVIRONMENTAL ASSESSMENT FOR EXPANSION OF ELECTRICITY GRID INFRASTRUCTURE IN SOUTH AFRICA

Biodiversity and Ecological Impacts (Aquatic Ecosystems and Species) - Estuaries

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR THE EXPANSION OF ELECTRICITY GRID INFRASTRUCTURE IN SOUTH AFRICA

Draft v3 Specialist Assessment Report for Stakeholder Review

ESTUARIES

Integrating Author/s	Lara van Niekerk [1]
Contributing Authors	Steven Weerts [1] Carla-Louise Ramjukadh[1] Susan Taljaard[1]

[1] Coastal Systems Research Group, Natural Resources and the Environment, CSIR, South Africa

CONTENTS

TABLES

FIGURES

ABBREVIATIONS AND ACRONYMS

CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
EFZ	Estuary Functional Zone
EGI	Electricity Grid Infrastructure
EIA	Environmental Impact Assessment
HDD	Horizontal Directional Drilling
IAP	Invasive Alien Plant
ICM	Integrated Coastal Management Act
KZN	KwaZulu-Natal
MAR	Mean Annual Runoff
MPA	Marine Protected Area
NEMA	National Environmental Management Act
NPAES	National Protected Areas Expansion Strategy
ROW	Right-of-way
SEA	Strategic Environmental Assessment
TDS	Total Dissolved Solids
ToPs	Threatened or Protected species
TSS	Total Suspended Solids
WUL	Water Use License

1 SUMMARY

This assessment aims, at a strategic level, to identify the potential impacts on estuaries of constructing and maintaining Electricity Grid Infrastructure (EGI) in two pre-identified routing corridors on the west and east coasts of South Africa.

Estuaries are highly productive and highly dynamic environments that require undisturbed “accommodation space” so that sedimentary processes can allow natural resetting of systems after floods and new channel configurations can establish. Estuaries support highly sensitive habitats and species of special concern. They play an important nursery function for estuarine and marine fish and crustaceans, which have economic value in subsistence, recreational and commercial fisheries in South Africa.

Key potential impacts of EGI development and operation to estuaries include:

- Alteration and destruction of estuarine habitat caused by infrastructure development, access roads and vegetation clearing;
- Altered estuarine physical and sediment dynamics caused by construction activities and infrastructure placement; e.g. infilling, altered channel migration, and increased mouth closure;
- Deterioration of water quality associated with the disturbance of sediment;
- Loss of connectivity and habitat fragmentation within estuaries and between estuaries, their upstream and freshwater catchments and downstream marine environments with associated ecological impacts.

These impacts are best avoided and mitigated at the design phase of EGI development. This can be achieved through the avoidance of placement of infrastructure, access roads and servitudes in Estuary Functional Zones (EFZs). These are areas of very high sensitivity. This report identifies and maps these areas. Additionally, coastal freshwater habitats in proximity to estuaries are identified as supporting habitat for estuaries. Impacts to these habitats have the potential to result in impacts to downstream estuaries, and they are consequently identified, within a 5 km buffer zone around EFZs, as areas of high sensitivity. Ideally these areas should also be avoided in the design phase and routing planned to avoid them. If unavoidable, mitigation measures must be undertaken to prevent damage to estuarine systems downstream.

2 INTRODUCTION

In January 2014 the Department of Environmental Affairs (DEA), mandated by Ministers and Members of the Executive Council (MinMec), commissioned the Council for Scientific and Industrial Research (CSIR) to undertake a Strategic Environmental Assessment (SEA) linked to SIP 10: Electricity Transmission and Distribution for all. This SEA (i.e. National DEA Electricity Grid Infrastructure (EGI) SEA) was aimed primarily at establishing routing corridors to enable the efficient and effective expansion of key strategic transmission infrastructure designed to satisfy national transmission requirements up to the 2040 planning horizon. The final EGI corridors, as an output of the 2016 EGI SEA, were gazetted in February 2018.

The current SEA commissioned by the DEA in 2017 considers the expansion of two of the corridors assessed in the 2016 SEA, specifically the Eastern and Western corridors (Figure 1).

Construction of EGI including transmission lines, interconnections, substations and road networks, have both positive and negative impacts at varying scales and at different stages of the power supply chain life cycle from extraction of fuels to construction and operational phases (Von Hippel and Williams, 2003). Evaluating potential impacts for the entire supply chain of EGI is important for optimising EGI interconnection opportunities and routing. Typically the environmental considerations of EGI development have received less emphasis than economic, technical and political issues, especially in developing regions, highlighting the importance of considering environmental impacts at an early stage (e.g. through conducting SEA’s) and identifying potential problems (e.g. routing of transmission lines through sensitive ecosystems, difficult terrain) (Von Hippel and Williams, 2003).

While a variety of environmental issues have been identified with the full life cycle of EGI, those related to impacts on estuarine ecosystems are the focus of this study.

3 SCOPE OF THIS STRATEGIC ISSUE UNDER EGI DEVELOPMENT

The primary objective of this study is to provide an assessment of estuarine ecosystems and associated biodiversity within the pre-identified expanded EGI corridors (Figure 1). The assessment will inform the SEA through identification of constraints (e.g. sensitive aquatic ecosystems, and critical areas for aquatic fauna and flora) and opportunities for the EGI development.

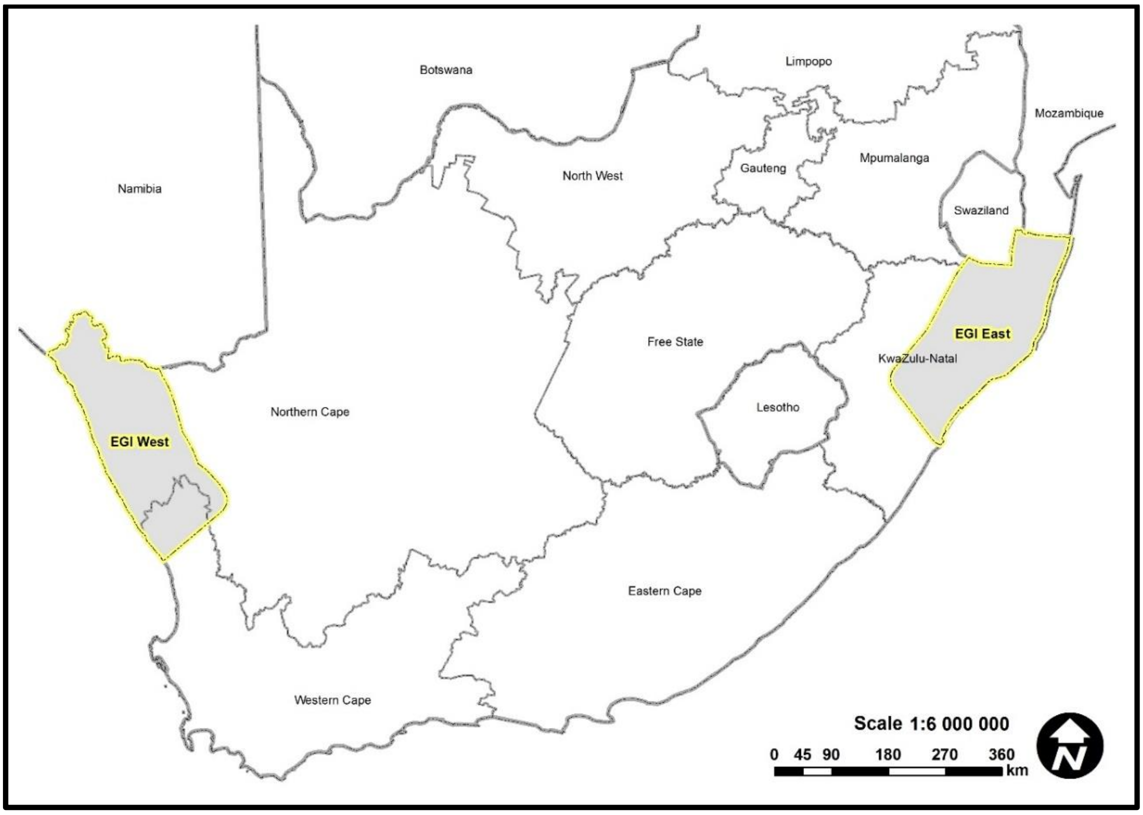

Figure 1: Overview of the proposed Expanded EGI corridors (East and West).

Potential impacts will result from the construction of the pylons, access and service roads, and maintenance of required servitudes in the Estuary Functional Zone (EFZ). During construction each pylon needed to support overhead powerlines can cause disturbance of an area of up to 1 ha. This area is needed in order to excavate and fill the foundations for each pylon, and for the assembly and raising of the pylon on-site. For each 100 km of 765 kV powerline this equates to disturbance and impact on an area of approximately 166 ha.

Vegetation clearing is needed for access during construction as well as for maintenance of a powerline. Initial access roads during construction are typically about 4 m wide, but this can reduce to simple two-tracks during the operation phase. Initial direct disturbance footprints of such roads are therefore approximately 40 ha per 100 km of powerline, but disturbance of wider areas and adjacent habitats can be expected over steep or uneven terrain due to the cut and fill that is usually required in order to make the site accessible for heavy vehicles. The powerline servitude needs to be maintained throughout the operational life of the powerline. Distance requirements for vegetation clearance in these servitudes depend on the nominal voltage of powerline (Table 1).

Table 1: Maximum servitude clearance distances (DEA, 2016).

Nominal Voltage	Maximum Vegetation Clearance
11 kV	4 m on either side of the centre line
22 kV	4 m on either side of the centre line
88 kV	5 m on either side of the centre line
132 kV	8 m on either side of the centre line
220 to 765 kV	From centre line to 10 m on either side of the outer conductors
533 kV DC	8 m either side of the centre line

Vegetation clearance involves the continuous trimming of vegetation where it is likely to encroach on the minimum vegetation clearance distance or where the vegetation will encroach on this distance before the next scheduled clearance. Minimum vegetation clearance distances are set by South African National Standards 10280 (safety regulations for overhead powerlines set in Table 2 below).

Table 2: Minimum vegetation clearance distances (DEA, 2016).

System nominal root mean square (r.m.s) voltage (kV)	Minimum Vertical Clearances (m)	Minimum Horizontal Clearances (m)
>1 up to and including 44	3	3
66	3.2	3
88	3.4	3
132	3.8	3
220	4.4	3
275	4.9	3
400	5.6	3.2
765	8.5	5.5

4 APPROACH AND METHODOLOGY

The approach adopted to assess risks associated with EGI on estuaries relied on available databases and information sources. Estuarine sensitivities were identified based on this information and expert judgment. Spatial analysis was used to develop sensitivity maps and these formed the basis for assessment of potential impacts and identification of mitigation requirements and monitoring plans.

4.1 Key links with other assessments

This specialist assessment focused exclusively on the direct impact of the EGI on estuarine abiotic processes and biotic responses within the EFZ. In South Africa the EFZ is generally defined by the +5 m topographical contour (as indicative of 5 m above mean sea level) and includes all estuarine open water area; estuarine habitats (sand and mudflats, rock and plant communities) and adjacent floodplain area whether developed or undeveloped. It therefore encompasses not only the estuary waterbody but also all the habitats that support physical and biological processes that characterise an estuarine system. However, given that estuaries are highly dependent on the condition of the rivers flowing into them and/or wetlands adjacent to estuaries, cross reference was also made to the Freshwater Specialist Assessment (De Winnaar & Ross-Gillespie, 2018) to ensure that estuarine function and ecological integrity was not impacted by upstream development and infrastructure. **In this report inflowing coastal rivers just above an estuary and/or coastal wetlands and seeps adjacent to estuaries were collectively referred to as supporting coastal freshwater ecosystems.** The connectivity and dependencies of estuaries on these linked coastal freshwater systems is well recognised by estuarine scientists.

This report does not focus on estuarine birds as these were assessed in a standalone Avifauna specialist study (refer to Froneman & van Rooyen (2018)).

4.2 Data sources

For this specialist study information on relevant estuaries within the proposed Expanded EGI corridors was obtained from available data sources. No additional field studies were undertaken. The data and information sources included:

- Van Niekerk L and Turpie JK (eds). 2012. National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. Available at: http://bgis.sanbi.org/nba/project.asp.
- Van Niekerk, L, Adams JB, Bate GC, Forbes N, Forbes A, Huizinga P, Lamberth SJ, MacKay F, Petersen C, Taljaard S, Weerts S, Whitfield AK and Wooldridge TH. 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, Taljaard S, Ramjukadh C-L, Adams JB, Lamberth SJ, Weerts SP, Petersen C, Audouin M, Maherry A. 2017. A multi-sector Resource Planning Platform for South Africa's estuaries. Water Research Commission Report No K5/2464. South Africa.
- Van Niekerk, L., Taljaard, S., Adams, J. B., Fundidi, D., Huizinga, P., Lamberth, S. J., Mallory, S., Snow, G. C., Turpie, J. K., Whitfield, A. K. and Wooldridge, T. H. 2015. Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa. WRC Report No K5/2187.
- Turpie, J.K., Wilson, G. and van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.
- The 2018 National Biodiversity Assessment is currently a work in progress, but where appropriate, interim findings from this study were considered here, e.g. updated results from the National Estuary Botanical Database, Nelson Mandela University.

Key environmental attributes that were identified, and data sourced for this study included the demarcation of the EFZ, ecological health condition, ecological importance and pressure status of estuaries (e.g. extent to which human disturbance already affected an estuary). Information on potential impacts, and possible mitigation measures, associated with the different construction methods/operations were sourced from international literature, as well as expert judgement.

4.3 Assumptions and limitations

The following assumptions and limitation apply to this estuarine assessment:

- This assessment considered only impacts associated with the construction of the pylons, access/service roads and the maintenance the servitudes. Each pylon will require an area of up to 1 ha, that will be disturbed during construction. While vegetation clearing is needed for access and construction purposes, the maximum width to be cleared within the servitude varies between 4 and 30 m.
- Due to the strategic nature of the assessment and the expansive area under investigation, a generic approach was applied, selecting a suite of key estuarine attributes considered appropriate to assess impact and associated risks during the construction and operational phases.
- This assessment provides a broad-scale sensitivity rating for estuaries across the various corridors. As all estuaries are sensitive to altered sediment and hydrodynamic processes more detailed spatially scaled sensitivity demarcation within the study areas will need to be refined during the detailed planning and construction phases.
- This assessment makes use of available secondary information, no fieldwork was undertaken and no additional raw data were collected and/or processed.
- All estuaries are important bird areas; however birds were not assessed in this estuarine study as they were dealt with in a separate Avifauna Assessment (refer to Froneman & Van der Merwe (2018) - Separate Annexure of the SEA Report for further details).

- While not considered here explicitly, estuarine connectivity with inflowing rivers is of crucial importance. It is assumed that the Freshwater Assessment (De Winnaar & Ross-Gillespie, 2018 - Separate Annexure of the SEA Report for further details) will deal with this aspect.

4.4 Relevant key legislation applicable to estuarine protection and use

Numerous pieces of legislation, policies and guidelines are applicable to the protection of estuarine aquatic ecosystems (Table 3). Critical aspects of these are the Recommended Ecological Categories as defined by the National Water Act (Act 36 of 1998, as amended) and set as desired states as part of the National Estuaries Biodiversity Plan (Turpie et al., 2012). In addition detailed Resource Quality Objectives for physical process, water quality, habitat and higher biota are set under the National Water Act (Act 36 of 1998, as amended). These provide the benchmark conditions which need to be maintained or restored in estuaries.

Table 3: Relevant key legislation applicable to the protection and use of estuaries.

Legislation	Specifications
National Environmental Management Act (Act 107 of 1998, as amended) and the associated Environmental Impact Assessment (EIA) Regulations of 2014 (as amended)	NEMA sets out the fundamental principles that apply to environmental decision making, some of which derive from international environmental law and others from the constitution. The National Environmental Management Act of 1998 (NEMA), outlines 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.” Of particular relevance to this assessment is Chapter 1(4r), which states that sensitive, vulnerable, highly dynamic or stressed ecosystems, such as coastal shores, estuaries, wetlands, and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure. GNR 324, Listing Notice 3, of the NEMA EIA Regulations (2014, as amended in April 2017) identifies the EFZ as a sensitive area.
National Water Act (Act 36, 1998)	Preliminary Reserve Determination and Classification. Set desired state (“management class”) and measurable targets for water flow (“Reserve”), and water quality, habitat and biota in estuaries (“Resource Quality Objectives”) (these are set specifically for each estuary).
National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) and National Protected Areas Expansion Strategy (NPAES)	Sets biodiversity targets for South Africa that need to be translated into site-specific targets for study area based on detailed quantitative assessments. These targets are articulated in the National Protected Areas Expansion Strategy (NPAES) (updated draft available from DEA). South Africa’s protected area network currently falls far short of sustaining biodiversity and ecological processes. The goal of the NPAES is to achieve cost-effective protected area expansion for ecological sustainability and increased resilience to climate change. It sets targets for protected area expansion, provides maps of the most important areas for protected area expansion, and makes recommendations on mechanisms for protected area expansion – this is relevant to estuaries included in the strategy. The National Estuarine Biodiversity Plan (Turpie et al., 2012) determined the core set of estuaries in need of formal protection to achieve biodiversity targets
Marine Living Resources Act (Act 18 of 1998)	Marine Living Resources Act. The management and control of exploited living resources in estuaries fall primarily under the Marine Living Resources Act (MLRA) (No. 18 of 1998). The primary purpose of the act is to protect marine living resources (including those of estuaries) through establishing sustainable limits for the exploitation of resources; declaring fisheries management areas for the management of species; approving plans for their conservation, management and development; prohibit and control destructive fishing methods and the declaration of Marine Protected Areas (MPAs) (a function currently delegated to the DEA). The MLRA overrides all other conflicting legislation relating to marine living resources.
National Environmental	Recreational waters. Water quality guidelines for the coastal environment: Recreational use (DEA, 2012). Set water quality targets for recreational waters to protect bathers

Legislation	Specifications
Management: Integrated Coastal Management Act (Act 24 of 2008, as amended) (ICM Act)	Protection of aquatic ecosystems. Water quality guidelines for protection of natural coastal environment (DWAF 1995, in process of being reviewed by DEA). This will set targets for use of specific chemicals in marine waters and sediments to protect ecosystems
National Estuarine Management Protocol	National Estuary Management Protocol sets the standards for Estuarine Management in South Africa (Regulation No. 341 of 2013 promulgated in support of section 33 of the ICM Act)
National Environmental Management: Protected Areas Act (No. 57 of 2003	To provide, within the framework of national legislation, including the National Environmental Management Act, for the declaration and management of protected areas; to provide for co-operative governance in the declaration and management of protected areas; to effect a national system of protected areas in South Africa as part of a strategy to manage and conserve its biodiversity; to provide for a representative network of protected areas on state land, private land and communal land; to promote sustainable utilisation of protected areas for the benefit of people, in a manner that would preserve the ecological character of such areas; and to promote participation of local communities in the management of protected areas, where appropriate. This is relevant to estuaries in protected areas.
National Ports Act (Act 12 of 2005)	Legal requirements as stipulated in terms of the National Ports Act (No. 12 of 2005) must be complied with in commercial ports – relevant to estuaries housing ports.
Ramsar Convention (The Convention of Wetlands of International Importance (1971 and amendments)	Protection and conservation of wetlands, particularly those of importance to waterfowl and waterfowl habitat. South Africa is a signatory to the Ramsar Convention and is thus obliged to promote the conservation of listed wetlands and the 'wise management' of all others.
IUCN Red List of threatened species	Provides the most comprehensive inventory of the global conservation status of plant and animal species. Uses a set of criteria to evaluate the extinction risk of thousands of species and subspecies. The criteria used are relevant to all species and all regions of the world.
The Convention on Biological Diversity (1992)	Focused on the conservation of biological diversity, the sustainable use of its components, the fair and equitable sharing of the benefits from the use of genetic resources
Conservation of Agricultural Resources Act (CARA, Act 43 of 1983)	Key aspects include legislation that allows for: Section 6: Prescription of control measures relating to the utilisation and protection of vleis, marshes, water sponges and water courses. These measures are described in regulations promulgated in terms of the Act, as follows; Regulation 7(1): Subject to the Water Act of 1956 (since amended to the Water Act 36 of 1998), no land user shall utilise the vegetation of a vlei, marsh or water sponge or within the flood area of a water course or within 10 m horizontally outside such flood area in a manner that causes or may cause the deterioration or damage to the natural agricultural resources. Regulation 7(3) and (4): Unless written permission is obtained, no land user may drain or cultivate any vlei, marsh or water sponge or cultivate any land within the flood area or 10 m outside this area (unless already under cultivation).

4.5 Permit requirements

Where any construction or operation will occur within the Very High or High sensitive areas, the following permits may be required:

- Where necessary, a water use licence (WUL) process will be required to authorise certain activities as per Section 21 of the National Water Act (Act no. 36 of 1998) based on the Department of Water and Sanitation (DWS) assessment requirements for all wetlands that occur within 500 metres of the EGI development.
- Permits likely to be required for any activities that require the discharge of an effluent into the EFZ under the ICM Act. This will set targets for use of specific chemicals in marine waters and sediments to protect ecosystems.
- Permits likely to be required for any activities that may affect listed Endangered and/or Vulnerable species, Threatened or Protected species (ToPs), and/or regionally protected fauna and flora.

5 KEY ATTRIBUTES OF THE PROPOSED EXPANDED EGI CORRIDORS

5.1 Background

An estuary is defined 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, back-flooding or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area, and when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline” (Van Niekerk and Turpie, 2012:29).

South African estuaries differ considerably in terms of their physicochemical and biotic characteristics (Colloty et al., 2002; Vorwerk et al., 2008) (Figure 2). Proactive planning and effective management of estuaries requires an understanding of changing estuarine patterns, processes and responses to global change pressures (i.e. those that arise directly from anthropogenic activities and climate change). As human population pressures escalate, the need for strategic management becomes increasingly evident (Boehm et al., 2017; Borja et al., 2017). Reactively protecting these ecosystems on an estuary-by-estuary basis is costly, time consuming and not feasible. Proactive planning requires a strategic assessment of change at a range of scales to ensure optimum resource use.

Estuaries and adjacent ecosystems form an interrelated network of life-support systems that includes neighbouring terrestrial and marine habitats. Many estuarine species are dependent on different habitats in order to complete their life cycles (Whitfield, 1998). Estuarine ecosystems are, therefore, not independent and isolated from other ecosystems. Rather, estuaries form part of regional, national and global ecosystems, directly through connections via water flows (e.g. the transport of nutrients and detritus) and indirectly via the movement of estuarine fauna (e.g. Gillanders, 2005; Ray, 2005). Linkages between individual estuaries and other ecosystems span scales ranging from a few hundred metres to thousands of kilometres. Therefore, impacts to a specific estuarine ecosystem may affect ecosystems seemingly remote from that estuary, and have ramifications for ecosystem goods and services that people rely on from areas distant over large spatial scales. The closure of Lake St Lucia for example, resulted in declines and eventual closure of a prawn fishery on the Thukela Banks over 100 km to the south.

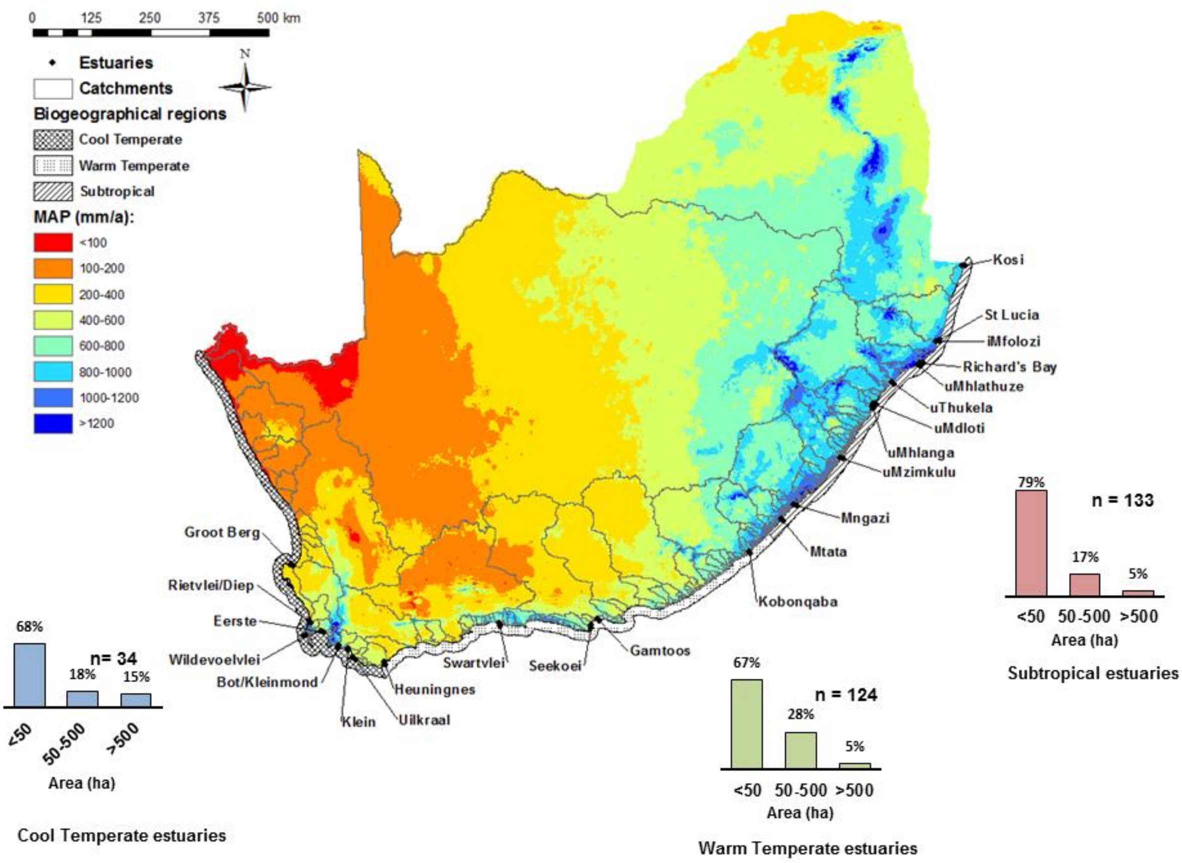

Figure 2: Map showing the three biogeographical regions, relative catchment size, mean annual precipitation (MAP) (in mm/a) and estuary size distribution (in ha) for South Africa (Van Niekerk et al. 2013).

South Africa has nearly 300 relatively small estuaries, the majority (>70%) of which are <50 ha in size. These estuaries fall into three biogeographical regions which characterise the South African coast; namely the Cool Temperate west coast, the Warm Temperate southern and south-east coast, and the Subtropical east coast (Emanuel et al., 1992; Harrison, 2002; Turpie et al., 2002) (Figure 2). In addition to obvious sea temperature differences, rainfall patterns in these regions vary significantly (Davies and Day, 1998; Lynch, 2004; Schulze and Lynch, 2007; Schulze and Maharaj, 2007). Annual runoff of South African rivers is highly variable and unpredictable in comparison with larger Northern Hemisphere systems, fluctuating between floods and extremely low (to zero) flows (Poff and Ward, 1989; Dettinger and Diaz, 2000; Jones et al., 2014) (Figure 2). Estuary catchment sizes range from very small (<1 km^2) to very large (>10 000 km^2), with those in the Cool Temperate region tending to be larger than those in the Warm Temperate and Subtropical regions (Jezewski et al., 1984; Reddering and Rust, 1990).

Strong wave action and high sediment availability results in more than 90% of South African estuaries having restricted inlets (or mouths). More than 75% of estuaries close for varying periods of time due to sand bar formation across the mouth (Whitfield, 1992; Cooper, 2001; Taljaard et al., 2009; Whitfield and Elliott, 2011). Most estuaries are highly dynamic with an average water depth of 1-5 m. The tidal range around the whole coast is microtidal (<2 m) but high wave energy, makes it a wave-dominated coast (Cooper, 2001).

Estuaries exhibit a high spatial heterogeneity, with each system characterised by its own unique geomorphology and physicochemical processes. Individual systems can be highly variable temporally and the full spatial extent (i.e. tidal limit or back-flooding mark) of many systems remains unknown. This makes it difficult to delineate the dynamic spatial area where estuarine processes occur within each system, the so-called EFZ. In South Africa the EFZ is generally defined by the +5 m topographical contour (as indicative of 5 m above mean sea level) and includes all the estuarine open water area; estuarine habitats (sand and mudflats, rock and plant communities) and adjacent floodplain area whether developed or undeveloped. It therefore encompasses not only the estuary water-body but also all the habitats that support physical and biological processes that characterise an estuarine system.

For the purposes of this study, and as is typical in estuarine assessment in a South African context, all permanent coastal water bodies (i.e. not ephemeral water bodies) sporadically or permanently linked to the sea were regarded as estuarine systems. Using existing estuarine vegetation and fish data sets, published and unpublished literature, as well as anecdotal information, all systems were evaluated (in terms of health and functionality) by an expert panel (Van Niekerk and Turpie, 2012).

5.2 Estuarine sedimentary processes of importance

Estuaries are complex water bodies and differ considerably from fluvial systems. In estuaries the flow reverses due to tidal inflows being stronger than freshwater outflows. Water quality charges in an estuary are also complex due to both upstream and downstream sources.

Estuaries also have two sources of sediment; that from the river (delivered primarily during floods) and a supply of marine sediment from the ocean delivered by littoral drift and transported by tidal currents into the estuary. Within estuaries, tidal sediment transport is a result of the interaction of both currents and waves. This is especially dynamic in the mouth region of estuaries and further up the system wave action is rapidly reduced. Wave-current interaction considerably complicates sediment transport predictions. During neap tides, maximum water velocities in the estuary are low with little sediment transport, while both velocities and transport increase towards spring tides. Significantly, in some estuaries over this neap to spring period, there is a net upstream sediment transport, e.g. in the Goukou (Beck et al., 2004). If there is a long-term net ingress of marine sediment (which is often the case), then the only plausible way for a long-term equilibrium to be established is for occasional large river floods to flush out this accumulated sediment.

Floods therefore, are the most important natural processes which erode and transport sediments out of estuaries. Large volumes of sediments can be removed in a very short time during major floods with a return period of 1 in 50 years and more. Smaller floods with return periods of 1-2 years can sometimes also have a significant influence. Floods of various scales therefore play a major role in the equilibrium between sedimentation and erosion in estuaries (Beck et al., 2004).

This is an important consideration because sedimentation of South African estuaries has created several environmental and social problems. Sediment transport imbalances are caused by changes in the river inflow (especially floods), increased catchment sediment yields, and hard structures in estuaries that change flow velocities. Reduced sediment transport capacities within estuaries and decreased flushing efficiencies cause increased sedimentation and in the long-term this may lead to the complete closure of estuaries.

Estuary channel formation is also highly dynamic on decadal time scales. During low flow periods shallow tidal flows can meander several sand banks in the EFZ. During floods rapid changes in estuarine morphology occur over very short time frames. The system can be completely reset and channels can be scoured by meters, only to be filled in over time again by catchment and marine sediment. These types of changes can be illustrated using the Thukela Estuary as an example (Figure 3). Scouring during flooding can be significant with numerical modelling studies indicating possible scour depths on larger river systems of between 20 and 30 m (Basson et al., 2017).

These dynamic processes are an integral part of the natural functioning of South African estuaries and need to be accounted for in proposals to develop within EFZs. In the context of the present work, proposed crossings of estuaries by powerlines and associated infrastructure need to be assessed with the knowledge that estuary channel formation can occur anywhere in the EFZ and that scouring during floods (with a return period of 1:10 years) is significantly deeper than the observed estuary bed levels under typical (non-flood) conditions.

Figure 3: Thukela Estuary under low flow conditions with a stable channel meandering between sand banks (left) and the Thukela Estuary under resetting flood conditions with high volumes of sediment being eroded from the system (right).

5.3 Estuarine habitat of importance

Estuaries are generally made up of a high diversity of habitat types, which include open water areas, un-vegetated sand-, mudflats and rock areas, and vegetated areas (plant communities). Plant community types can be subdivided into submerged macrophytes, salt marsh, mangroves, reeds and sedges (Adams et al., 2018).

- **Open water area:** Un-vegetated basin and channel waters which are measured as the water surface area. The primary producers are the phytoplankton consisting of flagellates, dinoflagellates, diatoms and blue-green algae which occur in a wide range of salinity ranging from freshwater to marine conditions.
- **Sand / mudflats / rock:** Soft (mobile) substrates (sand and mud) and hard (non-mobile) substrates (rocks) and shorelines areas. Habitat mapping from aerial photographs cannot distinguish between sand and mud habitats and therefore in databases used for the purposes of this study are presented as a single area. The dominant primary producers of these habitats are the benthic microalgae.
- **Macroalgae:** Macroalgae may be intertidal (intermittently exposed) or subtidal (submerged at all times), and attached or free floating. Filamentous macroalgae often form algal mats and increase in response to nutrient enrichment or calm sheltered conditions when the mouth of an estuary is closed. Typical genera include *Enteromorpha* and *Cladophora*. Many marine species can get washed into an estuary and providing that the salinity is high enough, can proliferate. These include *Codium*, *Caulerpa*, *Gracilaria* and *Polysiphonia*.
- **Submerged macrophytes:** Submerged macrophytes are plants that are rooted in the substrate with their leaves and stems completely submersed (e.g. *Stukenia pectinata* and *Ruppia cirrhosa*) or exposed on each low tide (e.g. the seagrass *Zostera capensis*). *Zostera capensis* occupies the intertidal zone of most permanently open Cape estuaries whereas *Ruppia cirrhosa* is common in temporarily open/closed estuaries. *Stukenia pectinata* occurs in closed systems or in the upper reaches of open estuaries where the salinity is less than 10 ppt.

- **Salt marsh:** Salt marsh plants show distinct zonation patterns along tidal inundation and salinity gradients. Zonation is well developed in estuaries with a large tidal range e.g. Berg, Knysna and Swartkops estuaries. Common genera are *Sarcocornia*, *Salicornia*, *Triglochin*, *Limonium* and *Juncus*. Halophytic grasses such as *Sporobolus virginicus* and *Paspalum* spp. are also present. Intertidal salt marsh occurs below mean high water spring and supratidal salt marsh above this. *Sarcocornia pillansii* is common in the supratidal zone and large stands can occur in estuaries such as the Olifants.
- **Reeds and sedges:** Reeds, sedges and rushes are important in the freshwater and brackish zones of estuaries. Because they are often associated with freshwater input they can be used to identify freshwater seepage sites along estuaries. The dominant species are the common reed *Phragmites australis*, *Schoenoplectus scirpoides* and *Bolboschoenus maritimus* (sea club-rush).
- **Mangroves:** Mangroves are trees that establish in the intertidal zone in permanently open estuaries along the east coast of South Africa, north of East London where water temperature is usually above 20°C. The white mangrove *Avicennia marina* is the most widespread, followed by *Bruguiera gymnorrhiza* and then *Rhizophora mucronata*. *Lumnitzera racemosa*, *Ceriops tagal* and *Xylocarpus granatum* only occur in the Kosi Estuary.
- **Swamp forest:** Swamp forests, unlike mangroves are freshwater habitats associated with estuaries in KwaZulu-Natal. Common species include *Syzygium cordatum*, *Barringtonia racemosa* and *Ficus trichopoda*. It is often difficult to distinguish this habitat from coastal forest in aerial photographs.

5.4 Species of special concern

5.4.1 Plants

Plant species listed in the estuarine botanical database were cross referenced against the South African Red List (http://redlist.sanbi.org) to produce a list of estuarine plant species of conservation significance (Table 4). Categorisation was made on the basis of the IUCN Red List categories and Criteria version 3.1 (IUCN, 2012).

Some macrophyte species (mangroves and eelgrass) have only recently been reassessed in the Red Data List and freshwater mangrove *Barringtonia racemosa* was only added in 2016. If categorised as a species of special concern the data provided for each assessment was tabulated. Further research on these species was also captured. If categorised as 'Least Concern' details pertaining to the state of the population was not captured unless noted in a particular study. While the spatial location of all species of special concern is not known for South Africa's estuaries, what becomes clear from Table 4 is that all estuaries support estuarine habitat of concern and should be deemed as highly sensitive.

Interference (harvesting, clearing, removal) of mangrove and swamp forest is regulated under the National Forests Act No. 84 of 1998 (RSA 1998) and destruction or harvesting of indigenous trees requires a licence. All mangrove trees and swamp forests are protected under this act. The taxonomy of some salt marsh species is under currently under review; which makes it difficult to determine their population sizes, report on their threat status or set targets for protection. However according to the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008, as amended), all coastal wetlands, which include salt marshes and mangroves, form part of the coastal protection zone. The purpose of establishing this zone is to restrict and regulate activities in order to achieve the aims as set out in the Act. Other laws pertaining to species in these areas: National Environmental Management Act 1998, Marine and Living Resources Act 1998, The National Environmental Management: Biodiversity Act 2004, and National Forestry Act 1998.

5.4.2 Fish

The IUCN Red List of Threatened Species includes many fish that occur in estuaries in South Africa (IUCN, 2018). Table 5 lists those known to occur commonly in South African systems (i.e. excluding species that only occur sporadically in South African estuaries, species at the margins of their biogeographical ranges and which are more common in estuaries further north) (Whitfield, 1998, pers. obs). By far the majority of these fish are categorised as species of Least Concern. The IUCN Red List categories and criteria (IUCN 2012) are designed to be applied to the entire (global) range of a species and fish listed in the Least Concern category here range from those which are actually quite common and (still) abundant in South African systems (e.g. *Rhabdosargus sarba*) to species which are uncommon, rare and in a national sense could be considered as endangered (e.g. *Microphis brachyurus*). Included in Table 5 as a species of special concern in the process of being IUCN red listed, is *Argyrosomus japonicus* (Dusky Kob), a species with South African populations at critically low levels (Griffiths, 1997; Mirimin et al., 2016). Predominant threats faced by the listed species include development (urban, commercial, recreational and industrial), agriculture, mining, resource use (fishing and harvesting of aquatic resources), modification of natural systems (flow modification and other), pollution and climate change (IUCN, 2018). All estuaries in the corridors function as habitats and nurseries for Critically Endangered or Endangered fish species of high recreational or conservation importance.

5.4.3 Mammals, Reptiles and Amphibians

Mammals, reptiles and amphibians are not traditionally assessed as part of estuarine studies. Given the overlap in sensitivity buffers between the Estuary Specialist Assessment (i.e. this report) and the Freshwater Specialist Assessment (De Winnaar and Ross-Gillespie, 2018), the detailed features maps and four-tier sensitivity maps developed for mammals, reptiles and amphibians in the later study can be regarded as applicable for estuaries.

Table 4: Macrophyte updates to the Red List of South Africa (Adams et al. 2018) (LC = Least Concern, EN = Endangered, NA = Not assessed, IUCN 2012).

Species	Common name	Category	Distribution	Habitat	Threats	Reference
Avicennia marina	White mangrove	LC	Widespread across the east coast from Chalumna to Kosi Bay and occurs in a large number of estuaries	Common and often dominant constituent of mangrove swamps (usually the inland fringes of mangrove associations) and is also a pioneer of new mud banks.	Continuous habitat loss due to urban, industrial development and infrastructure development	Adams et al., 2016a
Bruguiera gymnorrhiza	Black mangrove	LC	Widespread along the east coast of South Africa from the Nahoon to Kosi Bay.	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets, mainly towards the seaward side of mangrove formation.	Coastal development, over harvesting	Adams et al., 2016b
Ceriops tagal	Indian mangrove	LC	Very limited distribution on the coast of South Africa	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets. The most inland of the rhizophoraceous mangroves.	No major threats	Adams et al., 2016c
Lumnitzera racemosa	Tonga mangrove	EN	Kosi Bay	Mangrove swamps, usually on the landward side.	Harvesting for firewood	Rajkaran et al., 2017
Rhizophora mucronata	Red mangrove	LC	Nahoon to Kosi Bay	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets, mainly in the seaward side of the mangrove formation.	Coastal development	Rajkaran et al., 2016
Xylocarpus granatum	Mangrove mahogany	NA	Single individual in Kosi Bay	Tidal mud of mangrove swamps, especially towards their upper limits.	Harvesting	SANBI, 2017
Barringtonia racemosa	Powder puff tree	LC	Coastal areas between the Eastern Cape and KwaZulu-Natal	Streamsides, freshwater swamps and less saline areas of coastal mangrove swamps.	Sensitive to salinity changes and tidal intrusion caused by infrastructure development and water abstraction as well as sea level rise associated to climate change. Fungal disease and chemical pollution is also problematic.	Von Staden, 2016
Zostera capensis	Eelgrass	LC	Olifants River Mouth on the Cape West Coast to Kosi Bay, northern KwaZulu-Natal.	Intertidal zone of permanently open estuaries. It occasionally persists in temporarily closed estuaries when conditions are saline.	Development, freshwater abstraction, catchment disturbance, eutrophication resulting in shading and outcompeting.	Adams & van der Colff, 2016

Table 5: Threatened South African estuarine fish species (CR = Critically Endangered, EN = Endangered, LC = Least Concern, DD = Data Deficient, IUCN 2012, * = Lower Risk/near threatened IUCN 1994 Categories & Criteria version 2.3, ** = Not IUCN listed, but critically low stocks in SA).

Scientific name	Common name	Red List status	Distribution (proposed Expanded EGI Corridor)
Syngnathus watermeyeri	Estuarine Pipefish	CR	East
Lithognathus lithognathus	White Steenbras	EN	West, East
Argyrosomus japonicus	Dusky Kob	EN**	East
Anguilla bicolor	Shortfin Eel	NT	East
Oreochromis mossambicus	Mozambique Tilapia	NT	West, East
Epinephelus malabaricus	Malabar Rockcod	NT	East
Pomatomus saltatrix	Elf	VU	West, East
Acanthopagrus vagus	Estuarine Bream	VU	East
Rhabdosargus globiceps	White Stumpnose	VU	West, East
Taenioides jacksoni	Bearded Goby	*LR/nt	East
Albula oligolepis	Smallscale Bonefish	DD	East
Hypseleotris cyprinoides	Golden Sleeper	DD	East
Oligolepis acutipennis	Sharptail Goby	DD	East
Megalops cyprinoides	Indo-Pacific Tarpon	DD	East
Liza dumerili	Groovy Mullet	DD	East
Microphis fluviatilis	Freshwater Pipefish	DD	East
Ambassis natalensis	Slender Glassy	LC	East
Anguilla marmorata	Marbled Eel	LC	East
Anguilla mossambica	African Longfin Eel	LC	East
Ablennes hians	Flat Needlefish	LC	East
Caranx ignobilis	Giant Trevally	LC	East
Caranx papuensis	Brassy Trevally	LC	East
Lichia amia	Garrick	LC	West, East
Scomberoides commersonnianus	Talang Queenfish	LC	East
Scomberoides lysan	Doublespotted Queenfish	LC	East
Chanos chanos	Milkfish	LC	East
Eleotris fusca	Dusky Sleeper	LC	East
Eleotris mauritiana	Widehead Sleeper	LC	East
Eleotris melanosoma	Broadhead Sleeper	LC	East
Elops machnata	Springer	LC	East
Stolephorus holodon	Natal Anchovy	LC	East
Stolephorus indicus	Indian Anchovy	LC	East
Thryssa setirostris	Longjaw Thryssa	LC	East
Gerres filamentosus	Threadfin Pursemouth	LC	East
Gerres longirostris	Smallscale Pursemouth	LC	East
Gerres oyena	Longtail Pursemouth	LC	East
Awaous aeneofuscus	Freshwater Goby	LC	East
Croilia mossambica	Burrowing Goby	LC	East
Favonigobius reichei	Tropical Sand Goby	LC	East
Glossogobius callidus	River Goby	LC	East
Glossogobius giuris	Tank Goby	LC	East
Oxyurichthys keiensis	Kei Goby	LC	East
Paratrypauchen microcephalus	Blind Goby	LC	East
Psammogobius biocellatus	Sleepy Goby	LC	East
Redigobius bikolanus	Bigmouth Goby	LC	East
Redigobius dewaali	Checked Goby	LC	East
Stenogobius kenyae	Kenyan River Goby	LC	East

Scientific name	Common name	Red List status	Distribution (proposed Expanded EGI Corridor)
Yongeichthys nebulosus	Shadow Goby	LC	East
Lobotes surinamensis	Tripletail	LC	East
Lutjanus argentimaculatus	River Snapper	LC	East
Monodactylus argenteus	Natal Moony	LC	East
Monodactylus falciformis	Cape Moony	LC	East
Chelon melinopterus	Giantscale Mullet	LC	East
Crenimugil crenilabis	Fringerlip Mullet	LC	East
Mugil cephalus	Flathead Mullet	LC	East
Myxus capensis	Freshwater Mullet	LC	East
Planiliza alata	Diamondscale Mullet	LC	East
Planiliza macrolepis	Largescale Mullet	LC	East
Valamugil buchanani	Bluetail Mullet	LC	East
Valamugil robustus	Robust Mullet	LC	East
Ophisurus serpens	Sand Snake-eel	LC	East
Sillago sihama	Silver Sillago	LC	East
Acanthopagrus berda	Black Bream	LC	East
Crenidens crenidens	Karenteen Seabream	LC	East
Diplodus capensis	Blacktail	LC	West, East
Rhabdosargus holubi	Cape Stumpnose	LC	West, East
Rhabdosargus sarba	Natal Stumpnose	LC	East
Rhabdosargus thorpei	Bigeye Stumpnose	LC	East
Hippichthys cyanospilos	Bluespeckled Pipefish	LC	East
Hippichthys heptagonus	Reticulated Pipefish	LC	East
Hippichthys spicifer	Bellybarred Pipefish	LC	East
Microphis brachyurus	Opossum Pipefish	LC	East
Amblyrhynchotes honckenii	Evileye Pufferfish	LC	East
Arothron immaculatus	Immaculate Pufferfish	LC	East
Chelonodon laticeps	Bluespotted Pufferfish	LC	East

5.5 Consideration of estuary condition and sensitivity to current and future impacts

Assessing the status and/or future impacts on estuarine ecosystems involves assessing anthropogenic pressures against a background of inherent variability and natural change (Gray and Elliott, 2009; Elliott, 2011). It requires an understanding of estuarine health, connectivity and coastal interaction on a regional scale, as well as consideration of resilience to natural and anthropogenic resetting events and recruitment processes. This requires an understanding of how pressures (including cumulative pressures) result in changes in the natural systems and the implications for resource use (Korpinen and Andersen, 2016).

Estuaries are by nature resilient systems, because their fauna and flora are adapted to living in ever changing conditions. However, development in and around estuaries can cause changes to the structural habitat of an estuary, resulting in local extinctions. Infrastructure development also prevents lateral movement of habitats such as salt marsh. Impacts caused by construction of hard structures in estuary floodplains are not easily reversible and can be mitigated at best. Even recovery from temporary disturbances can take decades to restore to natural conditions. For example, the crossing of the Nhlabane Estuary in KwaZulu-Natal by a mining dredger in 1993 involved construction of temporary sand berms across the estuary mid-way along the system (Jerling, 2005). Due to continuous freshwater inputs from groundwater seepage, the then closed estuary soon became fresh leading to change in the zooplankton community, including the appearance of freshwater taxa such as rotifers, *Cyclopoids* (*Mesocyclops* sp. *and Thermocyclops* sp.), freshwater *Cladocerans* and insect larvae. Estuarine species became less abundant or were lost from the system completely, including the copepod *Acartia natalensis*, the mysid *Mesopodopsis* *africana*, and larval stages of polychaetes, decapods and fish. Not all taxa recovered after the mouth reopened (Jerling, 2005). In addition, fine sediment intruded into the estuary from the berm wall area and caused a rapid decline in benthic densities and number of taxa. Recovery of the affected area was slow and characterized by initial proliferation of opportunistic colonizers (Vivier and Cyrus, 1999).

Coastal development along most of South Africa's coast has resulted in a continuous escalation of pressures on estuaries. While many of these estuaries are small, they act as a network, and incremental losses collectively add up to be significant and impact a large area of an estuarine system. Ribbon development along the coast is particularly problematic in this regard, well demonstrated by the KwaZulu-Natal south coast where urbanisation and development has led to significant habitat modification in all estuaries. Road and rail infrastructure negatively affects nearly every estuary along this coast. Bridge foundations and abutments, and road and rail berms have led to infilling of systems and consequential habitat destruction. They have resulted in changes to the natural flow and scouring dynamics in estuaries. Development across floodplains and channel stabilisation has affected natural flow patterns resulting in localised scour and deposition. Sugar cane farming along the banks of a large number of systems has led to infilling of floodplains, general constriction of tidal flows and large-scale loss of marginal vegetation and natural vegetation buffers around the estuaries. This has caused ever increasing "gaps" between functional estuaries along the coastline and large numbers of poor condition systems adjacent to each other is a concern. Little research has been done on the direct consequences of declining estuary condition and this type of loss of connectivity in an estuarine network, especially with respect to the ability of individual and collective systems to absorb and recover from events. It is nevertheless increasingly recognised that in the case of estuaries, the health of neighbouring systems matters as it ensures overall resilience of a regional network of estuaries. Future telemetry and genetic studies will assist in understanding this aspect of estuarine connectivity better, and inform the development of guidelines for regional resource allocation.

In particular it is important to preserve coastal connectivity to ensure recruitment from healthy neighbouring systems in the event of natural and anthropogenic disasters. In order to accommodate flood events, sea storms and climate change, estuary floodplains and supporting habitats must be protected from infrastructure development to ensure resilience to extreme flooding (and allow for lateral channel movement), negate the need for premature artificial breaching of systems, and prevent coastal squeeze of estuarine habitats. Linear coastal infrastructure development (ribbon development) such as that potentially associated with the EGI development under consideration here holds regional scale risks for estuarine ecosystems.

Artificial breaching especially has emerged as a management dilemma in recent years, where conflict arises because of emergency breaching applications (or illegal breachings) to protect poorly planned development which are located within the EFZ and to close to estuarine back-flood levels. Back-flooding in estuaries is a predictable, natural (and necessary) system process. Premature artificial breaching should therefore not been seen as a solution for poorly planned infrastructure development as it has significant consequences for estuarine ecology. It results in shifts in seasonal connectivity patterns with the marine environment, reduced access to important biological (nursery and feeding) habitats, reduced productivity, increased susceptibility to alien species invasions and a decline in nursery function. Artificial breaching is a listed activity as it requires the removal of more than 5 m^3 of sand from a breach and therefore requires provincial and in some cases national government approval. Authorities are increasingly taking a strong stance against this practise as demonstrated by in recent court judgements in the case of the Klein Estuary and St Lucia/Mfolozi.

5.6 Description of estuaries in corridors/feature maps

Available information was used to describe important environmental attributes of estuaries within each of the applicable corridors. This includes a brief overview of present health conditions, biodiversity importance and important uses of estuaries in the expanded EGI corridors under consideration here. Estuarine resources in these areas are described below and important ecological and socio-economic attributes of estuaries within each corridor are summarised in Appendix A, Table A.1.

5.6.1 Expanded Western EGI Corridor

In total seven estuaries fall within the Expanded Western EGI corridor. These have a combined estuarine habitat area of 5 300 ha (Figure 4). They include the Orange, Spoeg, Groen, Sout, Buffels, Swartlintjies and Olifants Estuaries. The Spoeg, Groen, Buffels and Swartlintjies are all small systems that extend less than 5 km into the proposed EGI corridor (Fielding, 2017). The remaining systems are longer and extend significant distances into the proposed EGI corridor (Olifants <20 km, Orange <10 km and Sout <10 km).

Three estuaries in this corridor (Swartlintjies, Spoeg and Groen) are in excellent or good condition (i.e. Categories A to B according to health status on the DWS scale, whereby “A” is near natural and “F” being extremely degraded) (Draft NBA, 2018). These systems have a high sensitivity to change as they will degrade from their near pristine state relatively easily (Fielding et al., 2017).

Of the seven estuaries in this corridor, the Orange and Olifants estuaries are of Very High biodiversity importance, ranking in the top estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). Four estuaries in the corridor are identified as national conservation priorities by the National Estuaries Biodiversity Plan (Turpie et al., 2012). These are the Orange, Spoeg, Groen and Olifants estuaries.

In addition two estuaries, the Olifants and Orange, are important fish nurseries that play a critical role in the maintenance and recovery of South Africa’s recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the Orange, Spoeg, Groen, Sout and Olifants estuaries are also considered important as they support sensitive estuarine habitats such as intertidal and supratidal saltmarsh. The Buffels, Swartlintjies Groen, Spoeg and Sout are relatively small but recent studies on the ecological water requirements have highlighted their regional importance as a very limited wetland type habitat for estuarine and coastal birds along arid west coast (DWS, 2017).

5.6.2 Expanded Eastern EGI Corridor

In total, 21 estuaries fall within the Expanded Eastern EGI Corridor, with a combined estuarine habitat area of 55 700 ha (Figure 5). Most of the estuaries in the region are not particularly long and extend less than 10 km into the corridor, with the exception of the St Lucia (<30 km), Thukela (<25 km), Mhlathuze (<15 km), Mfolozi (<15 km) and Kosi (<10 km).

Only five estuaries in this corridor are in an excellent or good condition (Categories A to B). These are Mdlotane, Matigulu/Nyoni, Mlalazi, Mgobezeleni and Kosi estuaries. These systems have a high sensitivity to change as they will degrade from their near pristine state relatively easily.

Durban Bay, Mlalazi, Mhlathuze, Mfolozi, St Lucia and Kosi estuaries are of Very High biodiversity importance, ranking amongst the top estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). In addition Mgeni, Mhlanga, Mdloti, Tongati, Mhlali, Mdlotane, Zinkwasi, Thukela, Matigulu/Nyoni, Richards Bay and Nhlabane estuaries are rated as Important from a biodiversity perspective.

Seventeen estuaries in the corridor are identified as conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012) and the KwaZulu-Natal Conservation Plan. These include Durban Bay, Mgeni, Mhlanga, Mhlali, Mvoti, Mdlotane, Zinkwasi, Thukela, Matigulu/Nyoni, Siyaya, Mlalazi, Mhlathuze, Richards Bay, Mfolozi, St Lucia, Mgobezeleni and Kosi estuaries.

Twelve estuaries are important fish nurseries that play a critical role in the maintenance and recovery of South Africa’s recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). These include Durban Bay, Mgeni, Zinkwasi, Thukela, Matigulu/Nyoni, Mlalazi, Mhlathuze, Richards Bay, Nhlabane, Mfolozi, St Lucia and Kosi.

From a habitat diversity and abundance perspective, all the estuaries, with the exception of Mvoti, are considered important as they support sensitive estuarine habitats such as mangroves, swamp forest and saltmarsh (intertidal and/or supratidal).

6 FEATURE SENSITIVITY MAPPING

6.1 Identification of feature sensitivity criteria

A generic suite of environmental and socio-economic sensitivity indicators, which could be mapped on the basis of existing knowledge and datasets, and which were suitable for assessing potential risks associated with this type of development were selected (Table 6). Base maps were produced for each corridor demarcating the presence and locations of these sensitivity indicators. Based on expert opinion, each of these indicators was allocated a sensitivity rating (i.e. very high, high, medium, and low, as indicated in Table 6). This allowed for the translation of base maps into sensitivity maps for each of the study areas.

The feature maps are shown in Figure 4 and Figure 5 for the Expanded Western and Eastern EGI corridors respectively.

6.2 Sensitivity Mapping

All estuaries under consideration here can be regarded as being systems of very high sensitivity based on one or more of the listed criteria in Table 6, e.g. priority estuary for conservation, an important nursery system, and/or as a system supporting endangered Red listed species such as White Steenbras.

Because of estuarine connectivity with, and dependencies on wider floodplain and riverine habitats, and because habitat impacts in estuaries accumulate over temporal and spatial scales, estuaries cannot be assessed as discrete units as done in the case of terrestrial systems. For this assessment the EFZ of each estuary within the proposed corridors was buffered at 5 km intervals to reflect the sensitivity of estuaries and their associated inflowing rivers, wetlands and coastal seeps to potential infrastructure development. This approach also allowed assessment of potential cumulative impacts of a linear structure crossing a number of estuaries within a region. Relative sensitivity of zones within each of the corridors are illustrated in Figure 6 and Figure 7.

6.2.1 Expanded Western EGI Corridor

There is only one estuary (Olifants) in this corridor that stretches far inland (< 20 km), with most of other systems ending within 10 km of the coast. These areas are demarcated as of very high sensitivity to infrastructure development. The rivers, wetlands and coastal seeps adjacent or just above the estuaries, as demarcated by the 5 km buffer around the EFZs, are deemed zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. Disturbance of their physical processes will in turn impact the downstream estuary health. The inflowing rivers, wetlands and coastal seeps adjacent or above the estuaries, as indicated by the 5 to 15 km buffer around the EFZs, are deemed zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

6.2.2 Expanded Eastern EGI Corridor

There are a number of very large and high biodiversity importance estuaries in the Expanded Eastern EGI Corridor, including the St Lucia and Kosi estuarine lake systems. These areas are demarcated as of very high sensitivity to infrastructure development. The rivers, wetlands and coastal seeps adjacent or just above the estuaries (demarcated by the 5 km buffer around the EFZ) are zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. Rivers, wetlands and coastal seeps adjacent or above the estuaries (in the 5 to 15 km buffer around the EFZs) are zones of medium sensitivity.

Table 6: Selected ecological sensitivity indicators and associated sensitivity ratings applicable to the proposed Expanded EGI corridors.

Sensitivity Indicator		Brief description/data source	Sensitivity Class	Zone of interest
Estuarine	Estuaries in Formally /desired protected areas	Marine, estuarine and terrestrial areas within the study area boundaries that are under formal protection or estuaries identified as desired protected areas in the National Estuaries Biodiversity Plan (Turpie et al., 2012).	Very High	EFZ
	Estuaries of high biodiversity importance	In South Africa, estuary biodiversity importance is based on the importance of an estuary for plants, invertebrates, fish and birds, using rarity indices (Turpie et al., 2002). The Estuary Importance Rating takes size, the rarity of the estuary type within its biographical zone, habitat and the biodiversity importance of the estuary into account (Turpie et al., 2002, Appendix A).	Very High	EFZ
	Important nurseries	Estuaries that are critically important nursery areas for fish and invertebrate populations and make an important contribution towards estuarine and coastal fisheries (Lamberth and Turpie, 2003; Van Niekerk et al., 2017).	Very High	EFZ
	Important estuarine habitats	Estuaries that support important rare or sensitive habitats (saltmarsh, mangroves, swamp forest) that provide important ecosystem services (Van Niekerk et al., 2017).	Very High	EFZ
	Natural or near natural condition estuaries	Estuaries in good condition (designated by A or B health categories) are more sensitive to development (likely to degrade in overall condition if impacted by development) (Van Niekerk et al., 2017).	Very High	EFZ
	Estuaries that support species of conservation importance	Estuaries that support species of conservation importance (IUCN Red listed species that are Critically Endangered).	Very High	EFZ
Supporting habitats	Coastal rivers, wetlands and seeps above or adjacent to estuaries	Coastal rivers, wetlands and seeps adjacent or just above the estuaries that <u>directly</u> influence the quality and quantity of freshwater and sediments entering estuaries.	High	5 km buffer around EFZ
	Coastal rivers, wetlands and seeps	The coastal rivers, wetlands and seeps adjacent or just above the estuaries that <u>indirectly</u> influence the quality and quantity of freshwater and sediments entering estuaries.	Medium	5 - 15 km buffer around EFZ
	Terrestrial environment	Terrestrial environment that are not linked to aquatic processes that directly or indirectly influence estuaries.	Low	15 km or more from EFZ

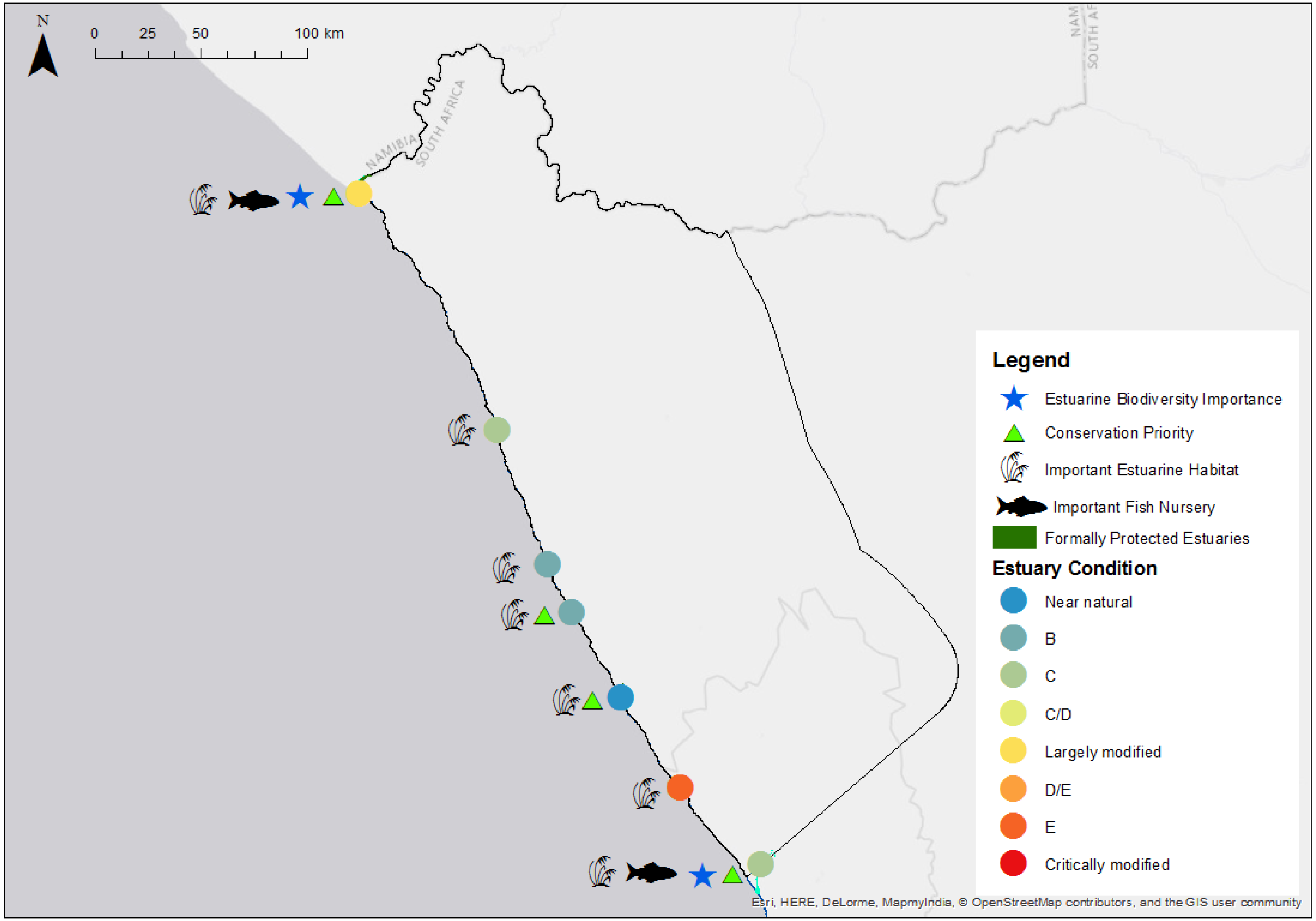

Figure 4: Estuarine feature map for the proposed Western Expanded EGI Corridor.

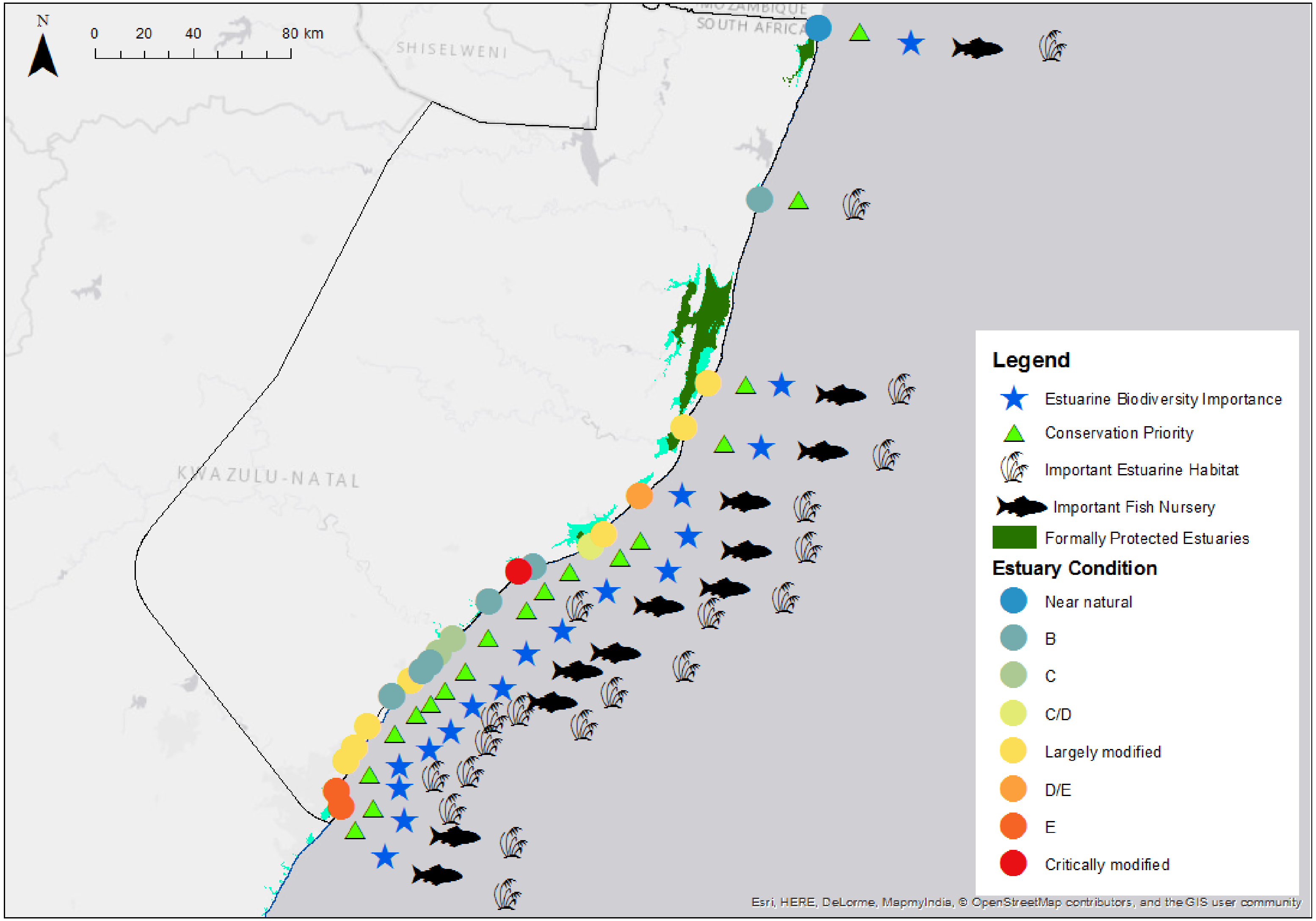

Figure 5: Estuarine feature map for the proposed Eastern Expanded EGI Corridor.

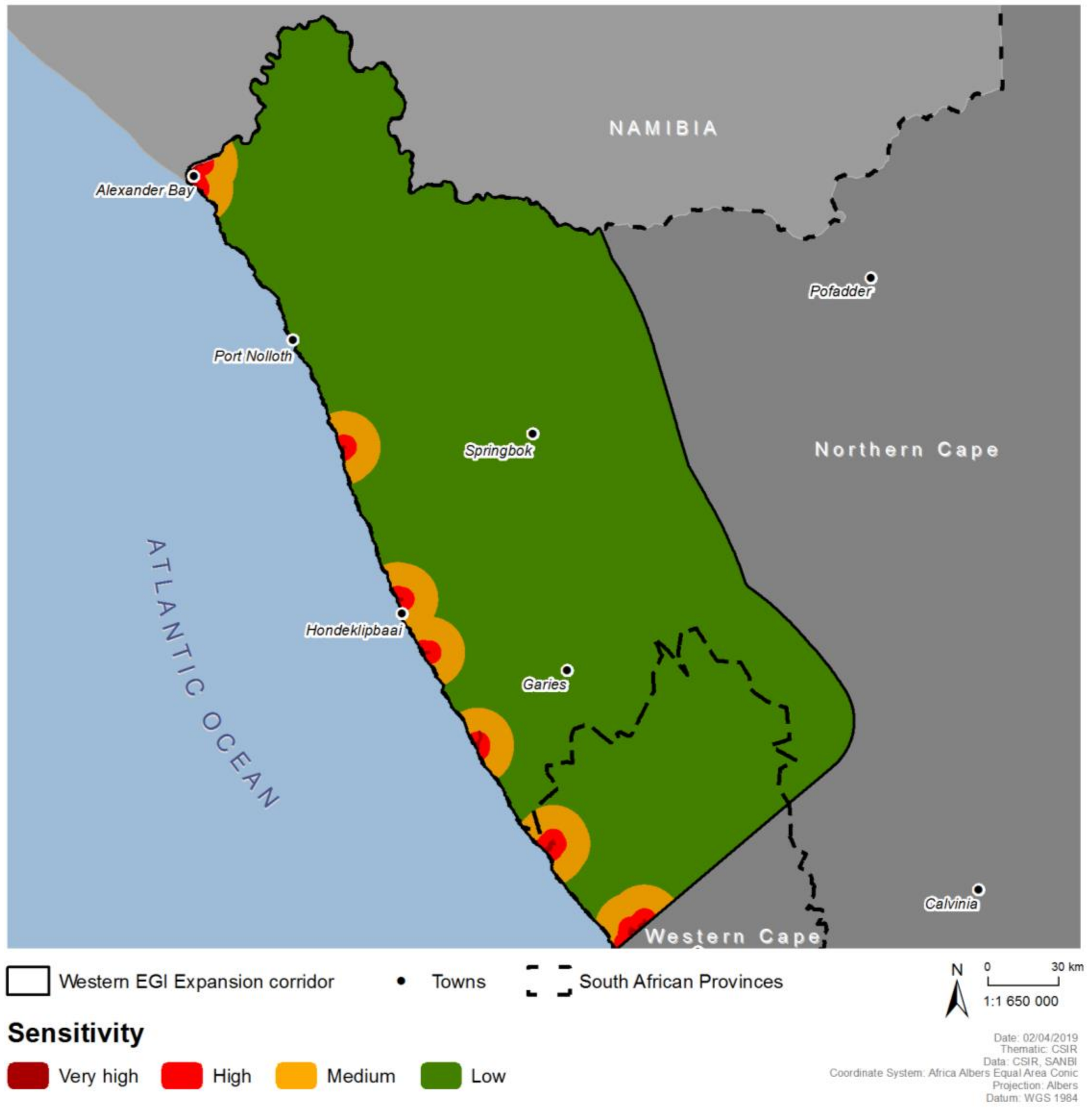

Figure 6: Sensitivity map for the estuaries, EFZ and associated features in the proposed Western Expanded EGI Corridor.

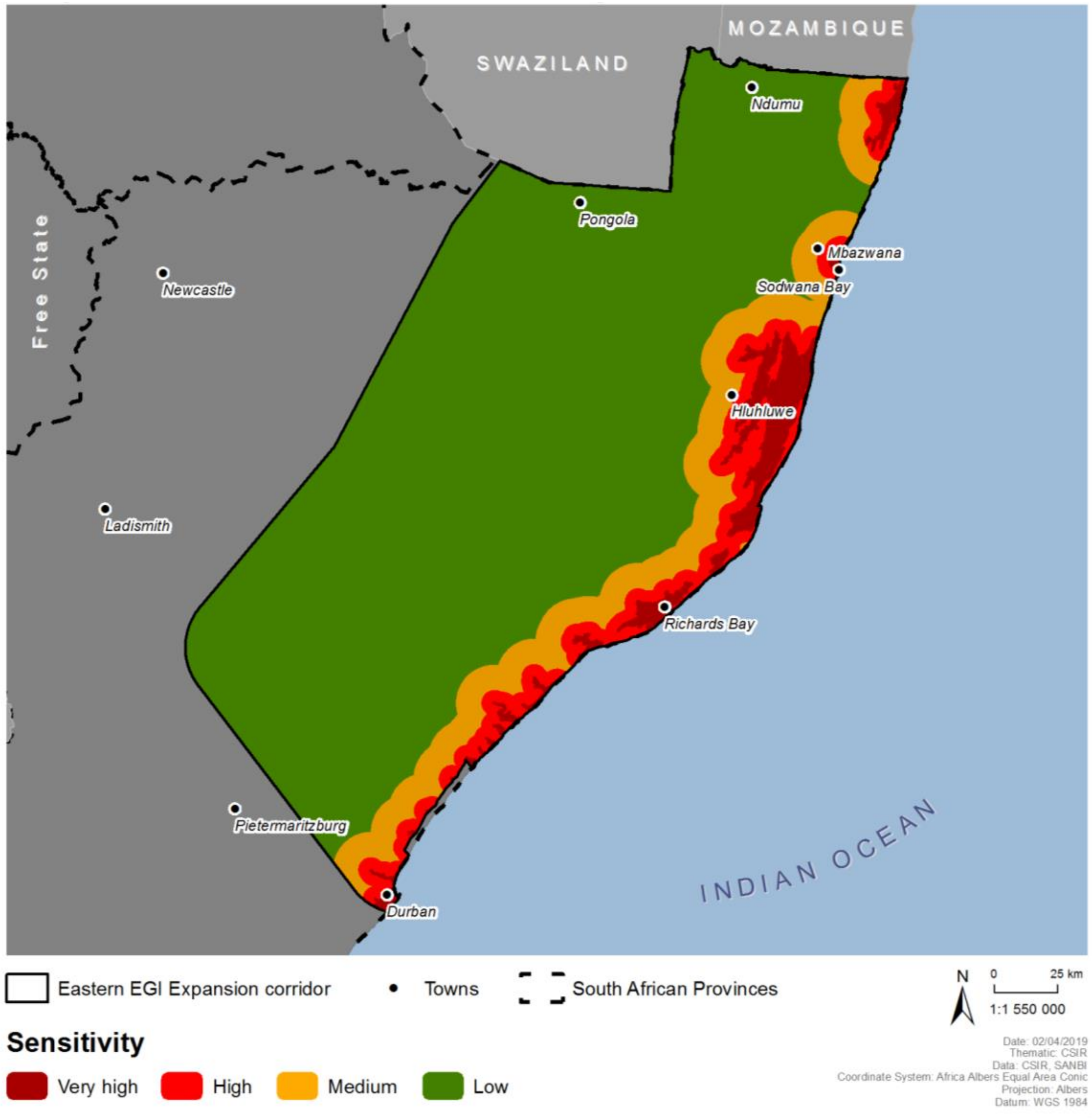

Figure 7: Sensitivity map for the estuaries, EFZ and associated features in the proposed Eastern Expanded EGI Corridor.

7 KEY POTENTIAL IMPACTS AND THEIR MITIGATION

The impacts associated with EGI range from those that are obvious (e.g. pylon construction and clearing areas for access/service roads) to those that are more subtle and which occur over longer timeframes (e.g. vegetation compositional changes from continued disturbance/clearing, disruption of long term sedimentary processes, deteriorating water quality, habitat fragmentation, and alien plant infestation). It is once again stressed that estuaries are highly dependent on the condition of the rivers flowing into them and/or adjacent wetlands. Cross reference is therefore made to the Freshwater Specialist Assessment (De Winnaar & Ross-Gillespie, 2018) to ensure that downstream estuarine functionality is not impacted on by infrastructure development.

The impacts to aquatic ecosystems associated with EGI were identified and discussed in detail as part of the 2016 EGI SEA. De Winnaar & Ross-Gillespie (2018) also highlight additional aquatic impacts as a result of the construction of pylons, substations, and associated EGI structures. Major impacts include:

- The **development of new access/services roads to enable construction**, as well as ongoing maintenance during the operational phase may result in the following impacts:
    - **Direct loss of estuarine and/or riparian vegetation** (and associated riparian buffers), including potentially sensitive/important habitat supporting species of conservation concern;
    - **fragmentation of estuarine hydrodynamic, sedimentary processes** and mouth dynamics (open/closed phases) causing changes in ecological patterns and processes, disruptions to species movement and dispersal, habitat connectivity, increased edge effects and disturbance, and establishment of invasive alien vegetation;
    - **Stormwater runoff** resulting in increased flows into receiving aquatic environments, often at discrete discharge points, with knock-on impacts such as bank erosion and collapse, scouring, channel incision, desiccation of estuarine/wetland/riparian soils and vegetation, increased turbidity, sedimentation and smothering of benthos. The combined effects will negatively affect the ecological integrity and ability of the estuarine and coastal freshwater ecosystems to function properly;
    - **Waste pollution and contamination** of aquatic environments from foreign materials (e.g. fuels/hydrocarbons, cement, and building materials) stockpiled or dumped and/or carried into estuarine and coastal freshwater ecosystems environments;
    - **Disruption of soil profile** through soil compaction/increased soil bulk density, reduced porosity, hydraulic conductivity, alter soil chemistry (soil pH, organic matter and nitrogen content);
    - **Compaction of soils and creation of preferential flow paths** with and adjacent to estuarine and upstream river/wetland habitats; and
    - **Direct loss of flora and fauna** (including species of conservation concern) that inhabit estuarine and upstream coastal freshwater ecosystems and adjacent buffer/fringe habitats.
- **Construction of substations and pylons and powerline servitudes –** The direct clearing and/or removal of vegetation to allow for the construction of substations and pylons, as well as to establish access/service roads to access the pylons and powerlines for on-going maintenance will result in impacts similar to those described above for the development of access roads, but which differ in terms of extent, duration and intensity. As noted above, the direct footprint of single pylon supporting a 765 kV powerline is 1 ha (including excavation, assembly and raising), while the development footprint for a substation extends up to 70 ha (including temporary construction camps, borrow pits, vehicle parking, and stock piles). Servitudes for accessing pylons/powerlines will require ongoing vegetation clearing to maintain an 8 m strip on either side of the centre line (for a 132 kV powerline) wherein grass/herbaceous vegetation regrowth is cut to a height of 8.5 m minimum vertical clearance (for a 765 kV line), and trees, in most cases, are removed.
    - In addition, pylon infrastructure may **alter estuarine physical dynamics, e.g. infilling, altered channel migrating, increased mouth closure**. Estuary channel morphology is highly dynamic. Estuarine channels can develop and migrate anywhere within the EFZ under the

influence of tidal flows, river flows and floods. Stabilising sections of the estuary morphology or floodplain for construction, operation and maintenance of EGI can lead to changes in long-term physical dynamics. Disruption of **channel and bed formation process will alter sediment structure, change estuary hydrodynamics, mouth dynamics, and ultimately impact catchment and marine connectivity**. This altered functioning of a system will ultimately affect the biota. Loss of estuarine productivity and connectivity will reduce nursery function and output to associated fisheries. **Given that estuary channels are highly dynamic and can develop and migrate anywhere in the EFZ, it is inevitable that infrastructure in the EFZ will disrupt estuarine physical processes. The nett result is that infrastructure will over time be exposed to erosion through channel migration resulting in a high risk of failure.**

- The sediment eroding from construction sites or cleared floodplains and servitudes could cause sediment deposition and accumulation in other parts of estuaries, causing drying out of floodplains, loss of water column habitat and premature mouth closure if the tidal flows are constricted. Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.
- Constricting or stabilizing channel migration will also ultimately **increase flood risk to riparian properties** as it will prevent estuarine channels from widening naturally under increased flows.
- **Deterioration of water quality associated with the disturbance of sediment and lack of stormwater management** leading to erosion and runoff, the use of water for construction and dust suppression, concrete/oil/hydraulic spills, and an overall need for strategic planning of water resource allocation. During the construction phase water quality may deteriorate as a result of sediment disturbance and/or the removal of estuarine vegetation, or pollution events, resulting in:
    - **decrease pH** as a result of disturbance of the anoxic sediment profiles characteristic of estuaries;
    - **increase the Total Dissolved Solids (TDS);**
    - **increase the Total Suspended Solids (TSS);**
    - **increase the organic matter content;** and/or
    - **Increase the nutrient content.**

This can have knock-on effects on the biota. It can result in algal blooms/eutrophication in estuaries, can cause anoxia or hypoxia and fish and invertebrate kills. Increased turbidity in clear water systems can lead to smothering of primary producers and disrupted predator-prey relationships.

- **Loss of connectivity and habitat fragmentation** as a result of EGI, and the associated access/services roads for ongoing maintenance, especially where areas are permanently impacted (e.g. through roads, substations and pylon bases). This presents a potential serious issue particularly to estuarine and associated coastal river fauna, and leads to populations becoming isolated, resulting in a reduction of inter-population connectivity and compromised genetic viability.
- **Habitat alteration and knock-on effects caused by Invasive Alien Plants (IAPs).** IAPs that already occur in the area are likely to encroach into and invade newly disturbed areas (such as construction camps, borrow pits, vehicle parking, and stock piles/ areas), as well as areas where conditions (such as soil moisture content) are changed because of development (e.g. areas around pylons/substations and along access roads). The spread of existing, and the introduction of new, problem plant species may be facilitated by movement of people and construction vehicles. IAP infestation within freshwater ecosystems will further degrade habitats and habitat availability for associated biota.

Overall, in this study impacts are characterised at the broadest scale in relation to the corridors as a means to identify preferred routes that will have the least possible impact on estuarine and associated coastal freshwater ecosystems and/or biota. Inappropriate routing of an EGI corridor could potentially impact areas with severe consequences for estuarine and associated coastal freshwater biodiversity. Taking this into consideration, it is important to acknowledge impacts at a finer scale in order to identify preferred alignments/positions of EGI within the two respective corridors.

The impacts described above are more broadly categorised below for further discussion in Table 7.

7.1 Design Phase

Many impacts potentially associated with the construction and operation of powerlines in the expanded EGI corridors can be avoided or mitigated in the design phase of the project by avoiding sensitive areas, most importantly avoiding development (placement of pylons, substations and other associated EGI structures) within EFZs. This will mitigate impacts associated with construction, as well as operation of such infrastructure. Impacts which can be mitigated at the design phase are:

- Loss of threatened/sensitive estuarine and supporting coastal river/wetland riparian habitat through clearing/infilling.
- Fragmentation of estuarine and supporting coastal river/wetland (mostly as a result of road construction).
- Alteration of hydrodynamic processes through disrupted estuarine morphological processes, interrupted surface and/or subsurface freshwater flows, as well as the concentration of water flows due to roads across floodplains, wetlands or rivers.

7.2 Construction Phase:

Construction phase impacts are associated with the development and installation of infrastructure (such as pylons, substations and associated EGI structures), and stringing of powerlines. These activities typically require development of access roads, laydown areas and construction camps. Impacts are:

- Physical destruction or damage of estuarine and supporting coastal river/wetland ecosystems by construction personnel and machinery operating within or in close proximity to drainage lines.
- Pollution (water quality deterioration) of estuarine and supporting coastal river/wetland ecosystems through the runoff of contaminants such as fuel, oil, concrete, wash-water, sediment and sewage into these ecosystems.
- Reduction in habitat quality through erosion and sedimentation of estuarine habitat and/or associated coastal wetlands and rivers.
- Erosion caused by loss of vegetation cover through site clearing and consequent sedimentation of estuarine and supporting coastal river/wetland ecosystems. Erosion is particularly a high risk in steep or incised systems.
- Excessive dust generation from road construction and vehicle traffic/haulage leading to impact on surrounding vegetation health and suspended solids/sediment entering nearby estuarine and supporting coastal river/wetland ecosystems.
- Disturbance of estuarine or freshwater aquatic and semi-aquatic fauna, as a result of the noise from construction teams and their machinery working within or in close proximity to aquatic ecosystem.
- Damage to vegetation from operating heavy machinery.

7.3 Operational Phase:

Operational phase impacts are typically associated with routine maintenance activities and occasional repairs needed. These activities typically require development (and maintenance) of a servitude as well as regular clearing of vegetation to meet national standards and safety regulations for overhead powerlines. Impacts include:

- Loss and/or reduction in estuarine and supporting coastal river/wetland habitat quality.
- Encroachment and proliferation of alien and invasive vegetation.
- Pollution (water quality deterioration) of estuarine/freshwater ecosystems and potential contamination of groundwater/subsurface drainage.

Table 7: Summary of key activities, impacts, possible effects and mitigations.

Activity	Key Impact	Possible Effect	Mitigation
Design Phase			
Placement of substations, foundations for pylons, construction camps, access roads and service roads within or close to the EFZ and/or coastal wetlands or rivers flowing into estuaries	Loss of threatened/ sensitive estuarine and supporting river/wetland riparian habitat through clearing/ infilling.	Removal of estuarine and/or coastal riparian vegetation, instream habitat, as well as adjacent terrestrial buffer habitat which could result in a loss of ecological functions and processes, aquatic biota (i.e. fauna and flora), and valuable ecosystem services.	Corridors to avoid all EFZs (very high sensitivity), and, if possible, avoid areas of high sensitivity.
	Fragmentation of estuarine and associated coastal freshwater habitat (mostly as a result of road construction)	Loss of ecosystem resilience and integrity through the disruption of biodiversity patterns and processes (e.g. fish movement/ migration)	Avoid road crossings and servitude clearance through estuaries and avoid and/or minimise these activities in associated coastal wetlands and rivers within 5 km of EFZ. Where it is not possible to avoid the crossing of inflowing rivers or wetlands, ensure that crossings are constructed to minimise impacts, as well as to ensure connectivity and avoid fragmentation of ecosystems, especially where systems are linked to a river channel. Designs to consider use of riprap, gabion mattresses, or similar adequate erosion control measures, with pipe crossings or culverts. As far as possible ensure access roads are linked to existing river crossings (e.g. bridges) to minimise disturbance from additional crossings.
	Alteration of hydrodynamic processes through disrupted estuarine morphological processes, interrupted surface and/or subsurface freshwater inflows, as well as the concentration of water flows due to roads traversing inflowing coastal wetlands or rivers.	Changes result in degradation of the ecological functioning of estuarine and coastal freshwater aquatic ecosystems that rely on a specific hydrological regime and associated hydrodynamics (mixing processes) to maintain their integrity. This also leads to geomorphologic impacts within systems.	Avoid road crossings and servitude clearance through estuaries. Avoid and/or minimise road crossings and servitude clearance through associated coastal wetlands / rivers within 5 km of the EFZ. Minimise the number of watercourse crossings for access roads. Ensure adequate watercourse crossings (i.e. culverts of the correct specification) are designed and constructed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible.

Activity	Key Impact	Possible Effect	Mitigation
Construction Phase			
Establishment of construction camps or temporary laydown areas within or in close proximity to estuaries and associated wetlands or rivers	Physical destruction or damage of estuarine and supporting coastal river/wetland ecosystems by construction workers and machinery operating within or in close proximity to drainage lines.	Loss of both faunal and floral biodiversity and the ecosystem services provided by these habitats directly through clearing, and indirectly through poaching/hunting.	All estuaries and their associated inflowing coastal wetlands and rivers should be treated as "no-go" areas and appropriately demarcated as such. No vehicles, machinery, personnel, construction materials, cement, fuel, oil or waste should be allowed into these areas without the express permission of and supervision by an on-site Environmental Control Officer (ECO). All construction activities (including establishment of construction camps, temporary lay-down areas, construction of haul roads and operation of heavy machinery) associated with wetlands and rivers should take place during the dry season to reduce potential impacts to coastal freshwater ecosystems and downstream estuaries. No fishing or hunting should be allowed in the proximity of aquatic habitats.
Construction of substations, foundations for pylons, construction camps, access roads and service roads within or close to the EFZ and/or coastal wetlands or rivers flowing into estuaries	Erosion caused by loss of vegetation cover through site clearing and consequent sedimentation of aquatic ecosystems. Erosion is particularly a high risk in steep systems.	The sediment eroding from the construction site and denuded floodplain can cause sediment deposition and build up in other parts of the estuary, causing drying out of the riparian zone, loss of water column habitat and can result in premature mouth closure if the tidal flows are constricted enough.	Avoid clearing of estuarine vegetation and associated coastal freshwater riparian vegetation. River/wetland bank stabilisation measures (gabions, eco logs, geofabric, sediment fences or similar adequate measures) are required when wetland or watercourse banks steeper than 1:5 are denuded during construction. Appropriate rehabilitation procedures/measures should be planned.
Stockpiling of materials and washing of equipment within or in close proximity to estuaries and associated wetlands or watercourses	Pollution (water quality deterioration) of estuarine and supporting coastal river/wetland ecosystems through the runoff of contaminants such as fuel, oil, concrete, wash-water, sediment and sewage into these ecosystems.	Habitat degradation which results in the loss of resilience of ecosystems through the disruption of ecological processes and thus a loss of ecosystem integrity.	No construction activities within estuaries (i.e. EFZ). Construction activities associated with the establishment of access roads through associated coastal wetlands or rivers (if unavoidable) should be restricted to a working area of 10 m in width on either side of the road, and these working areas should be clearly demarcated. No vehicles, machinery,

Activity	Key Impact	Possible Effect	Mitigation
			personnel, construction material, cement, fuel, oil or waste should be allowed outside of the demarcated working areas.
Construction of haul roads for movement of machinery and materials	Reduction in habitat quality through erosion and sedimentation of estuarine habitat and/or associated coastal wetlands and rivers. Excessive dust generation from road construction and vehicle traffic/haulage leading to impact on surrounding vegetation health and suspended solids/sediment entering nearby estuarine and supporting coastal river/wetland ecosystems		There should be as little disturbance to surrounding vegetation as possible when construction activities are undertaken, as intact vegetation adjacent to construction areas will assist in the control of sediment dispersal from exposed areas. Furthermore dust suppression methods (e.g. spraying surfaces with water obtained from a suitable, licenced/approved source) should be used to minimise the transport of wind-blown dust.
Operation of heavy machinery within or in close proximity to an estuary or associated inflowing wetlands or rivers	Disturbance of estuarine or freshwater aquatic and semi-aquatic fauna, as a result of the noise from construction teams and their machinery working within or in close proximity to an aquatic ecosystem. Damage to vegetation from operating heavy machinery.		No fuel storage, refuelling, vehicle maintenance or vehicle depots should be allowed within 30 m of the edge of any estuary/river/wetlands or drainage lines.
			Refuelling and fuel storage areas, and areas used for the servicing or parking of vehicles and machinery, should be located on impervious bases and should have bunds around them. Bunds should be sufficiently high to ensure that all the fuel kept in the area will be captured in the event of a major spillage.
			Vehicles and machinery should not be washed within 30 m of the edge of any estuary, river or wetland.
			No effluents or polluted water should be discharged directly into any estuary or associated coastal river or wetland.
			If construction areas are to be pumped of water (e.g. after rains), this water should be pumped into an appropriate settlement area, and not allowed to flow

Activity	Key Impact	Possible Effect	Mitigation
			straight into any estuary or associated coastal river or wetland.
			No spoil material, including stripped topsoil, should be temporarily stockpiled within 30 m of the edge of any estuary, river, wetland or drainage line. Estuarine or associated coastal aquatic ecosystems located in close proximity to construction areas (i.e. within ~30 m) should be inspected on a regular basis by the ECO for signs of disturbance from construction activities, and for signs of sedimentation or pollution. If signs of disturbance, sedimentation or pollution are noted, immediate action should be taken to remedy the situation and, if necessary, an estuarine or freshwater ecologist should be consulted for advice on the most suitable remediation measures.
			Workers should be made aware of the importance of not destroying or damaging the vegetation along estuaries and associated freshwater ecosystems, of not undertaking activities that could result in the pollution of estuaries, rivers or wetlands, and of not killing or harming any animals that they encounter. This awareness should be promoted throughout the construction phase and can be assisted through erecting appropriate signage
			Fixed point photography should be implemented to monitor vegetation changes and potential site impacts occurring during construction phase.
Operational Phase			
Clearing or trimming of natural estuarine and associated wetland or riparian vegetation	Loss and/or reduction in estuarine and supporting coastal river/wetland habitat quality	Degradation of ecological integrity and changes to species community composition as well as habitat structure	One of the options that could be explored to mitigate against the potential vegetation clearing/trimming impacts would be to consider constructing taller pylons in certain areas that are high enough to allow for the growth of relatively tall vegetation.

Activity	Key Impact	Possible Effect	Mitigation
	Growth stimulation, encroachment and proliferation of alien vegetation/invasive species		Fixed point photography could be used to monitor long-term vegetation changes and potential site impacts
Application of herbicides	Pollution (water quality deterioration) of estuarine/freshwater ecosystems and potential contamination of groundwater/subsurface drainage		Avoid the use of herbicides in close proximity (closer than 50 m) to the EFZ and within 10 km of EFZ of inflowing coastal wetlands/ rivers. Do not spray riparian/or wetland areas within 50 m of the coastal freshwater aquatic ecosystem.

1

8 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

8.1 Design and Planning phase

The careful and informed planning of EGI development through firstly establishing preferred powerline routes, determining suitable sites for substations, placement of pylons, and needs for ancillary infrastructure (e.g. access roads) has **the potential to greatly reduce impacts on estuarine and associated freshwater aquatic ecosystems through simply avoiding areas of very high sensitivity, and as far as possible avoiding areas of high sensitivity.** Where estuarine areas cannot be avoided, then a detailed investigation should be followed to determine whether the EGI alignment and development footprint can avoid the actual estuarine ecosystems (i.e. estuary) and associated aquatic and riparian buffers.

Where it is impossible to avoid estuaries and associated aquatic ecosystems and buffers altogether, then it will be necessary to undertake more detailed specialist studies, and if necessary investigate needs and opportunities for offsets. Preference should be given to position EGI within already disturbed/degraded areas. Mitigation specific to impact significance should be considered that is cognisant of the mitigation hierarchy, where very high significance impacts are avoided, while high and medium significance impacts are mitigated as far as possible. Offsets should only be considered once alternatives and mitigation measures have been exhausted. Indeed, in the case of estuaries there is very little if any potential for off sets. Any estuarine ecosystem that will be affected by EGI development within the proposed Expanded EGI Corridors must be subject to an appropriate site-specific estuarine specialist investigation.

8.2 Construction phase

Given the high sensitivity and ecological importance of estuaries it is recommended that clearing of estuarine vegetation and disturbance of estuarine processes be avoided, i.e., no EGI development should occur within the EFZs.

However, this phase may include the construction of pylons and substations, and stringing of transmission lines, as well as the construction of the access and service roads, and will thus include a number of impacts typical of construction activities (as described above), such as erosion and degradation/disturbance of coastal habitats and vegetation (including areas for access via roads and servitudes and movement of heavy machinery), and earthworks and vegetation/habitat clearing. Specific measures and actions required during the construction phase are presented in De Winnaar & Ross-Gillespie (2018), and Table 7 provides key measures applicable to protect downstream estuarine physical and ecological processes from knock-on effects. Additional measures to include are:

- Timing of construction activities should occur in the dry season as far as possible;
- Appointment and involvement of an ECO to provide oversight and guidance to all construction activities, as well as ensure full consideration and implementation of the Environmental Management Programme (EMPr); and
- Environmental monitoring (or biomonitoring) should be required pre-; during- and post-construction at strategically selected monitoring sites (refer to De Winnaar & Ross-Gillespie (2018) for more detail on coastal freshwater ecosystem requirements).

Some key mitigation measures to include from the perspective of protecting estuarine and coastal freshwater ecosystem processes are:

- Detailed site-specific assessment required if construction is planned for within the EFZ.
- An onsite ECO is required to provide oversight and guidance to all construction activities.
- Environmental monitoring or biomonitoring is required pre-, during- and post-construction at pre-selected monitoring sites. This should include fixed point photography or remote sensing should be implemented to monitor changes and long term impacts.
- Construction activities to occur, if possible, while the estuary mouth is open to minimise impacts to biodiversity.
- Dust suppression is required to prevent smothering of estuarine vegetation.

8.3 Operations phase

Assuming that EGI development does not occur in the EFZ as a result of very high sensitivity and ecological importance of estuaries, this phase will predominantly include activities typical of routine maintenance, such as clearing/trimming of coastal riparian or wetland vegetation within 5 km of the estuaries, as well as IAP control and application of herbicides. Specific measures and actions required during the operational phase are presented in De Winnaar & Ross-Gillespie (2018), but some key measures to include from the perspective of protecting estuarine processes are:

- Fixed point photography could be used to monitor long-term vegetation changes and potential site impacts.
- Avoid the use of herbicides in close proximity (closer than 50 m) to wetlands or rivers and do not disturb riparian/or wetland buffer areas.
- At all times care should be taken not to destabilise riparian areas and increase the sediment load down-stream to the estuary.

8.4 Rehabilitation and post-closure

Rehabilitation and post-closure measures would most likely be required for areas in and around pylons within or in proximity to estuarine and associated freshwater ecosystems (as indicated on sensitivity maps), as well as for areas degraded by access routes, operation of vehicles/heavy machinery, and servitudes infested by IAPs. In general, the following processes/procedures are recommended (James and King, 2010; De Winnaar & Ross-Gillespie, 2018):

- Initiation - rehabilitation project team and specialists identify problem/target areas, establish reference condition and desired states, and define rehabilitation targets and objectives;
- Planning - to account for constraints, budgeting and timeframes;
- Analysis - evaluation of alternatives and strategies to achieve the objectives, and to develop preliminary designs and inform feasibility;
- Implementation - including detailed engineering designs, construction and inspections; and
- Monitoring - to establish need for maintenance and repair of interventions, as well as provide feedback regarding success and failure.

Additional points to be considered regarding rehabilitation of degraded areas within and adjacent to coastal freshwater and estuarine ecosystems include:

- IAP clearing and control – an IAP control programme should be developed and implemented based on site-specific details, including, but not limited to, types of IAPs, growth forms, densities and levels of infestation, potential dispersal mechanisms, and knock-on impacts to freshwater and estuarine ecosystems caused during implementation (e.g. herbicide drift and contamination);
- Erosion control and re-vegetation – the objective should be to establish indigenous vegetation cover as soon as possible, as well as to control and limit secondary impacts caused by rainfall-runoff. Where necessary geotextile fabrics, brush mattresses/bundles, geocells, and hydroseeding with a suitable grass seed mix should be considered, while more severe cases of erosion/bank collapse will require more advanced stabilisation methods (e.g. reshaping, planting, concrete blocks, riprap, and gabions/reno mattresses).

8.5 Monitoring requirements

Given the high sensitivity and ecological importance of estuaries it is recommended that EGI development should not occur within the EFZs. However, EGI development may involve construction and operation activity within or in proximity to coastal freshwater ecosystems such as rivers, wetlands and seeps that flow into estuaries. Where impacts to estuaries and/or coastal freshwater ecosystems within 5 km of estuaries cannot be avoided, monitoring measures should be implemented at a minimum; with additional supporting input from in-depth specialist studies where required.

For all construction activities within 5 km of an estuary, monitoring of a potential impact is recommended at sites to be determined in-field by qualified and experienced estuarine and/or freshwater ecosystems specialists. Sampling is required prior to construction taking place to allow for the establishment of the systems baseline condition (i.e. its state prior to development activities). Monthly monitoring is recommended for the duration of construction to evaluate trends, with summer and winter monitoring at three year intervals recommended thereafter during the operation phase.

Depending on the impact site, monitoring/sampling is to be conducted by estuarine/freshwater specialists with relevant qualifications and experience pertaining to estuarine sediment dynamics, physical processes, water quality and ecology (or freshwater aquatic ecology if in coastal freshwater ecosystem). Resource Quality Objectives (RQO) as set under the NWA provides the benchmark conditions to maintain in estuaries or rivers.

Monitoring effort should be appropriate to the nature and intensity of potential impacts, and information from monitoring should be used to inform and influence EGI development activities to prevent environmental damage, or ensure that remediation measures after the fact are successful in rehabilitating impacted habitats. This will require the development of case-specific monitoring plans, but some guidelines are presented here which are based on those developed for use in RQO studies. Table 8 8 details these monitoring requirements for estuaries, with critical features highlighted in blue. These requirements are specifically important in the event of construction within an estuary and its EFZ is impossible to avoid. Monitoring of water quality, microalgae, invertebrates, fish and birds should be conducted even if the estuary or EFZ is not directly impacted, but where upstream activities occur which may cause indirect impacts to an estuary (Table 8).

Note: There are no prescriptive estuarine methods for the monitoring of reptiles, amphibians and mammals. The monitoring programme should be implemented as prescribed by the Freshwater Ecosystems Specialist Assessment Report (De Winnaar & Ross-Gillespie, 2018).

Table 8: Requirements for monitoring ecological components of estuaries following direct and indirect impacts from EGI development.

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
In the event of direct impacts in EFZ	Hydrodynamics	Record water levels	Continuous	Near mouth
		Aerial photographs of estuary	During spring low tide Before construction, during operation, and every 3 years afterwards	Entire estuary
	Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Before construction, during operation, and every 3 years afterwards	Entire estuary
		Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	Before construction, during operation, and every 3 years afterwards (with invert sampling)	Entire estuary
	Water Quality	Record longitudinal salinity and temperature (pH, dissolved oxygen, and suspended solids/turbidity profiles)	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (3-10 stations)
	Macrophytes	Ground-truthed maps; Record number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit; Record percentage plant cover, salinity, water level, sediment moisture content and turbidity on a series of permanent transects along an elevation gradient; Take measurements of depth to water table and ground water salinity in supratidal marsh areas	Summer survey before construction, during operation, then Summer survey every 3 years afterwards	Entire estuary
	Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements.	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)
	Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of hole densities; Measures of sediment characteristics at each station.	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 20 stations)
	Birds	Undertake counts of all water associated birds, identified to species level.	Summer and winter surveys before construction, once off during operation, then Summer and winter survey every year	Entire estuary (3 – 5 sections)
In the event of indirect impacts (e.g. through relevant upstream impact within 10 km of an estuary)	**Water Quality**	Record longitudinal salinity and temperature (pH, dissolved oxygen, and suspended solids/turbidity profiles).	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (3-10 stations)
	Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements.	Summer and winter survey before construction, during operation, then every summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of hole densities; Measures of sediment characteristics at each station	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 10 stations)
	Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey before construction, during operation, then every Summer and winter survey every 3 years afterwards	Entire estuary (5 – 20 stations)

In cases where freshwater ecosystems within 5 km upstream of estuaries are likely to be affected by EGI development appropriate measures of monitoring should be considered, including (De Winnaar & Ross-Gillespie, 2018):

- Upstream and downstream biomonitoring to include appropriate indicators/measures of assessing rivers (e.g. diatoms, water quality/clarity, macro-invertebrates using the SASS5 method, instream and riparian habitat using the IHI method) and wetland habitats (e.g. WET-Health and WET-EcoServices) of a potential impact is recommended at suitable sites to be determined in-field by a specialist.
- Monitoring/sampling is to be conducted by suitably qualified specialists (e.g. DWS accredited SASS 5 practitioners) with sufficient experience in assessing aquatic ecology and water quality;
- A single sampling event is recommended prior to construction taking place to serve as a reference condition;
- Monthly monitoring is recommended for the duration of construction to evaluate trends;
- Biannual monitoring is recommended thereafter during the operational phase, up to the point in time when the monitoring can establish that the systems are stable;
- Fixed point photography to monitor changes and long term impacts.

9 GAPS IN KNOWLEDGE

The most critical information gap relates to the site specific sedimentary processes occurring within each estuary. Without this detailed estuary-specific sediment process understanding, predicting impacts of any structures within an estuary EFZ is difficult. Estuarine physical processes are highly dynamic requiring detailed information over long planning horizons, e.g. understanding the impacts of a 1:100 year flood.

To address this, the following detailed information is required at each estuarine system which may be affected by location of infrastructure, roads or servitudes within the EFZ. This detailed information would be required prior to the construction of the EGI, and for the actual site specific assessments.

- Estuary bathymetry of the entire system corrected to mean sea level (not just at the crossing site);
- Information on the sediment structure (i.e. sediment core samples taken to bed rock or at a minimum 20 m depth at small to medium sized systems and a depth of > 20 m at estuaries with a high Mean Annual Runoff (MAR));
- Estimates of daily sediment loads from the catchment;
- Hourly flood hydrograph of the 1:5, 1:10, 1:20, 1:50 and 1:100 year flood to determine the scouring potential at each system;
- Detailed flood and sediment modelling to determine the degree to which the estuary may scour below its current bed level during a flood (before infilling occurs again).

10 REFERENCES

Adams, J, Fernandes, M, and Riddin, T, 2018. Chapter 6: Estuarine Habitat extent and trend. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol4/A

Adams, J., Rajkaran, A. & van der Colff, D. 2016a. *Avicennia marina* (Forssk.) Vierh. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Adams, J., Rajkaran, A. & van der Colff, D. 2016b. *Bruguiera gymnorrhiza* (L.) Lam. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Adams, J., Rajkaran, A. & van der Colff, D. 2016c. *Ceriops tagal* (Perr.) C.B.Rob. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30.

Adams, J., van der Colff, D. 2016. *Zostera capensis* Setch. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Appleton CC, Forbes AT and Demetriades NT (2009). The occurrence, bionomics and potential impacts of the invasive freshwater snail *Tarebia granifera* (Lamarck, 1822) (Gastropoda: *Thiaridae*) in South Africa. *Zoologische Medelingen Leiden* 83(4):525-536.

Basson, GR, Bosman, DE & Vonkeman JK 2017. Proposed new uMfolozi River N2 Road Bridge. Hydrodynamic modelling of scour and hydrodynamic forces. *Stormwater Hydraulics*, STIAS, 10 Marais Road, Stellenbosch University.

Beck JS, A Kemp, AK Theron, P Huizinga and GR Basson (2004). Hydraulics of Estuarine Sediment Dynamics in South Africa: Implications for Estuarine Reserve Determination and the Development of Management Guidelines. WRC Report No. 1257/1/04. Pretoria, South Africa.

Boehm, A.B., Ismail, N.S., Sassoubre, L.M., Andruszkiewicz, E.A. 2017. Oceans in Peril: Grand Challenges in Applied Water Quality Research for the 21st Century. *Environmental Engineering Science* 34: 3-15.

Borja, A., Elliott, M., Snelgrove, P.V.R., Austen, M.C., Berg, T., Cochrane, S., Carstensen, J., Danovaro, R., Greenstreet, S., Heiskanen, A., Lynam, C.P., Mea, M., Newton, A., Patricio, J., Uusitalo, L., Uyarra, M.C., Wilson, C. 2017. Bridging the Gap Between Policy and Science in Assessing the Health Status of Marine Ecosystems. *Frontiers in Marine Science* 4:32.

Colloty, B.M., Adams, J.B., Bate, G.C. 2002. Classification of estuaries in the Ciskei and Transkei regions based on physical and botanical characteristics. *South African Journal of Botany* 68: 312-321.

Cooper, J.A.G. 2001. Geomorphological variability among microtidal estuaries from the wave-dominated South African coast. *Geomorphology* 40: 99-122.

Davies, B., Day, J. 1998. *Vanishing Waters*. University of Cape Town Press, Cape Town, South Africa.

De Winnaar, G. & Ross-Gillespie, V. 2018. Freshwater Ecosystems. *In* Snyman-van der Walt, L., Walsdorff, A. & Abed, R. (*Eds*.) Strategic Environmental Assessment for EGI Development. CSIR: Stellenbosch.

DEA (Department of Environmental Affairs) 2012. South African Water Quality Guidelines for coastal waters. Volume 2: Guidelines for recreational use.

DEA (Department of Environmental Affairs) 2016. Strategic Environmental Assessment for Electricity Grid Infrastructure in South Africa. CSIR Report Number: CSIR/02100/EMS/ER/2016/0006/B. Stellenbosch.

Dettinger, M.D., Diaz, H.F. 2000. Global Characteristics of Stream Flow Seasonality and Variability. *Journal of Hydrometeorology* 1: 289-310.

DWA (Department of Water Affairs). 2013. Water Resource Protection and Assessment Policy Implementation Process. Resource Directed Measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries. Version 3. Pretoria.

DWAF (Department of Water Affairs and Forestry) 1995. South African water quality guidelines for coastal waters. Volume 1. Natural Environment. Volume 3: Mariculture, Volume 4: Industrial Use. Pretoria: Department of Water Affairs.

DWAF (Department of Water Affairs and Forestry) 2008. Water Resource Protection and Assessment Policy Implementation Process. Resource Directed Measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries. Version 2. Pretoria.

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

Elliott, M. 2011. Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures –A numbered guide. *Marine Pollution Bulletin* 62: 651-655.

Emanuel, B.P., Bustamante, R.H., Branch, G.M., Eekhout, S., Odendal, F.J. 1992. A zoogeographic and functional approach to the selection of marine reserves on the west coast of South Africa. *South African Journal of Marine Science* 12: 341-354.

Froneman, A. & Van Rooyen, C. 2018. Avifauna. *In* Snyman-van der Walt, L., Walsdorff, A. & Abed, R. (*Eds*.) Strategic Environmental Assessment for EGI Development. CSIR: Stellenbosch.

Fielding, P. 2017. Draft Management Plan for the Buffels Estuary. Report prepared for the Kamiesberg Local Municipality.

Fielding, P., Massey, V., Clark, B. 2017. Draft Management Plan for the Swartlintjies Estuary. Report prepared for the Kamiesberg Local Municipality.

Gillanders BM 2005. Using elemental chemistry of fish otoliths to determine connectivity between estuarine and coastal habitats. *Estuarine, Coastal and Shelf Science* 64: 47-57.

Gillanders, B.M., Kingsford, M.J. 2002. Impact of changes in flow of freshwater on estuarine and open coastal habitats and the associated organisms. *Oceanography and Marine Biology: An Annual Review* 40: 233-309.

Gray, J.S., Elliott, M. 2009. *Ecology of Marine Sediments. From Science to Management*, 2nd Edn. Oxford University Press, New York. 256 pp.

Griffiths, M.H., 1997. Management of South African dusky kob *Argyrosomus japonicus* (Sciaenidae) based on per-recruit models. *South African Journal of Marine Science*, 18: 213-228.

Harrison, T. D. 2002. Preliminary assessment of the biogeography of fishes in South African estuaries. *Marine and Freshwater Research* 53: 479-490.

IUCN 2012. 2001 IUCN Red List Categories and Criteria version 3.1. Second edition. *International Union for Conservation of Nature*, Gland, Switzerland. 32 pp.

IUCN 2018. The IUCN Red List of Threatened Species. Version 2018-1. <http://www.iucnredlist.org>. Downloaded on 05 July 2018.

James, C.S. and King, J.K. 2010. Ecohydraulics for South African Rivers: A review and guide. Pretoria: Water Research Commission, WRC Report No. TT 453/10.

Jerling, HR (2005) Zooplankton community changes in Nhlabane estuary, South Africa, induced by man-made structures and drought, African Journal of Aquatic Science, 30:1, 29-35, DOI: 10.2989/16085910509503831

Jezewski, W.A., Pyke, P.D., Roberts, C.P.R. 1984. Estuarine and Lake Freshwater Requirements. Department of Water Affairs and Forestry, Pretoria, South Africa. Technical Report No TR123.

Jones, N.E., Schmidt, B.J., Melles, S.J. 2014. Characteristics and distribution of natural flow regimes in Canada: a habitat template approach. *Canadian Journal of Fisheries and Aquatic Science* 71: 1616-1624.

Korpinen, S., Andersen, J. 2016. A global review of cumulative pressure and impact assessments in marine environments. *Frontier Marine Science* 3:153.

Lamberth, S.J., Turpie, J.K. 2003. The role of estuaries in South African fisheries: economic importance and management implications. *African Journal of Marine Science* 25: 131-157.

Lynch, S.D. 2004. Development of a raster database of annual, monthly and daily rainfall for Southern Africa. WRC Report 1156/1/04, Water Research Commission, Pretoria, South Africa, pp 78.

Mirimin, L., Macey, B., Kerwath, S., Lamberth, S., Bester-van der Merwe, A., Cowley, P., Bloomer, P. and Roodt-Wilding, R., 2016. Genetic analyses reveal declining trends and low effective population size in an overfished South African sciaenid species, the dusky kob (*Argyrosomus japonicus*). *Marine and Freshwater Research* 67(2): 266-276.

Poff, N.L., Ward, J.V. 1989. Implications of Streamflow Variability and Predictability for Lotic Community Structure: A Regional Analysis of Streamflow Patterns. *Canadian Journal of Fisheries and Aquatic Sciences* 46: 1805-1818.

Rajkaran, A., Adams, J. & van der Colff, D. 2016. *Rhizophora mucronata* Lam. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Rajkaran, A., Adams, J. & van der Colff, D. 2017. *Lumnitzera racemosa* Willd. var. *racemosa*. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Ray GC 2005. Connectivities of estuarine fishes to the coastal realm. *Estuarine, Coastal and Shelf Science* 64: 18-32.

Reddering, J.S.V., Rust, I.C. 1990. Historical changes and sedimentary characteristics of southern African estuaries. *South African Journal of Science* 86: 425-428.

SANBI. 2017. *Xylocarpus granatum* J.König. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Schulze, R.E., Lynch, S.D. 2007. Annual Precipitation. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06, Section 6.2. Water Research Commission, Pretoria, RSA.

Schulze, R.E., Maharaj, M. 2007. Rainfall Seasonality. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06, Section 6.5. Water Research Commission, Pretoria, RSA.

Taljaard, S., Snow, G., Gama, P., Van Niekerk, L. 2009. Verification of a conceptual model of water quality for small temporarily open/closed estuaries: East Kleinemonde Estuary, South Africa. *Marine and Freshwater Research* 60: 234-245.

Turpie, J.K and Clark B 2009. Development of a Conservation Plan for temperate South African estuaries on the basis of biodiversity importance, ecosystem health and economic costs and benefits. CAPE programme.

Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S., Van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA* 28: 191-206.

Turpie, J.K., Wilson, G. and van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

Turpie, JK, Taljaard, S, Van Niekerk, L, Adams, J, Wooldridge, T, Cyrus, D, Clark, B & 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.

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

Van Niekerk L, Taljaard S, Ramjukadh C-L Adams JB, Lamberth SJ, Weerts SP, Petersen C, Audouin M, Maherry A. 2017. A multi-sector Resource Planning Platform for South Africa's estuaries. Water Research Commission Report No K5/2464. South Africa.

Van Niekerk, L, Adams JB, Bate GC, Forbes N, Forbes A, Huizinga P, Lamberth SJ, MacKay F, Petersen C, Taljaard S, Weerts S, Whitfield AK and Wooldridge TH. 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, JB Lamberth, SJ, MacKay, F, Taljaard, S, Turpie, JK, Ramhukad, C-L, South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol4/A. Draft Report.

Van Niekerk, L., Taljaard, S., Adams, J. B., Fundidi, D., Huizinga, P., Lamberth, S. J., Mallory, S., Snow, G. C., Turpie, J. K., Whitfield, A. K. and Wooldridge, T. H. 2015. Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa. WRC Report No K5/2187.

Vivier, L and Cyrus, D.P. 1999. Dune Mining and the Nhlabane Estuary, South Africa: the Effect of a Dredger Crossing on the Zoobenthic Community, *Marine Pollution Bulletin*, Volume 39, Issues 1–12.

Von Hippel, D.F. and Williams, J.H. (2003). Environmental Issues for Regional Power Systems in Northeast Asia. In: *Third Workshop on Northeast Asia Power Grid Interconnections*. [online] Vladivostok: Russian Federation. Available at: http://nautilus.org/archives/energy/grid/2003Workshop/ [Accessed Mar. 2018].

von Staden, L. 2016. *Barringtonia racemosa* (L.) Roxb. National Assessment: Red List of South African Plants version 2017.1. Accessed on 2018/05/30

Vorwerk, P.D., Froneman, P.W., Paterson, A.W., Strydom, N.A., Whitfield, A.K., 2008. Biological responses to a resumption in river flow in a fresh water deprived, permanently open southern African estuary. *Water SA* 34: 597-604.

Whitfield, A.K. 1998. Biology and ecology of fishes in Southern African estuaries. *Icthyological Monograph of the J.L.B. Smith Institute of Ichthyology* 2: 1-223.

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

Whitfield, A., Elliott, M. 2011. Ecosystem and Biotic Classifications of Estuaries and Coasts. In: Wolanski E and McLusky DS (eds.) *Treatise on Estuarine and Coastal Science*, Vol 1. Academic Press, Waltham, pp. 99-124.

Appendix A : Summary of important environmental and socio-economic attributes of estuaries in each of the Corridors

Table A1: Summary of important environmental and socio-economic attributes of estuaries in the proposed Expanded EGI corridors.

Estuary	Distance in km from corridor coastal boundary							Reference Mean Annual runoff (m3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest	
Western Corridor																			
Orange	x	x						10833.01	x	Very Important	SA/CAPE	D	5	144	602	1	0	0	3633
Buffels	x							9.33		Ave Importance		D	1	0	0.33	0	0	0	9.99
Swartlientjies	x							0.21		Ave Importance		B	1	0	0	0	0	0	0
Spoeg	x							1.07	x	Ave Importance	SA	A/B	2	0	31.3	0	0	0	32.21
Groen	x							0.46	x	Ave Importance	SA	B	1	0	12	0	0	0	31
Sout	x	x						1.50		Ave Importance		E	1	0	140.2	0	0	0	271.12
Olifants	x	x	x	x				1070.10	x	Very Important	SA/CAPE	C	5	91.9	849.1	47.7 4	0.0	0	1353.6 8

Estuary	Distance in km from corridor coastal boundary							Reference Mean Annual runoff (m3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest	
Eastern Corridor																			
Durban Bay	x	x						36.33	x	Very Important	SA	E	5	0.0	0.0	8	16.0	5	1148
Mgeni	x	x	x					671.30	x	Important	SA	E	3	8.4	0.0	1	31.7	0.5	107.79
Mhlanga	x							13.34		Important	SA	D	1	0.0	0.0	0	0.0	0.2	82.78
Mdloti	x							100.19	x	Important		D	1	0.0	0.0	0	0.0	7.8	58.1
Tongati	x							70.79	x	Important		D	1	0.0	0.0	0	0.0	3.4	37.3
Mhlali	x							56.26	x	Important	SA	C/D	1	0.0	0.0	0	0.0	7	42
Mvoti	x							374.66	x	Ave Importance	SA	D	1	0.0	0.0	0	0.0	2	111
Mdlotane	x							6.04		Important	SA	B	1	0.0	0.0	0.71	0.0	12.33	25.42
Nonoti	x							36.24		Ave Importance		C	1	0.0	0.0	2.5	0.0	1	27
Zinkwasi	x							14.49		Important	SA	B/C	5	0.0	0.0	0	0.0	11.28	71.16
Tugela/Thukela	x	x	x					3753.60	x	Important	KZN priority	C	3	0.0	0.0	0	0.0	0.27	133.32
Matigulu/Nyoni	x	x						192.27	x	Important	SA	B	5	0.0	0.0	0.5	0.0	2	127
Siyaya	x							6.50		Ave Importance	SA	F	1	0.6	0.0	0.08	0.0	3.72	9.52
Mlalazi	x	x						164.31	x	Very Important	SA	B	5	0.0	39.3	0.001	60.7	3.46	238.771
Mhlathuze	x	x						645.00	x	Very Important	SA	C/D	5	60.0	0.0	28.5	652.1	0	1714.6
Richards Bay	x	x	x					0.00		Important	SA	D	5	52.0	0.0	0	267.	16	2044

Estuary	Distance in km from corridor coastal boundary							Reference Mean Annual runoff (m3x106)	Flood risk	Biodiversity Importance rating	Conservation Priority set (NBA 2012 Biodiversity Plan)	Estuary health (A=Natural, F=Severely degraded)	Important Fish Nursery (5=High, 1+Low)	Important Estuarine habitat (ha)					Total habitat area (ha)
	0-5	5-10	10-15	15-20	20-25	25-30	30-35							Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Mangroves	Swamp forest	
																	0		
Nhlabane (Present)	x	x						29.00		Important		D/E	3	0.0	0.0	1.1	0.0	0.3	14.4
Mfolozi	x	x	x					885.00	x	Very Important	SA	D	5	0.0	0.0	0	78.2	1683.1	3458.5
St Lucia	x	x	x	x	x	x		417.89	x	Very Important	SA	D	5	414.7	0.0	431.5	209.5	17.4	40832.8
Mgobezeleni	x							0.00		Ave Importance	SA	B	1	0.0	0.0	0	4.5	4	15.3
Kosi	x	x						0.00		Very Important	SA	A/B	5	58.0	229.0	652	71.0	869	5396

1