Great Kei (<15 km), Thukela (<15 km), Mhlathuze (<15 km), Mfolozi (<15 km), Coega (<10 km), Kariega, (<10 km), Kleinemond Wes (<10 km), Mgwalana (<10 km), Bira (<10 km), Nahoon (<10 km), Mbashe (<10 km), Mtamvuna (<10 km), Mzimkulu (<10 km), Matigulu/Nyoni (<10 km), Mlalazi (<10 km), Richards Bay(<10 km) and Nhlabane (<10 km).

Seventy-nine estuaries in this corridor are in an excellent or good condition (Categories A to B). These systems vary from very small to large permanently open systems (refer to Appendix A for more detail). They are highly sensitive to change as they will degrade from their near pristine state relatively easily.

A total of 14 estuaries in this corridor are of very high biodiversity importance, ranking with the top estuaries in South Africa, namely Kariega, Kowie, Great Fish, Mpekweni, Mtati, Mgwalana, Keiskamma, Great Kei, Mbashe, Mngazana, Mlalazi, Mhlathuze, Mfolozi and St Lucia estuaries (Turpie et al., 2002; Turpie and Clark, 2009). In addition, 37 systems are also rated as important from a biodiversity perspective, namely Sundays, Bushmans, Kasuka, Riet, Kleinemond Wes, Kleinemond Oos, Bira, Gqutywa, Tyolomnqa, Nahoon, Qinira, Gqunube, Kwelera, Cefane, Qolora, Nxaxo/Ngqusi, Qora, Nqabara/Nqabarana, Xora, Mtata, Mzimvubu, Mzamba, Mtamvuna, Mzimkulu, Fafa, Mkomazi, Mgeni, Mhlanga, Mdloti, Tongati, Mhlali, Mdlotane, Zinkwasi, Thukela, Matigulu/Nyoni, Richards Bay, Nhlabane estuaries.

Sixty-one estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). These include Sundays, Bushmans, Kariega, Great Fish, Mgwalana, Bira, Gqutywa, Keiskamma, Ngqinisa, Ncera, Gqunube, Kwelera, Kwenxura, Quko, Great Kei, Ncizele, Nxaxo/Ngqusi, Ngqwara, Qora, Ngadla, Nqabara/Nqabarana, Mbashe, Xora, Mtata, Mngazana, Mzimvubu, Sikombe, Kwanyana, Mtolane, Mnyameni, Mpahlanyana, Mpahlane, Mzamba, Mtentwana, Mtamvuna, Mpenjati, Zotsha, Mzimkulu, Damba, Koshwana, Intshambili, Mhlabatshane, Mfazazana, Kwa-Makosi, Mkomazi, Umgababa, Msimbazi, Lovu, Mgeni, Mhlanga, Mhlali, Mvoti, Mdlotane, Zinkwasi, Thukela, Matigulu/Nyoni, Siyaya, Mlalazi, Mhlathuze, Richards Bay, Mfolozi/St Lucia estuaries. In addition, 53 estuaries are identified as 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 the Sundays, Bushmans, Kariega, Kasuka,Kowie, Kleinemond Wes, Kleinemond Oos, Great Fish, Mpekweni, Mtati, Mgwalana, Bira, Gqutywa, Keiskamma, Kiwane, Tyolomnqa, Gxulu, Buffalo, Nahoon, Gunube, Kwelera, Cefane, Kwenxura, Quko, Morgan, Great Kei, Kobonqaba, Nxaxo/Ngqusi, Qora, Nqabara/Nqabarana, Mbashe, Xora, Mtata, Mngazana, Mzimvubu, Mzamba, Mtamvuna, Mzimkulu, Mhlabatshane, Mkomazi, Umgababa, Msimbazi, Lovu, Mgeni, Zinkwasi, Thukela, Matigulu/Nyoni, Mlalazi, Mhlathuze, Richards Bay, Nhlabane, Mfolozi and St Lucia estuaries.

From a habitat diversity and abundance perspective 96 estuaries are considered important as they support sensitive estuarine habitats such as mangroves, swamp forest or saltmarsh (intertidal and supratidal). These included Coega, Sundays, Boknes, Bushmans, Kariega, Kowie, Riet, Kleinemond Wes, Kleinemond Oos, Great Fish, Mpekweni, Mtati, Mgwalana, Bira, Gqutywa, Mtana, Keiskamma, Tyolomnqa, Ncera, Gxulu, Goda, Nahoon, Qinira, Gqunube, Kwelera, Bulura, Cintsa, Cefane, Kwenxura, Nyara, Quko, Morgan, Great Kei, Gxara, Kobonqaba, Nxaxo/Ngqusi, Ngqwara, Nqabara/Nqabarana, Mbashe, Xora, Mtata, Mngazana, Mzimvubu, Sikombe, Mnyameni, Mzamba, Mtamvuna, Sandlundlu, Tongazi, Kandandhlovu, Mpenjati, Umhlangankulu, Kaba, Mbizana, Bilanhlolo, Kongweni, Zotsha, Mbango, Mzimkulu, Mtentweni, Mhlangamkulu, Damba, Koshwana, Intshambili, Mhlabatshane, Mhlungwa, Mfazazana, Kwa-Makosi, Mnamfu, Fafa, Sezela, Mzinto, Mpambanyoni, Mkomazi, Umgababa, Lovu, Little Manzimtoti, Manzimtoti, Sipingo, Mgeni, Mhlanga, Mdloti, Tongati, Mhlali, Mdlotane, Nonoti, Zinkwasi, Thukela, Matigulu/Nyoni, Siyaya, Mlalazi, Mhlathuze, Richards Bay, Nhlabane, Mfolozi and St Lucia estuaries.

4.6.5 Phase 4 corridor

Three estuaries are situated within the Phase 4 corridor, with a combined estuarine habitat area of about 46 200 ha (Figure 11). Note there is overlap with St Lucia lakes system in Phase 7 corridor. Two of the systems in the corridor are very large, with St Lucia extending about 30 km and Kosi extending about 10 km in land. The Mgobezeleni extends less than 10 km inland.

The Mgobezeleni and Kosi estuaries are in an excellent to good condition (Categories A to B). These systems are highly sensitive to change as they will degrade from their near pristine state relatively easily. The St Lucia and Kosi estuarine lake systems are of very high biodiversity importance (Turpie et al., 2002; Turpie and Clark, 2009). All three estuaries in the corridor, St Lucia, Mgobezeleni and Kosi, are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). St Lucia and Kosi 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 St Lucia, Mgobezeleni and Kosi estuaries are all considered important as they support sensitive estuarine habitats such as mangroves, swamp forest and saltmarsh.

4.7 Identification of feature sensitivity criteria

A generic suite of environmental and socio-economic sensitivity indicators, which could be mapped using existing knowledge and datasets, and which were suitable for assessing potential risks associated with the type of development assessed here (gas pipeline crossing) were selected (Table 3). 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 (very high, high, medium, low, Table 3). This allowed for the translation of base maps into sensitivity maps for each of the study areas.

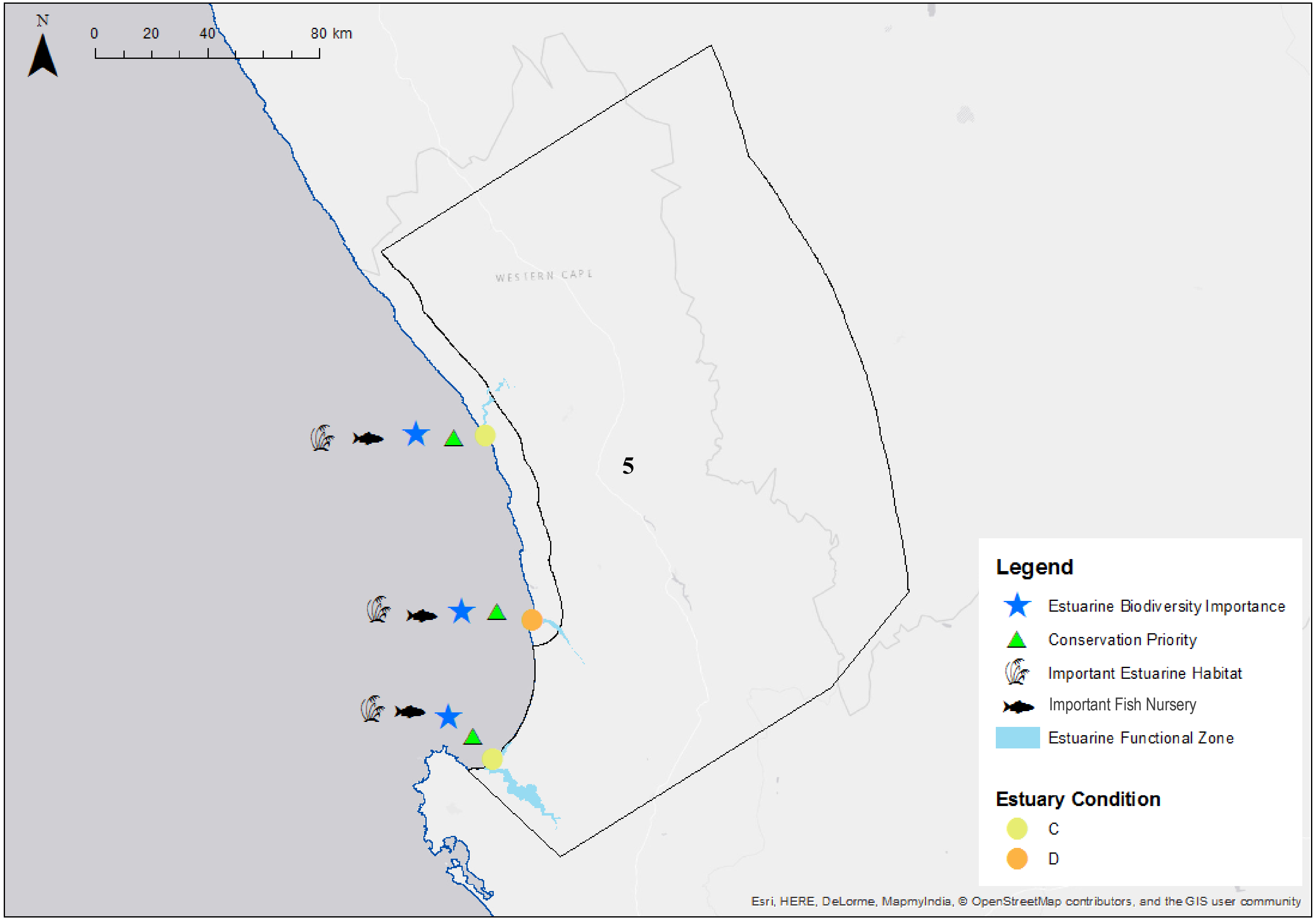

Figure 6: Estuarine feature map for the proposed Phase 5 Gas Pipeline corridor.

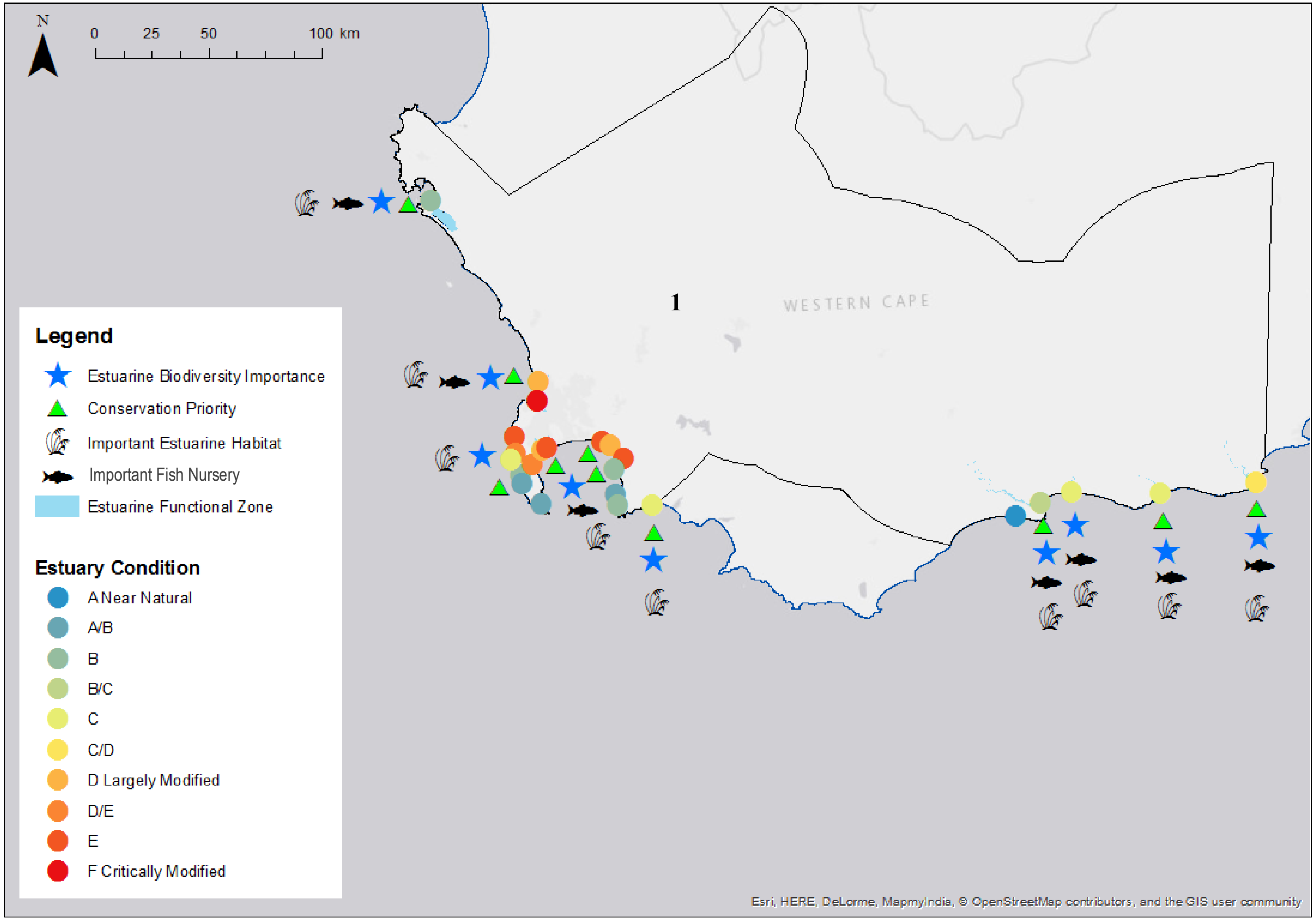

Figure 7: Estuarine feature map for the proposed Phase 1 Gas Pipeline corridor.

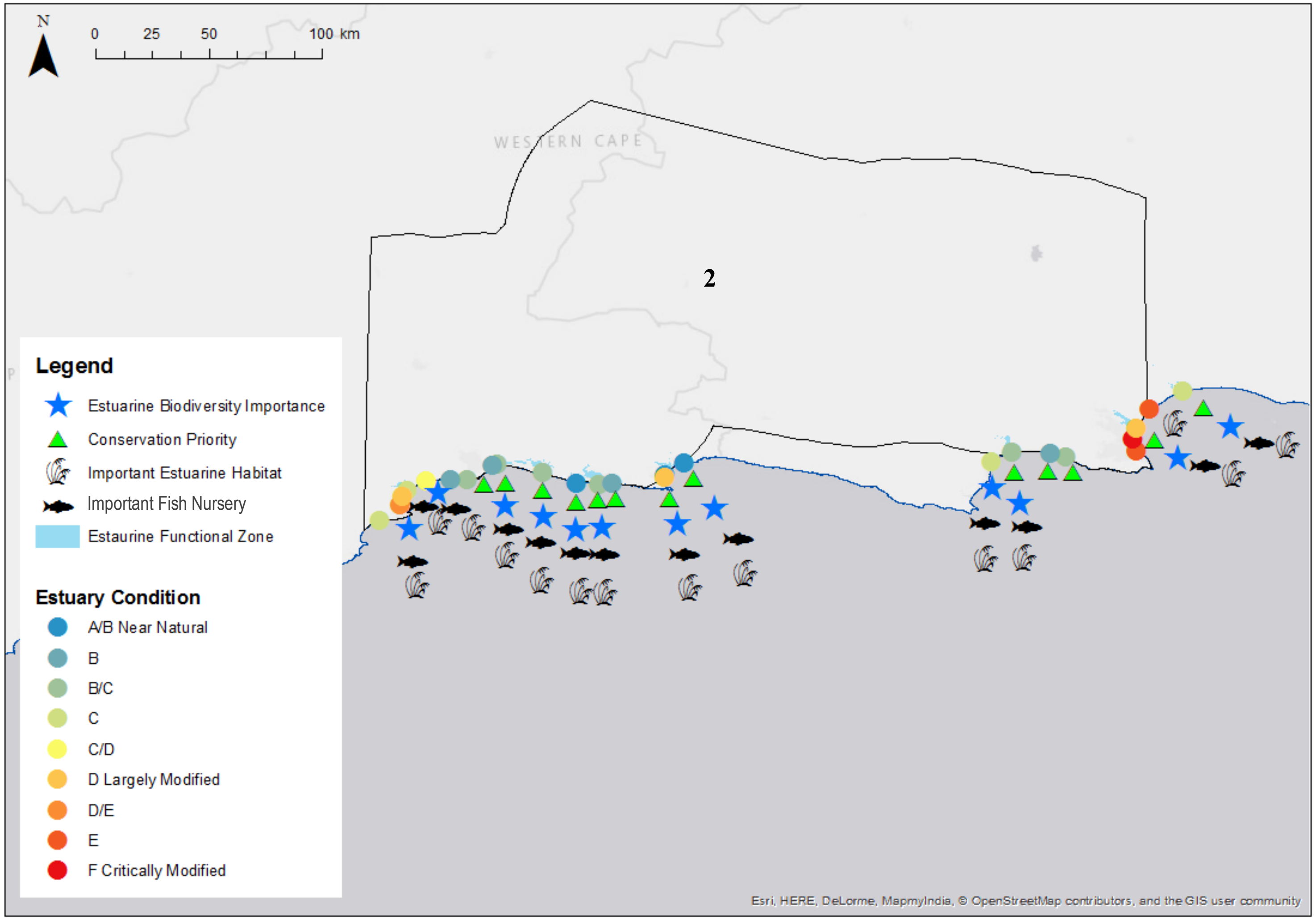

Figure 8: Estuarine feature map for the proposed Phase 2 Gas Pipeline corridor.

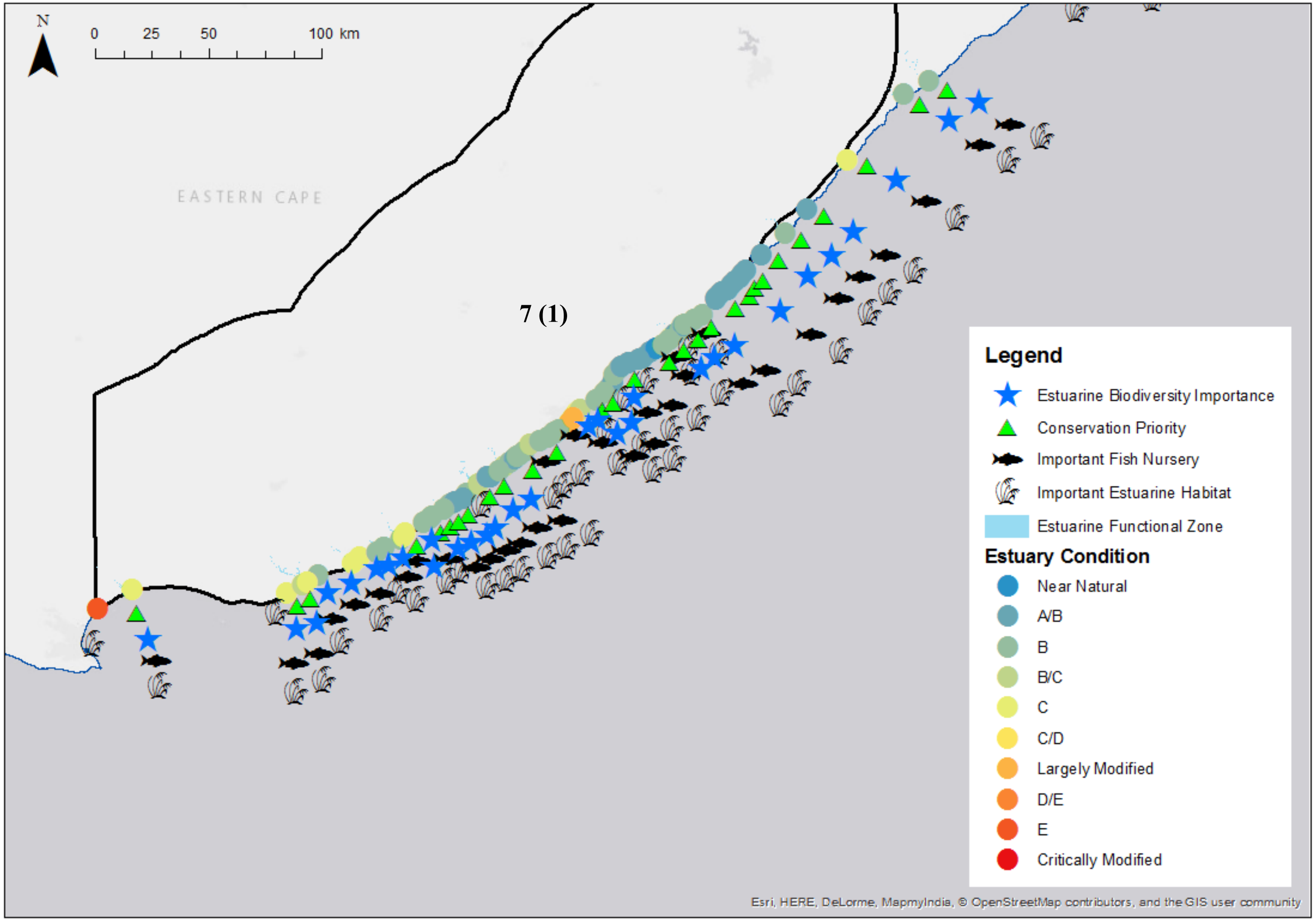

Figure 9: Estuarine feature map for the proposed Phase 7 Gas Pipeline corridor (Part 1).

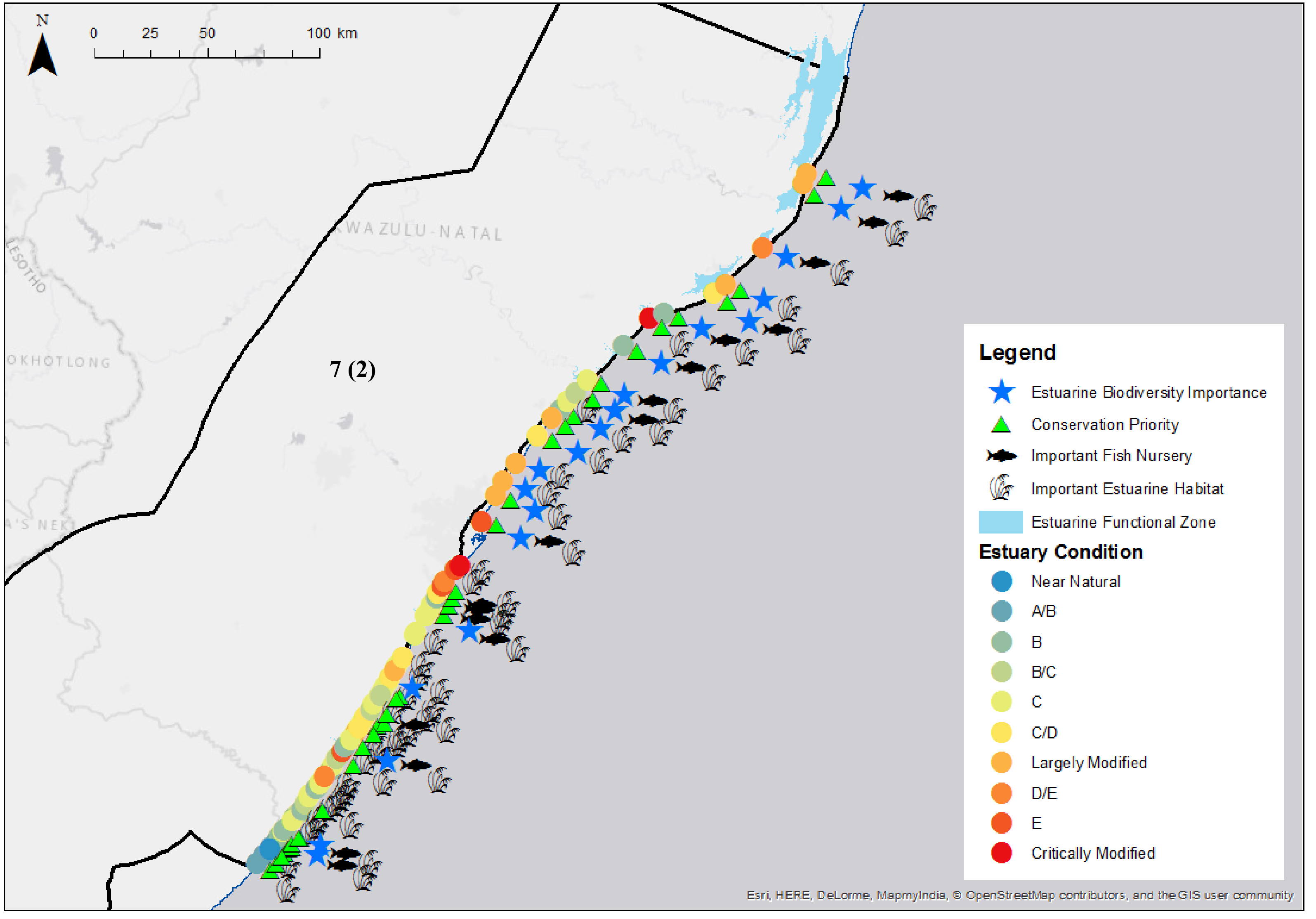

Figure 10: Estuarine feature map for the proposed Phase 7 Gas Pipeline corridor (Part 2).

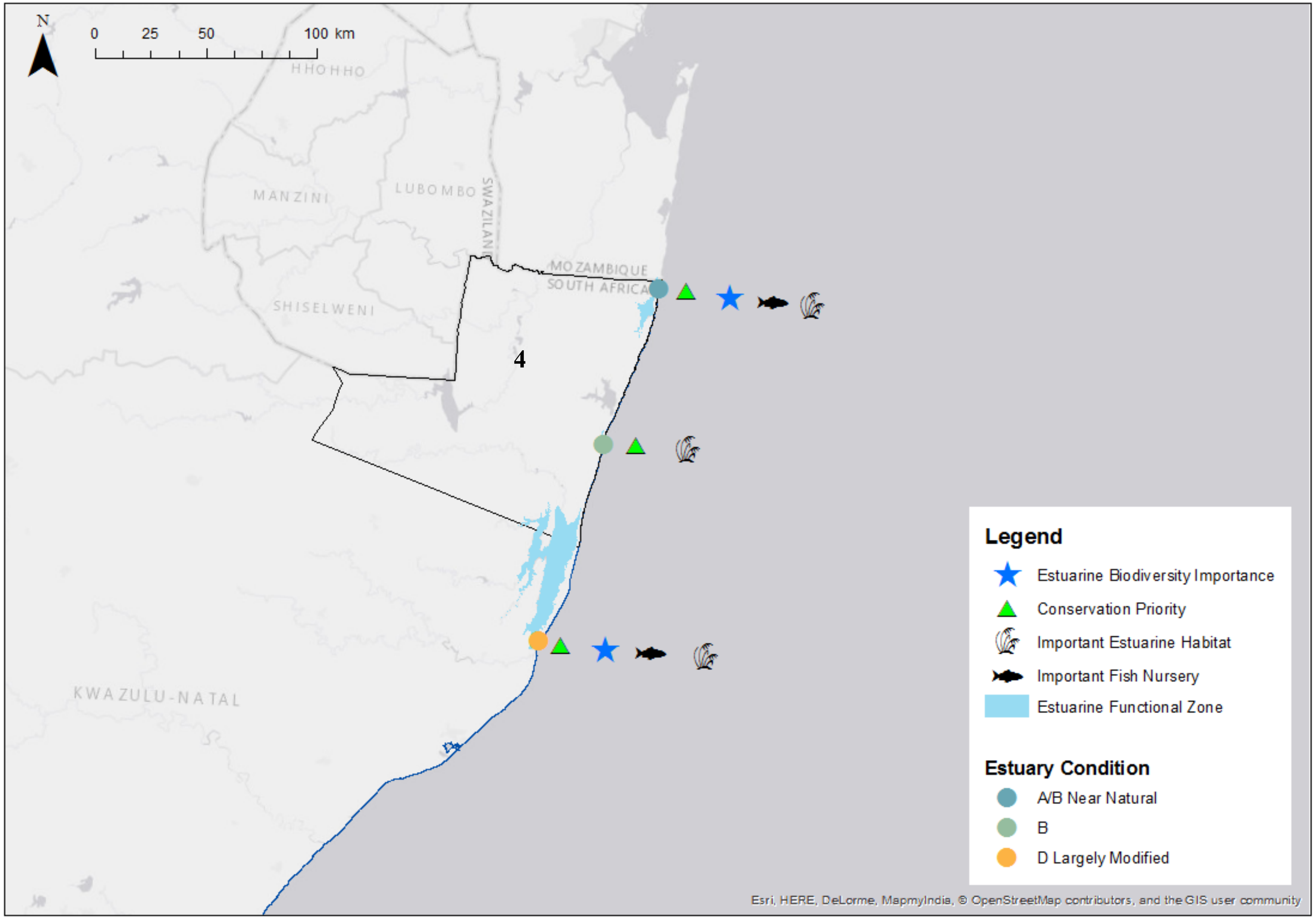

Figure 11: Estuarine feature map for the proposed Phase 4 Gas Pipeline corridor.

Table 3: Selected ecological sensitivity indicators and associated sensitivity ratings (applicable to all proposed Gas Pipeline corridors)

Sensitivity Indicator	Brief description/data source	Sensitivity Class	Zone of interest
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 B).	Very High	EFZ
Important nurseries	Estuaries that are critically important nursery areas for fish and invertebrates 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 A or B health category are more sensitive to development (likely to degrade in overall condition) (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 fish species that are Endangered or Critically Endangered)	Very High	EFZ
Other estuaries	All estuarine habitats are highly sensitive to disturbance in the EFZ.	High	EFZ
Coastal rivers, wetlands and seeps above or adjacent to estuaries	The coastal rivers, wetlands and seeps adjacent or just upstream of estuaries that directly 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 upstream of estuaries that indirectly influence the quality and quantity of freshwater and sediments entering estuaries.	Medium	5 - 15 km buffer around EFZ
Terrestrial environment	Terrestrial environment that is not linked to aquatic processes that directly or indirectly influence estuaries.	Low	15 km or more from EFZ

4.8 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 3, 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 (and dependencies) on wider floodplain and riverine habitats, and because habitat impacts in estuaries accumulate over temporal and spatial scales, estuaries can thus not be assessed as discrete units as done in the case of terrestrial systems. For this assessment the EFZ of each estuary within the proposed gas pipeline corridor were 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 allows 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 12 to Figure 17.

4.8.1 Phase 5 corridor

While there are only three estuaries in this corridor they are very large systems of high biodiversity importance that stretch as far as 25 km into the corridor (see Figure 12). These areas are of Very High sensitivity to infrastructure development. The coastal rivers, wetlands and seeps adjacent or just upstream the estuaries, as 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 delivered to these estuaries. The coastal rivers, wetlands and seeps adjacent or above the estuaries, as demarcated by the 5 to 15 km buffer around the EFZ, are zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

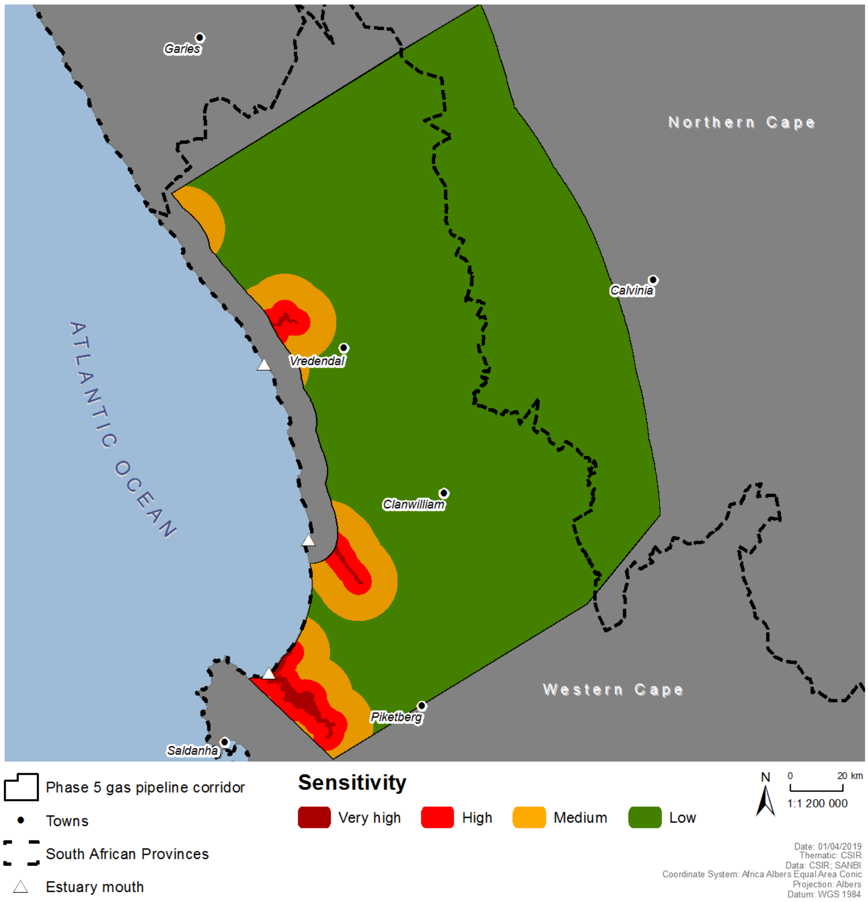

Figure 12: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 5 Gas Pipeline corridor.

4.8.2 Phase 1 corridor

A total of 25 estuaries are located in the Phase 1 corridor, many of high biodiversity importance (Figure 13). The larger systems (the Breede and Gourits estuaries) stretch more than 25 km into the corridor. These areas are of Very High sensitivity to infrastructure development. Rivers, wetlands and coastal seeps adjacent or just above the estuaries, within a 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. These areas also provide important habitat for species, such as eels, that occur both in estuaries and freshwater aquatic ecosystems. The coastal rivers, wetlands and seeps adjacent or above the estuaries, as demarcated in a 5 to 15 km buffer around the EFZ, are zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

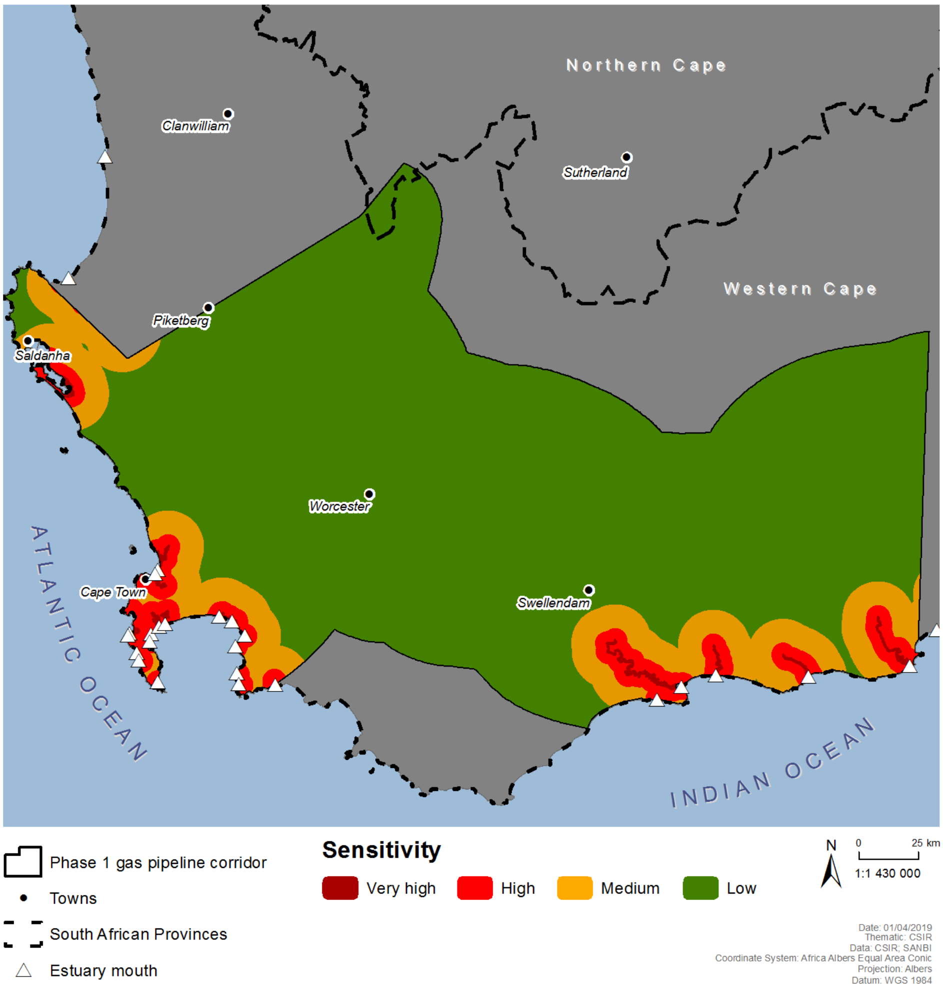

Figure 13: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 1 Gas Pipeline corridor.

4.8.3 Phase 2 corridor

There are 26 estuaries in this corridor, a significant number of which are of High biodiversity importance and which stretch as much as 25 km into the corridor, i.e. Sundays Estuary (Figure 14). These areas are of Very High sensitivity to infrastructure development. Coastal seeps, wetlands and rivers adjacent or just above the estuaries, within a 5 km buffer around the EFZ, are deemed zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. The coastal seeps, wetlands and rivers adjacent or above the estuaries, within the 5 to 15 km buffer around the EFZ, are zones of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

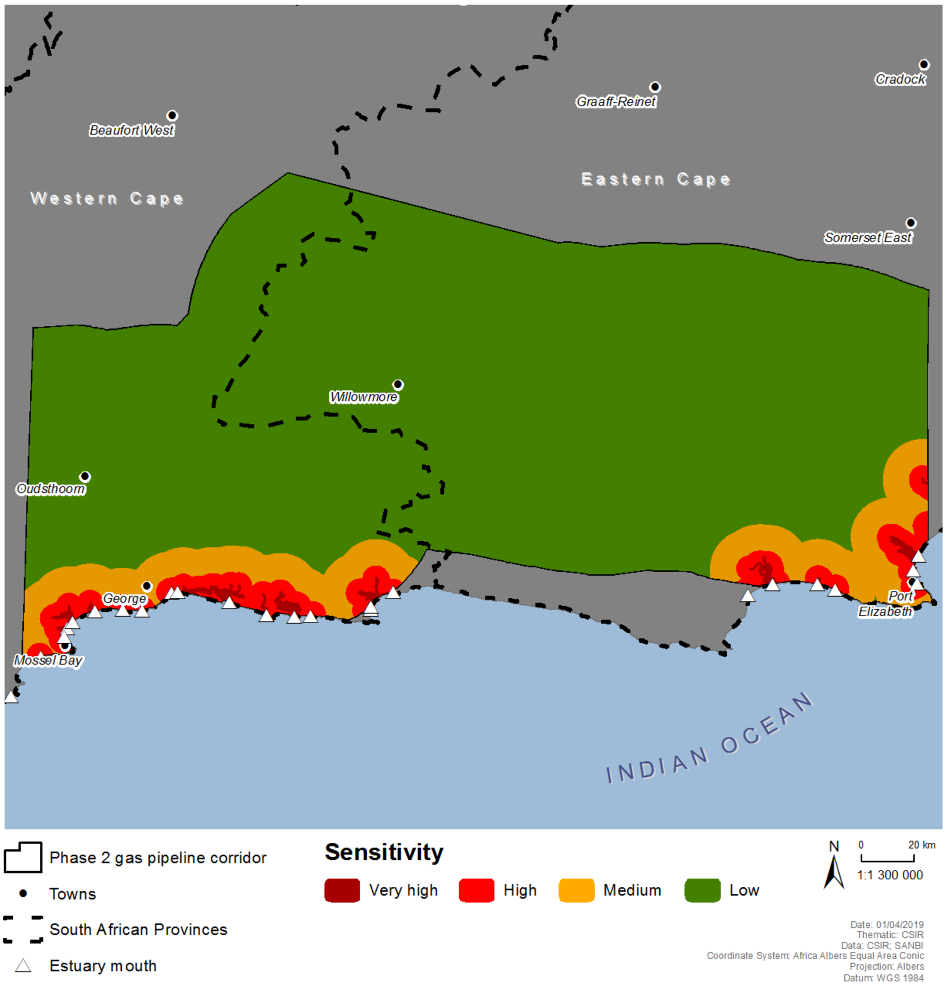

Figure 14: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 2 Gas Pipeline corridor.

4.8.4 Phase 7 corridor

While there are a high number of estuaries in the Phase 7 corridor, most of them are relatively small and do not penetrate far inland. Exceptions are the Sundays and St Lucia estuaries (Figure 15 and Figure 16). These areas are demarcated as of very high sensitivity to infrastructure development. Rivers, wetlands and coastal seeps adjacent or just above the estuaries, within 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. Disturbance of their physical processes will impact on the downstream estuary health. Due to the high number of estuaries in close proximity to each other the entire coastal zone in this area is of either very high- or high sensitivity. The inflowing rivers, wetlands and coastal seeps adjacent or above the estuaries, within the 5 to 15 km buffer around the EFZs, are of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

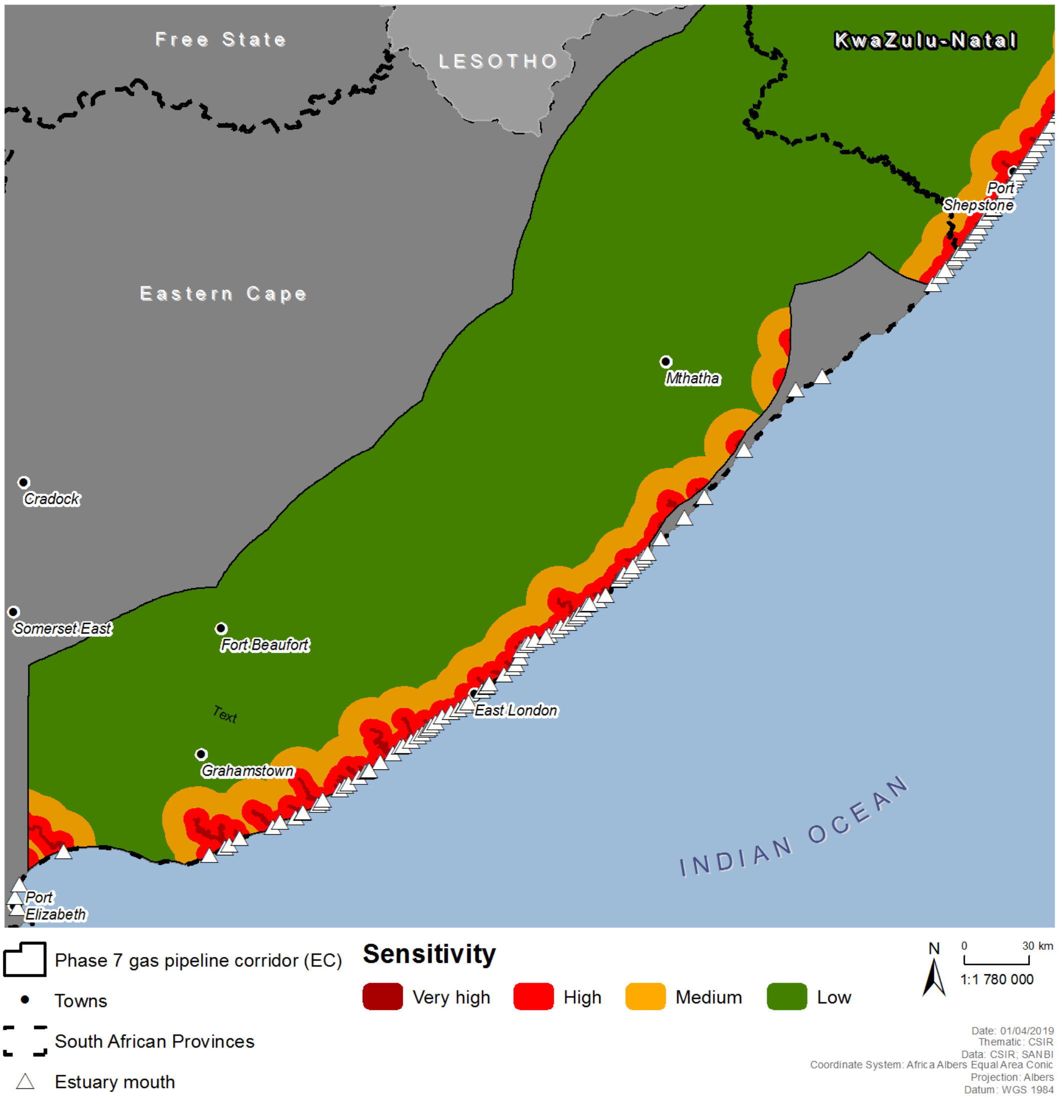

Figure 15: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 7 Gas Pipeline corridor (Eastern Cape).

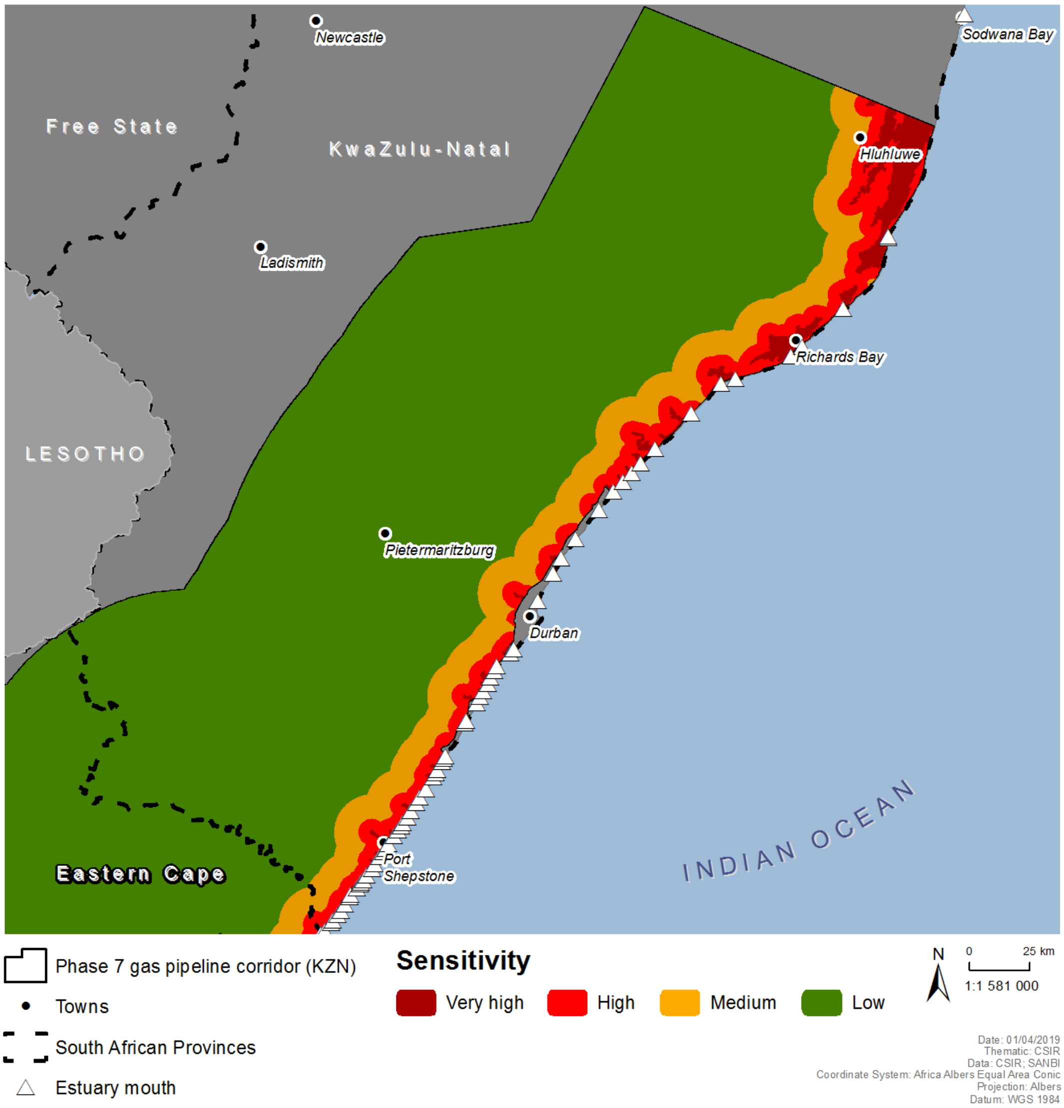

Figure 16: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 7 Gas Pipeline corridor (KwaZulu-Natal).

4.8.5 Phase 4 corridor

While there are only three estuaries in this corridor, these include the St Lucia and Kosi estuarine lake systems, which are very large and of high biodiversity importance. These areas are of very high sensitivity to infrastructure development (Figure 17). Rivers, wetlands and coastal seeps adjacent or just above the estuaries, within the 5 km buffer around the EFZs, are zones of high sensitivity as they directly influence the quality and quantity of freshwater and sediments entering estuaries. Disturbance of their physical processes will impact the estuaries downstream. Rivers, wetlands and coastal seeps adjacent or above the estuaries, in the 5 to 15 km buffer around the EFZs, are of medium sensitivity as they indirectly influence the quality and quantity of freshwater and sediments entering estuaries.

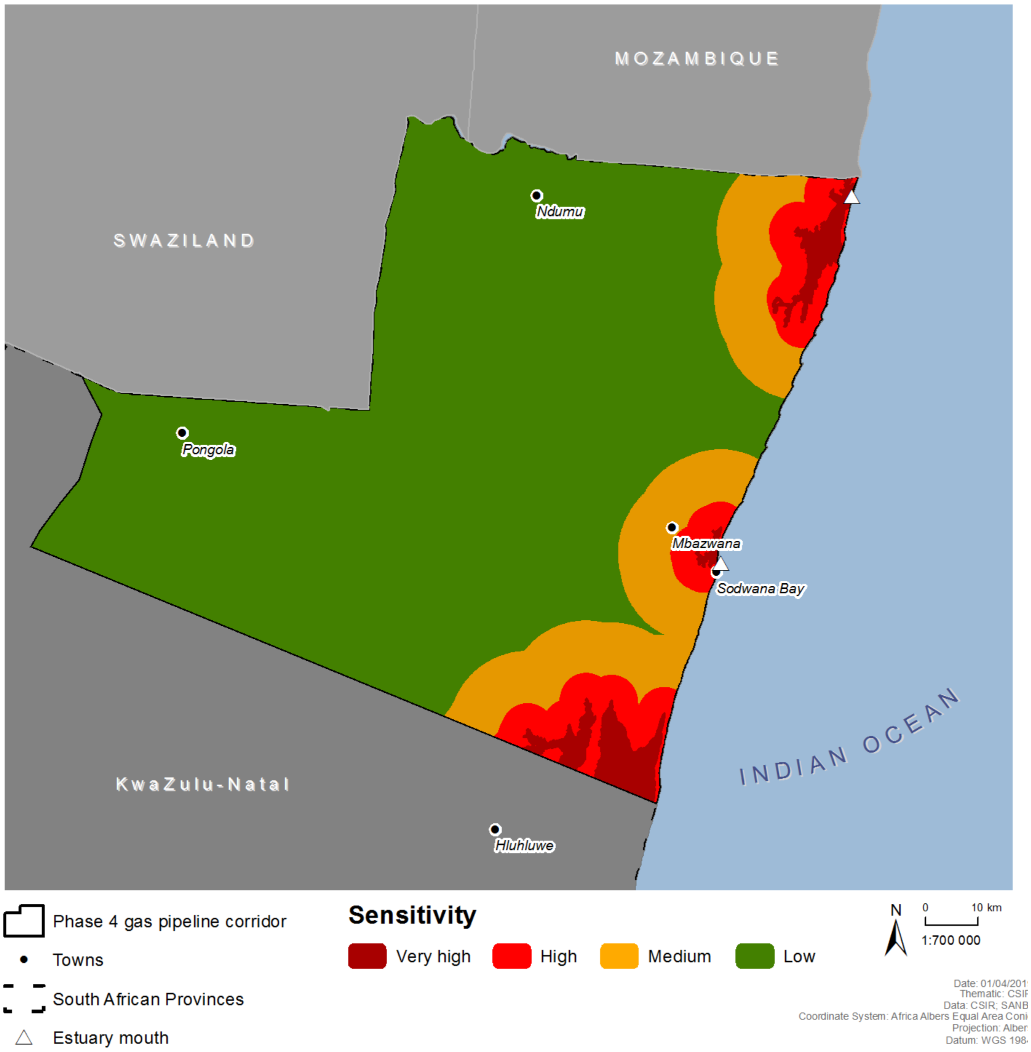

Figure 17: Sensitivity map for the estuaries, EFZ and associated features in the proposed Phase 4 Gas Pipeline corridor.

5 KEY POTENTIAL IMPACTS AND THEIR MITIGATION

Expanding production of natural gas and oil is driving demand for new or improved pipelines globally. The potential for these to negatively impact aquatic systems has been highlighted (Reid and Anderson, 1998; Lévesque and Dubé, 2007; Castro et al., 2015). These linear transportation systems cut across landscapes, intersecting a wide variety of sensitive aquatic habitats, including estuaries, with resultant environmental impacts (Chen and Gao, 2006; Yu et al., 2010). The construction of pipelines primarily affects physical and chemical characteristics of aquatic ecosystems, with knock-on detrimental effects on the associated biota such as invertebrates, fish and birds (Reid and Anderson, 1999; Chen and Gao, 2006; Lévesque and Dubé, 2007; Yu et al., 2010; Castro et al., 2015).

Impacts associated with gas pipeline development range from those that are obvious (e.g. excavation of trenches for pipelines and maintenance of vegetation within pipeline servitudes) to those that are more subtle and which occur over longer timeframes (e.g. disruption of estuarine channel dynamics, vegetation changes from continued servitude maintenance, and habitat fragmentation).

Major activities that may result in impacts on the estuarine environment include the **development of access roads to enable** construction, as well as permanent servitudes for ongoing maintenance during the operational phase. A variety of impacts ensue, including:

- Direct loss of estuarine vegetation (and associated riparian buffers), including potentially sensitive/important habitat supporting species of conservation concern.
- Fragmentation of estuarine hydrodynamic and sedimentary processes, resulting in an indirect loss of ecological processes such as species movement, dispersal and migrations, loss of habitat connectivity, increased edge effects and disturbance, and establishment of invasive alien plants (IAPs).
- Stormwater runoff causing increased flows in the receiving aquatic (estuarine and coastal river) environments, particularly in relation to runoff discharge points, which in turn can result in a number of impacts such as bank erosion and collapse, scouring and channel incision, headcut erosion, desiccation of wetland/riparian soils and vegetation, increased turbidity, sedimentation and smothering of benthos. The combined effects negatively affect the ecological integrity and ability of the aquatic ecosystems to function properly.
- Pollution and contamination of aquatic environments from foreign materials (e.g. fuels/hydrocarbons, cement, and building materials) being dumped and/or carried into aquatic environments.
- Compaction of soils and creation of preferential flow paths within and adjacent to wetland and river habitats.
- Direct loss of flora and fauna that inhabit wetland/river ecosystems and adjacent buffer/fringe habitats (including species of conservation concern or valuable as resources, harvested locally or further afield).

Stripping and removal of vegetation and topsoil to prepare the ROW for pipeline construction will result in similar impacts to the development of access roads, but will differ in terms of extent, duration and intensity. Typical ROWs are between 30 to 50 metres wide, translating to roughly one hectare for every 200 to 300 metres of pipeline constructed. Thus, the total area of vegetation that is removed will be based on the total length of pipeline and its servitude (which may be kept clear of deep rooted vegetation – shallow rooted plants such as short grasses are allowed to grow within the servitude) that passes through estuarine and associated coastal freshwater habitats.

Trenching and excavation to bury pipelines including the excavations for pigging stations, which will be positioned every 250 to 500 km. Trenching and excavations have the potential to cause mortality of fauna that inhabit aquatic habitats, in particular fossorial fauna (i.e. animals adapted to living in the sediment) but also less mobile fauna that are moving across the excavation path.

Construction of permanent and hard structures, such as gas pipelines (and possibly pigging stations) in the EFZ will markedly impact on long-term estuarine sediment dynamics. Estuary channels are highly dynamic and typically migrate across the wider EFZ on longer time scales. It is inevitable that pipe infrastructure across estuaries will disrupt estuarine physical processes (unless suspended or bridged above the entire EFZ, or drilled far below bed level). The likelihood is that pipe infrastructure, over time, will be exposed through lateral erosion and channel migration resulting in a high risk of failure.

Maintenance of the gas pipeline servitude (approximately 10 m wide) for accessing the pipeline and pigging stations will require ongoing vegetation management and clearing to maintain a strip of grass/herbaceous vegetation, with deep rooted trees/shrubs removed in most cases. This prevents rehabilitation of most estuarine vegetation, results in long term losses of valuable wetland flora, and associated fauna, and also impacts on physical processes. Such developments also provide access to estuaries and in doing so makes them susceptible to higher levels of exploitation than is already the case.

The development of both the pipeline and a servitude, as well as pigging stations and associated access roads, all potentially result in permanent loss of connectivity and habitat fragmentation. This presents a potential serious issue for many estuarine associated fauna, and contributes to populations becoming isolated, resulting in a reduction of inter-population connectivity and compromised genetic viability. For example, inappropriately designed and constructed pipelines could prevent fish from moving/migrating freely between an estuary and associated river system.

Drawing from available information, the key potential impacts that can lead to degradation/loss of estuarine biodiversity/ecosystem services were identified and assessed in this report:

<u>Construction phase:</u>

1. Estuarine habitat destruction and direct loss of estuarine vegetation caused by vegetation clearing;
2. Altered estuarine physical and sediment dynamics caused by pipeline construction; e.g. infilling, altered channel migration, increased mouth closure;
3. Deterioration of water quality associated with the disturbance of sediment;
4. Loss of connectivity and habitat fragmentation between system's upper catchments and/or marine environments with associated ecological impacts (e.g. loss of fish recruitment).

<u>Operational phase:</u>

5. Ongoing habitat destruction as a result of access roads and the clearing of the operational servitude;
6. Altered estuarine physical and sediment dynamics as a result of the instream pipeline crossing trapping sediment and increasing flood risk;
7. Deterioration of water quality through reduced tidal flows, spills and leakages;
8. Loss of connectivity and habitat fragmentation between upper catchment and/or marine environment and associated ecological impacts (e.g. fish recruitment).

Each of the key potential impacts listed above are discussed in greater detail below, together with possible mitigation measures. The nature and intensity of these impacts is likely to vary considerably depending on type of construction method.

5.1 Construction phase

5.1.1 Impact 1: Estuarine habitat destruction

Construction activities within and around the EFZ will result in habitat destruction, and loss of estuarine and riparian habitat (e.g. mangroves, saltmarshes, reeds, swamp forest). This in turn will directly degrade and reduce ecological function and productivity of affected estuaries. The removal of the natural vegetation in and around an estuary will also indirectly result in bank erosion by tidal action and river flow and floods causing destabilisation of the estuary channel, mud- and sand bank habitat (see Impact 2, Section 5.1.2). Habitat losses may occur from secondary impacts. Increased sedimentation during construction and backfilling of the trench in the estuary could cause drying out of the riparian habitat and loss of estuarine and associated floodplain vegetation.

The movement of heavy vehicles and machinery during construction within the ROW and the EFZ, riparian area and floodplain will affect the soil profile through soil compaction, which will result in the increased soil bulk density, reduced porosity, and reduced hydraulic conductivity. In addition soil chemistry (reflected in soil pH, organic matter and nitrogen content) in the trenched area will be altered.

Construction and the clearance of vegetation for the ROW will lead to the destruction of estuarine vegetation which will decrease overall estuarine habitat, reduce protection for biota and cause loss of nursery area. The destruction of estuarine habitat will affect estuarine invertebrates, fish and birds resulting in population and diversity reductions of these fauna. Unpredictable trophic network and knock-on impacts are likely. For example, decreased mangrove areas will decrease overall estuarine productivity and abundance of invertebrates, which will affect food availability for fish and birds. This in turn will impact on estuarine nursery function and the productivity for estuarine and coastal fisheries. In addition, the disturbance of estuarine habitat often results in a change in ecological functioning, and can allow for the introduction of IAPs; which in turn can further negatively impact estuarine functioning.

While disturbances from the construction of the pipeline may not be long-term, the restoration of altered habitat and recovery of invertebrate, fish and bird population can be prolonged (and is not assured). This depends on the overall complexity and health of the systems (Yu et al., 2010). There are no examples in South Africa of successful estuarine restoration following largescale degradation as has occurred in systems such as Nhlabane, Mhlanga, and St Lucia in KwaZulu-Natal. In most cases it has only been possible to restore a degree of functionality as reflected by the overall low health score in Appendix A.

Potential mitigation measures

- Preserve natural estuarine indigenous vegetation such as mangroves and saltmarsh.
- Avoid construction or ROW clearance in the EFZ.
- Adopt below ground pipe construction methods (HDD rather than trenching).
- Where possible, suspend pipelines over the EFZ, using existing infrastructure, e.g. existing road and rail bridges.

5.1.2 Impact 2: Altered estuarine physical and sediment dynamics caused by pipeline construction; e.g. infilling, altered channel migration, and increased mouth closure

Estuaries are high energy environments and their channel morphology is highly dynamic. Estuarine channels can develop and migrate anywhere within the EFZ under the influence of tidal flows, river inflow and floods. Stabilising sections of the estuary morphology or floodplain through pipeline construction can lead to changes in long-term physical dynamics, i.e. disrupting channel and bed formation, altering sediment structure, changing estuary hydrodynamics, mouth dynamics, and ultimately catchment and marine connectivity. This can lead to altered functioning of a system and ultimately affect biota. Loss of estuarine productivity and connectivity in turn will reduce nursery function and associated fisheries value derived along the South African coast.

Sediment eroding from a construction site and backfilling of the trench 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 premature mouth closure if the tidal flows become constricted (loss of marine habitat access). Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.

Potential mitigation measures

- No road infrastructure within the EFZ.
- No pipe infrastructure such as Pipeline Intelligence Gauge Stations (PIGS) within the EFZ.
- No trenching within the EFZ.
- No pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved with elevated water tables.
- No pipe infrastructure within the 1:100 year potential estuarine bed scouring levels.
- If pipeline infrastructure cannot be avoided within the EFZ, HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels (estimated to be on average deeper than 20 m, (Personal communication, Prof G Basson, Stellenbosch University, 2018).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges.

5.1.3 Impact 3: Deterioration of water quality associated with sediment disturbance

During the construction phase, water quality may deteriorate as a result of sediment disturbance, the removal of estuarine vegetation, or pollution events, which could result in the following:

- 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
- increase the nutrient content.

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

Disturbance of estuarine water quality results in a change in ecological functioning, and increases the risk of introduction and establishment of invasive alien species (vegetation, invertebrates and fish). Currently, deteriorating water quality in KZN estuaries is contributing to the establishment of floating invasive macrophytes in pest proportions as well as the spread of the invasive snail *Tarebia granifera* (Appleton et al., 2009, van Niekerk and Turpie, 2011). Once established invasive species out compete indigenous species and disrupt ecosystem processes.

Potential mitigation measures

- No road infrastructure within the EFZ.
- No pipe infrastructure such as PIGS within the EFZ.
- No trenching within the EFZ.
- No pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved at elevated ground water levels.
- No pipe infrastructure within the 1:100 year potential estuarine bed scouring levels.
- If pipeline infrastructure cannot be avoided within the EFZ, HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels (estimated to be on average deeper than 20 m, (Personal communication, Prof G Basson, Stellenbosch University, 2018).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges.

5.1.4 Impact 4: Loss of connectivity and habitat fragmentation between upper catchment and/or marine environment

Estuaries are highly connected aquatic systems, with river inflow and tidal flows maintaining important circulatory processes and ensuring catchment and marine connectivity. Road infrastructure and construction activities can disrupt processes that support this connectivity, affecting the migration of invertebrates and fish across freshwater-estuarine-marine systems. As noted, estuaries serve as nursery habitats for both estuarine and marine fish. These systems also act as migratory destinations or stops for many birds as well.

Thus, road infrastructure and pipeline construction pose a direct (e.g. road through EFZ, pipeline construction cutting through an estuary) and indirect (e.g. prolonged mouth closure due to infilling of open water area) threat to estuarine connectivity and can increase habitat fragmentation.

A major concern is also the cumulative impact of pipeline construction on a multitude of estuaries along a stretch of coast and the collective risk it poses to estuarine connectivity and functioning. While the individual impacts may appear small, the cumulative resulting shifts in estuarine physical process, connectivity and production can be significant.

Potential mitigation measures

- No road infrastructure within the EFZ.
- No pipe infrastructure such as PIGS within the EFZ.
- No trenching within the EFZ.
- No pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved at elevated ground water levels.
- No pipe infrastructure within the 1:100 year potential estuarine bed scouring levels.
- If pipeline infrastructure cannot be avoided within the EFZ, HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels (estimated to be on average deeper than 20 m, Personal communication, Prof G Basson, Stellenbosch University).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges.

5.2 Operational phase

5.2.1 Impact 5: Habitat destruction as a result of ongoing vegetation clearing of access roads and servitude for maintenance

Similar to Impact 1 (Section 5.1.1), access roads and the clearing of the operational servitude within and around the EFZ will result in estuarine and riparian habitat (e.g. mangroves, saltmarshes, reeds, swamp forest) destruction and fragmentation. This, in turn, will directly degrade and reduce estuarine function and productivity. The destruction of estuarine habitat will affect estuarine invertebrates, fish and birds resulting in a decrease in abundance and diversity. For example, decreased mangrove areas will decrease overall estuarine productivity and abundance of invertebrates, which will affect food availability for fish and birds. This in turn will impact on estuarine nursery function and the productivity for estuarine and coastal fisheries.

The ongoing removal of the natural vegetation in and around an estuary will also result in bank erosion by tidal action and river flow and floods causing destabilisation of the estuary channel, mud/sand bank habitats. In addition, the disturbance of estuarine habitat often results in a change in ecological functioning, and can allow for the introduction of IAPs; which in turn can further alter estuarine functioning.

Potential mitigation measures

- Preservation of natural indigenous vegetation such as mangroves and saltmarsh.
- Regular Control of I&APs

5.2.2 Impact 6: Altered estuarine physical and sediment dynamics as a result of the instream pipeline crossing trapping sediment and increasing flood risk

Stabilising sections of the estuary morphology or floodplain through pipeline infrastructure and the placements of pigging stations or block valves can lead to changes in long-term physical and sediment dynamics, i.e. disrupt channel and bed formation, alter sediment structure, mouth dynamics, and ultimately catchment and marine connectivity. This can cause altered functioning of impacted estuaries and ultimately affect the biota and value derived from these systems. Loss of estuarine productivity and connectivity in turn can reduce nursery function and estuarine contribution to coastal fisheries.

Over time migrating estuarine channels will expose pipeline infrastructure, changing flow velocities, and cause ongoing sediment erosion from such sites. This, in turn, can cause sediment deposition and accumulation 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. Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.

Stabilizing or constricting natural channel migration will also ultimately increase flood risk to riparian properties as it will prevent estuarine channels from increasing in dimension under high flow and flood regimes. Natural flood attenuation processes in estuaries can therefore be detrimentally impacted. During large floods (1:10 to 1:100 year) most estuaries scour down to -20 to -30 m if not constrained by bed rock. This scour channel is filled in by post-flood sediment. Constructing a hard structure in the EFZ will disrupt this process.

It should also be noted that floods (in the case of estuaries the cumulative flow of the entire catchment) pose a significant risk to pipe failure and the destruction of associated pipe infrastructure. Failure in turn represents a risk of altered estuarine habitat (i.e. hard structures now exists where only soft bedforms should occur) and water quality risk (pollution).

Potential mitigation measures

- Monitor the condition of the infrastructure to ensure that there is no exposed section and ongoing erosion occurring.
- Should the pipe become exposed it would require the suspension of operations and the HDD of the pipe at greater depths below ground within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- Operational staff should be made aware of the sensitivities of estuarine and freshwater environments.

5.2.3 Impact 7: Deterioration of water quality through reduced tidal flows, spills and leakages

During the operational phase water quality in estuaries that are crossed by gas pipelines can be impacted in the same way as during the construction phase. The likelihood of impacts arising might be reduced as operational impacts will largely be limited to periods when pipeline maintenance is taking place. Some long-term impacts (for example increased suspended solids) might occur as a result of the placement of the pipelines themselves. Similar knock-on effects to the estuarine biota might also be expected.

Potential mitigation measures

- Monitor the condition of the infrastructure to ensure that there is no exposed section, ongoing erosion or leakages.
- Should the pipe become exposed it would require the suspension of operations and the HDD of the pipe at greater depths below ground within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- Operational staff should be made aware of the sensitivities of estuarine and freshwater environments.

5.2.4 Impact 8: Loss of connectivity and habitat fragmentation between upper catchment and/or marine environment and associated ecological impacts

Permanent roads (mainly associated with pigging stations), the operational servitude and pipeline infrastructure, and maintenance activities associated with long-term operation will disrupt processes that support estuarine connectivity, affecting the migration of invertebrates and fish across freshwater-estuarine-marine systems.

Potential mitigation measures

- Monitor the condition of the infrastructure to ensure that there is no exposed section and ongoing erosion occurring.
- Should the pipe become exposed it would require the suspension of operations and the HDD of the pipe at greater depths below ground within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- Operational staff should be made aware of the sensitivities of estuarine and freshwater environments.

6 RISK ASSESSMENT

6.1 Likelihood and consequence levels

Quantitative assessment of impact likelihood was not possible but an indication of relative likelihood of different impacts (without and with mitigation, based on expert opinion and available knowledge) is provided below in Table 4.

Consequence is a function of the impact under consideration and sensitivity of the affected area. Consequences were rated qualitatively as modifications to estuaries following a similar approach as that applied in water reserve determination studies (Table 5). Cognisance was taken of the sensitivity of the receiving environment to a particular impact. Thus, a moderate degradation in a very sensitive estuary was regarded as having a greater consequence than a similar degradation in water quality in a lower sensitive system.

Consequences of impacts associated are not generic across different sensitivity zones (e.g. as represented by the sensitivity indicators), rather consequence is a function of the type of impact and the sensitivity rating (Table 3).

Table 4: Relative likelihood of relevant potential impacts occurring within the selected production systems (VU = very unlikely, NL = not likely, L= likely, VL = very likely).

Potential impact	Likelihood					
	Without mitigation	With mitigation				
		Isolated Trench	Shallow Pipe-jack/HDD	Deep HDD (>-20 m) No access roads	No development Avoid EFZ	Suspending pipelines
Construction phase:						
Estuarine habitat destruction	VL	VL	VL	NL	VU	VU
Altered estuarine physical and sediment dynamics	VL	VL	L	NL	VU	VU
Deterioration of water quality	VL	L	L	NL	VU	VU
Loss of connectivity and habitat fragmentation	VL	VL	L	NL	VU	VU
Operational phase:						
Estuarine habitat destruction	VL	VL	VL	NL	VU	VU
Altered estuarine physical and sediment dynamics	VL	VL	L	NL	VU	VU
Deterioration of water quality	VL	L	L	NL	VU	VU
Loss of connectivity and habitat fragmentation	VL	VL	L	NL	VU	VU

Table 5: Description of consequence levels to impacts to estuaries used in the risk assessment.

Consequence	General description
Slight	• Limited modification in all zones • Ecosystem attributes largely unmodified and little influence on other uses • Small changes in natural habitats and biota in the area may occur, but the ecosystem functions are essentially unchanged • Natural conditions and the resilience and adaptability of biota are not compromised • Characteristics of the resource are determined by unmodified natural disturbance regimes • Modification is of a temporary nature
Moderate	• Some modification in sensitive zones • Moderate modification in non-sensitive zones • A loss and change of natural habitat and biota occurs, but the basic ecosystem functions are still predominantly unchanged • Moderate modification of the abiotic template and exceedance of the resource base occurs of a permanent nature
Severe	• Moderate modification in sensitive zones • High modification in non-sensitive zones • Largely modified. A large loss of natural habitat, biota and basic ecosystem functions occurs, with risk of modifying the abiotic template and exceeding the resource base • Loss of well-being and survival of intolerant biota. Associated increase in the abundance of tolerant species does not assume pest proportions • Modification is of a permanent nature
Extreme	• High modification in sensitive zones • Extreme modification in non-sensitive zones • Seriously and critically modified with loss of natural habitat, biota and basic ecosystem functions • Modification is of a permanent nature

6.2 Risk assessment results

Risks were assessed based on the relationship between likelihood and consequence as illustrated in Table 6 .This was applied to all the process systems for the different sensitivity ratings (Table 7).

Table 6: Risk assessment look-up table showing relationship: Likelihood x Consequence = Risk.

		Consequence			
		Slight	Moderate	Severe	Extreme
Likelihood	Very likely (VL)	Low (L)	Moderate (M)	High (H)	Very high (VH)
	Likely (L)	Low (L)	Moderate (M)	High (H)	Very high (VH)
	Not likely (NL)	Low (L)	Low (L)	Moderate (M)	High (H)
	Very unlikely (VU)	Low (L)	Low (L)	Moderate (M)	Moderate (M)

Table 7: Risk Assessment for different locations in various corridors without and with mitigation

Impact	Location sensitivity rating	Without mitigation			Isolated Trench			Pipe-jack/ HDD Shallow depths			HDD >20 m depth / No access roads			No development or trenching in EFZ / Cross at existing infrastructure or pipe bridges		
		Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk
Construction Phase																
Estuarine habitat destruction	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Severe	VL	High	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Moderate	VL	Moderate	Severe	NL	Moderate	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Slight	VL	Low	Moderate	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	VL	Low	Slight	NL	Low	Slight	VU	Low
Altered physical and sediment dynamics	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Extreme	L	Very high	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Severe	L	High	Moderate	NL	Low	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	L	Moderate	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
Deterioration of water quality	Very high	Severe	VL	High	Moderate	L	Moderate	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Slight	L	Low	Slight	L	Low	Moderate	NL	Low	Moderate	VU	Low
	Medium	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low

Impact	Location sensitivity rating	Without mitigation			Isolated Trench			Pipe-jack/ HDD Shallow depths			HDD >20 m depth / No access roads			No development or trenching in EFZ / Cross at existing infrastructure or pipe bridges		
		Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk
Loss of connectivity and habitat fragmentation	Very high	Severe	VL	High	Severe	VL	High	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Moderate	VL	Moderate	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Medium	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
Operational Phase																
Estuarine habitat destruction	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Severe	VL	High	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Severe	VL	High	Moderate	NL	Low	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	VL	Low	Slight	NL	Low	Slight	VU	Low
Altered physical and sediment dynamics	Very high	Extreme	VL	Very high	Extreme	VL	Very high	Severe	VL	High	Severe	NL	Moderate	Moderate	VU	Low
	High	Severe	VL	High	Severe	VL	High	Severe	VL	High	Moderate	NL	Low	Moderate	VU	Low
	Medium	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	VL	Moderate	Moderate	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low

Impact	Location sensitivity rating	Without mitigation			Isolated Trench			Pipe-jack/ HDD Shallow depths			HDD >20 m depth / No access roads			No development or trenching in EFZ / Cross at existing infrastructure or pipe bridges		
		Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk	Conse-quence	Likeli-hood	Risk
Deterioration of water quality	Very high	Severe	VL	High	Severe	L	High	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Moderate	L	Moderate	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Medium	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	L	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
Loss of connectivity and habitat fragmentation	Very high	Severe	VL	High	Severe	VL	High	Moderate	L	Moderate	Moderate	NL	Low	Moderate	VU	Low
	High	Moderate	VL	Moderate	Moderate	VL	Moderate	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Medium	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low
	Low	Slight	VL	Low	Slight	VL	Low	Slight	L	Low	Slight	NL	Low	Slight	VU	Low

7 LIMITS OF ACCEPTABLE CHANGE

7.1 Relevant legislation, policies and guidelines

Legislation, policies and guidelines applicable to the protection of estuarine aquatic ecosystems are summarised in Table 8. Emerging as most critical in the context of the present assessment is the Recommended Ecological Category as defined by the National Water Act (Act 36 of 1998) (NWA) and set as desired state as part of the National Estuaries Biodiversity Plan (Turpie et al., 2011). In addition detailed Resource Quality Objectives for physical processes, water quality, habitat and higher biota are set under the NWA. These provide the benchmark conditions to maintain estuaries (or restore them).

Table 8: Relevant key legislation applicable to estuarine protection.

Legislation	Specifications
National Environmental Management Act (NEMA) (107 of 1998) and the associated Environmental Impact Assessment (EIA) Regulations of 2014 (as amended)	GNR 324 Listing Notice 3, NEMA EIA Regulations (2014, as amended in April 2017) identifies the EFZ as a sensitive area.
National Water Act (36 of 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 (10 of 2004)	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 the Department of Environmental Affairs (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. 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 (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 Management: Integrated Coastal Management Act (ICM Act) (24 of 2008, as amended)	Recreational waters. Water quality guidelines for the coastal environment: Recreational use (DEA, 2012). Set water quality targets for recreational waters to protect bathers.
	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 (57 of 2003)	Sets specific targets for protected areas (site specific as set in regulations/government notices) – relevant to estuaries in protected areas.
National Port 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 which have ports in them.

7.2 Permit requirements

Where any construction or operation will occur within the Very Highly sensitive or Highly 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 NWA based on the DWS assessment requirements for all wetlands that occur within 500 metres of the gas pipeline development.
- Permits are 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 specific chemical in marine waters and sediments to protect ecosystems.
- Permits are 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.

8 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

8.1 Planning phase

Estuarine physical processes are highly dynamic. Any hard structures within the EFZ will impact on estuarine dynamics over long-time scales. In most cases the most effective mitigation is to avoid the estuaries and not construct pipeline infrastructure through or below them. This approach also poses less risk to the pipe infrastructure (e.g. floods and associated scouring may expose the pipelines set across estuaries and damage them).

Thus, the correct planning of the preferred gas pipeline alignment and associated ancillary infrastructure (e.g. access roads and pigging stations) has the potential to greatly reduce impacts on estuaries and associated coastal freshwater ecosystems that feed into them through simply avoiding areas of very high and high sensitivity. In order to further significantly reduce potential impacts on estuaries and associated supporting coastal freshwater biodiversity (inflowing rivers and/or wetlands/seeps with in a 10 km radius of the EFZ), sub-quaternary catchments classified with a very high or high sensitivity should also be avoided (as per the freshwater assessment (Appendix C.1.7 of the Gas Pipeline SEA Report) by De Winnaar & Ross-Gillespie (2018)). Where these coastal freshwater ecosystems cannot be avoided, detailed desktop investigation should be conducted, followed by specialist in-field assessments and verification to determine whether the fine-scale, micro-sited gas pipeline alignment and development footprint can avoid the actual estuary, EFZ, associated coastal freshwater ecosystems, and associated buffers (as per the freshwater assessment (Appendix C.1.7 of the Gas Pipeline SEA Report) by De Winnaar & Ross-Gillespie (2018)), as well as to determine appropriate management actions to be implemented as required.

Where it is impossible to avoid estuarine ecosystems it will be necessary to undertake more detailed specialist sedimentary studies and impacts assessments to determine the depth to which HDD need to be undertaken in the EFZ. Where it is impossible to avoid coastal freshwater ecosystems (i.e. wetland and river habitats draining into estuaries) and their associated buffers altogether, it will be necessary to undertake more detailed specialist studies, impacts assessments, and if necessary investigate needs and opportunities for offsets. Note, that opportunities for off sets do not exist in estuaries. Preference should be given to the position of gas pipelines 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. Any coastal freshwater ecosystems that will be affected by gas pipeline development must be subject to a condition of authorisation. See De Winnaar & Ross-Gillespie (2018) for more detail (Appendix C.1.7 of the Gas Pipeline SEA Report).

8.2 Construction phase

Given the high sensitivity and ecological importance of estuaries it is recommended that no clearing of estuarine vegetation and no disturbance of estuarine processes, i.e. no pipeline development should occur within or below the EFZs. If development cannot be avoided, HDD should be done to levels below potential bed scouring (1:100 year return period). Given the dynamic nature of estuaries, this would involve HDD across the entire length of the EFZ at depth potentially exceeding 20m (personal communication, Prof G Basson, Stellenbosch University).

In addition, construction may involve the establishment of ROWs and construction of pipelines and pigging stations within or in proximity to coastal freshwater ecosystems (rivers, wetland and seeps) feeding into estuaries. Typical impacts that can be expected are disturbance to wildlife through noise/light pollution, creation of dust, erosion and degradation/disturbance of habitats and vegetation (including areas for access via roads and servitudes and movement of heavy machinery), and bulldozing and vegetation/habitat clearing. Specific measures and actions required during the construction phase are presented in De Winnaar & Ross-Gillespie (2018) (Appendix C.1.7 of the Gas Pipeline SEA Report), but some key measures to include from the perspective of protecting downstream estuarine physical and ecological processes from knock-on effects are:

- Timing of construction activities to occur in the dry season as far as is practicable;
- Appointment and involvement of an Environmental Control Officer (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) required for pre-construction, during construction and post construction at strategically selected monitoring sites based on additional detail specified in Section 8.5 below.
- Avoid the EFZ and avoid and/or minimise road crossings through coastal wetlands and rivers within a 10 km radius of estuaries which may negatively impact estuaries downstream. Minimise the number of coastal river and wetland access roads crossings upstream of estuaries. Ensure adequate freshwater 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. In the case of river crossings, bank stabilisation measures (gabions, eco logs, geofabric, sediment fences) are required when wetland or watercourse banks steeper than 1:5 are denuded during construction. Appropriate rehabilitation procedures/measures should be planned to minimise the risk of increased sediment load in coastal rivers leading to downstream deposition in associated estuaries.
- Avoid clearing of estuarine vegetation within the EFZ in any manner to prevent estuarine erosion. Avoid clearing of riparian indigenous vegetation upstream of estuaries within 10 km of the EFZ as far as possible and implement rehabilitation of riparian vegetation as soon as possible to stabilise soil. In addition, 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) should be used to minimise the transport of wind-blown dust.
- All estuaries and coastal rivers / wetlands within 10 km of an estuary should be avoided as far as possible. If avoidance is possible the areas must be 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 ECO.
- All construction activities (including establishment of construction camps, temporary lay-down areas, construction of haul roads and operation of heavy machinery), should take place during the dry season to reduce potential impacts to estuaries and associated inflowing coastal freshwater ecosystems within 10 km of an estuary.
- No construction activities may occur within estuaries (i.e. EFZ). Construction activities associated with the establishment of access roads through inflowing associated coastal wetlands or rivers (if unavoidable) within 10 km of an estuary should be restricted to a working area of 10 m in width

either side of the road, and these working areas should be clearly demarcated. No vehicles, machinery, personnel, construction material, cement, fuel, oil or waste should be allowed outside of the demarcated working areas.

- Construction camps, toilets, temporary laydown areas and borrow pits should be located outside of the EFZ and recommended buffer areas around inflowing coastal wetlands and rivers within 10 km of an estuary and should be rehabilitated following construction. Pits or excavations should be checked regularly by the on-site ECO and plans put in place for species rescue and relocation
- No fuel storage, refuelling, vehicle maintenance or vehicle depots should be allowed within 30 m of the edge of any estuary, coastal river or coastal wetlands.
- 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, wetland or watercourse.
- No effluents or polluted water should be discharged directly into any estuary, river or wetland areas.
- No spoil material, including stripped topsoil, should be temporarily stockpiled within 30 m of the edge of any estuary, wetland or river. 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 and/or freshwater ecologist should be consulted for advice on the most suitable remediation measures depending on the site and potential downstream impact.
- Workers should be made aware of the importance of not destroying or damaging the vegetation along estuaries, coastal rivers and coastal wetland areas, of not undertaking activities that could result in the pollution of drainage lines 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 to monitor vegetation changes and potential site impacts occurring during construction phase.
- In the case of construction of a coastal river upstream of an estuary, fish should be rescued from within the isolated area and returned live to the associated river / wetland immediately downstream of the worksite. The construction area should then be excavated; the pipe is laid in place and backfilled. Once the bed and banks of the river/wetland are re-established the diversion should be removed and water returned to the channel. Reclamation is done to stabilize the disturbed area and restore vegetation along the banks. At all-time care should be taken not to increase the sediment load down-stream to the estuary.

8.3 Operations phase

- Assuming that no pipeline development would 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 riparian or wetland vegetation upstream of the estuaries (to maintain pipeline servitudes), 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) (Appendix C.1.7 of the Gas Pipeline SEA Report), 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 (close than 50 m) to wetlands or rivers and do not disturb riparian/or wetland buffer areas.

- At all-time 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

Assuming that no pipeline development would occur in any EFZs as a result of very high sensitivity and ecological importance of estuaries, rehabilitation and post-closure measures would mostly be required for ROWs across or in proximity to associated supporting coastal freshwater ecosystems, as well as for areas degraded by access routes, operation of vehicles/heavy machinery, and infestation of servitudes by IAPs in the freshwater reaches upstream of estuaries. In general, the following processes/procedures are recommended (James and King, 2010; De Winnaar & Ross-Gillespie, 2018):

- Initiation – to assemble the rehabilitation project team/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 – a including detailed engineering designs, construction and inspections; and
- Monitoring – to establish need for maintenance and repair of interventions, as well as provide feedback regard success and failure.

Additional points to be considered regarding rehabilitation of degraded areas within and adjacent to supporting coastal freshwater ecosystems (i.e. coastal rivers, wetland and seeps flowing into estuaries) include (De Winnaar & Ross-Gillespie, 2018):

- 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, knock-on impacts to freshwater 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, where possible, no pipeline development should occur within the EFZs. However, pipeline construction may involve the establishment of ROWs and construction of pipelines and pigging stations within or in proximity to coastal freshwater ecosystems such as rivers, wetland and seeps feeding into estuaries. Where impacts to estuaries (i.e. HDD) and/or coastal freshwater ecosystems within 10 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 the 10 km above an estuary as delineated by the EFZ, monitoring of a potential impact is recommended at suitable sites to be determined in-field by estuarine and/or freshwater ecosystems specialists as required. 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 pertaining to estuarine sediment dynamics, physical processes, water quality and ecology (or freshwater aquatic ecology if in coastal freshwater ecosystem). Resource Quality Objectives as set under the NWA provide the benchmark conditions to maintain in estuaries or rivers. **Table 10 details the monitoring requirements for estuaries, with critical features highlighted in blue. These requirements are specifically important in the event of HDD through an estuary and its EFZ is impossible to avoid.** Monitoring of other aspects (e.g. water quality, microalgae, invertebrates, fish and birds) are required even if the estuary or EFZ is not directly impacted, but where upstream activities may cause indirect impacts to an estuary (Table 10).

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) (Appendix C.1.7 of the Gas Pipeline SEA Report).

Table 9: Requirements for monitoring ecological components of estuaries following direct and indirect impacts from gas pipeline development.

	Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
In the event of direct impacts (e.g. through trenching)	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)
	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)

In cases where freshwater ecosystems upstream of estuaries are likely to be affected by gas pipeline 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 operation 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 for the purposes of confident assessment of estuarine impacts relates to the site specific sedimentary processes occurring within each potentially affected estuary. Without this detailed estuary-specific sediment process understanding it is difficult to assess likelihood and consequences of impacts arising from planned structures across and under estuaries. Most important in this regard are issues relating to planned pipelines obstruction to flows during floods and causing long-term estuary bed transformation and infilling. Estuarine physical processes are highly dynamic requiring detailed information over long planning horizons, e.g. understanding the impacts of a 1:100 year flood.

Once a specific project has been determined (based on market demand and the securing of a source of gas), the following detailed information is required at each system in the event an estuary is crossed. This information would be required prior to the construction of the gas pipeline, to inform the depth of HDD, e.g. 20m below bed level 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 at a depth of > 20 m at estuaries with a high Mean Annual Runoff (MAR));
- Estimates of daily sediment loads from the catchment;
- Hourly flood hydrographs 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 during a flood (before infilling occurs again).

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Appendix A : List of estuaries and their key features for each corridor

Table A.1: Summary of important environmental and socio-economic attributes of estuaries in each of the proposed Gas Pipeline corridors

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Phase 5																				
Olifants	x	x						1070.10	x	Very Important	SA/CAPE	C	5	91.9	849.1	47.74	0.0	0	1353.68	x
Verlorenvlei	x	x	x					52.21		Important	SA	D	3	16.2	7.6	3.68	0.0	0	34.74	x
Groot Berg	x	x	x	x	x	x	x	916.00	x	Very Important	SA/CAPE	C	5	1667.0	2545.0	206	0.0	0	6799	x
Phase 1																				
Langebaan	x							-		Very Important	SA	B	5							x
Rietvlei/Diep	x	x						63.29	x	Important	SA/CAPE	D	5	0.0	0.0	0	0.0	0	0	x
Sout (Wes)	x	x						31.11		Ave Importance		F	1	0.0	0.0	0	0.0	0	99.7	x
Houtbaai	x							15.18		Ave Importance		E	1	0.0	0.0	0	0.0	0	21.05	x
Wildevoëlvlei	x							2.14		Very Important		D/E	1	12.7	0.0	0	0.0	0	230.87	x
Bokramspruit	x							2.01		Ave Importance		C	1	0.0	0.0	0	0.0	0	1.2	x
Schuster	x							2.57		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^{3}x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Krom	x							6.99		Ave Importance	SA/CAPE	A/B	1	0.0	0.0	0	0.0	0	8.7	x
Buffels Wes	x							0.45		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	3.75	x
Elsies	x							0.59		Ave Importance		D/E	1	0.0	0.0	0	0.0	0	18.45	x
Silvermine	x							3.75		Ave Importance		E	1	0.0	0.2	2.02	0.0	0	6.52	x
Sand	x	x						21.73		Important	SA/CAPE	D	5	11.6	0.0	0	0.0	0	155.48	x
Zeekoei	x							22.33		Ave Importance		E	1	0.0	0.0	0.2	0.0	0	3.17	x
Eerste	x							104.60	x	Ave Importance	SA/CAPE	E	2	0.3	0.0	0	0.0	0	10.2	x
Lourens	x							66.27	x	Ave Importance	SA/CAPE	D	1	0.0	0.0	0	0.0	0	7.09	x
Sir Lowry's Pass	x							0.14		Ave Importance		E	1	0.0	0.0	0	0.0	0	2.95	x
Steenbras	x							33.70		Ave Importance		B	1	0.0	0.0	0	0.0	0	1.88	x
Rooiels	x							8.64		Ave Importance		A/B	1	0.0	0.0	0.03	0.0	0	4.13	x
Buffels (Oos)	x							9.70		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.9	x
Palmiet	x							256.30	x	Important	SA/CAPE	C	1	0.1	0.0	0	0.0	0	33	x
Klipdrifsfontein	x							0.24		Ave Importance	SA/CAPE	A	1	0.0	0.0	0	0.0	0	0.6	x
Breë	x	x	x	x	x	x		1785.00	x	Very Important	SA	B/C	5	20.5	29.6	6	0.0	0	1564.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Duiwenhoks	x	x	x					94.19	x	Very Important		C	4	26.0	0.0	0	0.0	0	98	x
Goukou (Kaffirkui	x	x	x					102.78	x	Very Important	SA/CAPE	C	4	57.0	0.0	5	0.0	0	324	x
Gourits	x	x	x	x				628.78	x	Important	SA/CAPE	C/D	5	137.8	0.0	0	0.0	0	525.5	x
Phase 2																				
Blinde	x							1.25		Ave Importance		C	1	0.0	0.0	0	0.0	0	5.4	x
Gericke	x							35.60		Ave Importance		D/E	1	0.0	0.0	0	0.0	0	0	x
Tweekuilen	x							0.30		Ave Importance		D/E	1	0.0	0.0	0	0.0	0	0	x
Hartenbos	x							4.63		Important		D	3	47.0	0.0	0	0.0	0	99	x
Klein Brak	x	x						53.37		Ave Importance		C	4	494.0	0.0	3	0.0	0	664	x
Groot Brak	x							36.79		Important		C/D	3	13.0	26.6	0	0.0	0	105.1	x
Maalgate	x							26.64		Ave Importance		B	1	0.0	0.0	0	0.0	0	28	x
Gwaing	x							43.53		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	9	x
Kaaimans	x							35.73		Ave Importance	SA	B	1	0.0	0.0	0	0.0	0	9.2	x
Wilderness	x							29.66		Very Important	SA/CAPE	B/C	5	42.3	0.0	4	0.0	0	295.3	x
Swartvlei	x	x						83.15	x	Very Important	SA/CAPE	B/C	5	135.6	0.0	219.39	0.0	0	1286.29	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							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)	IUCN Critically/ Endangered Fish species
	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		
Goukamma	x	x						57.50		Important	SA/CAPE	A/B	3	1.5	5.2	0	0.0	0	18.21	x
Knysna	x	x						83.20	x	Very Important	SA/CAPE	B/C	5	551.9	0.0	238	0.0	0	2038.72	x
Noetsie	x							4.36		Ave Importance	CAPE	B	1	0.0	0.0	0	0.0	0	13.4	x
Piesang	x							5.20		Important	SA	D	3	1.5	0.0	0	0.0	0	20	x
Keurbooms	x	x						232.00	x	Very Important	SA/CAPE	A/B	5	72.2	41.8	88.73	0.0	0	674.74	x
Matjies	x							5.10		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	2.8	x
Kabeljous	x							11.52		Important		C	3	0.0	10.5	21.51	0.0	0	117.94	x
Gamtoos	x	x						388.84	x	Very Important	SA/CAPE	B/C	5	92.9	80.8	5.14	0.0	0	501.25	x
Van Stadens	x							17.19		Ave Importance	SA/CAPE	B	1	0.0	0.0	0	0.0	0	24.2	x
Maitland	x							12.86		Ave Importance	SA/CAPE	B/C	1	0.0	0.0	0	0.0	0	18.65	x
Baakens	x							4.11		Ave Importance		E	1	0.0	0.0	0	0.0	0	0	x
Papenkuils	x							2.92		Ave Importance		F	1	0.0	0.0	0	0.0	0	0	x
Swartkops	x	x	x					97.62	x	Very Important	SA/CAPE	D	5	165.0	5.0	44.7	0.0	0	531.2	x
Coega (Ngcura)	x	x						10.13		Ave Importance		E	1	0.0	2.3	1.2	0.0	0	10.14	x
Sundays	x	x	x	x	x			273.00	x	Important	SA/CAPE	C	5	21.8	0.0	0	0.0	0	485.7	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x10^6)	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)	IUCN Critically/ Endangered Fish species
	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		
Phase 7																				
Coega	x	x						10.13		Ave Importance		E	1	0.0	2.3	1.2	0.0	0	10.14	x
Sundays	x	x	x	x	x			273.00	x	Important	SA/CAPE	C	5	21.8	0.0	0	0.0	0	485.7	x
Boknes	x							14.44		Ave Importance		C	1	1.5	5.0	0.5	0.0	0	20	x
Bushmans	x	x	x	x				42.86		Important	SA/CAPE	B/C	5	118.3	0.0	39.8	0.0	0	340.9	x
Kariega	x	x						21.69		Very Important	SA/CAPE	C	5	36.1	364.4	3.26	0.0	0	565.35	x
Kasuka	x							4.30		Important		B	3	0.0	0.0	0	0.0	0	20.7	x
Kowie	x	x	x					31.82		Very Important		C	5	35.2	0.0	8.2	0.0	0	126.83	x
Rufane	x							1.20		Ave Importance		C	1	0.0	0.0	0	0.0	0	0.81	x
Riet	x							2.42		Important		B	1	0.0	17.4	2.64	0.0	0	73.06	x
Kleinemond Wes	x	x						6.00		Important		B	3	0.0	7.1	8.2	0.0	0	47.8	x
Kleinemond Oos	x							2.86		Important		B	3	2.5	2.8	14.5	0.0	0	46.94	x
Klein Palmiet	x							0.82		Ave Importance		B	1	0.0	0.0	0.02	0.0	0	0.531	x
Great Fish	x	x	x					513.29	x	Very Important	SA/CAPE	C	5	133.0	65.0	0	0.0	0	368	x
Old Womans	x							1.11		Ave Importance		C	1	0.0	0.0	0	0.0	0	25.12	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							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)	IUCN Critically/ Endangered Fish species
	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		
Mpekweni	x							2.44		Very Important		B	3	0.0	27.2	1.59	0.0	0	141.41	x
Mtati	x							6.03		Very Important	CAPE	B	3	0.0	54.3	3.2	0.0	0	286.35	x
Mgwalana	x	x						9.71		Very Important	SA	B	3	0.0	7.6	1.12	0.0	0	226.72	x
Bira	x	x						12.01		Important	SA	B	3	0.0	2.6	5.3	0.0	0	163.54	x
Gqutywa	x							3.52		Important	SA/CAPE	B	3	0.0	1.2	2.5	0.0	0	51.64	x
Ngculura	x							0.65		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.35	x
Mtana	x							1.06		Ave Importance		B	1	0.0	2.5	2.54	0.0	0	15.69	x
Keiskamma	x	x	x	x				138.94	x	Very Important	SA/CAPE	B/C	5	210.4	91.3	12	0.0	0	744.53	x
Ngqinisa	x							1.18		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	12.67	x
Kiwane	x							5.32		Ave Importance		A/B	3	0.0	0.0	3.56	0.0	0	18.8	x
Tyolomnqa	x	x	x					35.56		Important		B	3	3.7	15.7	0	0.0	0	107.44	x
Shelbertsstroom	x							0.63		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	0.46	x
Lilyvale	x							1.11		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.3	x
Ross' Creek	x							0.55		Ave Importance		A/B	1	0.0	0.0	0.2	0.0	0	1.3	x
Ncera	x							10.99		Ave Importance	SA	B	1	0.0	2.9	1	0.0	0	28.4	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							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)	IUCN Critically/ Endangered Fish species
	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		
Mlele	x							2.00		Ave Importance		B	1	0.0	0.4	0	0.0	0	3.6	x
Mcantsi	x							2.84		Ave Importance		B	1	0.0	0.5	0	0.0	0	9	x
Gxulu	x							15.56		Ave Importance		B/C	3	1.0	11.9	0	0.0	0	48.5	x
Goda	x							6.19		Ave Importance	CAPE	B	1	0.0	1.9	0	0.0	0	17.2	x
Hlozi	x							1.75		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.7	x
Hickman's	x							1.42		Ave Importance		B	1	0.0	0.8	0	0.0	0	4.3	x
Mvubukazi	x							0.00		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.1	x
Ngqenga	x							0.43		Ave Importance		B	1	0.0	0.0	0	0.0	0	0.1	x
Buffalo	x							96.03		Ave Importance		D	3	0.0	0.1	0	0.0	0	98	x
Blind	x							0.65		Ave Importance		D	1	0.0	0.1	0	0.0	0	0.5	x
Hlaze	x							0.32		Ave Importance		C/D	1	0.0	0.1	0	0.0	0	1.5	x
Nahoon	x	x						38.20		Important		C	3	2.8	0.0	2.3	1.6	0	58.72	x
Qinira	x							8.44		Important		B/C	1	16.8	5.7	0	0.0	0	72.13	x
Gqunube	x							34.07		Important	SA	B	3	3.7	2.2	0.8	0.0	0	53.4	x
Kwelera	x							34.83		Important	SA	B	3	9.3	7.2	2.3	0.0	0	50.1	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							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)	IUCN Critically/ Endangered Fish species
	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		
Bulura	x							3.73		Ave Importance		B	1	2.8	5.6	0.4	0.0	0	35.5	x
Cunge	x							0.32		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0.35	x
Cintsa	x							3.99		Ave Importance		B	1	7.0	7.1	0	0.0	0	29.3	x
Cefane	x							3.95		Important		B	3	28.1	21.4	0	0.0	0	82.7	x
Kwenxura	x							16.89		Ave Importance	SA/CAPE	A/B	3	0.0	3.3	0	0.0	0	29.1	x
Nyara	x							4.34		Ave Importance		A/B	1	1.1	6.3	0	0.0	0	17.1	x
Mtwendwe	x							1.07		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0	x
Haga-haga	x							2.15		Ave Importance		A/B	1	0.0	0.3	0	0.0	0	3.4	x
Mtendwe	x							1.41		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0	x
Quko	x							17.18		Ave Importance	SA/CAPE	A	3	3.9	0.0	0	0.0	0	36.18	x
Morgan	x							2.74		Ave Importance		B	3	0.0	2.0	0	0.0	0	24	x
Cwili	x							1.18		Ave Importance		B	1	0.0	0.0	0	0.0	0	1.2	x
Great Kei	x	x	x					954.93	x	Very Important	SA/CAPE	C	5	5.8	6.2	0	0.0	0	222.4	x
Gxara	x							3.44		Ave Importance		A/B	1	0.0	1.9	0	0.0	0	23.9	x
Ngogwane	x							0.79		Ave Importance		B	1	0.0	0.0	0	0.0	0	9.12	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Qolora	x							8.90		Important		B	1	0.0	0.0	0	0.0	0	22.9	x
Ncizele	x							1.00		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	6.635	x
Timba	x							0.35		Ave Importance		B	1	0.0	0.0	0	0.0	0	0	x
Kobonqaba	x							36.22		Ave Importance		B	3	2.3	4.5	1	0.5	0	26.4	x
Nxaxo/Ngqusi	x							23.27		Important	SA/CAPE	B	3	2.4	8.6	0.04	9.5	0	153.98	x
Cebe	x							5.69		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	16.53	x
Gqunqe	x							6.96		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	17.94	x
Zalu	x							1.69		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	12.36	x
Ngqwara	x							5.24		Ave Importance	SA	A/B	1	0.0	2.3	0	0.0	0	19.36	x
Sihlontlweni/Gcin	x							2.21		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	11.01	x
Nebelele	x							1.05		Ave Importance		A/B	1	0.0	0.0	0	0.0	0	0	x
Qora	x							78.52	x	Important	SA/CAPE	A/B	3	0.0	0.0	8.5	0.0	0	89.63	x
Jujura	x							11.27		Ave Importance		A/B	1	0.0	0.0	0.05	0.0	0	4.77	x
Ngadla	x							1.56		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	13.884	x
Shixini	x							42.28		Ave Importance	CAPE	A/B	1	0.0	0.0	0	0.0	0	22.1	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							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)	IUCN Critically/ Endangered Fish species
	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		
Nqabara/Nqabarana	x							76.44	x	Important	SA	A/B	3	0.0	0.0	1.2	11.8	1.23	112.96	x
Mbashe	x	x						801.82	x	Very Important	SA/CAPE	B	5	2.3	0.0	1.5	9.2	4.8	127.15	x
Xora	x							53.00	x	Important	SA	A/B	3	0.0	13.0	2.6	25.5	0	159.76	x
Mtata	x							392.20	x	Important	SA	C	3	0.0	21.0	0	31.5	0	166.79	x
Mngazana	x							49.34	x	Very Important	SA	B	5	1.3	7.4	2	118.0	7.8	199.05	x
Mzimvubu	x							2665.58	x	Important	SA	B	5	0.0	0.0	0	0.0	5	392.03	x
Sikombe	x							6.79		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	1.18	11.48	x
Kwanyana	x							3.99		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	7.13	x
Mtolane	x							1.78		Ave Importance	SA	A	1	0.0	0.0	0	0.0	0	1.29	x
Mnyameni	x							45.87		Ave Importance	SA	A/B	1	0.0	0.0	0	5.0	0.01	32.92	x
Mpahlanyana	x							1.11		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	3.85	x
Mpahlane	x							2.73		Ave Importance	SA	A/B	1	0.0	0.0	0	0.0	0	3.92	x
Mzamba	x							67.43	x	Important	SA	B	3	0.0	0.0	0	0.3	4.74	70.99	x
Mtentwana	x							1.26		Ave Importance	SA	C	1	0.0	0.0	0	0.0	0	11.43	x
Mtamvuna	x	x						275.19	x	Important	SA	B	5	0.0	0.0	0	1.0	0.1	96.7	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Zolwane	x							2.19		Ave Importance		B	1	0.0	0.0	0	0.0	0	2.3	x
Sandlundlu	x							5.07		Ave Importance		C	1	0.0	0.0	0	0.0	0.25	10.5	x
Ku-Boboyi	x							1.00		Ave Importance		B	1	0.0	0.0	0	0.0	0	5.1	x
Tongazi	x							7.00		Ave Importance		B/C	1	0.0	0.0	0	0.0	3	6.78	x
Kandandhlovu	x							1.53		Ave Importance		B	1	0.0	0.0	0	0.0	5.2	11.2	x
Mpenjati	x							23.61		Ave Importance	SA	B/C	1	0.0	0.0	0	0.0	6	28.6	x
Umhlangankulu	x							2.87		Ave Importance		C	1	0.0	0.0	0	0.5	4	15.8	x
Kaba	x							3.15		Ave Importance		C	1	0.0	0.0	0	0.0	1.1	5.1	x
Mbizana	x							36.30		Ave Importance		B	1	0.0	0.0	0	0.0	3	28.4	x
Mvutshini	x							1.66		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	3.88	x
Bilanhlolo	x							5.02		Ave Importance		C	1	0.0	0.0	0	0.0	1.1	4.6	x
Uvuzana	x							1.05		Ave Importance		C	1	0.0	0.0	0	0.0	0	6.1	x
Kongweni	x							1.95		Ave Importance		D/E	1	0.0	0.0	0	0.5	0.25	7.17	x
Vungu	x							27.79		Ave Importance		B	1	0.0	0.0	0	0.0	0	7.13	x
Mhlangeni	x							9.29		Ave Importance		C	1	0.0	0.0	0	0.0	0	15.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Zotsha	x							15.74		Ave Importance	SA	B/C	1	0.0	0.0	0	0.0	5	29.3	x
Boboyi	x							8.25		Ave Importance		B/C	1	0.0	0.0	0	0.0	0	14.3	x
Mbango	x							3.00		Ave Importance		E	1	0.0	0.0	0	0.0	2	12.9	x
Mzimkulu	x	x						1452.49	x	Important	SA	B	5	0.0	0.0	0	0.0	15	117.9	x
Mtentweni	x							12.07		Ave Importance		C	1	0.0	0.0	0	0.0	4.5	18.48	x
Mhlangamkulu	x							2.06		Ave Importance		C	1	0.0	0.0	0	0.0	0.2	100.1	x
Damba	x							4.56		Ave Importance	SA	D	1	0.0	0.0	0	0.0	9	19.65	x
Koshwana	x							2.06		Ave Importance	SA	C/D	1	0.0	0.0	0	0.0	6	18.18	x
Intshambili	x							6.48		Ave Importance	SA	C	1	0.0	0.0	0	0.0	6.25	10.45	x
Mzumbe	x							58.53	x	Ave Importance		C/D	1	0.0	0.0	0	0.0	0	35.8	x
Mhlabatshane	x							6.46		Ave Importance	SA	B/C	3	0.0	0.0	0	0.0	11.5	19.27	x
Mhlungwa	x							5.78		Ave Importance		C	1	0.0	0.0	1.5	0.0	1	16.5	x
Mfazazana	x							2.77		Ave Importance	SA	C	1	0.0	0.0	0	0.0	5	15.6	x
Kwa-Makosi	x							3.23		Ave Importance	SA	B/C	1	0.0	0.0	0	0.0	7	14.95	x
Mnamfu	x							3.08		Ave Importance		C	1	0.0	0.0	0	0.0	4	14.28	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^3x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Mtwalume	x							57.60		Ave Importance		C	1	0.0	0.0	0	0.0	0	38.8	x
Mvuzi	x							1.65		Ave Importance		C	1	0.0	0.0	0	0.0	0	17.8	x
Fafa	x							46.45		Important		C/D	1	0.0	0.0	0	0.0	6.6	32.9	x
Mdesingane	x							2.02		Ave Importance		D	1	0.0	0.0	0.5	0.0	0	7.14	x
Sezela	x							3.92		Ave Importance		C	1	0.0	0.0	0	0.0	0	28	x
Mkumbane	x							3.79		Ave Importance		C	1	0.0	0.0	0	0.0	0	12.25	x
Mzinto	x							23.17		Ave Importance		C/D	1	0.0	0.0	0	0.0	4.5	29.5	x
Mpambanyoni	x							60.06	x	Ave Importance		C	1	0.0	0.0	0	0.0	0.25	12.57	x
Mahlongwa	x							13.76		Ave Importance		C	1	0.0	0.0	0	0.0	0	13.9	x
Mkomazi	x							1077.74	x	Important	SA	C	5	0.0	0.0	0	1.0	10	88	x
Ngane	x							3.83		Ave Importance		C	1	0.0	0.0	0	0.0	0	8.36	x
Umgababa	x							10.56		Ave Importance	SA	C	3	0.0	0.0	0	0.0	2.6	61.7	x
Msimbazi	x							10.04		Ave Importance	SA	B	3	0.0	0.0	0	0.0	0	28.2	x
Lovu	x							119.10	x	Ave Importance	SA	C/D	3	0.0	0.0	0	0.0	5	39.5	x
Little Manzimtoti	x							2.84		Ave Importance		E	1	0.0	0.0	0	0.0	6.5	9.6	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^{3}x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Manzimtoti	x							5.30		Ave Importance		D/E	1	0.0	0.0	0	0.0	2.5	21.17	x
Mbokodweni	x							31.52	x	Ave Importance		E	1	0.0	0.0	0	0.0	0	17.74	x
Sipingo	x							109.40		Ave Importance		F	1	0.0	3.0	0	3.8	16	26.6	x
Mgeni	x							671.30	x	Important	SA	E	3	8.4	0.0	1	31.7	0.5	107.79	x
Mhlanga	x							13.34		Important	SA	D	1	0.0	0.0	0	0.0	0.2	82.78	x
Mdloti	x							100.19	x	Important		D	1	0.0	0.0	0	0.0	7.8	58.1	x
Tongati	x							70.79	x	Important		D	1	0.0	0.0	0	0.0	3.4	37.3	x
Mhlali	x							56.26	x	Important	SA	C/D	1	0.0	0.0	0	0.0	7	42	x
Mvoti	x							374.66	x	Ave Importance	SA	D	1	0.0	0.0	0	0.0	2	111	x
Mdlotane	x							6.04		Important	SA	B	1	0.0	0.0	0.71	0.0	12.33	25.42	x
Nonoti	x							36.24		Ave Importance		C	1	0.0	0.0	2.5	0.0	1	27	x
Zinkwasi	x							14.49		Important	SA	B/C	5	0.0	0.0	0	0.0	11.28	71.16	x
Thukela	x	x	x					3753.60	x	Important	KZn priority	C	3	0.0	0.0	0	0.0	0.27	133.32	x
Matigulu/ Nyoni	x	x						192.27	x	Important	SA	B	5	0.0	0.0	0.5	0.0	2	127	x
Siyaya	x							6.50		Ave Importance	SA	F	1	0.6	0.0	0.08	0.0	3.72	9.52	x

Estuary	Distance estuary ingress into development corridors indicated at 5 km intervals.							Reference Mean Annual runoff (m^{3}x106)	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)	IUCN Critically/ Endangered Fish species
	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		
Mlalazi	x	x						164.31	x	Very Important	SA	B	5	0.0	39.3	0.001	60.7	3.46	238.771	x
Mhlathuze	x	x	x					645.00	x	Very Important	SA	C/D	5	60.0	0.0	28.5	652.1	0	1714.6	x
Richards Bay	x	x						0.00		Important	SA	D	5	52.0	0.0	0	267.0	16	2044	x
Nhlabane	x	x						29.00		Important		D/E	3	0.0	0.0	1.1	0.0	0.3	14.4	x
Mfolozi	x	x	x					885.00	x	Very Important	SA	D	5	0.0	0.0	0	78.2	1683.1	3458.5	x
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	x
Phase 4																				
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	x
Mgobezeleni	x							0.00		Ave Importance	SA	B	1	0.0	0.0	0	4.5	4	15.3	x
Kosi	x	x						0.00		Very Important	SA	A/B	5	58.0	229.0	652	71.0	869	5396	x

Appendix B: Peer Review and Specialist Response Sheet

Peer Reviewer: Professor Janine Adams; Nelson Mandela University

EXPERT REVIEW AND SPECIALIST RESPONSES: Estuaries - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Response from Specialist**
Janine Adams	Whole Document			Don't use etc, check throughout document	This has been corrected throughout the report
Janine Adams	pg 13	19		Fix superscript	This has been corrected
Janine Adams	pg 23		Table 2	Legend should indicate what numbers 1-7 are	Relevant description has been added
Janine Adams	pg 25	12		...in the density of benthic organisms and number of taxa	This has been corrected
Janine Adams	pg 25	20		delete "along this coast", repeat in the sentence	This has been corrected
Janine Adams	pg 25	32, 33		change to....especially with respect to the ability of individual and collective systems to absorb and recover from events.	This has been corrected
Janine Adams	pg 38	27, 28		change to....stretch more than 25 km into the corridor	This has been corrected
Janine Adams	pg 39		Figures 12-16	Sensitivity map...	This has been corrected
Janine Adams	pg 43	7, 12, 13		Check here and throughout document for chronological ordering of in text references, must be from earliest to most recent date	This has been corrected
Janine Adams	pg 45	31		delete "increase"	This has been corrected
Janine Adams	pg 46	18		"reduce" instead of "reduced"	This has been corrected
Janine Adams	pg 48	16		increases	This has been corrected
Janine Adams	pg 49	11		threat	This has been corrected
Janine Adams	pg 50	10		alter	This has been corrected
Janine Adams	pg 50	20		Over time	This has been corrected
Janine Adams	pg 50	31		delete "any"	This has been corrected
Janine Adams	pg 51	7		periods when, delete "which"	This has been corrected
Janine Adams	pg 60	10, 11		This will set targets for use of specific chemicals in marine waters....	This has been corrected
Janine Adams	pg 61	5, 14		take out of bold	This has been corrected
Janine Adams	pg 62	24, 26		take out of bold	This has been corrected
Janine Adams	pg 63	5		check Section number	This has been corrected
Janine Adams	pg 64	31		be excavated	This has been corrected
Janine Adams	pg 64	37, 38		no bold	This has been corrected
Janine Adams	pg 65	10		would mostly be required for ROWs	This has been corrected

EXPERT REVIEW AND SPECIALIST RESPONSES: Estuaries - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Response from Specialist**
Janine Adams	pg 65	14		are recommended	This has been corrected
Janine Adams	pg 66	9		where required	This has been corrected
Janine Adams	pg 71	4		correct spelling of Fernandes	This has been corrected
Janine Adams	pg 71-76			check that species names are in italics	This has been corrected
Janine Adams	Overall comments			The report is relevant and uses the most up-to-date datasets to come to relevant conclusions	Noted
Janine Adams	Overall Comments			The report is thorough and represents the impacts and possible mitigation actions accurately.	Noted

Strategic Environmental Assessment for the Development of a Phased Gas Pipeline Network in South Africa

Appendix C.1.7

Biodiversity and Ecological Impacts (Aquatic Ecosystems and Species) - Wetland and Rivers

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

FRESHWATER ECOSYSTEMS

Contributing Authors	Gary de Winnaar[1], Dr Vere Ross-Gillespie[1]

[1] GroundTruth, Hilton

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TABLES

FIGURES

ABBREVIATIONS AND ACRONYMS

ADU	Animal Demographic Unit
AOO	Area of Occupancy
ASPT	Average Score Per Taxon
BSP	Biodiversity Sector Plan
CBA	Critical Biodiversity Area
C-Plan	Conservation Plan
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
ECO	Environmental Control Officer
EI	Ecological Importance
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
EN	Endangered
EOO	Extent of Occurrence
ES	Ecological Sensitivity
GBIF	Global Biodiversity Information Facility
GIS	Geographic Information System
GP	Gas Pipeline
HGM	Hydrogeomorphic
IAP	Invasive Alien Plant
IHI	Index of Habitat Integrity
IRP	Integrated Resource Plan
IUCN	International Union for Conservation of Nature
LC	Least Concern
m.a.s.l	Metres above sea level
NBA	National Biodiversity Assessment (2011)
NDP	National Development Plan
NFEPA	National Freshwater Ecosystem Priority Areas
PA	Protected Area - statutory
PES	Present Ecological State
QV	Quality Value
ROW	Right of way
SA	South Africa
SAIAB	South African Institute for Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SASS	South African Scoring System
SEA	Strategic Environmental Assessment
Spp	Species
SQ4	Sub-quaternary catchment
ToPs	Threatened or Protected species
TSP	Threatened Species Programme
VU	Vulnerable
WULA	Water Use License Application

1 SUMMARY

In order to realise the potential of gas reserves in South Africa, and to contribute to the transition to a low carbon economy, the Operation Phakisa Offshore Oil and Gas Lab has set a target of achieving 30 exploration wells in the next ten years (from 2014). This sparked plans to accelerate gas to power development as recognised by the Government's Integrated Resource Plan (IRP), which included pre-planning for State Owned Entities to develop gas transmission servitudes across South Africa. As a result, initiatives were identified – development of a phased gas pipeline network being one of the identified initiatives. However, in order for gas pipeline development to go-ahead, Environmental Authorisation (EA) in terms of the Environmental Impact Assessment Regulations, 2014 (as amended in 2017) would be required. Strategic planning for gas pipeline servitudes also needs to be undertaken well in advance of final planning as a means to uphold Operation Phakisa, while preventing unnecessary delays through the EA process. The Council for Scientific and Industrial Research (CSIR) was commissioned by the National Department of Environmental Affairs (DEA) to undertake a Strategic Environmental Assessment (SEA) in order to identify and pre-assess environmental sensitivities within the identified gas pipeline corridors. GroundTruth was appointed by the CSIR to assess the corridors specifically in terms of freshwater ecosystems (i.e. wetland and river ecosystems) and fauna and flora associated with these systems.

The scope for the freshwater ecosystem/biodiversity study was provided by the CSIR to ensure that the approach and methodology followed was scientifically defensible and adequately defined within the context of the SEA. In particular, the approach was intended to be spatially explicit, drawing from available data depicting the distribution and extent, as well as importance and sensitivity of freshwater ecosystems and selected fauna and flora that inhabit these systems.

The study was based on a combination of desktop assessments building on strengths of mapping and geospatial analyses using geographical information systems (GIS), with input from meetings and discussions with relevant authorities and experts. This ensured a thorough interpretation of existing data incorporating defensible and rigorous methodologies. Data was sourced from various custodians, which was largely facilitated through the South African National Biodiversity Institute (SANBI) and their online data portal, BGIS (Biodiversity GIS). The data covered a range of spatial scales, from local (i.e. municipalities) to regional (i.e. provinces) to national. For wetlands, the spatial data was obtained as polygon features, while rivers were defined as lines and fauna/flora as points. Fauna and flora selected for the freshwater study included conservation important species (based on the latest available conservation assessments) that are dependent on wetland and river systems that include surrounding fringe habitats. In terms of fauna, the data collation and analysis focused on certain taxonomic groups, namely: aquatic macro-invertebrate (at the family level), dragonflies and damselflies (Family: Odonata), freshwater fish (Class: Actinopterygii), amphibians (Order: Anura), reptiles (Order: Reptilia) and mammals (Order: Mammalia). All data of freshwater ecosystem and selected key species was reviewed and refined to allow for integration to an appropriate scale/resolution. The sub-quaternary (SQ4) catchments for South Africa were used as the most appropriate scale for the spatial analyses and assessments of freshwater ecosystems within the SEA corridors. All spatial/GIS data was assessed firstly in terms of applicability/suitability, then merged/joined with other layers, then clipped according to the relevant gas pipeline corridors in order to assess the sensitivity-level of the corridors. Metrics were also used to calculate sensitivity using a four-tiered categorisation (i.e. low, medium, high and very high) as requested by the CSIR. A more detailed description of the data used and methods followed is presented in Section 4 of the freshwater specialist report, along with the relevant legislation/regulatory requirements and applicable assumptions and limitations for the study.

The results from the freshwater study are presented as a series of maps illustrating freshwater features and their current sensitivity (as per the four-tiered sensitivity classes) for each of the nine gas pipeline corridors as provided by the CSIR. Maps are arranged according to the respective corridors in Section 6 to provide an overview of river, wetland and freshwater biota sensitivity. In addition, a brief summary of the present state of freshwater ecosystems/biodiversity within each corridor is also provided in Section 5, which describes some of the key sensitivities, as well as drivers and pressures affecting freshwater

ecosystems and biodiversity. Corridors found to be most sensitive (with high to very high sensitivity) are as follows:

- In terms of **river ecosystems** the Phase 3 Corridor is most sensitive, followed by Phase 8, then Phase 2.
- In terms of **wetland ecosystems** the Phase 2 Corridor is most sensitive, followed by Phase 1, then Phase 8.
- In terms of **freshwater biota (i.e. fauna and flora)** the Phase 1 Corridor is most sensitive, followed by Phase 8, then Phase 2.
- In terms of **overall sensitivity (i.e. combined river, wetland and biota)** the Phase 1 Corridor is most sensitive, followed closely by Phase 2 and Phase 8.

The primary purpose of the maps and spatial products are to assist the CSIR in integrating a number of key strategic issues such as (but not limited to) terrestrial biodiversity and socio-economics into the overall SEA, as well as to identify problem areas (or nick points) where special precautions and measures may be required to limit impacts from gas pipeline development. In terms of the freshwater study the spatial deliverables can assist planning and development of gas pipelines through a two-step process: firstly, to use the SQ4 catchments maps to identify areas where pipeline construction and operation will have the lowest impact on freshwater ecosystems, and secondly, to use the actual feature data to plan pipeline routing within the SQ4 catchments of each corridor.

Impacts that will potentially affect river and wetland ecosystems and associated fauna and flora have been identified to provide a generic evaluation of pipeline activities for various stages of development, from planning to construction to operation. Each activity is discussed in terms of the cause and effects that these will have on freshwater ecosystems. Appropriate, and again generic, mitigation measures are also provided as recommendations for preventing and/or minimising impacts to freshwater ecosystems/biodiversity. Part of the evaluation includes a risk assessment to rate the identified impacts with respect to the four-tiered sensitivity classes. The risk assessment also includes an evaluation of impacts both with and without mitigation. However, it is acknowledged that additional steps will be required once pipeline routes and alternatives have been established (i.e. desktop screening, ground-truthing and infield delineation and assessments).

In addition to the recommended mitigation measures, "best practice" (or "good practice") guidelines and management actions are provided, and include practical, target-directed recommendations for monitoring of aspects, along with considerations on how to interpret and implement the four-tiered maps. Lastly, several gaps in knowledge are mentioned in terms of influencing this freshwater study and assessment.

2 INTRODUCTION

In 2012, the National Development Plan (NDP) was adopted to accelerate infrastructure development in order to address service delivery, backlogs and facilitate economic growth and job creation. This led to the launch of Operation Phakisa in July 2014 to fast-track service delivery, and to help implement the NDP.

The oil and gas sector within South Africa is in an early development phase, but nevertheless has the potential to create large value for the country in the long-term. Added to this are potential resources of oil and gas. In order to realise the potential of the gas reserves in the country, and to contribute to the transition to a low carbon economy, the Operation Phakisa Offshore Oil and Gas Lab has set a target of achieving 30 exploration wells in the next ten years (from 2014). In addition, the need to accelerate the planning for gas to power as part of the Government's Integrated Resource Plan (IRP) and for State Owned Entities to pre-plan for the logical development of gas transmission servitudes within South Africa was recognised. Based on these needs, initiatives were identified with the development of a phased gas pipeline network being one of them.

The development and operation of infrastructure for the bulk transportation of dangerous goods (including gas using a pipeline exceeding 1000 m in length) is identified as activity 7 of Listing Notice 2 of 2014 as amended (GN R325, 2017) and therefore requires Environmental Authorisation (EA) in terms of the Environmental Impact Assessment Regulations, 2014 (as amended in 2017). Strategic planning for servitudes also needs to be undertaken well in advance of the final planning of a gas transmission pipeline system. To ensure that when required, obtaining an EA is not a cause for delay and to support the Operation Phakisa, the National Department of Environmental Affairs (DEA) in partnership with the National Department of Energy (DoE) and the National Department of Public Enterprises (DPE), representing iGas, Eskom and Transnet, has commissioned the Council for Scientific and Industrial Research (CSIR) in April 2017 to undertake a Strategic Environmental Assessment (SEA). The aim of this SEA is to identify and pre-assess environmental sensitivities within suitable gas routing corridors and, where required, expand the identified electricity power corridors (DEA, 2016: https://egi.csir.co.za), to facilitate a streamlined EA process for the development of energy infrastructure related to gas and electricity.

Upon gazetting of the energy corridors, it is envisaged that the EA process for gas pipeline and transmission infrastructure will be streamlined in specific areas identified through the SEA process as being less sensitive to the negative impacts associated with the development of these infrastructure. This should incentivise potential developers to plan and develop in the least sensitive areas. The SEA process also provides a platform for coordination between the various authorities responsible for issuing authorisations, permits or consents and thereby will further contribute to a more streamlined EA process. The preliminary corridors were identified as part of the Operation Phakisa and will link specific supply and demand areas. This study is therefore intended to inform the SEA, specifically in terms of freshwater ecosystems and biota (fauna and flora) in relation to the preliminary corridors. This specialist report focuses on the impact of the proposed gas pipeline development on freshwater ecosystems.

Freshwater ecosystems, i.e. wetlands and rivers, are valuable ecosystems and it is well documented that they provide numerous ecological and hydrological functions (Cowan, 1995; Breen *et al.*, 1997; Mitchell, 2002). These functions include improving water quality (reductions in suspended sediments, excess plant nutrients and other pollutants), streamflow regulation (flood attenuation, water storage and sustaining streamflow), groundwater recharge, erosion control, and the maintenance of biodiversity for wetland-dependant fauna and flora (Kotze and Breen, 1994). Consequently, wetlands and rivers provide many important services to human society. At the same time, through continued negative perceptions by humanity, they remain ecologically sensitive and vulnerable systems (Turner *et al.*, 2003). Historically, freshwater ecosystems have been subjected to numerous pressures from surrounding developments and changing land use, to the extent that many wetlands and rivers have been severely degraded or completely lost (Kotze *et al.*, 1995). This has largely been as a result of human activities, either through direct disturbance, or indirectly from impacts upstream (Breen *et al.*, 1997). More than two decades ago, it was estimated that over half of South Africa's wetlands had been lost (Kotze *et al.*, 1995). The current situation is no doubt even greater, and of the remaining systems, 48% are classified as Critically Endangered (Nel and Driver, 2012). Thus, freshwater ecosystems need to be safeguarded as much as possible from on-going and future development in order to maintain, or even improve the status of existing wetland and river habitats.

3 SCOPE OF THIS STRATEGIC ISSUE

The primary objective of this study is to provide an assessment of freshwater ecosystems (i.e. rivers and wetlands) and associated biodiversity within pre-identified corridors (Figure 1). The assessments will inform the SEA through identification of constraints (e.g. sensitive rivers and wetland ecosystems, critical areas for aquatic fauna and flora, etc.) and opportunities for the development of gas pipelines.

This assessment is focused primarily on the interpretation of existing data, and is based on defensible and, if available, standardised and recognised methodologies. The focus is primarily to review the environmental wall-to-wall mapping outputs produced by the CSIR and SANBI (specifically relating to the gas pipeline corridors), and to discuss the direct, indirect and cumulative impacts. Any gaps in information linked to aquatic biodiversity associated with rivers and wetlands with respect to the gas pipeline corridors were identified as potential shortcomings needing to be addressed through further screening and ground-truthing assessments.

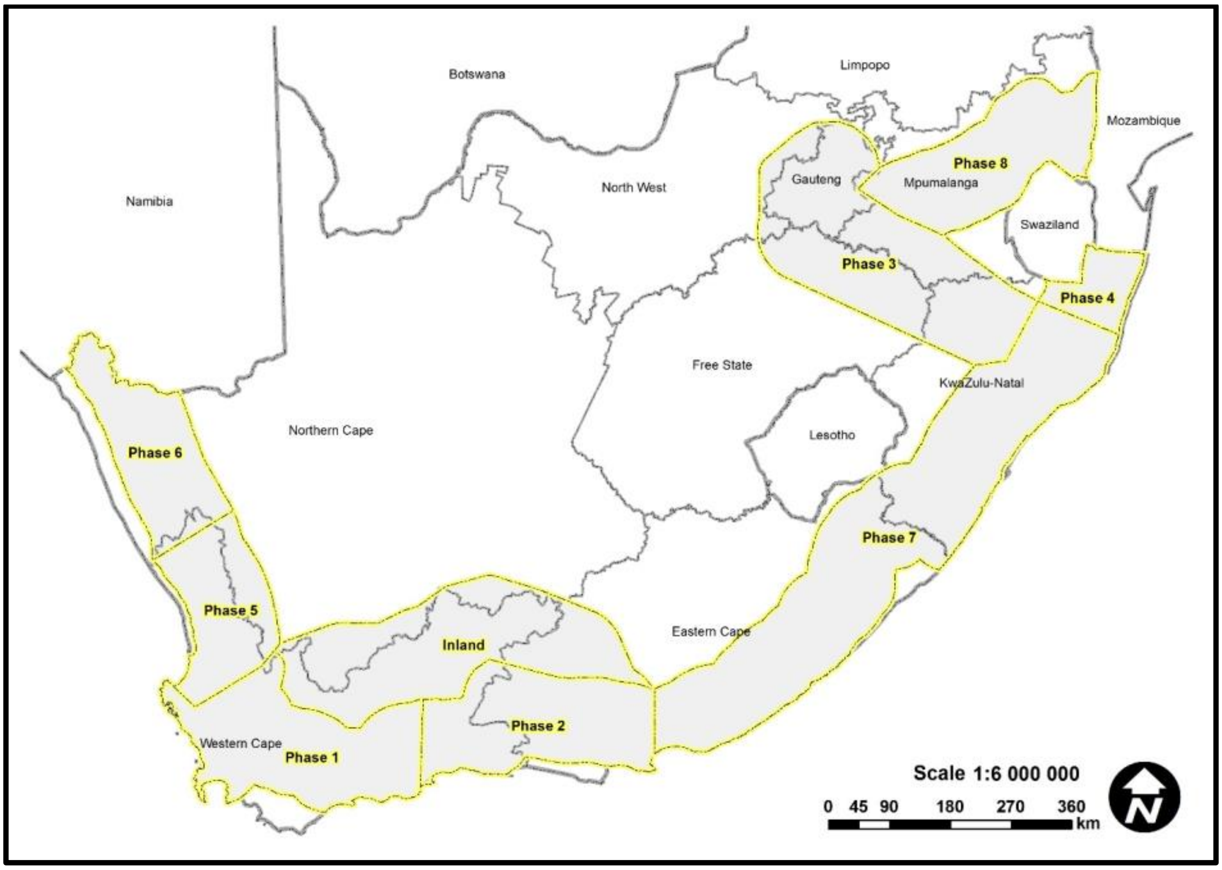

Figure 1: Overview of the proposed gas pipeline corridors

The study methodology developed as part of this project is intended to inform future SEAs in terms of specialist assessment methodologies. The study also incorporates a review of available data and information (e.g. the CSIR environmental wall-to-wall mapping, SANBI datasets, etc.), and builds on discussions with the relevant organisations related to aquatic ecosystems and biodiversity (e.g. SANBI, National Department of Water and Sanitation (DWS), etc.). This is to ensure that the outcomes of the study are accepted by these agencies, and will be taken into consideration for future authorisation and commenting within the areas assessed.

The assessment of freshwater ecosystems and biodiversity includes the following:

- Review of existing literature (including the latest research undertaken both locally, nationally and internationally), mapping/aerial photographs, and habitat and species data to compile a baseline description applicable to each corridor;
- Identification of any additional features of interest (large waterfalls, spray zones etc.) or any gaps in information within the corridors not identified in the existing sensitivity analysis, making use of datasets made available through the draft environmental constraints map and additional information sourced by the specialist;
- High level distribution mapping for sensitive aquatic species occurring within South Africa;
- Review and update, where required, the environmental sensitivity/attribute map for the proposed gas pipeline corridors provided by the CSIR and SANBI and develop/verify the approach for classing each sensitivity feature according to a four-tiered sensitivity rating system (i.e. very high, high, medium or low);
- Assess the proposed corridors in terms of the potential impacts associated with the construction and operation of gas pipelines, taking cognisance of the relative sensitivity of areas, and outline proposed management actions to enhance benefits and avoid/reduce/offset negative impacts – this was done as per the impact assessment methodology provided by the CSIR Project Team;
- Based on the findings of the assessment, provide the relevant information and produce an updated four-tiered sensitivity map related to the field of expertise and the relevant corridors.
- Provide input to the pre-construction site specific environmental assessment protocol (e.g. additional information and level of assessment required in each sensitivity category before an authorisation with respect to aquatic biodiversity impacts), checklist, norms or standards/Minimum Information Requirements, and Environmental Management Programme (EMPr) for the development of the gas pipelines.

Further to the above scope of work, the following information and data was considered as a minimum as part of the study, with more recent data consulted as appropriate:

- The latest Systematic Biodiversity Plans relevant to the study area, including input layers where applicable, as well as relevant land-use and impact assessment guidelines associated with these plans, e.g. the National Freshwater Ecosystem Priority Areas (NFEPA) technical report (Nel *et al.* 2011), and its associated implementation manual (Driver *et al.*, 2011).
- The 2011 National Biodiversity Assessment (NBA), including its spatial layers (specifically layers that were not used for the environmental constraints map), but that are relevant at a finer scale (Nel and Driver, 2012).
- The latest species information available for the study area in particular, but not limited to, sensitive species that are dependent on these riparian zones, including specific Red Listed plants (Raimondo *et al.*, 2009), butterflies, (Mecenero *et al.*, 2013), reptiles (Bates *et al.*, 2014).
- Fine-scale spatial biodiversity information, e.g. additional wetland or species information that may not have been included in a systematic biodiversity plan.

It is important to note that the outputs from this study will form the basis of a planning and decision-support document for gas pipeline development in the respective corridors. The aim of the planning document will be to inform and focus further aquatic project-level assessments (as they relate to rivers and wetlands) with respect to gas pipeline development in the respective corridors (i.e. serve as a scoping exercise).

The key deliverables and reporting requirements of this project include:

- Specialist Assessment Report based on a specialist report template provided by the CSIR for the SEA, for review and comment, but covering the following:
  - Summary of key points, including degree-of-certainty terms;
  - Introduction – brief discussion of the essential background on the Strategic Issue;
  - Definition of issue scope and key terms;
  - Key attributes and sensitivities of the study areas towards the development of a gas pipeline within the Gas Pipeline Corridors - baseline description of each proposed corridor

(study area) relating to the issue topic and spatial sensitivity analysis (for spatially explicit topics), inclusive of a literature review in line with the strategic issue;
    - Description of methodology and approach to the study;
    - Description of the key potential impacts (positive and negative, including direct, indirect and cumulative) that are associated with gas pipeline development activities relating to the issue topic (inferred and distilled from the Project Description document provided to Authors), and their spatial and temporal distributions, including required mitigation measures;
    - The sensitivity delineation should be undertaken in the context of the development of a gas pipelines;
    - The results of a structured risk and opportunity assessment which evaluates the impacts, with and without mitigation, for each study area, and clearly defines consequence terms;
    - Updated four-tiers sensitivity map;
    - Outline proposed mitigation measures and management actions to enhance benefits and avoid/reduce/offset negative impacts for construction and operation phase. This will form part of the EMPr;
    - Best practice and management guidelines for gas pipeline development (including inputs in the norms or standards/Minimum Information Requirements, and the Site Specific Environmental Assessment Protocols and Checklist), monitoring requirements and recommendations for future site-specific assessment in relation to the Strategic Issue;
    - Gaps in knowledge; and
    - References.
- Geographic Information System (GIS) Assessment Dataset and additional information sourced by the specialist;
- Metadata for the Assessment Dataset (DEA metadata template, must be used - template will be provided upon appointment);
- GIS based four-tiered consolidated sensitivity map of all sensitivity features identified through the assessment showing the location and spatial extent for each sensitivity feature and associated buffering. The sensitivity rating should be illustrated according to the following coloration scheme: Dark Red/Very High, Red/High, Orange/Medium, Green/Low; and
- A guideline on the interpretation and implementation of the four tier maps as well as permit requirements (where applicable) for each corridor. This section should also make recommendations on requirements for additional terrestrial and aquatic biodiversity specialist studies (if any) within the different tiers of sensitivity specialist before an authorisation can be considered. Recommendations should be focused around the objective of streamlining without compromising environmental protection. This information will be incorporated into the Decision-Making Tools that will ultimately govern development in the corridors.

Note that this Specialist Assessment Report was peer reviewed prior to release to stakeholders for review. The report was updated, as required, following the peer review findings. A copy of the peer review report and responses from the Specialist Team is included in Appendix 3 of this report.

4 APPROACH AND METHODOLOGY

4.1 Study Methodology

The study was based on a combination of desktop assessments building on strengths of GIS mapping and geospatial analyses, and builds on meetings and discussions with relevant authorities and experts. This ensured a thorough interpretation of existing data incorporating defensible and rigorous methodologies. The following steps outlined below were followed.

4.1.1 Briefing session

A representative from the GroundTruth team attended a one-day briefing session at the CSIR in Stellenbosch to meet the Integrating Authors and Contributing Authors to discuss and define the assessment phase of the project. The briefing session served to refine/agree on the scope of work, deliverables and timing, as well as to make sure all available data and information from the CSIR could be obtained upfront and as timeously as possible.

4.1.2 Literature review and data collation

The accuracy of information generated for the SEA is only as good as the information on which they are derived. Thus, as far as possible, the quality and validity of data obtained for the assessment of aquatic biota and ecosystems has been reviewed and refined to allow for integration to an appropriate scale/resolution. This process included the collation of datasets from a variety of sources, which were subsequently reviewed and assessed for suitability/relevance for the spatial assessments associated with freshwater rivers and wetlands. The datasets used in this component of the SEA, and sources where the data was obtained are indicated in Section 4.2.

4.1.3 Assigning a suitable spatial scale for analysis

All spatial data obtained for the freshwater ecosystem component were considered in terms of a suitable spatial unit/scale of measurement deemed practical for the purpose of assessing the gas pipeline corridors, as well as the alignment of associated infrastructure within the corridors. The sub-quaternary (SQ4) catchments for South Africa was decided as the most appropriate scale for the spatial analyses and assessment of freshwater ecosystems within the SEA corridors. This allowed for the scaling up of data to assess the corridors relative to each other.

4.1.4 Analysis and integration of GIS data

All spatial/GIS data obtained for the freshwater component were assessed firstly in terms of applicability/suitability, then merged/joined with other layers, then clipped according to the relevant gas pipeline corridors as provided by the CSIR in order to assess the sensitivity-level of the corridors. All spatial analyses were undertaken using ArcGIS 10 software (version 10.4.1).

4.1.5 Application of metrics for sensitivity analyses

4.1.5.1 River threat status and sensitivity:

Threat status has been applied to river ecosystems as per thresholds defined in the Freshwater Component of the 2011 South African NBA (Nel and Driver, 2012), but using updated Present Ecological State (PES) information. The 2011 NBA used PES data from 2000 (Kleynhans, 2000) whereas the report here draws on the more recent PES, Ecological Importance (EI) and Ecological Sensitivity (ES) data from the DWS (2014).

In addition to the threat status calculation, a metric was developed to integrate EI and ES component scores from the 2014 DWS study, the derived threat status (as above), as well as stream order. EI and ES scores represent ecological importance and sensitivity scores for freshwater ecosystems as separate, yet complimentary, components of PES. They are not currently accounted for in the threat status calculation, which uses river length and overall PES category/river health condition, but nevertheless provide valuable information regarding ecological sustainability. EI refers to biophysical aspects in the reach that relates to its capacity to function sustainably, whereas ES considers reach attributes that relate to the sensitivity of biophysical components to general environmental changes such as flow, physico-chemical and geomorphic modifications. EI and ES categories were ranked as scores from one to four (i.e. very low and Low = 1, moderate = 2, high = 3, and very high = 4), along with threat status (i.e. Critically Endangered or CR = 4, Endangered or EN = 3, Vulnerable or VU = 2, Least Concern or LC = 1). These scores were then considered in relation to stream order as per the following equation, such that the higher the score, the higher the overall sensitivity of the river ecosystem:

River Sensitivity = Threat Score + (EI Score + ES Score / Stream Order)

In basic terms, the higher the score the more sensitive the freshwater system. In addition, the metric favours higher order streams in the catchment which feed downstream systems.

4.1.5.2 Wetlands threat status and sensitivity:

The extent and distribution of wetland ecosystems (and their importance and sensitivity) was defined using a variety of available wetland datasets. These datasets cover a range of scales (i.e. national and provincial, down to fine-scale mapping for certain local municipalities), and include a variety of information pertaining to wetland habitats, such as wetland types, condition and conservation importance. The objective of the wetland mapping was to define areas containing wetland habitat in terms of sensitivity and importance based on the information available. A composite wetland layer was developed with this in mind, and followed a systematic process of sourcing, reviewing/analysing, cleaning and collating relevant datasets for each province. Provincial datasets were then collated, and routinely cleaned of any redundant data. Field attributes contained in the combined wetland coverage were categorised using four sensitivity classes as summarised in Table 1. A hierarchical selection process was followed to assign the highest sensitivity to each wetland feature contained in combined coverage.

Table 1: Criteria for assigning sensitivity classes for wetland attributes.

Sensitivity class/value	Wetland attribute
Low sensitivity (sensitivity value = 1)	Wetland probability, non-NFEPA wetlands, least threatened wetlands, other natural areas (ONAs) as aquatic features, protected aquatic features.
Medium sensitivity (sensitivity value = 2)	NFEPA wetlands, nearly threatened wetlands, ecological support areas (ESAs) as aquatic features.
High sensitivity (sensitivity value = 3)	Ramsar site wetlands, KZN priority wetlands, Endangered or Vulnerable wetlands, optimal critical biodiversity areas (CBA2s) as aquatic features.
Very high sensitivity (sensitivity value = 4)	Critically Endangered wetlands, irreplaceable critical biodiversity areas (CBA1s) as aquatic features.

Due to large size of the combined wetland coverage, it was deemed practical to remove wetland features smaller than 0.50 and 0.25 hectares for the low and medium sensitivity classed wetlands. For the Western Cape, a more rigorous cleaning process was required due to the impractical file sizes that were created as a result of combining multiple fine-scale datasets. Thus for the Western Cape, aquatic CBA features less than one hectare, and aquatic ESA features less than two hectares were removed. Furthermore, it was found that the ESA layers were particularly cumbersome, so only ESA features that are connected to CBAs were included in the final wetland layer for the Western Cape.

The threat status of wetlands was defined using the national wetland vegetation groups (Nel and Driver, 2012). Wetlands occurring within a particular wetland vegetation group (or region) were assigned the threat category of that region, and then allocated a threat score (i.e. CR = 4, EN = 3, VU = 2, LC = 1). The threat scores were combined with the initial wetland sensitivity values (based on Table 1 above) by adding the scores and values together to produce an overall risk/sensitivity score of wetlands within the study area.

In order to account for the aerial extent of wetland habitat, the risk/sensitivity scores for each wetland feature were multiplied by the proportion of wetland (of a particular risk/sensitivity) within each SQ4 catchment. These area-weighted risk/sensitivity scores were then summed together for each SQ4 catchment, and then collapsed into the four sensitivity classes using a quantile data split.

The final result of the wetland integration and spatial analysis was a SQ4 coverage showing areas of low, medium, high and very high sensitivity taking into account threat status, and importance/sensitivity and extent of wetland habitat. However, it is also prudent to consult the combined wetland feature map, which displays the actual sensitivity scores for each wetland feature.

4.1.5.3 Freshwater biota (species and families):

Information of freshwater biota was used as an additional level of detail in order to assess the sensitivity/importance of SQ4 catchments within the gas pipeline corridors. To achieve this, taxonomic groups that are representative of freshwater ecosystems were considered, especially where data of known localities was found to be sufficiently detailed and accessible. These groups include: freshwater plants, aquatic macro-invertebrates, dragonflies/damselflies (i.e. Family: Odonata), freshwater fish, amphibians, obligate reptiles and obligate mammals. Information of the conservation status/importance of species from these taxonomic groups was considered particularly important in terms of being able to establish the sensitivity of areas. To achieve this, data of Red Listed species was sourced to obtain the latest available assessments (global and national) of species done according to the International Union for Conservation of Nature (IUCN) criteria and Red Listing requirements (IUCN, 2012). Species selected primarily for this study included freshwater species of conservation importance, i.e. species listed as Threatened (i.e. Critically Endangered, Endangered and Vulnerable), Near Threatened and Data Deficient.

4.1.5.4 Freshwater plants (Kingdom: Plantae):

The conservation status of a large number of plants occurring within South Africa has been assessed by Raimondo *et al.* (2009). As with the other taxa, freshwater plants listed as Threatened, Near Threatened and Data Deficient were selected for this study, which includes 141 species of plants (Appendix 1) that inhabit a range of freshwater habitats, broadly including wetlands, rivers and riparian areas. Point localities (approximately 4 129 records) for the selected plant species were obtained from the SANBI Threatened Species Programme (TSP) database (SANBI, 2018). As with the other taxonomic groups, these point records were assigned to SQ4 catchments to derive a presence/absence coverage, which were then classified into the four sensitivity classes (i.e. low, medium, high, very high).

Aquatic macro-invertebrates (Class: Insecta):
Species-level data for invertebrates is generally limited or biased toward certain groups (e.g. butterflies and dragonflies/damselflies), however, family-level data is more obtainable. Furthermore, families of most macro-invertebrates (94 families) have variable tolerances to water quality and quantity impacts with specific Quality Values (QV - an indication of their sensitivity to land use and water quality/quantity impacts ranging from 1 to 15) - this is the basis of river health biomonitoring.

Point localities for the 94 macro-invertebrate families recorded from a total of 4 350 river sites in South Africa, of which 3 202 (or 73%) are located within the gas pipeline corridors, were assigned to a 1:10 000 grid vector. For each grid cell the total diversity was calculated from which two separate but complementary indices were then derived, namely:

- South African Scoring System (SASS) Score - sum of all families multiplied by their respective QV as occurring within a particular grid cell; and
- Average Score Per Taxon (ASPT) - the SASS Score divided by the total number of recorded families for a particular grid cell.

SASS Scores and ASPT values were then assigned to a river ecoregion (Level 2) by selecting grid cells where more than half of the grid cell falls within a particular ecoregion. Average SASS Scores and ASPT values was calculated for each river ecoregion using all grid cell data within each ecoregion. Average ASPT values were then classified into four sensitivity classes (i.e. low, medium, high, very high) using a Quantile split in the dataset using ArcGIS 10 software (version 10.4.1).

Dragonflies and Damselflies (Family: Odonata):
All species of Odonata (i.e. dragonflies and damselflies) have been assessed in terms of their conservation status/importance within South Africa (IUCN, 2017; Samways and Simaika, 2016). Species listed as Threatened, Near Threatened and Data Deficient, were selected for this study, which includes 27 listed species (Appendix 2). Point localities (approximately 712 records) where these conservation important dragonflies and damselflies have been recorded were obtained from the SANBI (TSP) database (SANBI, 2018). Point records were assigned to SQ4 catchments to derive a presence/absence coverage of each species per catchment. The SQ4 catchments were then classified into four sensitivity classes (i.e. low, medium, high, very high) based on the presence/absence of conservation important dragonflies and damselflies where catchments supporting Critically Endangered species have a “very high” sensitivity, Endangered and Vulnerable species have a “high” sensitivity, Near Threatened and Data Deficient species have a “medium” sensitivity, and all remaining catchments not known to support conservation important species have a “low” sensitivity.

Freshwater Fish (Class: Actinopterygii):
Most of the freshwater fish that occur within South Africa have been recently assessed and are now Red Listed, with only a few species still requiring assessments (Coetzer, 2017). Forty nine species of conservation importance were selected for this study (Appendix 2). Point localities (approximately 1 194 records) for 28 of these selected species were obtained from the Global Biodiversity Information Facility (GBIF) database via the South African Institute for Aquatic Biodiversity (SAIAB). These point records were assigned to SQ4 catchments to derive a coverage of presence or absence of each species per catchment based on known point locations. Distribution data for the other 21 selected fish species was spatially defined by selecting SQ4 catchments where each species occurs as inferred from the IUCN Red List of Threatened Species Map Viewer (IUCN, 2017). As with dragonflies and damselflies, all SQ4 catchments were then classified into four sensitivity classes (i.e. low, medium, high, very high) based on the presence/absence of conservation important freshwater fish.

Amphibians (Order: Anura):
The conservation status of most amphibians occurring within South Africa has been assessed by Minter *et al.* (2004). As with the other freshwater taxa, amphibians listed as Threatened, Near Threatened and Data Deficient selected for this study includes 29 listed species (Appendix 2). Point localities (approximately 11 444 records) for these selected species were obtained from the SANBI (TSP) database (SANBI, 2018). These point records were assigned to SQ4 catchments to derive a coverage of presence or absence of each species per catchment based on the known point locations. The SQ4 catchments were then classified into four sensitivity classes (i.e. low, medium, high, very high) based on the presence/absence as done for the other freshwater taxonomic groups.

Reptiles (Order: Reptilia):
The conservation status of most reptiles (i.e. terrapins, geckos, lizards, chameleons, and snakes) that occur within South Africa have been assessed by Bates *et al.* (2014). Reptiles listed as Threatened, Near Threatened and Data Deficient selected for this study includes six listed species (Appendix 2). In addition, only those reptiles that are defined as freshwater ecosystem obligates (i.e. species that is entirely or mostly dependent on aquatic, wetland and riparian habitats to exist) were considered. Point localities (approximately 4 452 records) for these selected species were obtained from the SANBI (TSP) database (SANBI, 2018). These point records were assigned to SQ4 catchments to derive a coverage of presence or absence of each species per catchment based on the known point locations. The SQ4 catchments were then classified into four sensitivity classes (i.e. low, medium, high, very high) based on the presence/absence as done for the other freshwater taxonomic groups.

Mammals (Order: Mammalia):
The conservation status of most mammals that occur within South Africa have been assessed by Child *et al.* (2016). As with the other taxa, only mammals listed as Threatened, Near Threatened and Data Deficient were selected for this study, which includes 11 listed species (Appendix 2). In addition, only those mammals that are defined as freshwater ecosystem obligates (i.e. species that is entirely or mostly dependent on aquatic, wetland and riparian habitats to exist) were considered. Point localities

(approximately 3 072 records) for these selected species were obtained from the SANBI (TSP) database (SANBI, 2018). These point records were assigned to SQ4 catchments to derive a coverage of presence or absence of each species per catchment based on the known point locations. The SQ4 catchments were then classified into four sensitivity classes (i.e. low, medium, high, very high) based on the presence/absence as done for the other freshwater taxonomic groups.

4.1.6 Integration of taxonomic groups

Sensitivity values of the aforementioned taxonomic groups, ranging from one to four (i.e. low to very high sensitivity), were combined into a single layer in order to calculate overall biotic sensitivity for each SQ4 catchment. Linear weightings were applied to each of the groups based on the ability of respective species being able to escape/disperse away from disturbance and impacts to habitats. Plants being sedentary were thus given the highest weighting of seven, followed by amphibians (six), reptiles (five), mammals (four), fish (three), dragonflies and damselflies (two), and macro-invertebrates (one). The weighted sensitivity values were summed together to produce a total score for each SQ4 catchment, which were then collapsed into the four sensitivity classes using a quantile data split.

4.1.7 Producing integrated four tier sensitivity maps

The sensitivity maps produced for rivers, wetlands and combined freshwater biota were also integrated into a single layer by summing the sensitivity values for each component. The total score for each SQ4 catchment were collapsed into the four sensitivity classes using a quantile data split. This coverage provides an integration of all data pertaining to freshwater biodiversity and ecosystems, and is particularly useful for identifying preferred alignments for gas pipeline infrastructure in order to reduce impacts on freshwater ecosystems and associated biodiversity.

4.2 Data Sources

Table 2: Data used in this assessment.

Data title	Source and date of publication	Data Description
SQ4 sub-quaternary drainage regions (referred to as SQ4 catchments)	DWS (2009)	Catchment areas that define the drainage regions of the NEFPA river reaches, which include 9 433 catchments ranging from 0.25 to 400 000 hectares. The gas pipeline corridors include 4 843 SQ4 catchments ranging from 0.1 to 115 000 hectares. These catchment areas are used as the primary spatial unit for analysis in the freshwater component.
River Ecoregions (Level 1 and 2)	Kleynhans *et al.* (2005)	A delineation of ecoregions for South Africa as derived from terrain, vegetation, altitude, geomorphology, rainfall, runoff variability, air temperature, geology and soil. There are 31 Level 1 and 219 Level 2 River Ecoregions in South Africa, of which 25 Level 1 and 97 Level 2 River Ecoregions occur within the gas pipeline corridors.
River Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES)	DWS (2014)	A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa conducted in 2013.
NFEPA rivers and wetlands	Nel *et al.* (2011)	The NFEPA coverages provide specific spatial information for rivers according to the DWS 1:500 000 rivers coverage, including river condition, river ecosystem types, fish sanctuaries, and flagship/free-flowing rivers. The NFEPA coverages also provide specific information for wetlands such as wetland ecosystem types and condition (note: wetland delineations were based largely on remotely-sensed imagery and therefore did not include historic wetlands lost through transformation and land use activities).
Ramsar Sites	Ramsar (2018)	Distribution and extent of areas that contain wetlands of international importance in South Africa.
National Wetland Vegetation Groups	Nel and Driver (2012)	A vector layer developed during the 2011 NBA to define wetland vegetation groups to classify wetlands according to Level 2 of the national wetland classification system (SANBI, 2010). The wetland vegetation groups provide the regional context within which wetlands occur, and is the latest available classification of threat status of wetlands that are broadly defined by the associated wetland vegetation group. This is considered more practical level of classification to the Level 4 wetland types owing to the inherent low confidence in the desktop classification of hydrogeomorphic units (HGM) that was used at the time of the 2011 NBA.
Provincial Wetland Probability Mapping	Collins (2017)	Mapping of wetland areas based on a concept of water accumulation in the lowest position of the landscape, which is likely to support wetlands assuming sufficient availability water to

Data title	Source and date of publication	Data Description
		allow for the development of the indicators and criteria used for identifying and delineating wetlands. This method of predicting wetlands in a landscape setting is more suitable for certain regions of the country than in others.
Mpumalanga Highveld Wetlands	SANBI (2014)	Wetland delineations for the Mpumalanga Highveld based on desktop mapping using Spot 5 imagery, supported by Google Earth, 1:50 000 contours, 1:50 000 rivers, exigent data, and NFEPA wetlands. This is an update of previous mapping through desktop digitising, ground-truthing and reviewing mapped data. Additional analysis was conducted to determine changes to ecosystem threat status, protection level and FEPAs.
Mpumalanga Biodiversity Sector Plan (BSP): Freshwater Assessment	Mpumalanga Tourism and Parks Agency (MTPA), CSIR and SANBI (2011)	Mapping of priority areas for freshwater biodiversity in Mpumalanga using FEPA layers to derive CBA rivers (i.e. FEPA rivers and free-flowing rivers), CBA wetlands (based on FEPA wetlands), CBA aquatic species (i.e. dragonflies/damselflies and crab taxa of conservation concern only), ESA wetland clusters (based on FEPA wetland clusters), and ESA wetlands (all non-FEPA wetlands). The MTPA land cover developed using SPOT 2010 imagery, together with high-resolution aerial imagery, was used to refine freshwater features mapping.
Gauteng Conservation Plan 3.3 prepared for the Gauteng Department of Agriculture and Rural Development - CBAs and EASs	Compaan (2011)	Represents priority areas for biodiversity conservation in Gauteng, primarily in the form of terrestrial features, but includes some areas supporting important aquatic features, principally wetland pans.
North West Biodiversity Sector Plan - Aquatic Critical Biodiversity Areas and Ecological Support Areas	North West Department of Rural, Environment and Agriculture Development (READ) (2015)	Layer showing all aquatic CBAs and ESAs for the North West province for use in CBA maps and general planning and distribution. The purpose and interpretation of the Aquatic CBA Map is described in the NW Biodiversity Sector Plan document and technical report.
KwaZulu-Natal Freshwater Systematic Conservation Plan	Ezemvelo KZN Wildlife (EKZNW) (2007)	This is the freshwater planning unit surface for KZN based on the 2007 Freshwater Systematic Conservation Plan (FSCP) run by Dr. Nick Rivers-Moore using MARXAN using catchment planning units. Catchments "earmarked" for freshwater conservation were selected as CBAs for this study as these areas represent optimal biodiversity areas required to meet biodiversity targets.
KwaZulu-Natal Vegetation Types	Scott-Shaw and Escott (2011)	This coverage represents an update of the KZN vegetation map as completed in September 2009. Several additions have been made which is represented in the Appendix 1 of the KwaZulu-Natal Vegetation Type Description Document for Vegetation Map 2011. These additions were made based on data that was received in an effort to make the map more current and representative of KZN's vegetation. The coverage includes a variety of wetland types with conservation statuses that are specific to KZN conservation planning.

Data title	Source and date of publication	Data Description
Eastern Cape Draft 2017 Biodiversity Conservation Plan (BCP) Aquatic Critical Biodiversity Areas	ECBCP (2017)	Coverage of Aquatic Critical Biodiversity Areas as obtained from the Eastern Cape Biodiversity Conservation Plan (BCP), which is currently in a draft.
Eastern Cape Fine-scale Planning	South African National Parks (2012)	Identified CBAs and ESAs (including aquatic features) from fine-scale planning within the Eastern Cape, including areas within and adjacent to the Addo Elephant National Park (2012), Baviaanskloof Mega Reserve Area (2006), the Garden Route (2009), and the Nelson Mandela Bay Municipality (2009).
Western Cape Biodiversity Spatial Plans (fine-scale mapping)	Cape Nature (2017)	The Western Cape Biodiversity Spatial Plans (WCBSP) are products of a systematic biodiversity planning process that maps terrestrial and aquatic CBAs and ESAs that require safeguarding to ensure the continued existence and functioning of species and ecosystems, including the delivery of ecosystem services. These spatial priorities are used to inform sustainable development in the Western Cape Province. Mapping regions for the BSPs include: Beaufort West, Berg River, Bitou, Breede Valley, Cape Agulhas, Cederberg, City of Cape Town, Drakenstein, George, Kannaland, Knysna, Laingsburg, Langeberg, Mossel Bay, Oudtshoorn, Overstrand, Prince Albert, Saldanha Bay, Swellendam, Theewaterskloof and Witzenberg. Aquatic CBAs and ESAs were selected for all the BSPs and merged together to create a complete BSP for the Western Cape.
Northern Cape Critical Biodiversity Areas	Northern Cape Department of Environment and Nature Conservation (2016)	Coverage of Aquatic Critical Biodiversity Areas as obtained from the Northern Cape Biodiversity Conservation Plan (BCP). Coverage of CBAs for the Northern Cape based on a Systematic Conservation Planning approach that incorporates data on biodiversity features (incorporating both pattern and process, and covering terrestrial and inland aquatic realms), condition, current Protected Areas and Conservation Areas, and opportunities and constraints for effective conservation.
Northern Cape District Municipality Aquatic Critical Biodiversity Areas	Botanical Society of South Africa (2007; 2008)	Identified and mapped aquatic CBAs for selected municipalities within the Northern Cape namely, Hantam District Municipality (2007) and Namakwa District Municipality (2008). CBAs are derived from one are many biodiversity features used in the mapping. Aquatic CBAs were selected and integrated with the more recent provincial mapping.
Freshwater aquatic plants	Raimondo *et al.* (2009), with spatial data provided by SANBI (2018)	Point locations (from a total of 4 129 records) of conservation important plant species (141 species) that inhabit wetland, river and riparian habitats
Dragonflies and damselflies (Odonata)	IUCN (2017) and Samways and Simaika (2016), with spatial data provided by	Point locations of dragonflies and damselflies taken from a total of 712 records within South Africa. This data includes records of the conservation important Odonata selected for this

Data title	Source and date of publication	Data Description
	SANBI (2018)	assessment.
Aquatic macro-invertebrates	DWS (2015)	Point shapefiles of 94 aquatic macro-invertebrate families recorded from 3 202 monitoring sites on rivers within South Africa.
Freshwater fish	Coetzer (2017)	Point locations for freshwater fish for South Africa taken from a total of 1 194 records. This data includes records for approximately half of the conservation important fish in South Africa.
Fish distributions	International Union for the Conservation of Nature (2017)	Distribution data for selected fish species where point data was found to be lacking/insufficient was obtained from the IUCN Red List of Threatened Species Map Viewer with data presented as catchment distributions. The IUCN distributions were spatially inferred using the SQ4 catchments for 21 of the selected fish species.
Amphibians	Minter *et al.* (2004), with spatial data provided by SANBI (2018)	Point localities (approximately 11 444 records) for these selected species were obtained from the SANBI TSP database (SANBI, 2018).
Reptiles	Bates *et al.* (2014), with spatial data provided by SANBI (2018)	Point locations of reptiles was taken from a total of 4 452 records.
Mammals	Child *et al.* (2016), with spatial data provided by SANBI (2018)	Point locations of mammals was taken from a total of 3 072 records.

4.3 Assumptions and Limitations

Table 3: Assumptions and limitations.

Limitation	Included in the scope of this study	Excluded from the scope of this study	Assumption
This is a desktop assessment of biodiversity sensitivity based largely on existing datasets, with some expert review and input from the consultant team.			
Suitable spatial scale and unit for analysis	Sub-Quaternary Catchments were used as the primary unit of scale for analyses allowing for integration of multiple datasets (e.g. points, lines, polygons) to ensure continuity in the output that are also comparable.	Data outputs as points or grid cells.	Data representing freshwater ecosystems and biota are contained and displayed using sub-quaternary catchments units. The integration of all data according to a suitable scale will be undertaken by CSIR.
Data accuracy and reliability	Use of existing datasets that have been verified, with some datasets further refined at the desktop level.	Ground-truthing and further infield verification of datasets.	Existing datasets are assumed accurate until such a time as they have been accurately verified.
Potential species-level data sampling bias	Available species datasets, including freshwater plants, aquatic invertebrates, dragonflies and damselflies, fish, amphibians, reptiles (freshwater obligates) and mammals (freshwater obligates)	Ground-truthing and further infield verification of datasets.	Species-level datasets are inherently biased by sampling effort. Datasets used in this study are likely to contain such bias and this has not been adjusted for or improved.
Wetland classification according to HGM units not available for all wetlands layers	The conservation importance/threat status of wetlands was determined using the national wetland vegetation groups.	Verification of HGM units and determination of wetland conservation/ threat status according to HGM type.	The spatial resolution of characterising the threat status of wetland is considered sufficient for the scale of study and ensures that the output layers are contiguous.
Occurrence of species, including Critically Endangered, Endangered, Vulnerable and other species of conservation concern is not exhaustive	Only point data for species of conservation concern was used based on current availability and sources.	Ground-truthing/ verification of species presence/absence from all areas, as well as modelled distribution data.	The latest available conservation assessments for species is considered conservative as additional records/localities overtime tend to reduce the threat status of a particular species. Added precaution is included in the GIS layers whereby point data has been assigned to sub-quaternary catchments.
Protected Areas layers	No protected areas layer data were included	Protected Areas layers were not used in this study.	Aquatic ecosystems and features are inherently less sensitive given the levels of protection.

Limitation	Included in the scope of this study	Excluded from the scope of this study	Assumption
			Protected areas will be accounted for in the main integration of all data layers and development of the cost surface - in this regard all freshwater ecosystems and features will be treated with a high sensitivity.
Working with large datasets, particularly fine-scale plans	The fine-scale GIS layers have been thinned out to make processing more efficient - allowing a suitable fine scale resolution for strategic planning, whilst ensuring efficient processing.	Small wetland fragments from fine-scale GIS data layers were excluded, and scaled according to sensitivity.	Site specific studies will utilise all information available (SEA threat and sensitivity layers) as well as the detailed fine-scale GIS layers. Such fine-scale detail is potentially excessive at the strategic planning phase.

4.4 Relevant Regulatory Instruments

A detailed list and description of all relevant regulatory instruments associated with freshwater ecosystems at an international, national scale, as well as provincial scale as per the compendium of South African Environmental Legislation (van der Linde, 2006) for each focus area (Table 4).

Table 4: International, national and provincial regulatory instruments relevant to freshwater ecosystems.

Instrument	Key objective	Feature
International Instrument		
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.	Ramsar Wetlands
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.	Species diversity
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	Species diversity

Instrument	Key objective	Feature
Regional Instrument		
SADC Protocol on Shared Watercourse Systems (1995)	The protocol provides for the utilisation of a shared watercourse system for the purpose of agricultural, domestic and industrial use and navigation within the SADC region. The protocol established river basin management institutions for shared watercourse systems and provides for all matters relating to the regulation of shared watercourse systems	Transboundary Rivers
	National Instrument	
National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)	The National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) provides for listing threatened or protected ecosystems, in one of four categories: critically endangered (CR), endangered (EN), vulnerable (VU) or protected. Activity 12 in Listing Notice 3 (of the 2014 EIA Regulations (as amended) in Government Notice R324 of 2017) relates to the clearance of 300 m^2 or more of vegetation, within Critical Biodiversity Areas.	Relevant to rivers and wetlands, critical biodiversity areas, threatened ecosystems and endangered species during all phases
National Environmental Management Act (Act 107 of 1998) 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.	Relevant to rivers and wetlands during all phases
NEMA EIA 2014 Regulations, as amended April 2017 (Government Gazette 40772)	These regulations provide listed activities that require EA prior to development because they are identified as having a potentially detrimental effect on natural ecosystems, including freshwater ecosystems. Different sorts of activities are listed as environmental triggers that determine different levels of impact assessment and planning required. The regulations detail the procedures and timeframes to be followed for a basic or full scoping and environmental impact assessment.	Relevant for gas pipeline construction/ development in proximity to wetlands, rivers and critical biodiversity areas
National Water Act (Act 36, 1998)	This act provides the legal framework for the effect and sustainable management of water resources. It provides for the protection, use, development, conservation, management and control of water resources as a whole. Water use pertains to the	Relevant to rivers and wetlands during all phases

Instrument	Key objective	Feature
	consumption of water and activities that may affect water quality and condition of the resource such as alteration of a watercourse. Water use requires authorisation in terms of a Water use licence (WUL) or General Authorisation (GA), irrespective of the condition of the affected watercourse. Includes international management of water.	
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).	Rivers and wetlands
National Environmental Management Waste Act (No. 59 of 2008)	Minimising the consumption of natural resources; avoiding and minimising the generation of waste; reducing, re-using, recycling and recovering waste; treating and safely disposing of waste as a last resort; preventing pollution and ecological degradation; securing ecologically sustainable development while promoting justifiable economic and social development; promoting and ensuring the effective delivery of waste services; remediating land where contamination presents, or may present, a significant risk of harm to health or the environment: and achieving integrated waste management reporting and planning; to ensure that people are aware of the impact of waste on their health, well-being and the environment; to provide for compliance with the measures set out in paragraph (a) and generally, to give effect to section 24 of the Constitution in order to secure an environment that is not harmful to health and well-being.	Relevant to construction and operation phases of gas development projects, which may impact rivers and wetlands
National Environmental Management: Protected Areas Act (No. 57 of 2003 as amended) {NEM:PPA}	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.	Any protected areas - and related freshwater ecosystems affected by gas development

Instrument	Key objective	Feature
Draft biodiversity offset policy	A Draft National Biodiversity Offset Policy was recently gazetted in March 2017 (NEMBA, 2017), and is in the process of being finalised. The offset policy is intended to establish the foundation for establishing an offset for biodiversity (including river and wetland ecosystems), ensuring that offset procedures are properly integrated into the EIA process to make sure that the mitigation hierarchy is exhausted. Should it be determined in the EIA that there will be residual impact that cannot be avoided and/or mitigate, then an offset will need to be established to account for the loss of biodiversity. The core principles for offsetting, as set out in the policy, should be used to guide the process of evaluating, designing and implementing an offset. It is essential that the offset process is introduced from the outset of the EIA.	River and wetland ecosystems and associated fauna and flora
National Water Resource Strategy (NWRS) 2004 and NWRS2 2013	Facilitate the proper management of the nation's water resources; provide a framework for the protection, use, development, conservation, management and control of water resources for the country as a whole; provide a framework within which water will be managed at regional or catchment level, in defined water management areas; provide information about all aspects of water resource management; identify water-related development opportunities and constraints	All rivers, wetlands and freshwater resources
The Water Services Act, (No. 108 of 1997 (RSA, 1997a)	The right of access to basic water supply and the right to basic sanitation necessary to secure sufficient water and an environment not harmful to human health or well-being; the setting of national standards and norms and standards for tariffs in respect of water services; the preparation and adoption of water services development plans by water services authorities; a regulatory framework for water services institutions and water services intermediaries; the establishment and disestablishment of water boards and water services committees and their duties and powers; the monitoring of water services and intervention by the Minister or by the 5 relevant Province; financial assistance to water services institutions; the gathering of information in a national information system and the distribution of that information; the accountability of water services providers: and the promotion of effective water resource management and conservation. Water supply services in an efficient equitable manner, as well as measures to promote water conservation and demand management which through Water Conservation and Water Demand Management (WC/WDM) strategies	Water resource allocation to develop gas pipelines - during construction and operation phases. Relevant to water resources in the vicinity of gas pipelines.
Resource Directed Measures including: the Ecological Reserve, National Water Resource Classification System (NWRCS) and Resource Quality Objectives (RQO's)	The main objective of the Chief Directorate: Resource Directed Measures (RDM) is to ensure protection of water resources, as described in Chapter 3 of the South African National Water Act - 1998 (No. 36 of 1998) and other related water management legislation and policies. The role of RDM is to provide a framework to ensure sustainable	Benchmark used for monitoring and evaluation of freshwater resources especially rivers in relation to the Reserve.

Instrument	Key objective	Feature
	utilization of water resources to meet ecological, social and economic objectives and to audit the state of South Africa's water resources against these objectives The aim of Water Resource Quality Objectives is to delineate units of analysis and describe the status quo of water resources, initiate stakeholder process and catchment visioning, quantify EWR's and changes in ecosystem services, identify scenarios within IWRM, draft management classes, produce RQO's (EcoSpecs, water quality), Gazette class configuration	
Water Research Act (Act 34 of 1971)	Promotes water related research	All water resources, and associated ecosystems
Provincial Instrument		
Catchment Management Strategies applicable to all provinces	Progressively develop a catchment management strategy for the water resources within its water management area. Catchment management strategies must be in harmony with the national water resource strategy. CMA must seek cooperation and agreement on water -related matters from the various stakeholders and interested persons. CMA must be reviewed and include a water allocation plan, set principles for allocating water to existing and prospective users, taking into account all matters relevant to the protection use, development conservation, management and control of resources	Rivers and wetlands
Western Cape		
Nature and Environmental Conservation Ordinance (Ordinance 19 of 1974; amended in 2000).	This ordinance is applicable in the Western Cape, Eastern Cape, Northern Cape and parts of the North West Province. This ordinance provides measures to protect the natural flora and fauna, as well as listing nature reserves in these provinces. This ordinance was amended in 2000 to become the Nature Conservation Laws Amendment Act. Lists of endangered flora and fauna can be found in this act.	Species diversity
Eastern Cape		
Cape Local Authorities Gas Ordinance 7 of 1912	Regulates gas and control gas related water pollution	Gas pipeline development affecting rivers and wetlands
Divisional Councils Ordinance 18 of 1976	Provides for the regulation and control of effluents refuse and stormwater	Gas pipeline development affecting rivers and wetlands

Instrument	Key objective	Feature
Nature and Environmental Conservation Ordinance (Ordinance 19 of 1974; amended in 2000).	This ordinance is applicable in the Western Cape, Eastern Cape, Northern Cape and parts of the North West Province. This ordinance provides measures to protect the natural flora and fauna, as well as listing nature reserves in these provinces. This ordinance was amended in 2000 to become the Nature Conservation Laws Amendment Act. Lists of endangered flora and fauna can be found in this act.	Species diversity
KwaZulu-Natal		
KwaZulu-Natal Nature Conservation Act, 1992 (Act 29 of 1992) as an amendment to the Natal Nature Conservation Ordinance (No. 15 of 1974)	According to the Natal Nature Conservation Ordinance No. 15 of 1974 and the KwaZulu-Natal Nature Conservation Act, 1992 (Act 29 of 1992), no person shall, among others: damage, destroy, or relocate any specially protected indigenous plant, except under the authority and in accordance with a permit from Ezemvelo KZN Wildlife (EKZNW).	Species diversity
Ezemvelo KZN Wildlife Guideline: Biodiversity Impact Assessment in KwaZulu-Natal	Provides guidelines for developers, applicants, environmental consultants and specialists to ensure that projects investigation timeframes are accurately determined, that feasibility studies accurately determine fatal flaws regarding biodiversity, and that the scope and reporting requirements of specialist studies allow for informed and sustained decisions to be made in terms of biodiversity.	Conservation and protection of river and wetland habitats and associated fauna and flora
South Barrow Loan and Ext Powers Ordinance 12 of 1920	Regulates water pollution	Rivers and wetlands
South Shepstone Loan and Extended Powers Ordinance 20 of 1920	Regulates water pollution and other pollutants	Rivers and wetlands
Water Services Ordinance 27 of 1963	Regulates matters relating to water , water pollution and sewage	Rivers and wetlands
Kloof Loan and Extended Powers Ordinance 16 of 1967	Regulates water pollution and other pollutants	Rivers and wetlands
Umhlanga Extended Powers and Loan Ordinance 17 of 1975	Regulates water pollution within Umhlanga and surrounding areas	Rivers and wetlands
Durban Extended Powers Cons Ordinance 18 of 1976	Regulates water pollution and other pollutants	Rivers and wetlands
Kwa-Zulu and Natal Joint Services Act 84 of	Regulates pollution of land water and waste management	Rivers and wetlands

Instrument	Key objective	Feature
1990		
Northern Cape Province		
Divisional Councils Ordinance 18 of 1976	Provides for the regulation and control of effluents refuse and storm water	Gas pipeline development affecting rivers and wetlands
Nature and Environmental Conservation Ordinance (Ordinance 19 of 1974; amended in 2000).	This ordinance is applicable in the Western Cape, Eastern Cape, Northern Cape and parts of the North West Province. This ordinance provides measures to protect the natural flora and fauna, as well as listing nature reserves in these provinces. This ordinance was amended in 2000 to become the Nature Conservation Laws Amendment Act. Lists of endangered flora and fauna can be found in this act.	Species diversity
North West Province		
Nature and Environmental Conservation Ordinance (Ordinance 19 of 1974; amended in 2000).	This ordinance is applicable in the Western Cape, Eastern Cape, Northern Cape and parts of the North West Province. This ordinance provides measures to protect the natural flora and fauna, as well as listing nature reserves in these provinces. This ordinance was amended in 2000 to become the Nature Conservation Laws Amendment Act. Lists of endangered flora and fauna can be found in this act.	Species diversity

5 BASELINE DESCRIPTION OF THE PROPOSED GAS PIPELINE CORRIDORS

A description of the freshwater ecosystems within corridors that stand to be impacted by the phased development of the gas pipeline in South Africa is presented in Table 5. These descriptions are provided together with a summary of the existing drivers and pressures, relating primarily to land use, within these corridors

Table 5: Description of freshwater ecosystems and species of the proposed Gas Pipeline corridors, including existing drivers and pressures.

Gas pipeline corridor	Description	Existing drivers and pressures
Phase 1 Corridor	**Rivers within the Phase 1 Corridor** are either perennial/permanently-flowing (approximately 55%) or ephemeral/non-perennial (approximately 45%), and are characteristic of the South Western Coastal Belt, Western Folded Mountains, Southern Folded Mountains and the Southern Coastal Belt ecoregions. Major river systems include the Berg, Bree, Gourits and Doring Rivers. Most (approximately 65%) of the river habitat in the corridor is currently Threatened (i.e. Critically Endangered, Endangered and Vulnerable). The upper reaches of the Doring River is a flagship/free-flowing river that drains the corridor. 30% of rivers in this corridor are in a natural/good condition, while 20% are in a fair condition, 44% are in a poor condition, and 6% are either very poor/critical condition. **Overall river sensitivity for the Phase 1 Corridor is as follows: very high (38%), high (30%), medium (27%), and low (5%).** **Wetland habitats within the Phase 1 Corridor** occupy a fair proportion of the corridor (~7%) comprising up to 221 different wetland types, dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the East Coast Shale Renosterveld region. The corridor boasts five Ramsar wetlands, namely Langebaan, False Bay Nature Reserve, Bot-Kleinmond Estuarine System, De Mond (Heuningnes Estuary) and De Hoop Vlei. A moderate proportion (~18%) of the wetlands in the corridor are characterised as NFEPA wetlands. Most notable is that 50% of the wetlands of the corridor are associated with the Critically Endangered wetland groups: East Coast Shale Renosterveld (20%), Rainshadow Valley Karoo (15%), West Coast Shale Renosterveld (9%) and Western Fynbos-Renosterveld Shale Renosterveld (6%). **Overall wetland sensitivity for the Phase 1 Corridor is as follows: very high (25%), high (60%), medium (13%), and low (2%).** **Threatened aquatic biota:** Three Endangered Odonata (*Proischnura polychromatica, Orthetrum rubens* and *Spesbona angusta*), as well as four Vulnerable and three Near Threatened species. *Orthetrum rubens* is a restricted species that is only known from the mountains of the Western Cape: since 2016 the only known extant population is in the Hottenstots-Holland Mountains, at	Approximately 67% of the Phase 1 Corridor comprises land that is largely natural with a small proportion (~1%) degraded. A significant proportion (20%) of the corridor is protected by over 100 different conservation areas (e.g. Koue Bokkeveld Mountain Catchment Area, Matroosberg Mountain Catchment Area, Langeberg Mountain Catchment Area). The remaining area is largely transformed by cultivation (~29%), but also urbanisation in and around Cape Town (2%) and plantations (1%). Impacts on freshwater ecosystems caused by land use activities vary across the corridor, however, combined effect has had a significant effect on freshwater ecosystem functioning and integrity. Key impacts include: • There has been rapid population growth within the Western Cape, and thus urbanization has increased, particularly since 2009. Informal settlements in particular have expanded and reactive spatial planning has led to poor or even absent basic service infrastructure. The result is unsustainable practices including increased illegal dumping and waste disposal in rivers, contributing to water pollution. The greatest instances of transformation are reported to be in Cape Town itself and other coastal nodes. • Very high (unacceptable) faecal contamination in the Berg, Bree, Diep, Gouritz and Kuils River systems. Inland water is generally considered not fit even for agricultural or industrial use. • Alien invasive species, which reduce both surface and ground water availability, increase fire risk and compete with indigenous species, which result in habitat loss and degradation. Alien invasive plants are a large problem, as are invasive fish species

Gas pipeline corridor	Description	Existing drivers and pressures
	Victoria Peak. *Spesbona angusta* is also restricted to a wetland at the base of Franschhoek pass, and thus careful conservation planning and improvement of wetland in terms of water depth and density of pools is required for this species (Veldtman *et al.*, 2017). *Proischnura polychromatica* has also only been recently recorded near Ceres, and also at the base of Franschhoek Pass, and are only known from sites where alien invasive trees have been removed (Veldtman *et al.*, 2017). The corridor supports an exceptionally high number of Red Listed fish (up to 22 species) of which four are Critically Endangered: *Pseudobarbus burchelli*, which is found in the Breede and Tradouw river systems, Pseudobarbus erubescens (endemic to the Twee River Catchment within Olifants system), *Pseudobarbus* sp. nov. 'doring' (Breekkrans and Driehoeks Tributaries of the Doring river, Olifants system), and *Pseudobarbus* sp. nov. 'heuningnes' (Heuningnes River System). In addition, 10 fish species are Endangered, three are Vulnerable, four are Near Threated and one is Data Deficient. The corridor also supports a high number of Red Listed amphibians (up to 16 species) of which five are Critically Endangered (*Arthroleptella rugosa, A. subvoce, Capensibufo rosei, Heleophryne rosei* and *Microbatrachella capensis*), two are Endangered, six are Near Threated and three are Data Deficient. *Arthroleptella rugosa* (Rough Moss frog) is a highly restricted species occurring only on the Klein Swartberg Mountain near Caledon, A. subvoce's status may be changed to a more threatened category (Turner and de Villiers, 2017); *Capensibufo rosei* is only found to occur on the Cape Peninsula, in two or three remaining populations; *Heleophryne rosei* is restricted to four streams on Table mountain area, and *Microbatrachella capensis* is a vital indicator of a unique and threatened ecosystem: coastal lowland blackwater wetlands. There is only one Red Listed reptile that occurs within the corridor, namely the Vulnerable *Bradypodion pumilum*. The Phase 1 Corridor supports known occurrences of the Critically Endangered Riverine Rabbit *Bunolagus monticularis*, which is restricted to the semi-arid Karoo, with an estimated Extent of Occurrence (EOO) of 54,227 km² and Area of Occupancy (AOO) 2,943 km² (2016 Mammal Red List *Bunolagus monticularis* CR). The Riverine Rabbit inhabits dense, discontinuous scrub vegetation along seasonal river beds and is dependent on soft, deep alluvial spoils along these river courses, for constructing burrows in order to breed. Other Red Listed mammals include the Vulnerable *Dasymys capensis*, as well as three species that are Near Threatened. This corridor supports the highest diversity of Red Listed plants with up to 75 species. Of this diversity, 16 are Critically Endangered, 23 are Endangered, 22 are Vulnerable, six are Near Threatened, four are Data Deficient and four are rare. **Overall species sensitivity for the Phase 1 Corridor is as follows: very high (50%), high (40%), medium (8%), and low (2%).**	within rivers – 17 in total. • Agriculture, also reported to be increasing in the Western Cape region, contributes to the pollution of freshwater resources, as a result of run-off of pesticides and fertilizers. In addition, over-abstraction of water for both agriculture and urban use forms a major problem in many areas. • Damage to river beds, wetlands and floodplains (channel modification) as a result of agricultural practices is also considered to be a major threat to freshwater ecosystems in this region. • Other pressures which impact on these systems include overgrazing and illegal harvesting of species • Further to this, within the Western Cape, water has been identified as a provincial risk, based on increased urbanization, climate change, failing infrastructure and consumer behaviour.

Gas pipeline corridor	Description	Existing drivers and pressures
Phase 2 Corridor	**Rivers within the Phase 2 Corridor** are either perennial/permanently-flowing (approximately 45%) or ephemeral/non-perennial (approximately 55%), and are largely characteristic of the Southern Folded Mountains ecoregion, as well as the Great Karoo and the Southern Eastern Coastal Belt ecoregions. Major river systems include the Olifants, Kouga, Doring Rivers and Sondags. A moderate proportion (approximately 41%) of the river habitat in the corridor is currently Threatened (i.e. Critically Endangered, Endangered and Vulnerable). The rivers are generally in either a natural/good (44 %) or fair (38%) condition, while 17% of the rivers are in either a poor, very poor or critical state. **Overall river sensitivity for the Phase 2 Corridor is as follows: very high (23%), high (50%), medium (25%), and low (2%).** **Wetland habitats within the Phase 2 Corridor** occupy a fair proportion of the corridor (~8%) comprising up to 133 different wetland types, dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the Albany Thicket and Eastern Fynbos-Renosterveld Sandstone Fynbos regions. The corridor contains one Ramsar wetland, the Wilderness Lakes, which cover 1 300 ha. A small proportion (~5%) of the wetlands in the corridor are characterised as NFEPA wetlands. Most notable is that more than 60% of the wetlands of the corridor are associated with the Critically Endangered wetland groups: Albany Thicket Valley (34%), and Lower Nama Karoo (29%). **Overall wetland sensitivity for the Phase 2 Corridor is as follows: very high (58%), high (36%), medium (4%), and low (2%).** **Threatened aquatic biota:** One Endangered species of Odonata (i.e. *Metacnemis valida*) which occurs in the corridor (status threatened by habitat loss and now only known from two sites on the Kubusi River in the vicinity of Stutterheim) (IUCN, 2017) http://www.iucnredlist.org/details/42840/0); as well as two Vulnerable and two Near Threatened species. In addition, there are three vulnerable species, and two near-threatened species of Odonata supported in this corridor. The corridor also supports one Critically Endangered fish (i.e. *Pseudobarbus senticeps*: a narrow range endemic species which is restricted to the Krom River system (IUCN, 2017), along with three Endangered, one Vulnerable, one Near Threated and one Data Deficient species. The only Red Listed amphibians that occur within the corridor include the Endangered *Afrixalus knysnae* and *Heleophryne hewitti*. *Afrixalus knysnae*[1] is known from around five locations at low altitudes, on either side of the border between the Eastern Cape and Western Cape Provinces and its EOO is 816 km^2, and its AOO is	Majority (91%) of the Phase 2 Corridor comprises land that is largely natural, with a reasonable proportion (13%) of the corridor protected by a number of conservation areas (e.g. Addo Elephant National Park and Baviaanskloof Nature Reserve). The remaining area is largely transformed by cultivation (~6%), but also plantations (2%) and urbanisation (1%) particularly along the coastal areas George, Knysna and Port Elizabeth. Key impacts affecting freshwater ecosystems include: • Urbanization, particularly in towns and cities within the coastal zone, resulting in increased pressure on infrastructure and affecting water quality; • Flow alteration caused by impoundments (e.g. Kouga, Clanwilliam, Darlington), affect downstream aquatic systems (e.g. channel characteristics, riparian vegetation, and instream and floodplain habitats) as well as river continuity • Increased agriculture and cultivation in this area has caused increased pressure on aquatic ecosystem, through processes such as channel modification, over abstraction of water for irrigation, river bank alteration and contamination of groundwater and rivers through the run-off of fertilizers, pesticides and herbicides. The abstraction of water for the irrigation of crops such as potatoes, grapes, deciduous and citrus fruits within the Olifants catchment, has resulted in extreme pressure on the flow of this system; • Plantations of alien invasive species have also caused increased pressure on aquatic systems as a result of the decreased flow and lowering of the groundwater table. Kouga and Baviaanskloof form the source of many of the freshwater systems in the Eastern Cape, including a large proportion of the catchments of the Gamtoos, Krom and Seekoei rivers. Invasive alien Acacia, Hakea and Pinus trees pose a serious threat to the conservation

[1] http://www.iucnredlist.org/details/56065/0

Gas pipeline corridor	Description	Existing drivers and pressures
	27 km^2. (IUCN, 2017) The ghost frog occurring in the Kammanassie Mountains may be Hewitt's ghost frog (*Heleophryne hewitti*), but at this stage this still needs to be confirmed and thus the status updates (Turner and de Villiers, 2017). There are no Red Listed reptiles that are known to occur within the corridor. The corridor supports a reasonable diversity of Red Listed mammals, including the Critically Endangered Riverine Rabbit *Bunolagus monticularis* (see info on status above), as well as one Vulnerable and four Near Threatened species. This corridor supports a low diversity of (up to 7) Red Listed plants. Nevertheless, one is listed as Critically Endangered (i.e. *Cotula myriophylloides*) and another is Endangered (i.e. *Felicia westae*). The other species comprise of two Vulnerable, one Near Threatened, one Data Deficient, and one rare species. **Overall species sensitivity for the Phase 2 Corridor is as follows: very high (18%), high (54%), medium (2%), and low (26%).**	of water (the uptake of water of these species is high) and natural vegetation in these mountains; • Alien trees are also known to accelerate riverbank erosion and reduce in-stream flow. They are also responsible for changes in fire regime and alteration of plant community composition. This is particularly relevant in this region, which experiences high levels of water stress, drought and associated increased fire risk.
Phase 3 Corridor	**Rivers within the Phase 3 Corridor** are predominantly perennial/permanently-flowing (81%), and drain a number of ecoregions, notably the Highveld ecoregion. Major river systems include the Vaal, Klip and Buffels Rivers. A significant (approximately 71%) proportion of the rivers that drain the corridor are Critically Endangered. Less than 20% of the rivers are considered to be in a natural/good condition, while 50% are in a fair condition, 23% are in a poor condition and 10% are in either a very poor or critical condition. **Overall river sensitivity for the Phase 3 Corridor is as follows: very high (46%), high (34%), medium (19%), and low (<1%).** **Wetland habitats within the Phase 3 Corridor** occupy a significant proportion of the corridor (~17%) comprising up to 127 different wetland types, dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the Mesic Highveld Grassland and Sub-escarpment Grassland regions. The corridor supports two Ramsar wetlands, namely Seekoeivlei Nature Reserve (4,754 ha) and the Blesbokspruit (1,858 ha). A small proportion (~8%) of the wetlands in the corridor are characterised as NFEPA wetlands. Most notable is that more than 50% of the wetland habitats within the corridor are associated with the Critically Endangered Mesic Highveld Grasslands (Groups 2, 3 and 4). **Overall wetland sensitivity for the Phase 3 Corridor is as follows: very high (5%), high (64%), medium (23%), and low (8%).** **Threatened aquatic biota:** Only one notable species of Odonata, considered as vulnerable (i.e. *Lestes dissimulans*) occurs in the corridor. Of the 12 Red Listed fish species that occur within the corridor, one is Critically Endangered (i.e. *Pseudobarbus burchelli*), which is found in the Breede	Approximately 62% of the Phase 3 Corridor comprises land that is largely natural with a further 2% degraded. A very small proportion (2%) of the corridor is protected by a number of small conservation areas, but also larger ones such as the Cradle of Humankind World Heritage Site. A significant area has been transformed by cultivation (~29%), urbanisation in and around Johannesburg (5%), plantations (2%), as well as mining (1%). Key impacts affecting freshwater ecosystems include: • Very high (unacceptable) faecal pollution in rivers flowing through Gauteng (e.g. the Jukskei River), largely due to discharge of untreated or poorly treated effluent from malfunctioning/overloaded waste water treatment works, as well as surcharging manholes; • Unsustainable and rapid urbanisation has resulted in the pollution of most river systems within this region. Pollution of the Vaal itself reached crisis point in January 2018 as a result of the acid mine drainage effluent and raw or partially treated sewage being pumped into the system; • A high concentration of mining and industrial activity in this area

Gas pipeline corridor	Description	Existing drivers and pressures
	and Tradouw river systems, while two are Endangered, two are Vulnerable, five are Near Threatened and two are Data Deficient. The only Red Listed amphibian that occurs within the corridor includes the Near Threatened *Hemisus guttatus*. There are no Red Listed reptiles that are known to occur within the corridor. The corridor supports the highest number of Red Listed mammals (up to 9 species) of which four are Vulnerable and five are Near Threated. This corridor supports a low diversity of (up to 8) Red Listed plants, but which includes two Endangered species (i.e. *Disa zuluensis* and *Kniphofia flammula*). Other Red Listed species include three Vulnerable and three Near Threatened species. **Overall species sensitivity for the Phase 3 Corridor is as follows: very high (8%), high (9%), medium (35%), and low (48%).**	places enormous pressure on the aquatic systems and has caused contamination of these systems though chemical leaching; • Transformation and damage of wetlands e.g. Klip River wetland, through illegal dumping, high levels of urbanization, poor infrastructure and wastewater treatment works, and erosion through the high volumes of wastewater that flow through the wetland; • Over-abstraction of water, and various impoundments (construction of dams e.g. the Vaal in particular), place huge pressure on the flow of rivers in this region; • The effects of agriculture are evident and contribute to the pollution of freshwater resources as a result of run-off of pesticides and fertilizers.
Phase 4 Corridor	**Rivers within the Phase 4 Corridor** largely form part of the Lowveld and Natal Coastal Plain ecoregions, with a smaller number of rivers draining off from the Lebombo Uplands. The rivers are either perennial/permanently-flowing (approximately 62%) or ephemeral/non-perennial (approximately 38%). Major river systems include the Phongolo and Mkuze Rivers – the Mkuze River and one of its tributaries, the Msunduzi, are the only flagship/free-flowing rivers that drain the corridor. Less than 30% of the rivers are considered to be Threatened (i.e. Critically Endangered, Endangered and Vulnerable). Almost half of the rivers are in a natural/good condition, 36% are in a fair condition, while 16% are in a poor/very poor condition. **Overall river sensitivity for the Phase 4 Corridor is as follows: very high (15%), high (35%), medium (48%), and low (2%).** **Wetland habitats within the Phase 4 Corridor** occupy a small proportion of the corridor (~4%) comprising up to 47 different wetland types, dominated by floodplain wetlands, particularly within the Indian Ocean Coastal Belt region. The corridor boasts four Ramsar wetlands covering up to 185 000 ha, namely Ndumo Game Reserve, Kosi Bay, Lake Sibaya, and the St. Lucia System. A significant proportion (~51%) of the wetlands in the corridor are characterised as NFEPA wetlands. Most notable is that 65% of the wetland habitats within the corridor are associated with the Endangered Lowveld wetland vegetation (Group 10). **Overall wetland sensitivity for the Phase 4 Corridor is as follows: very high (20%), high (43%), medium (28%), and low (9%).**	Approximately 72% of the Phase 4 Corridor comprises land that is largely natural, with a significant proportion of the area protected by existing conservation areas (e.g. Isimangaliso Wetland Park, Tembe Elephant Park, Ndumo Game Reserve, Ithala Game Reserve). The remaining area has been largely degraded (~15%) or is transformed by cultivation, plantations, urbanisation and rural settlements. Impacts on freshwater ecosystems caused by land use activities vary across the corridor, however, combined effect has had a significant effect on freshwater ecosystem functioning and integrity. Key impacts affecting freshwater ecosystems include: • Extensive urbanisation causing transformation and degradation of freshwater ecosystems, notably in the greater Durban region, which continues to expand up along the coast, as well as Richards Bay; • Water quality impacts and pollution associated with urban areas (e.g. domestic and industrial effluents, failing water treatment infrastructure, etc.) and agriculture (e.g. pesticides, herbicides

Gas pipeline corridor	Description	Existing drivers and pressures
	Threatened aquatic biota: The only Critically Endangered Odonata for South Africa occurs along the Phongolo River in the north-western corner of the Phase 4 Corridor, namely *Chlorocypha consueta*. The Endangered *Diplacodes pumila* also occurs in the corridor along with six species listed as Vulnerable and four species listed as Near Threatened. One Endangered fish, *Silhouettea sibayi*_occurs in coastal rivers that flow through the corridor. The corridor also supports two vulnerable species, three Near Threatened and two Data Deficient species of fish. The only Red Listed amphibians that occur within the corridor include the Endangered *Hyperolius pickersgilli* and the Near Threatened *Hemisus guttatus*. The corridor supports two Red Listed reptiles, namely the Hinged Terrapin *Pelusios rhodesianus*, (Vulnerable) which is known from a few water bodies along the coastal region – and *Macrelaps microlepidotus* (Near Threatened), which is found in forests and coastal bush. Up to eight Red Listed mammals occur within the Phase 4 Corridor, including five rodents/shrews, as well as Spotted-necked Otter *Hydrictis maculicollis* (Vulnerable) and Cape Otter *Aonyx capensis* (Near Threatened). This corridor supports a moderate diversity of (up to 24) Red Listed plants, including two that are Endangered (i.e. *Albizia suluensis* and *Mondia whitei*). The majority of the Red Listed plants occurring with the corridor are either Vulnerable (12 species) or Near Threatened (9 species), while one is considered rare. **Overall species sensitivity for the Phase 4 Corridor is as follows: very high (54%), high (12%), medium (31%), and low (3%).**	and fertiliser applications) all of which are contaminating receiving aquatic environments; • Flow alteration caused by large impoundments (e.g. Inanda, Hazelmere and Goedertrouw and Pongolapoort Dams), inter-basin transfers, WWTW return flows, and stormwater runoff from hardened surfaces and sewer reticulation, all of which affect downstream aquatic systems (e.g. channel characteristics, riparian vegetation, and instream and floodplain habitats) as well as river continuity; • Cultivation of wetlands and floodplains (notably sugarcane), especially along the coastal region; • Illegal sand mining, as well as and other mining activities, particularly in the Richards Bay region; • Transformation and alteration of watercourses through canals, diversion structures, weirs, road crossings, flood control berms; • Abstraction of water for irrigation and extensive forestry, which is having a significant impact on groundwater and linked wetlands in the Maputaland region; • Erosion and degradation, especially linked to overgrazing, which is notable in the more rural areas; and • Excessive infestation of numerous IAPs, particularly along rivers and around wetlands, as well as instream (e.g. Water Hyacinth).
Phase 5 Corridor	**Rivers within the Phase 5 Corridor** are mostly ephemeral/non-perennial (approximately 61%), while around 39% are considered to be perennial/permanently-flowing. These rivers drain a number of ecoregions, such as the South Western Coastal Belt, Western Folded Mountains and the Great Karoo. Major river systems include the Doring, Olifant and Sout. Less than 25% of the rivers are considered to be Threatened (i.e. Critically Endangered, Endangered and Vulnerable). More than 60% of the rivers are in a natural/good condition, 8% are in a fair condition, while 30% are in a poor/very poor condition. **Overall river sensitivity for the Phase 5 Corridor is as follows: very high (27%), high (35%), medium (36%), and low (2%).** **Wetland habitats within the Phase 5 Corridor** occupy a small proportion of the corridor (~3%)	A large portion (81%) of the Phase 5 Corridor comprises land that is largely natural, with a fairly small proportion (8%) of the corridor protected by a number of conservation areas (e.g. Cederberg Wilderness Area, Moedverloren Nature Reserve and Tankwa Karoo National Park). The remaining area is mostly transformed by cultivation (~19%), with <1% attributed to plantations, urbanisation (e.g. Citrusdal and Vredendal) and mining. Key impacts affecting freshwater ecosystems include:

Gas pipeline corridor	Description	Existing drivers and pressures
	comprising up to 90 different wetland types, dominated by channelled-valley bottom wetlands, particularly within the Northwest Sand Fynbos region. The corridor contains a single Ramsar wetland, namely Verlorenvlei, which is approximately 1,500 ha. A moderate proportion (~23%) of the wetlands in the corridor are characterised as NFEPA wetlands. Almost all of the wetland habitats within the corridor are associated with Least Threatened wetland vegetation groups (e.g. the Knersvlakte and Trans-Escarpment Succulent Karoo). **Overall wetland sensitivity for the Phase 5 Corridor is as follows: high (15%), medium (30%), and low (55%).** **Threatened aquatic biota:** Two species of Odonata that are listed as Vulnerable (i.e. *Syncordulia gracilis* and *S. legator*) occur in the corridor, along with two species that are Near Threatened. Of the 14 Red Listed fish species that occur within the corridor, three are listed as Critically Endangered (i.e. *Pseudobarbus burchelli, P. erubescens* and *P.* sp. Nov. 'doring'), while six are considered Endangered, four are Near Threatened, and one is Data Deficient. The only Red Listed amphibian that occurs within the corridor includes the Near Threatened *Breviceps gibbosus*. There is also only one Red Listed reptile that occurs within the corridor, namely the Vulnerable *Bradypodion pumilum*. The Critically Endangered Riverine Rabbit *Bunolagus monticularis* occurs in a few, isolated localities within the corridor (see above for ecology and habitat). The only other Red Listed mammals include two that are Near Threatened. This corridor supports a moderate diversity of Red Listed plants of up to 25 species, including two that are Critically Endangered (i.e. *Pilularia bokkeveldensis* and *Senecio cadiscus*), while ten are Endangered, nine are Vulnerable and four are Near Threatened. **Overall species sensitivity for the Phase 5 Corridor is as follows: very high (34%), high (18%), medium (12%), and low (36%).**	• Pollution from application of fertilizers, herbicides and pesticides, as well as point-source discharges from urban centres (e.g. Bitterfontein); • Grazing by livestock, particularly high/concentrated levels of along watercourses, causing overgrazing and trampling within and adjacent to river and wetland systems, which in turn leads to increased erosion and changes in vegetation structure (notably, the loss of riparian habitat); • Increases in woody vegetation along rivers, in particular by *Acacia karoo*, as well as infestations of invasive alien species (e.g. *Tamarix spp.* and *Prosopis glandulosa*). These deep-rooted species are able to readily consume groundwater. Heavily infested areas have a significant impact on the hydrology of catchments, as well as outcompeting indigenous species; • More localised, yet severe impacts, linked to sand mining and other mining activities (e.g. alluvial diamond mining at the mouth of the Gariep River and along the west coast); • Groundwater utilisation both for domestic and agricultural uses; • Construction of weirs and dams along river systems, which alters the natural hydrological flows, which is most notable for the Gariep River as a consequence of numerous, large dams/impoundments in the catchment; and • Road crossings, which cause concentration of surface runoff and localised sheet and gulley erosion in proximity to rivers and wetlands.
Phase 6 Corridor	**Rivers within the Phase 6 Corridor** are all non-perennial/ephemeral in character with exception of the Gariep River, which receives most of its flow from its headwaters in Lesotho and the Vaal River. Most of the river habitats fall within the Namaqua Highland Ecoregion, while a smaller number of systems occur within the Nama Karoo and the Orange River Gorge. Only 5% of the river habitat is considered to be Threatened (i.e. Endangered and Vulnerable). The Doring River and the lower Olifants River are the only flagship/free-flowing rivers in the corridor. The PES of rivers is generally good, with 30% of the rivers assessed to be in fair condition, while a very small proportion (1%) are in a poor state. **Overall river sensitivity for the Phase 6 Corridor is as follows:**	Approximately 98% of the Phase 6 Corridor comprises land that is largely natural, thus only a very small proportion is transformed through urbanisation, agricultural and mining developments. A reasonable proportion (12%) of the corridor is protected by a number of conservation areas (e.g. Richtersveld National Park and Namaqua National Park). Impacts on freshwater ecosystems from associated land use activities of the transformed landscape are relatively localised within the corridor context. More widespread impacts to freshwater systems tend to be linked

Gas pipeline corridor	Description	Existing drivers and pressures
	very high (1%), high (25%), medium (21%), and low (53%). **Wetland habitats** occupy a very low proportion of the corridor (<1%) owing to the xeric climatic conditions of the Succulent Karoo. Nevertheless, the area supports up to 44 wetland types, dominated by floodplain wetland habitat along the lower Gariep River and channelled-valley bottom wetlands within the Namaqualand Hardeveld region. One Ramsar wetland occurs within the corridor, and is located at the mouth of the Gariep River. A moderate proportion (17%) of the wetlands in the corridor are characterised as NFEPA wetlands, which predominantly include floodplain wetland along the Gariep River and seeps within the Namaqualand Hardeveld region. A small proportion (12%) of the wetland habitats are associated with the Endangered Gariep Desert wetland vegetation group. **Overall wetland sensitivity for the Phase 6 Corridor is as follows: very high (5%), high (23%), medium (57%), and low (15%)** **Threatened aquatic biota:** There are no known occurrences of Red Listed Odonata and fish from the Phase 6 Corridor. Three Red Listed amphibians are known to occur in the corridor, namely *Breviceps macrops* (Near Threatened), which inhabits sandy habitats along Namaqualand coast, *Capensibufo deceptus*[2] (Data Deficient) which occurs in shallow temporary pools with emergent sedge-like plants in Mountain Fynbos or Grassy Fynbos in the Fynbos Biome (IUCN, 2017) and *Breviceps branchi* (Data Deficient), which is only known from a single specimen collected near the Holgat River. One Critically Endangered reptile, *Pachydactylus rangei*, inhabits dry river beds and surrounding dunes/sanding environments in the north western corner of the corridor. One Red Listed mammal occurs within the corridor, namely the Near Threatened *Otomys auratus*. This corridor supports a low diversity of (up to 6) Red Listed plants. Of these, two are Vulnerable (i.e. *Isoetes eludens* and *Oxalis dines*), while four are Near Threatened. **Overall species sensitivity for the Phase 6 Corridor is as follows: very high (5%), high (0%), medium (32%), and low (63%).**	to livestock farming practices and infestation of invasive alien plants. The combined effect of anthropogenic pressures results in both localised and widespread impacts that affect functioning and integrity of freshwater ecosystems. Key impacts affecting freshwater ecosystems include: • Pollution from application of fertilizers, herbicides and pesticides, as well as point-source discharges from urban centres (e.g. Springbok and Vioolsdrif); • Grazing by livestock, particularly high/concentrated levels of along watercourses, causing overgrazing and trampling within and adjacent to river and wetland systems, which in turn leads to increased erosion and changes in vegetation structure (notably, the loss of riparian habitat); • Increases in woody vegetation along rivers, in particular by *Acacia karoo*, as well as infestations of invasive alien species (e.g. *Tamarix spp.* and *Prosopis glandulosa*). These deep-rooted species are able to readily consume groundwater. Heavily infested areas have a significant impact on the hydrology of catchments, as well as outcompeting indigenous species; • More localised, yet severe impacts, linked to sand mining and other mining activities (e.g. alluvial diamond mining at the mouth of the Gariep River and along the west coast); • Groundwater utilisation both for domestic and agricultural uses; • Construction of weirs and dams along river systems, which alters the natural hydrological flows, which is most notable for the Gariep River as a consequence of numerous, large dams/impoundments in the catchment; and • Road crossings, which cause concentration of surface runoff and localised sheet and gulley erosion in proximity to rivers and wetlands.

[2] http://www.iucnredlist.org/details/112716175/0

Gas pipeline corridor	Description	Existing drivers and pressures
Phase 7 Corridor	**Rivers within the Phase 7 Corridor** flow through a number of ecoregions, notably the South Eastern Uplands, but also the Norther Eastern Uplands, North Eastern Coastal Belt and Eastern Coastal Belt. The rivers are predominantly perennial/permanently-flowing (87%), and major river systems include the Groot-Kei, Mbhashe, Mzimvubu, Mzimkhulu, Mkomazi, uMngeni, Thukela, Mhlatuze and Mfolozi Rivers. Less than 30% of the rivers are considered to be Threatened (i.e. Critically Endangered, Endangered and Vulnerable). This corridor contains a significant number of the remaining flagship/free-flowing rivers in the country, namely: the Mfolozi and Thukela River systems in the northern parts of the corridor, and the Mzimkhulu, Mtamvuna, Mtentu, Ntakatye, Nqabarha, Kobonqaba River. More than 60% of the rivers are in a natural/good condition, 8% are in a fair condition, while 30% are in a poor/very poor condition. **Overall river sensitivity for the Phase 7 Corridor is as follows: very high (14%), high (44%), medium (40%), and low (2%).** **Wetland habitats within the Phase 7 Corridor** occupy a large proportion of the corridor (~12%) comprising up to 155 different wetland types dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the Subescarpment Grassland region. The supports three Ramsar wetlands, including parts of the St. Lucia System, located in the north eastern corner of the corridor, as well as uMgeni Vlei Nature Reserve (958 ha) and Ntsikeni Nature Reserve (9,200 ha). A moderate proportion (~20%) of the wetlands in the corridor are characterised as NFEPA wetlands. A very small proportion (3%) of the wetland habitats are associated with the Endangered Lowveld wetland vegetation (Group 10), while 56% occur within the Vulnerable Lowveld wetland vegetation (Group 11). **Overall wetland sensitivity for the Phase 7 Corridor is as follows: high (10%), medium (52%), and low (38%).** **Threatened aquatic biota:** Of the ten species of Red Listed Odonata that are known to occur within the corridor, three are listed as Endangered (i.e. *Chlorolestes apricans, Diplacodes pumila* and *Metacnemis valida*), while five are considered Vulnerable and two near threatened. The corridor also supports up to 15 Red Listed fish, of which seven are Endangered and three are Vulnerable, two are near threatened and three are Date Deficient. Of the 9 Red Listed amphibians that occur within the corridor, one is Critically Endangered (i.e. *Vandijkophrynus amatolicus*), while five are Endangered, one is Vulnerable and two are Near Threatened. *Vandijkophrynus amatolicus*[3] has a severely fragmented population and is known only from the Winterberg and Amathole Mountains, centred on Hogsback. The species has a very narrow EOO is	Approximately 65% of the Phase 7 Corridor, which stretches across most of the Eastern Cape and KwaZulu-Natal, comprises land that is largely natural, with a fairly large area (6%) degraded by existing land management practices. A small proportion (4%) of the area is protected by a number of small conservation areas, but also larger ones (e.g. Addo Elephant National Park, Hluhluwe-Imfolozi Game Reserve and Isimangaliso Wetland Park). The remaining area is transformed by cultivation (19%), urbanisation and rural settlements (5%) and plantations (5%). Key impacts affecting freshwater ecosystems include: • Extensive urbanisation causing transformation and degradation of freshwater ecosystems, notably in the greater Durban area, which continues to expand down? along the coast, as well as Pietermaritzburg and a within numerous of coastal towns south of Durban; • Water quality impacts and pollution associated with urban areas (e.g. domestic and industrial effluents, failing water treatment infrastructure, etc.) and agriculture (e.g. pesticides, herbicides and fertiliser applications), all of which are contaminating receiving aquatic environments; • Very high (unacceptable) faecal contamination in the uMngeni, Mlazi and Mdloti Rivers, as well as numerous rivers draining the eThekwini Metropolitan and Pietermaritzburg; • Stormwater runoff from hardened surfaces and sewer reticulation in and around urban areas; • Altered flows and water quality caused by large impoundments (e.g. Midmar, Albert Falls, Inanda, Goedertrouw and Umtata Dams), inter-basin transfers, which severely affect downstream aquatic systems (e.g. channel characteristics, riparian vegetation, thermal regimes, instream and floodplain habitats,

[3] http://www.iucnredlist.org/details/3176/0

Gas pipeline corridor	Description	Existing drivers and pressures
	98 km^2, and there is ongoing decline in the extent and quality of habitat. (IUCN, 2017) This corridor supports the highest number of Red Listed reptiles, including two Vulnerable, one Near Threatened and one Data Deficient species. The corridor also supports a high diversity of Red Listed mammals (up to 8 species), including three that are Vulnerable and five that are Near Threatened. This corridor supports a high diversity of (up to 39) Red Listed plants. Of these, two are Critically Endangered (i.e. *Isoetes wormaldii* and *Kniphofia leucocephala*), while six are Endangered, 17 are Vulnerable, 11 are Near Threatened, two are Data Deficient and one is rare. **Overall species sensitivity for the Phase 7 Corridor is as follows: very high (26%), high (10%), medium (47%), and low (17%).**	etc.), as well as upstream/downstream river continuity; • Illegal sand mining, as well as and other mining activities, particularly along coastal areas; • Transformation and alteration of watercourses through canals, diversion structures, weirs, road crossings, flood control berms; • Cultivation of wetlands and floodplains (notably sugarcane), especially along the coastal region; • Abstraction of water for large-scale irrigation, as well as streamflow reduction associated with extensive plantations; • Erosion and degradation, especially linked to overgrazing, which is notable in the more rural areas; and • Excessive infestation of numerous IAPs, particularly along rivers and around wetlands, as well as instream (e.g. Water Hyacinth).
Phase 8 Corridor	**Rivers within the Phase 8 Corridor** are predominantly perennial/permanently-flowing (80%), and flow through ecoregions such as the Highveld, Northern Escarpment Mountains, North Eastern Highlands, and down through the Lowveld. Major river systems include the Olifants, Komati, Crocodile and Sabie Rivers. A significant proportion (approximately 71%) of the rivers are considered to be Threatened (i.e. Critically Endangered, Endangered and Vulnerable). The Elands River (tributary of the Olifants River) is the only flagship/free-flowing river within the corridor. Less than 25% of the rivers are in a natural/good condition, 47% are in a fair condition, 23% are in a poor condition, while 6% are in a poor condition. **Overall river sensitivity for the Phase 8 Corridor is as follows: very high (46%), high (32%), medium (21%), and low (<1%).** **Wetland habitats within the Phase 8 Corridor** occupy a large proportion of the corridor (~12%) comprising up to 93 different wetland types, dominated by channelled-valley bottom wetlands, and largely characteristic of the Mesic Highveld Grassland region. There are no Ramsar wetlands that occur within the corridor, and a small proportion (~8%) of the wetlands are classified as NFEPA wetlands, mostly in the form of channelled-valley bottoms, depressions and seeps. Nevertheless, a significant (75%) of the wetlands are associated with Critically Endangered wetland groups, notably the Mesic Highveld Grassland Group 4 (54%) and Group 3 (9%). **Overall wetland sensitivity for the Phase 8 Corridor is as follows: very high (12%), high (72%), medium (13%), and low (3%).**	Approximately 65% of the Phase 8 Corridor comprises land that is largely natural with a further 2% degraded. A fairly large proportion (16%) of the corridor is protected by conservation areas, including parts of Kruger National Park. The remaining area is mostly transformed by cultivation (~19%) and plantations (11%), and to a lesser extent by urbanisation (3%) and mining (1%). Key impacts affecting freshwater ecosystems include: • Plantations, concentrated in the central highlands, resulting in a number of impacts to freshwater ecosystems (e.g. streamflow reduction particularly dry-season baseflows, increased turbidity and sedimentation, removal of riparian vegetation and buffer zones, invasive alien plant infestation, loss of species diversity and abundance, etc.); • Mining related acitivities (notably for coal resources) resulting in pollution of surface waters caused predominantly by acidification (i.e. acid mine drainage) and other mining-related effluents; • Run-of-river abstraction and small farm dams for irrigation, which is more pronounced in the western parts of the corridor;

Gas pipeline corridor	Description	Existing drivers and pressures
	Threatened aquatic biota: The corridor supports two species of Odonata that are listed as Endangered (i.e. *Ceriagrion suave* and *Diplacodes pumila*), along with three that are Near Threatened. There are also 13 Red Listed fish that are known to inhabit the corridor, including the Critically Endangered *Chiloglanis bifurcus* and *Enteromius treurensi*. *Chiloglanis bifurcus*[4] is an instream species, endemic to the Inkomati River System and within this system it is restricted to altitudes between 900 metres above sea level (m.a.s.l) to 1200 m.a.s.l. In addition there are also 3 endangered fish species, one Vulnerable, five Near Threatened, and two Data Deficient. There are no Red Listed amphibians that are known to occur within the corridor. Only one Red Listed reptile occurs within the corridor, namely the Near Threatened *Macrelaps microlepidotus*. The corridor supports a high diversity of Red Listed mammals (up to 7 species), including three that are Vulnerable and four that are Near Threatened. This corridor supports a moderate diversity of Red Listed plants, including one that is Critically Endangered (i.e. *Aloe simii*) and one that is Endangered (i.e. *Disa zuluensis*). The majority of the Red Listed plants occurring with the corridor are either Vulnerable (7 species) or Near Threatened (7 species), while one is Data Deficient and two are rare. **Overall species sensitivity for the Phase 8 Corridor is as follows: very high (41%), high (34%), medium (9%), and low (16%).**	• Urbanisation in and around towns such as Emalahleni, Middleberg, Ermelo and Nelspruit placing increased pressure on water resources, largely due to increased stormwater runoff and decreased water quality from both point and non-point sources linked to residential and industrial areas); • Very high (unacceptable) faecal pollution in regions such as Witbank/Middleburg and Nelspruit, which is affecting river systems such as the Crocodile and Olifants; and • Extensive maize cultivation and livestock farming resulting in removal and/or degradation of freshwater habitat.
Inland Corridor	**Rivers within the Inland Corridor** are mostly ephemeral/non-perennial (95%), and are largely characteristic of the Great Karoo ecoregion, but also form part of the Nama Karoo and Drought Corridor ecoregions. Major river systems include the Dwyka, Kariega and Sondags Rivers. Less than 25% of the river habitat in the corridor is currently Threatened (i.e. Critically Endangered and Endangered). The rivers are mostly in a natural/good condition (60%), 34% of rivers are in a fair condition, while 6% are in a poor condition. **Overall river sensitivity for the Inland Corridor is as follows: very high (14%), high (50%), medium (31%), and low (5%).** **Wetland habitats within the Inland Corridor** occupy a fair proportion of the corridor (~7%), with up to 62 different wetland types dominated by channelled-valley bottom wetlands and depressions that are largely characteristic of the Nama Karoo. There are no Ramsar wetlands within the corridor, and a very small proportion (~1%) of wetlands are classified as NFEPA wetlands. Nevertheless, a significant portion (79%) of the wetlands are associated with Critically Endangered wetland groups, notably the Lower Nama Karoo (60%) and the Rainshadow Valley Karoo (11%). **Overall wetland sensitivity for the Inland Corridor is as follows: very high (26%), high**	Almost the entire (99%) area of the Inland Corridor comprises land that is largely natural, with only a very small proportion transformed by cultivation (1%) and urbanisation (<1%). A very small proportion (3%) of the corridor is protected by a few conservation areas (e.g. Karoo National Park and Tankwa Karoo National Park). Impacts on freshwater ecosystems from associated land use activities of the transformed landscape are thus relatively localised. More widespread impacts to freshwater systems tend to be linked to livestock farming practices and infestation of invasive alien plants. The combined effect of anthropogenic pressures results in both localised and widespread impacts that affect functioning and integrity of freshwater ecosystems. Key impacts affecting freshwater ecosystems include: • Weirs and dams (including large water supply dams, e.g. De

[4] http://www.iucnredlist.org/details/4632/0

Gas pipeline corridor	Description	Existing drivers and pressures
	(56%), medium (4%), and low (14%). **Threatened aquatic biota:** There are no Red Listed species of Odonata known to occur within the Inland Corridor. Only two Red Listed fish occur within the corridor, namely the Endangered *Pseudobarbus asper*, and the Data Deficient *Sandelia capensis*. There are no Red Listed amphibians and reptiles that are known to occur within the Inland Corridor. The corridor is most notable in terms of supporting significant populations of the Critically Endangered Riverine Rabbit *Bunolagus monticularis*, which is restricted to the semi-arid Karoo, with an estimated EOO of 54,227 km² and AOO of 2,943 km² (2016 Mammal Red List *Bunolagus monticularis* CR). The Riverine Rabbit inhabits dense, discontinuous scrub vegetation along seasonal river beds and is dependent on soft, deep alluvial spoils along these river courses, for constructing burrows in order to breed. Other Red Listed mammals include the Near Threatened *Serval Leptailurus* and the Near Threatened *Otomys auratus*. This corridor supports the lowest number of Red Listed plants, with only one Vulnerable plant (i.e. *Lachenalia longituba*) and one rare plant (i.e. *Pelargonium denticulatum*) occurring within the corridor. **Overall species sensitivity for the Inland Corridor is as follows: very high (11%), high (13%), medium (6%), and low (70%).**	Hoop, Leeugamka, Vanrynevelspas), which affect instream and riparian habitat continuity, as well as regulate flows downstream; • Livestock grazing and trampling (including overgrazing, particularly in more rural areas), leading to increased erosion and sedimentation of systems; • Intensive cultivation immediately adjacent and along the banks of rivers; • Encroachment and infestation of woody vegetation, including invasive *Tamarix spp.*; and • Channel incision and headcut erosion, resulting in lowered groundwater table and drying of riparian and wetland habitats.

The following figures (Figure 2 to 5) show the distribution of freshwater features (i.e. rivers, wetlands, flora and fauna) associated with the various gas pipeline corridors as developed following the collation and compilation of available spatial datasets (see data sources in Section 4.2).

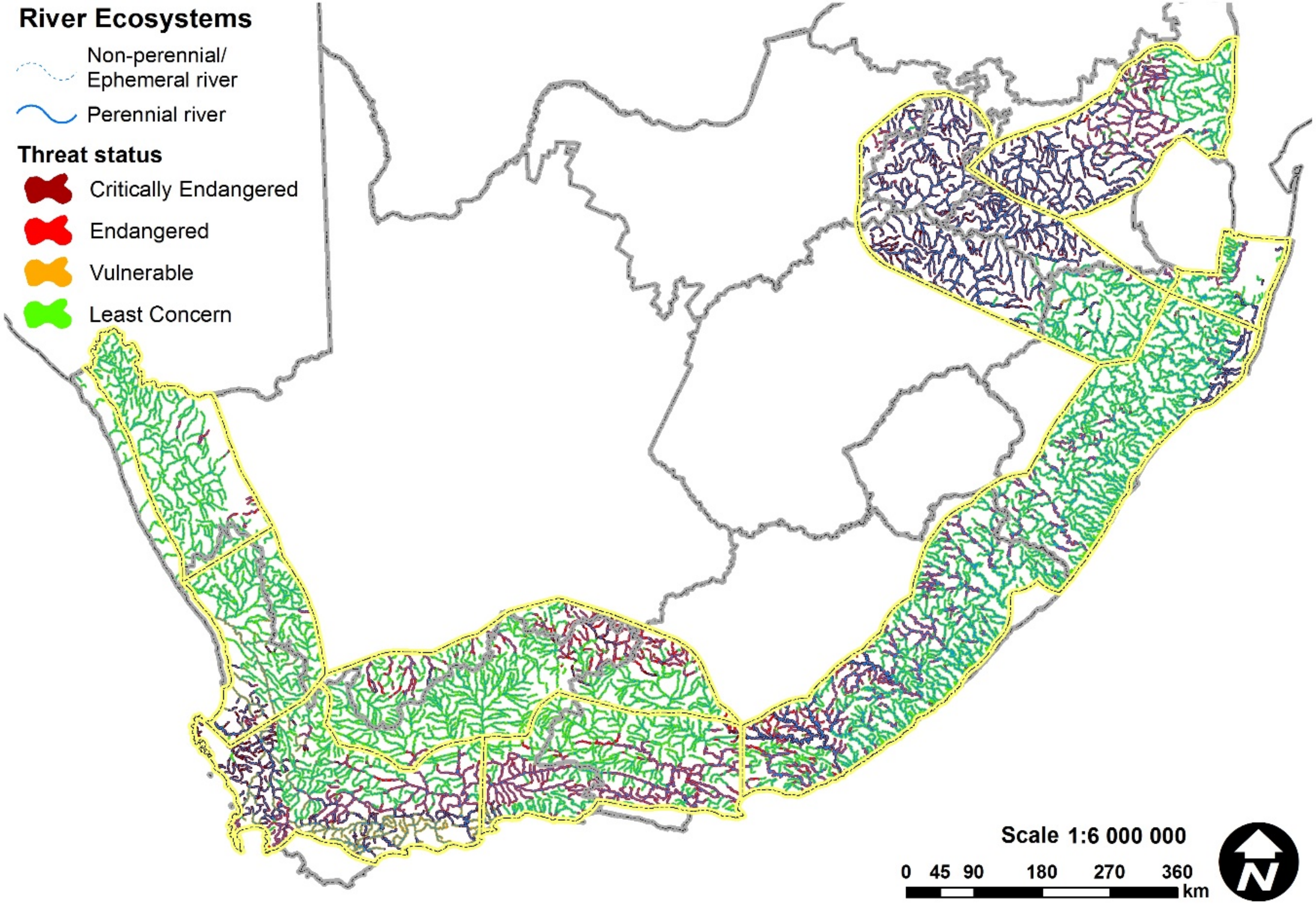

Figure 2: Flow (perennial and non-perennial) and threat status of rivers that flow through the gas pipeline corridors developed using the PES, EI and ES data from DWS (2014).

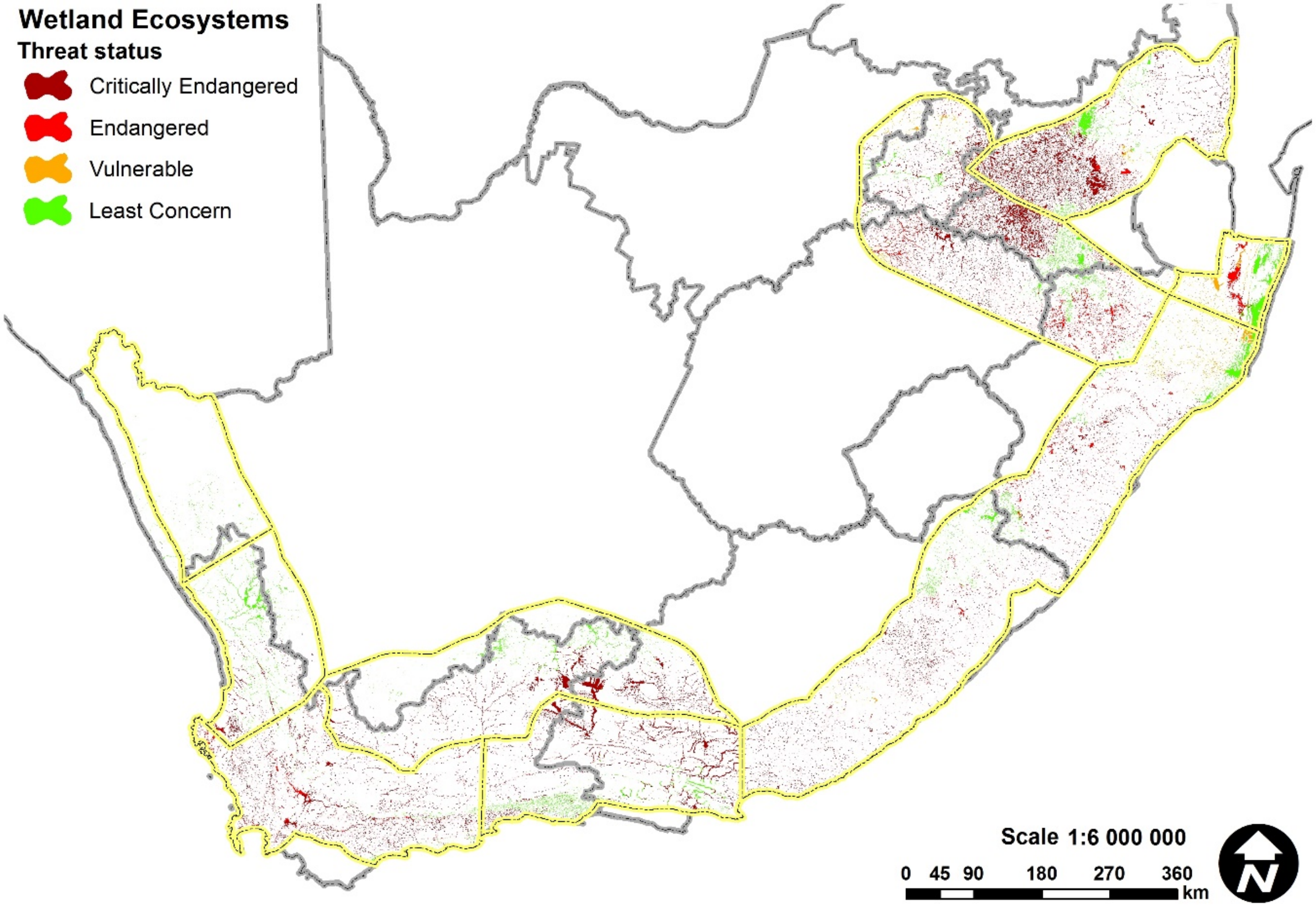

Figure 3: Wetland threat status based on the national wetland vegetation group regions of Nel and Driver (2012) applied to all wetlands of the collated wetland coverage developed for the gas pipeline corridors

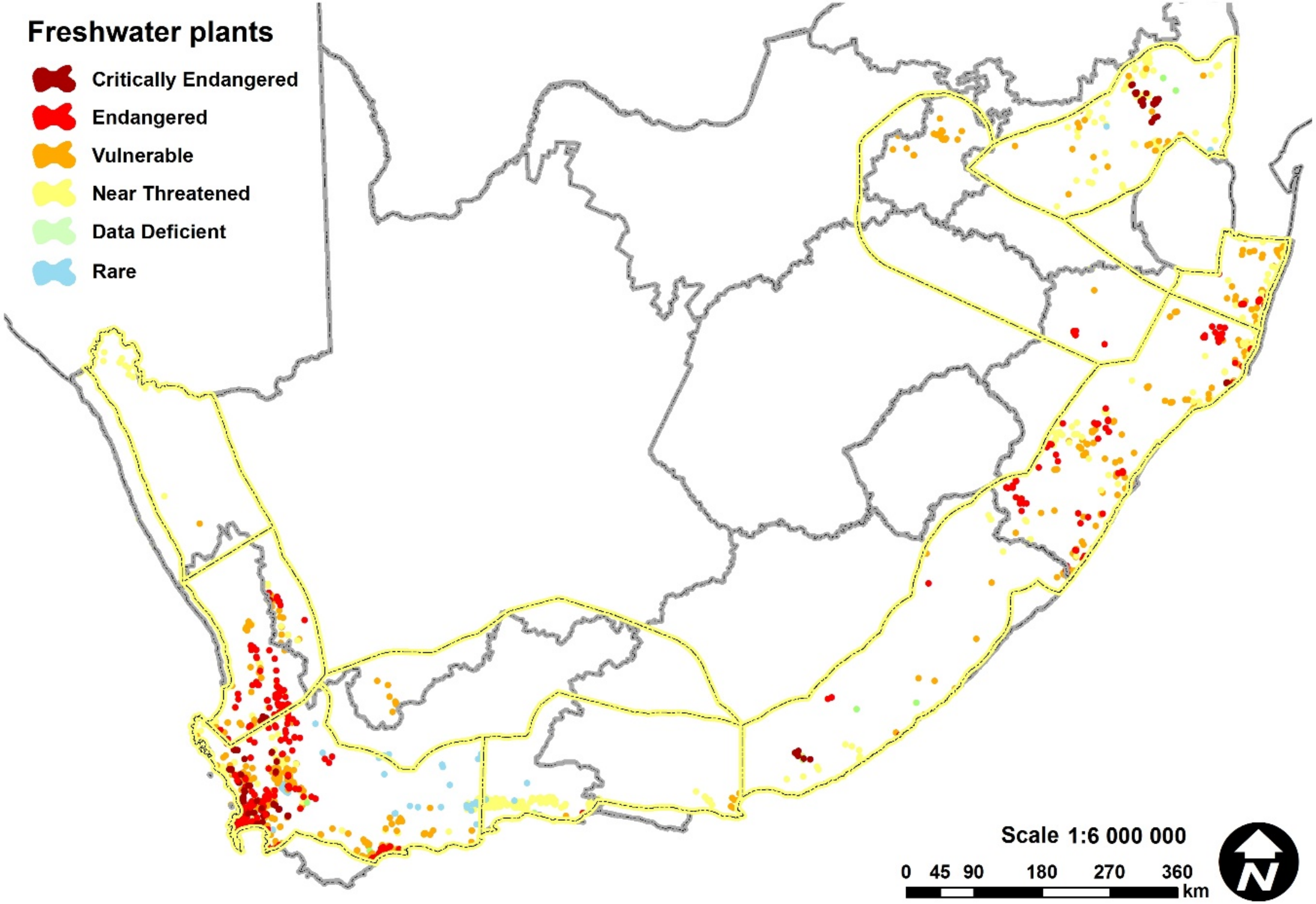

Figure 4: Point localities and corresponding threat status of freshwater plants based on known occurrence data within the gas pipeline corridors

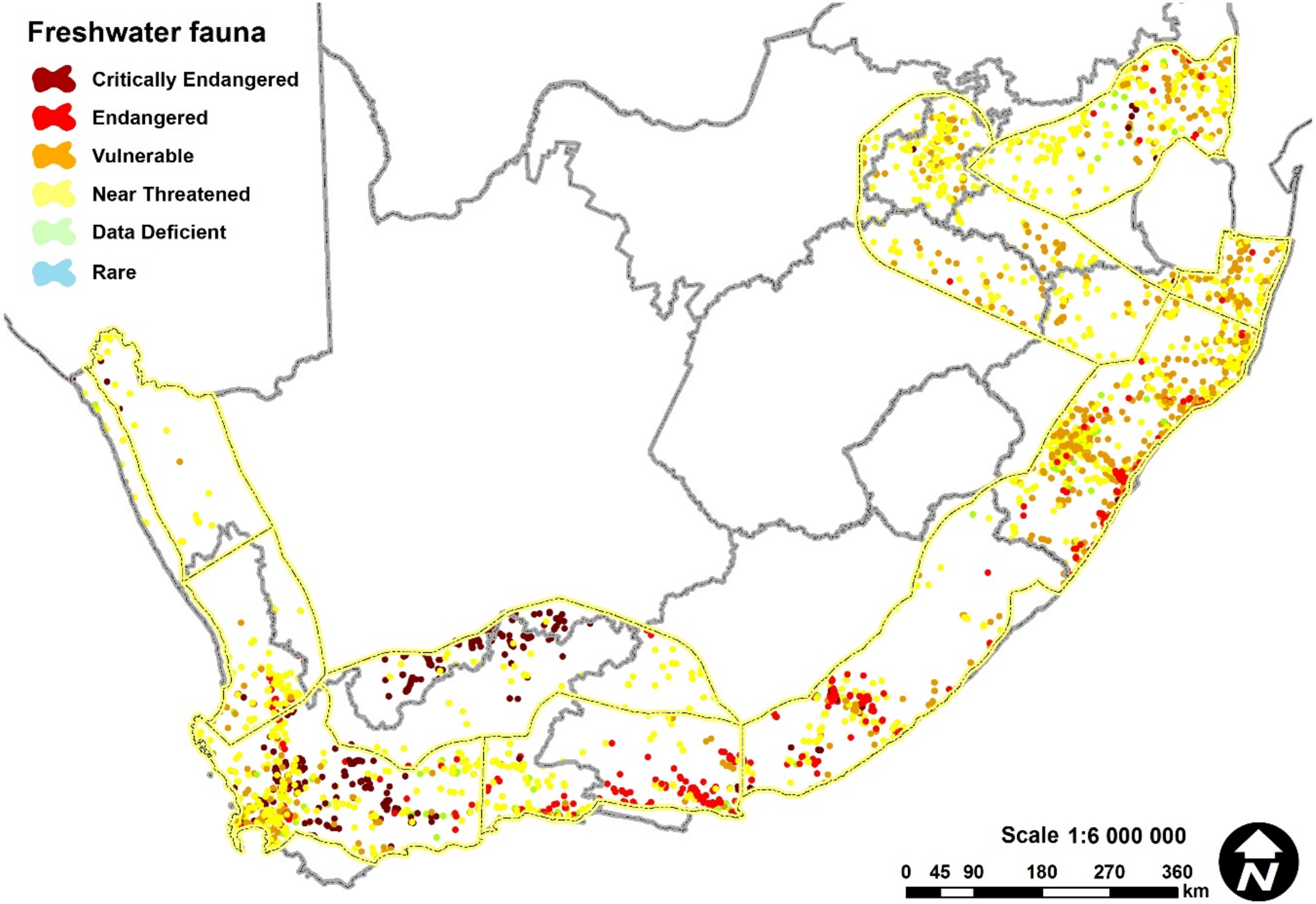

Figure 5: Point localities and corresponding threat status of freshwater fauna based on known occurrence data within the gas pipeline corridors

6 SENSITIVITY MAPPING

6.1 Identification sensitivity criteria for features

Table 6 provides a list and description of the sensitivity criteria considered during this assessment of the proposed Gas Pipeline corridors.

Table 6: Data and criteria used to assign sensitivity to freshwater ecosystems within the proposed Gas Pipeline corridors.

Category	Feature Class	Data Source + Date of Publications	Data Description, Preparation and Processing
Freshwater ecosystems	Wetlands	Combined wetlands layer comprising: NFEPA (2011); Provincial Wetland Probability Mapping (2017); Fine scale planning - Western Cape (2017); Conservation Plans, Biodiversity Sector Plans (BSP's), and Critical Biodiversity Areas (CBA's) and Ecological Support Areas (ESAs) - KZN (2007) and Northern Cape (2016); National wetland vegetation groups (2012); KZN wetlands/vegetation types (2011); KZN Priority Wetlands; Ramsar Sites.	The combined wetland layer was processed according to two metrics as described in more detail in Section 4.1. **Threat:** National Wetland Vegetation Groups (2012) **Sensitivity:** Ramsar wetlands, Threatened wetlands, Irreplaceable and Optimal CBAs as aquatic features, KZN priority wetlands, NFEPA wetlands, ESAs as aquatic features, wetland probability mapping, and ONAs as aquatic features.
	Rivers	PES EI and ES DWS Resource Quality Information Services (2014), using the NFEPA rivers coverage (2011)	Metrics were applied that integrate data pertaining to river ecosystems to define river threat status and river importance/sensitivity (as described in Section 4.1). PES, river types and river length were used to derive river threat using updated PES data (2014) based on thresholds defined in the 2011 NBA. River sensitivity/importance was based on the 2014 EI and ES dataset. Overall river sensitivity scores were determined as: Threat Score (PES score and river length as per NBA) + (EI+ES score/ Stream Order)
Freshwater biota	Flora: Plants	Raimondo *et al.* (2009), with spatial data provided from the SANBI Threatened Species Programme database (2018)	Species of conservation concern, and their respective conservation status (i.e. CR, EN, VU, NT, DD and rare), that inhabit freshwater ecosystems and adjacent fringe habitats/ buffers were selected based on known point localities, and assigned to sub-quaternary (SQ4) catchments. The SQ4 catchments were then classified into four sensitivity classes based on presence/ absence of selected
	Fauna: Aquatic macro-invertebrates	DWS Resource Quality Information Services (2015)	

Category	Feature Class	Data Source + Date of Publications	Data Description, Preparation and Processing
	Fauna: Odonata	IUCN (2017) and Samways and Simaika (2016), with spatial data provided from the SANBI Threatened Species Programme database (2018)	freshwater fauna and flora (i.e. low = no occurrence, medium = rare or NT, high = VU or EN, very high = CR or DD). ASPT values for aquatic macro-invertebrate families as recorded from various river sampling sites was used to defined importance/sensitivity of DWS Level 2 Ecoregions.
	Fauna: Fish	Coetzer (2017), with spatial data provided from the SAIAB, and International Union for the Conservation of Nature (2017)	
	Fauna: Amphibians	Minter *et al.* (2004), with spatial data provided from the SANBI Threatened Species Programme database (2018)	
	Fauna: Reptiles (freshwater ecosystem obligate)	Bates *et al.* (2014), with spatial data provided from the SANBI Threatened Species Programme database (2018)	
	Fauna: Mammals (freshwater ecosystem obligate)	Child *et al.* (2016), with spatial data provided from the SANBI Threatened Species Programme database (2018)	

The feature types considered in the sensitivity analysis and the rating given to each feature and buffered area (Table 7).

Table 7: Sensitivity ratings assigned to freshwater ecosystem features in all of the proposed Gas Pipeline corridors.

Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
Wetlands: Critically Endangered wetlands and Irreplaceable CBAs (aquatic)	Very High	200 m
Wetlands: Ramsar wetlands, KZN priority wetlands, Endangered or Vulnerable wetlands, Optimal CBA (aquatic)	High	100 m
Wetlands: NFEPA wetlands, Near Threatened wetlands and ESA (aquatic)	Medium	50 m
Wetlands: probable wetland, non-NFEPA wetlands, least threatened wetlands, ONA (aquatic), formally protected aquatic features	Low	32 m
River ecosystems (including instream and riparian habitats)	Very High	200 m
	High	100 m
	Medium	50 m
	Low	32 m
Freshwater fauna and flora: Critically Endangered or Data Deficient species	Very High	N/A – all species of conservation concern localities are assigned to sub-quaternary (SQ4) catchments, thereby presenting a variable buffer.
Freshwater fauna and flora: Endangered or Vulnerable species	High	
Freshwater fauna and flora: Near Threatened or Rare species	Medium	
Freshwater fauna and flora: Least Threatened species	Low	

Figure 6 to Figure 41 depicts the sensitivity of freshwater ecosystems and associated features in the proposed Gas Pipeline corridors.

6.2 Phase 1 Corridor

6.2.1 Rivers

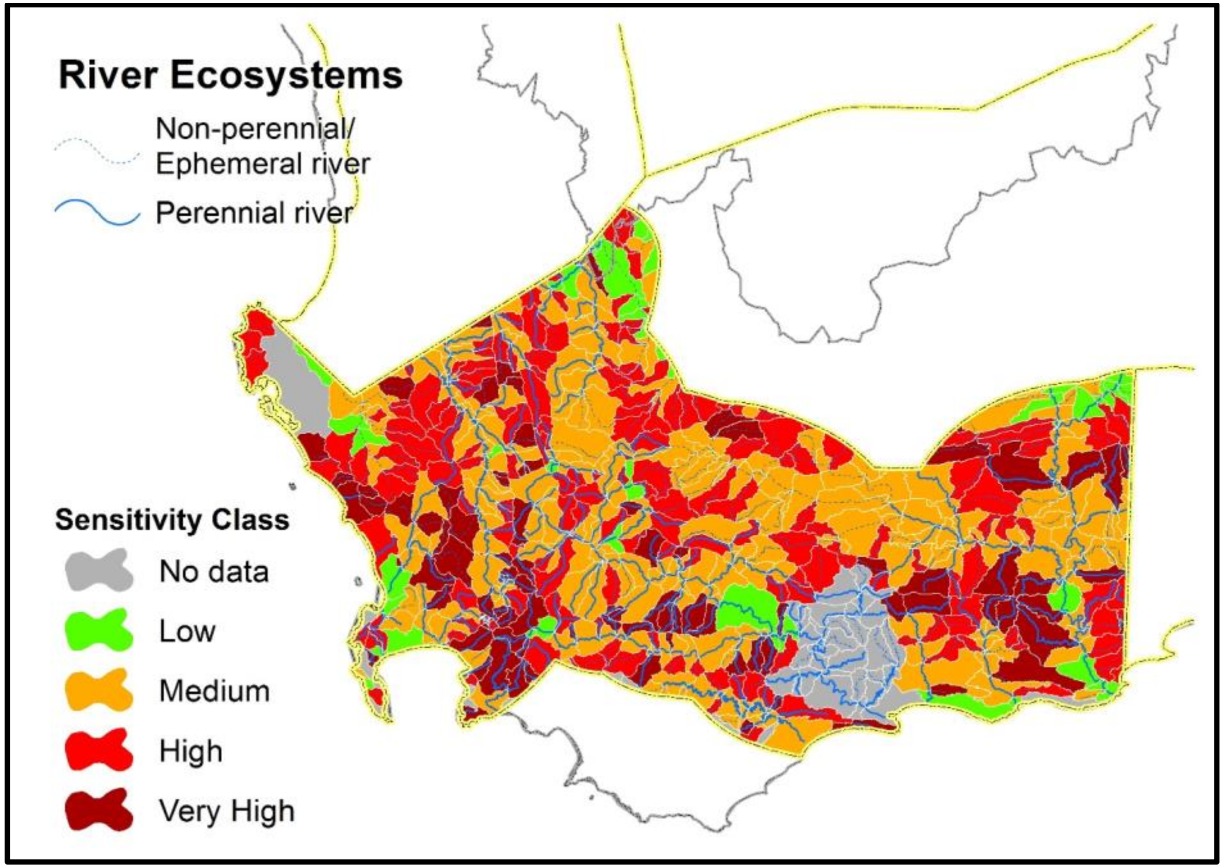

Figure 6: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 1 corridor using PES, EI and ES data from DWS (2014).

6.2.2 Wetlands

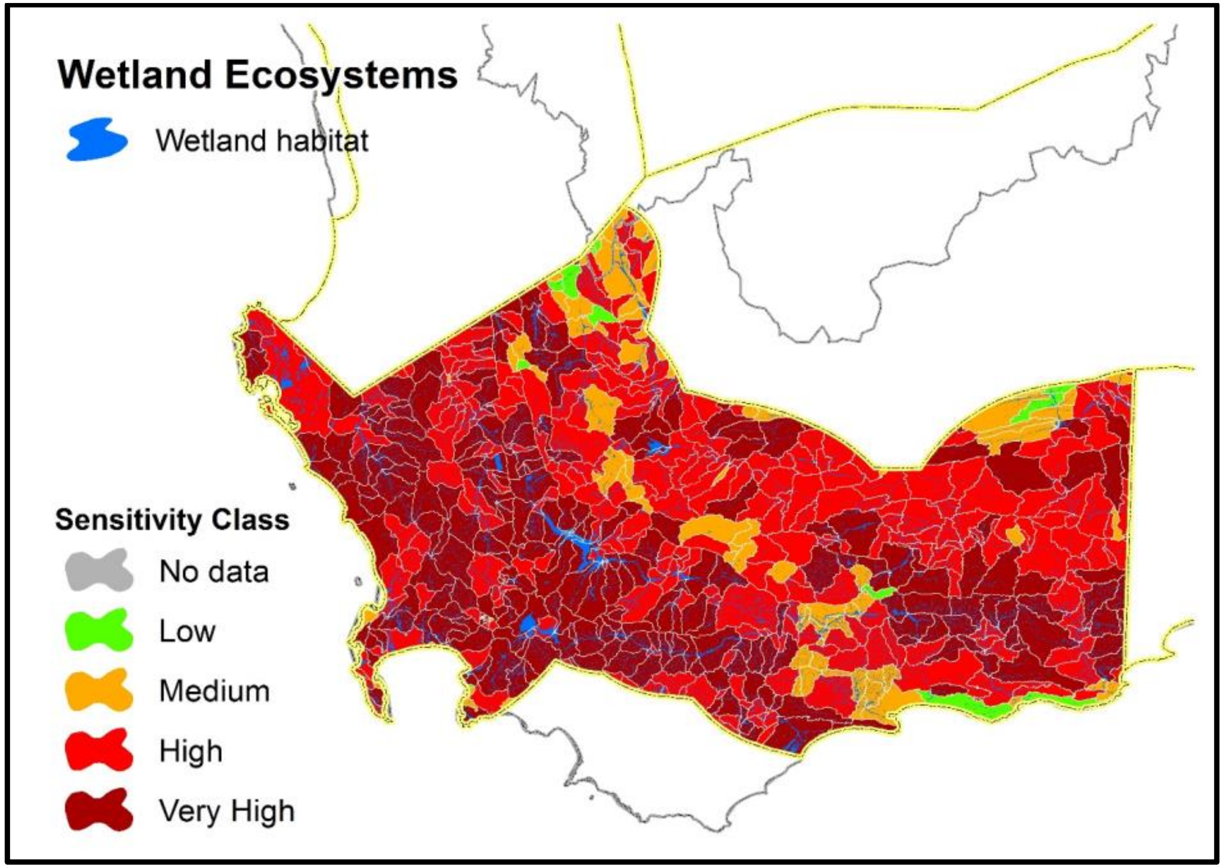

Figure 7: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 1 corridor.

6.2.3 Freshwater biota (fauna and flora)

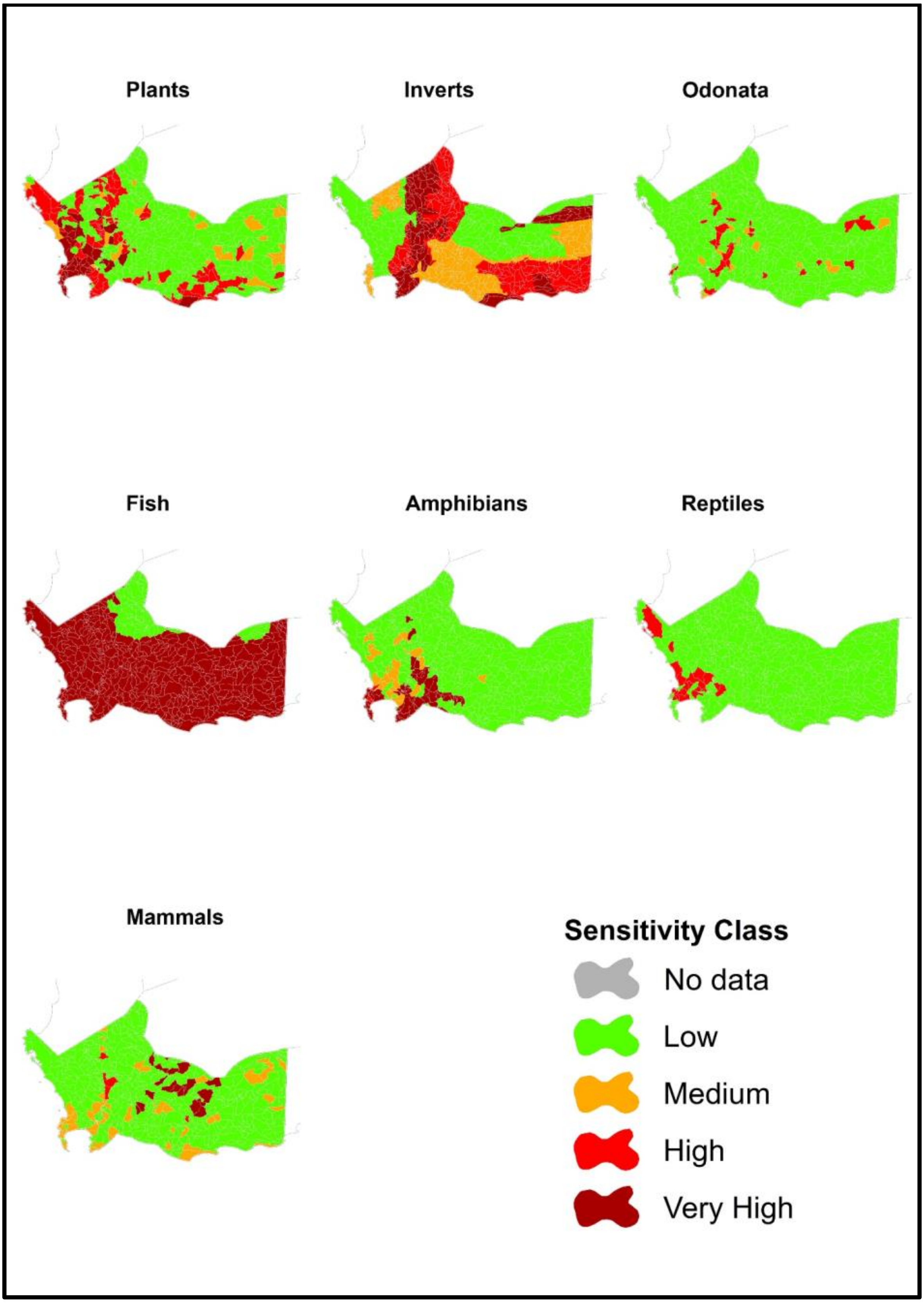

Figure 8: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 1 corridor in relation to sub-quaternary catchments.

6.2.4 Freshwater ecosystems and biota (combined)

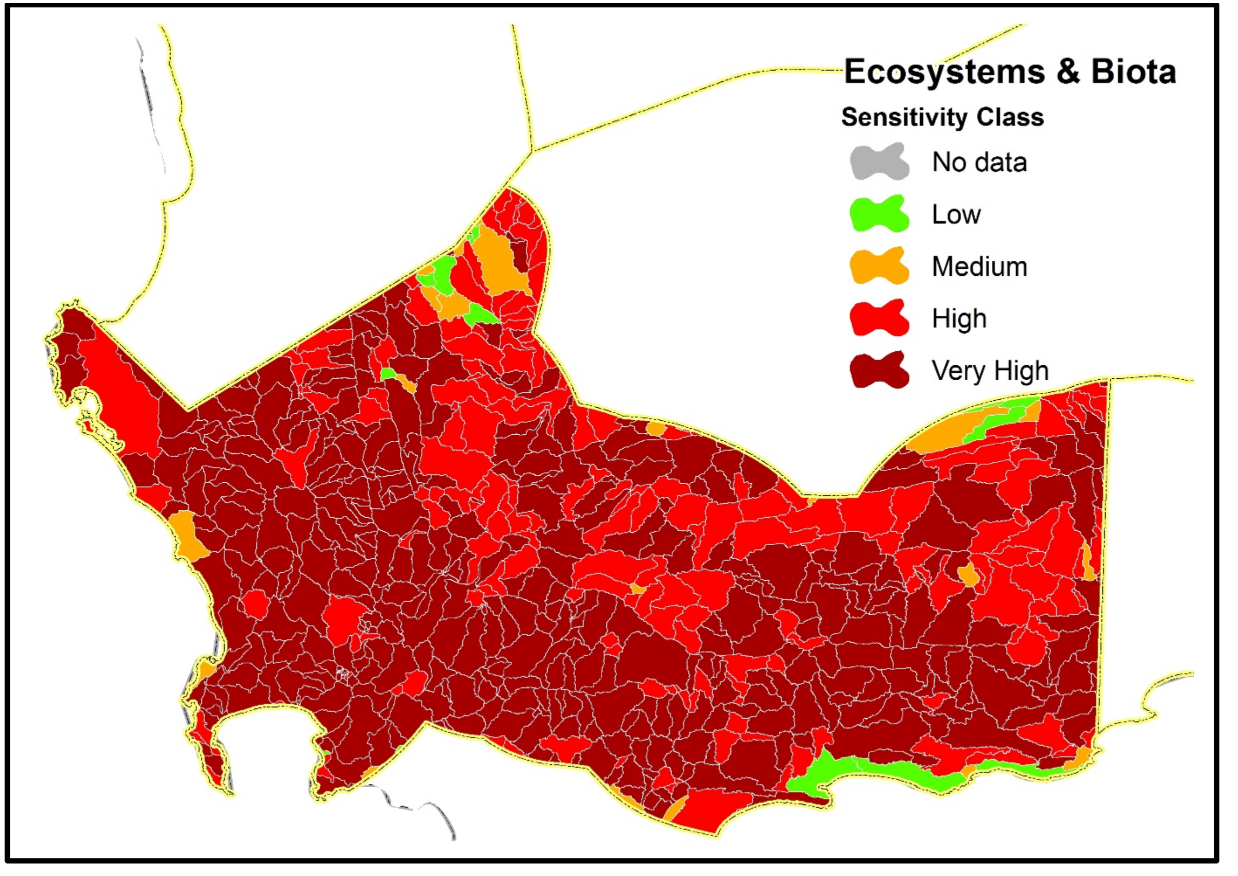

Figure 9: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 1 corridor.

6.3 Phase 2 Corridor

6.3.1 Rivers

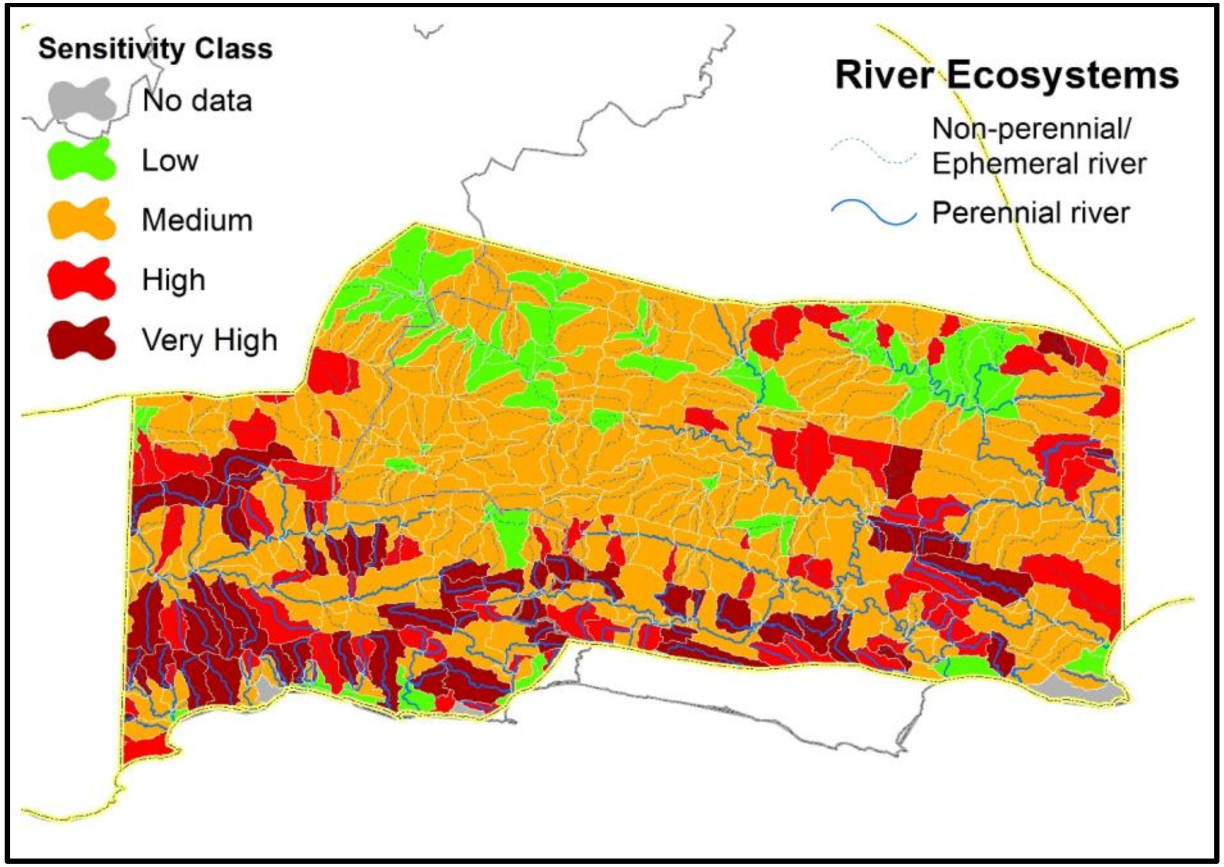

Figure 10: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 2 corridor using PES, EI and ES data from DWS (2014).

6.3.2 Wetlands

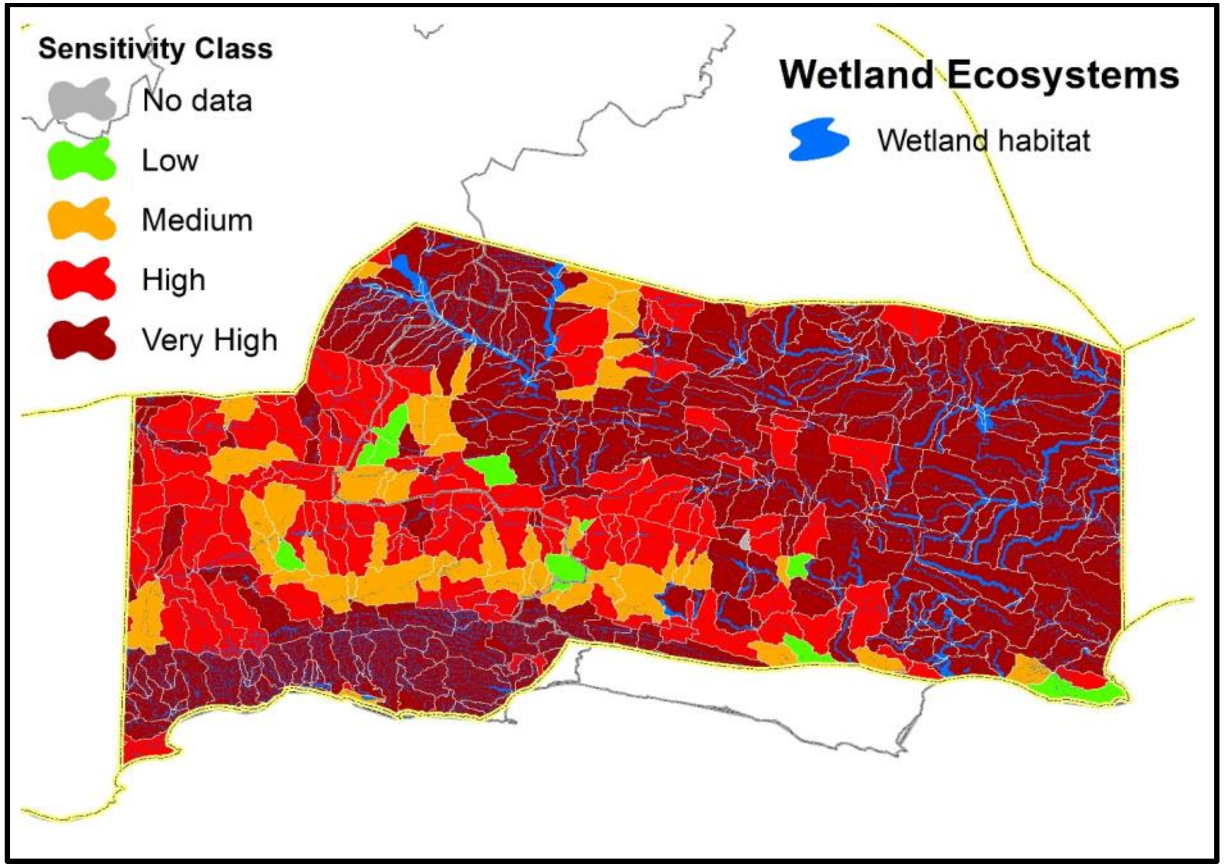

Figure 11: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 2 corridor.

6.3.3 Freshwater biota (fauna and flora)

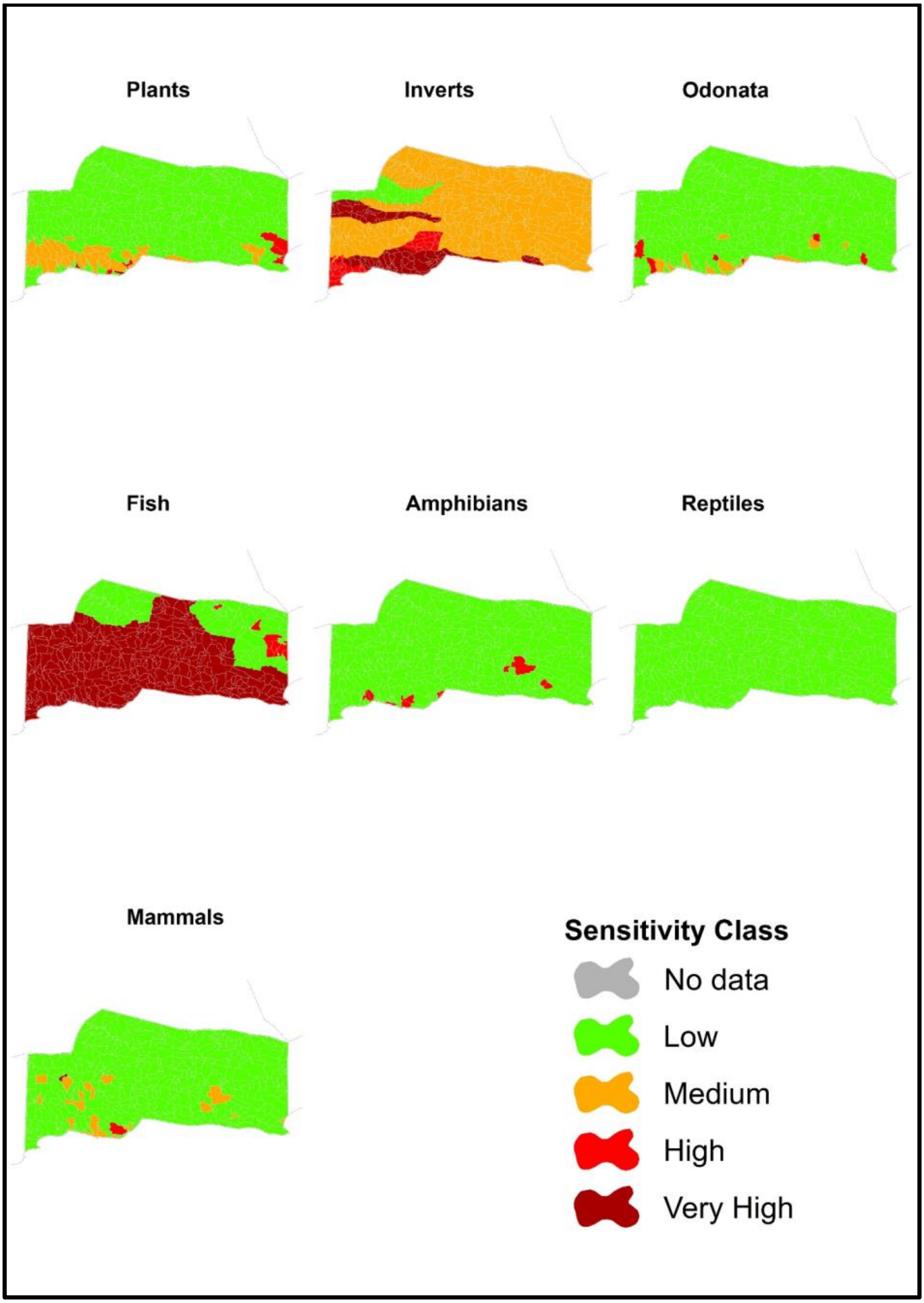

Figure 12: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 2 corridor in relation to sub-quaternary catchments

6.3.4 Freshwater ecosystems and biota (combined)

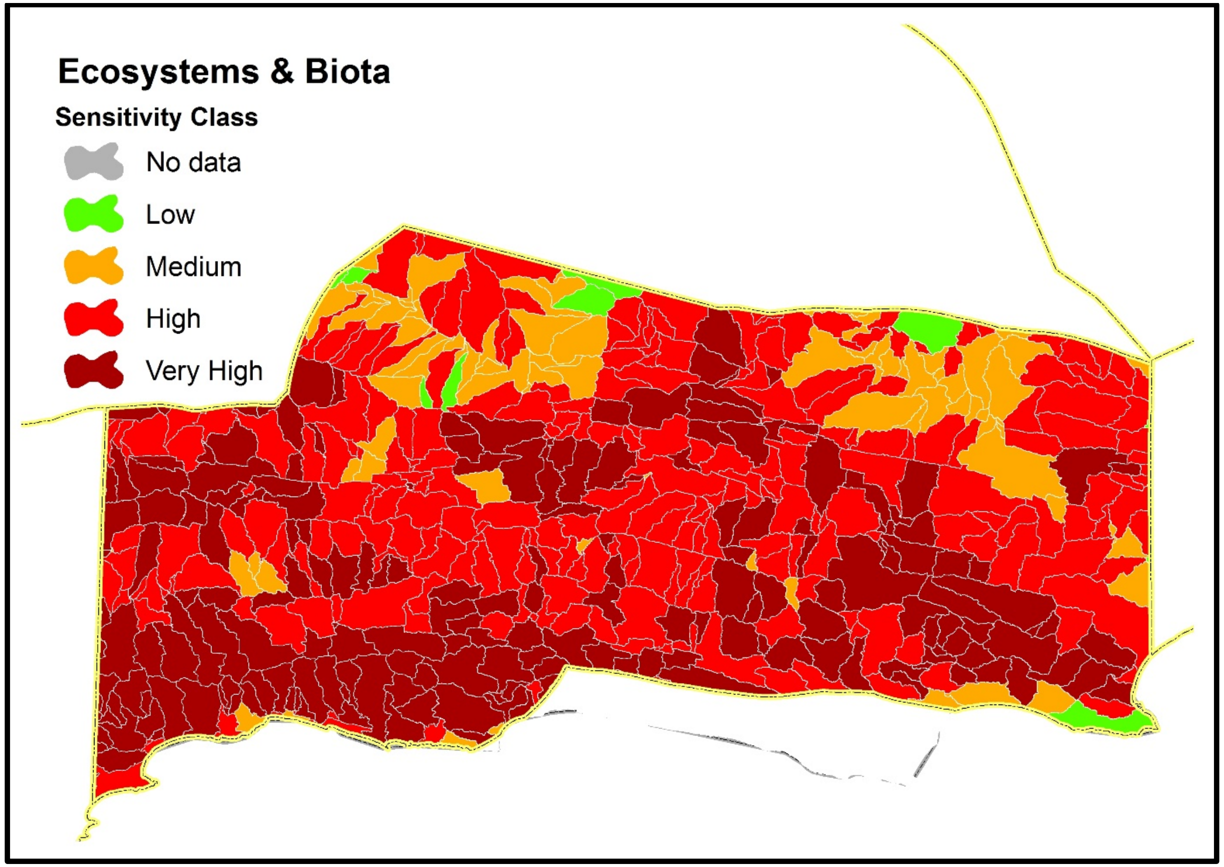

Figure 13: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 2 corridor.

6.4 Phase 3 Corridor

6.4.1 Rivers

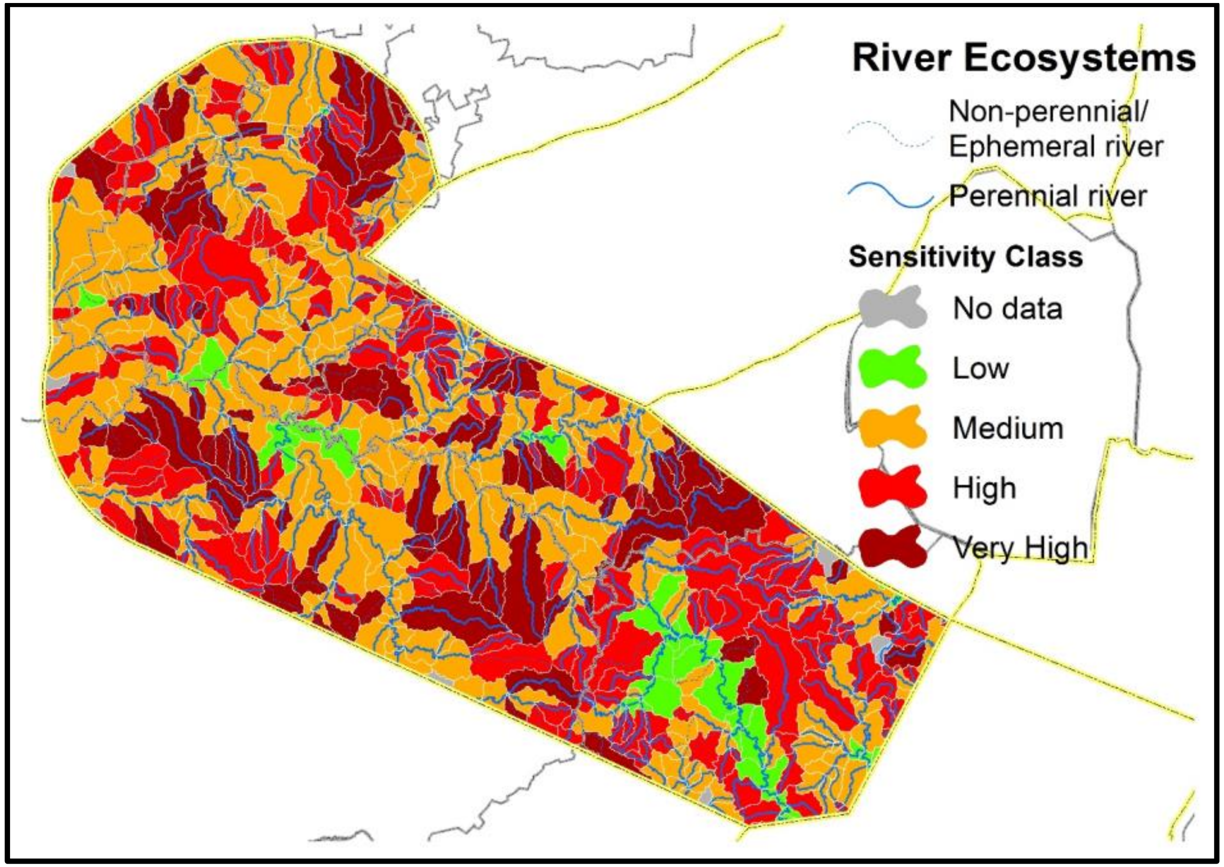

Figure 14: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 3 corridor using PES, EI and ES data from DWS (2014).

6.4.2 Wetlands

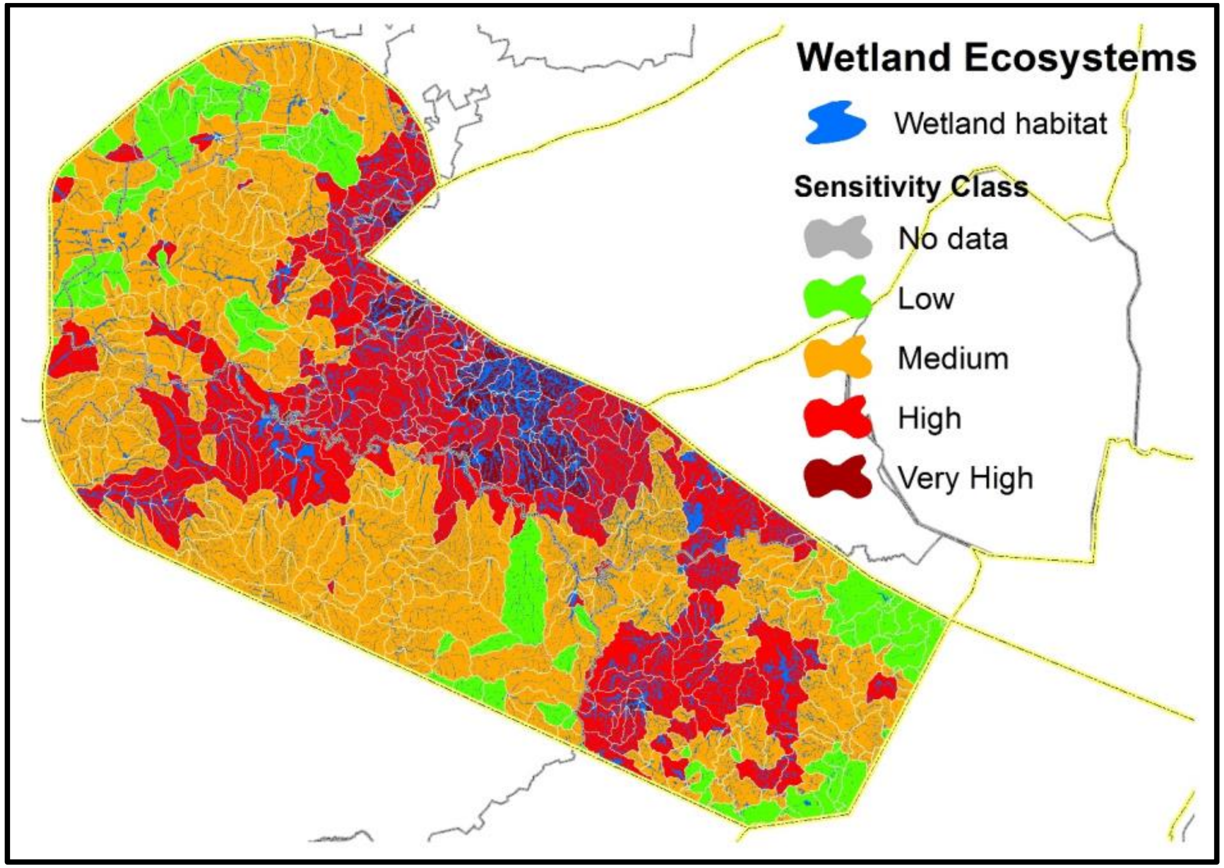

Figure 15: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 3 corridor.

6.4.3 Freshwater biota (fauna and flora)

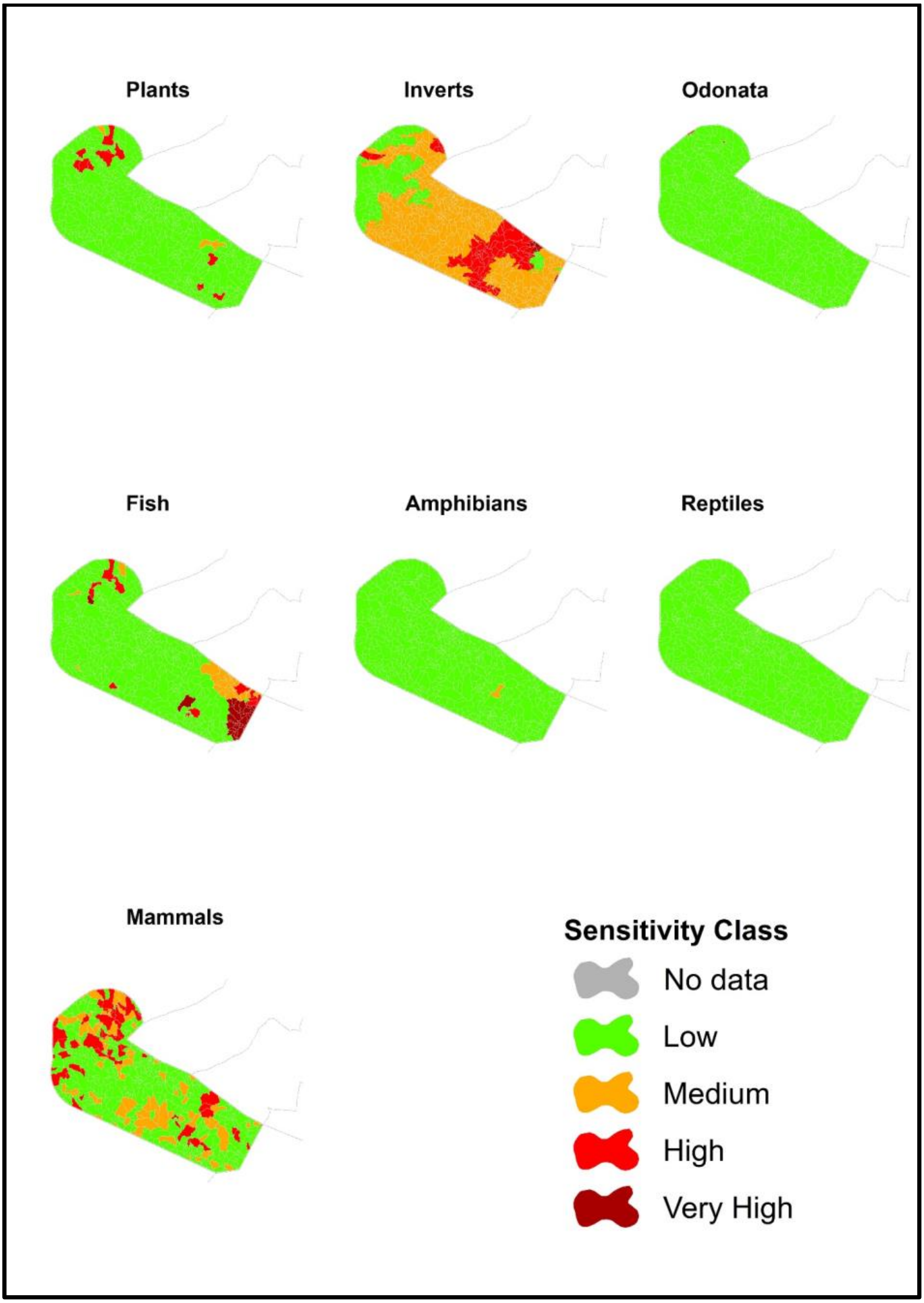

Figure 16: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 3 corridor in relation to sub-quaternary catchments

6.4.4 Freshwater ecosystems and biota (combined)

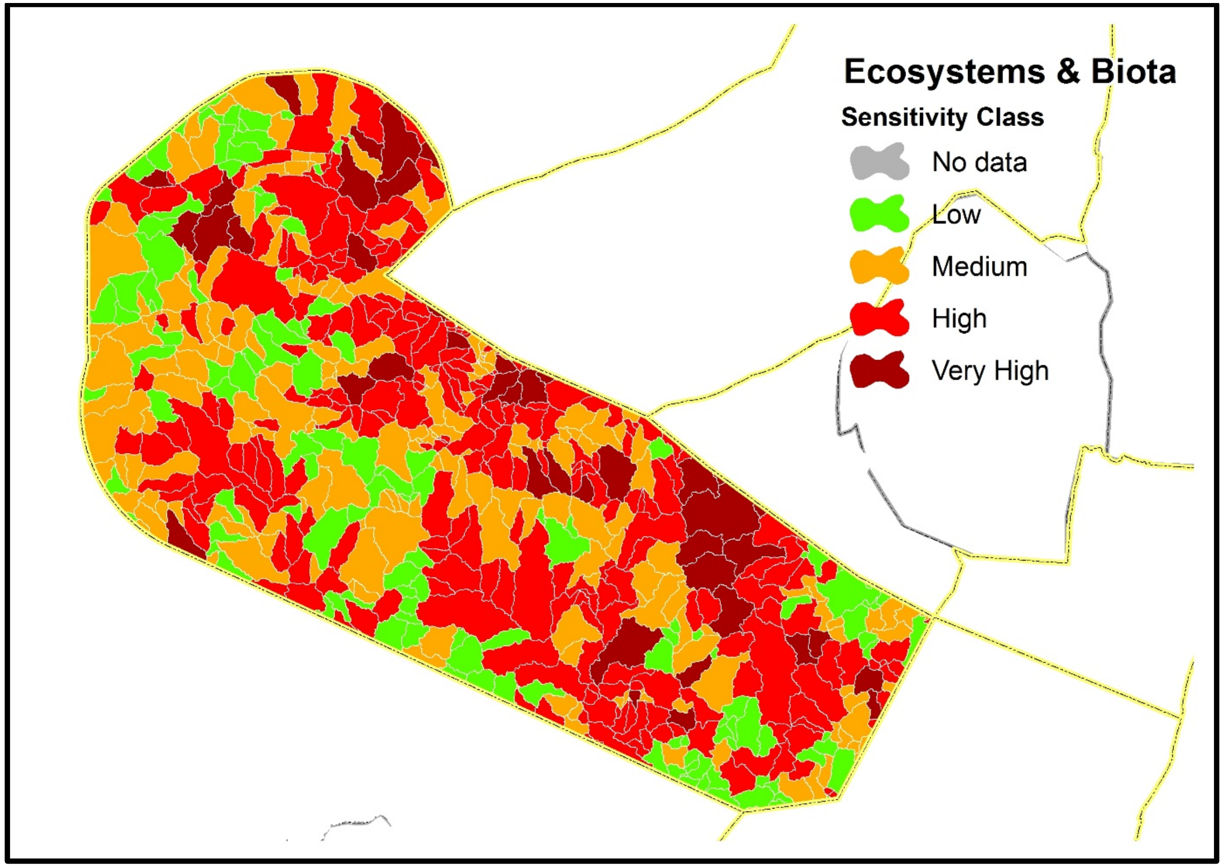

Figure 17: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 3 corridor.

6.5 Phase 4 Corridor

6.5.1 Rivers

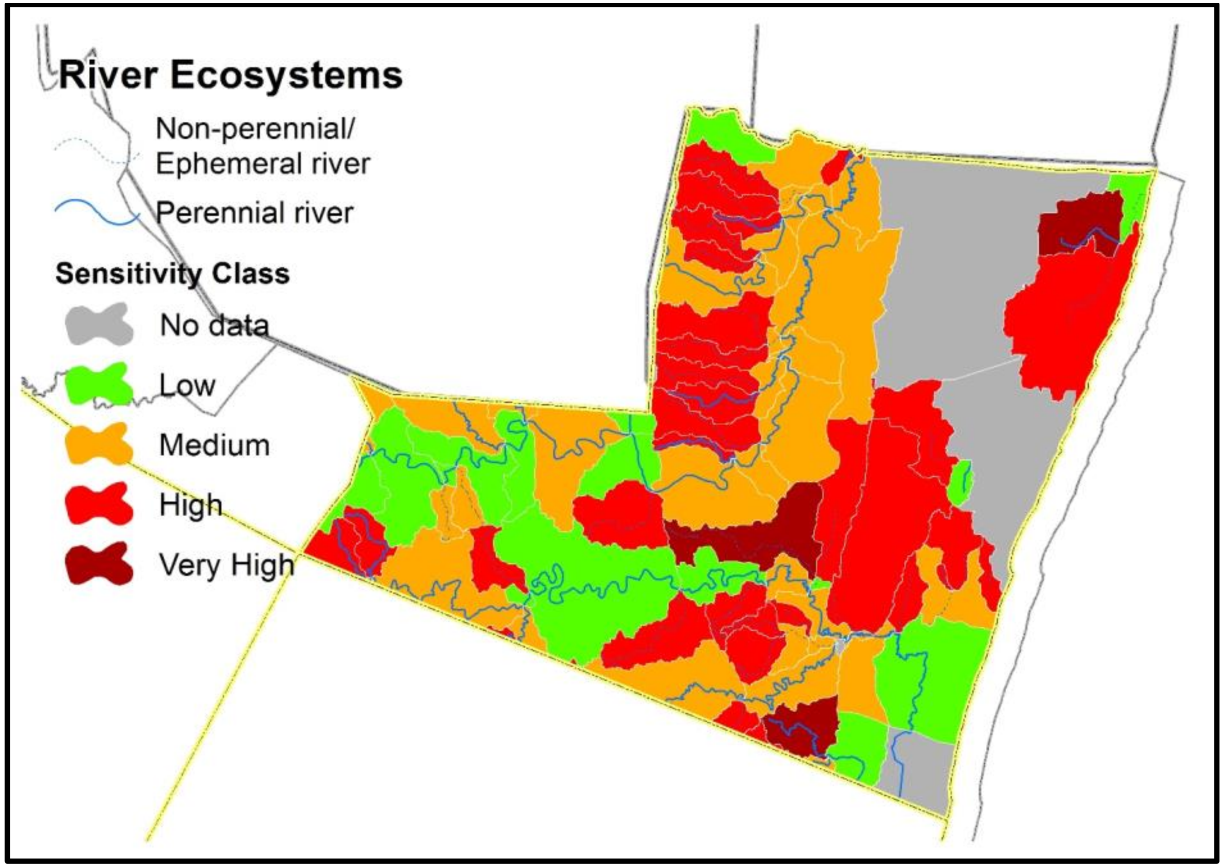

Figure 18: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 4 corridor using PES, EI and ES data from DWS (2014).

6.5.2 Wetlands

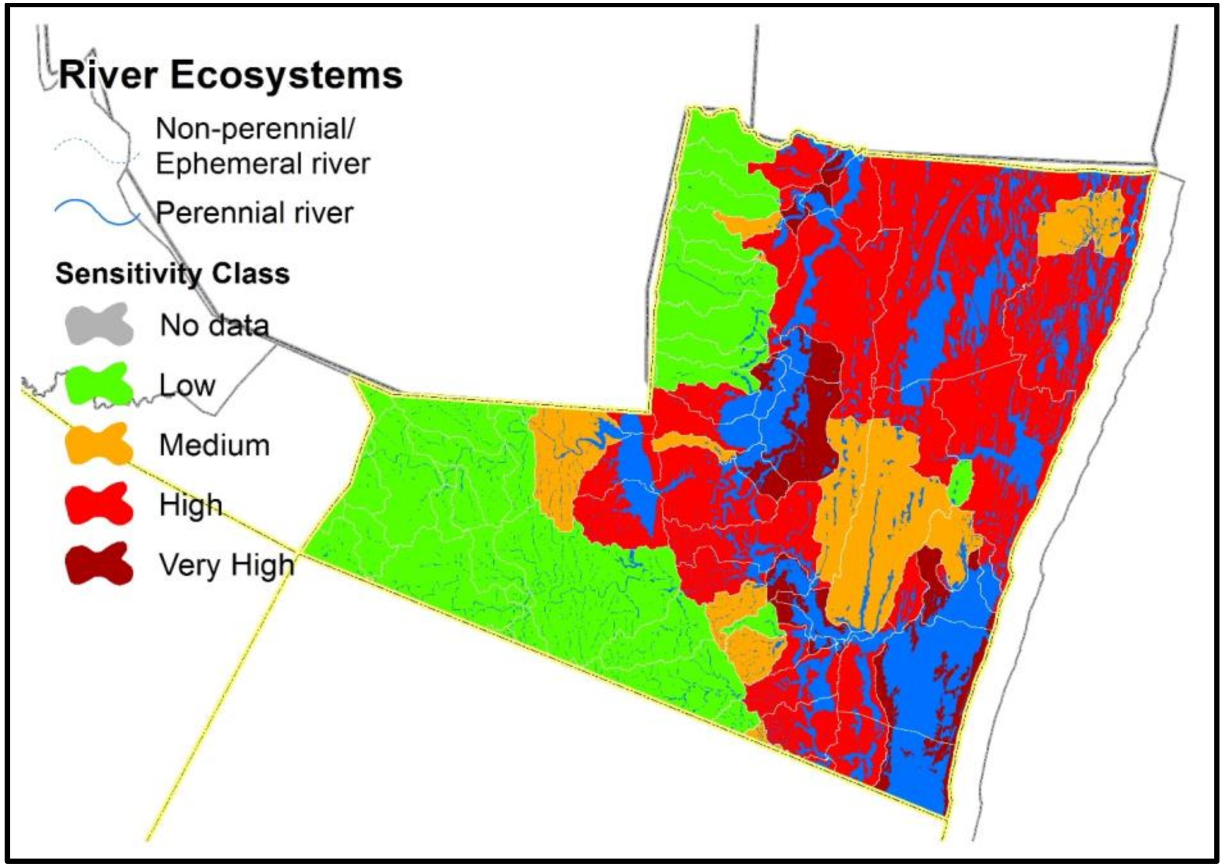

Figure 19: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 4 corridor.

6.5.3 Freshwater biota (fauna and flora)

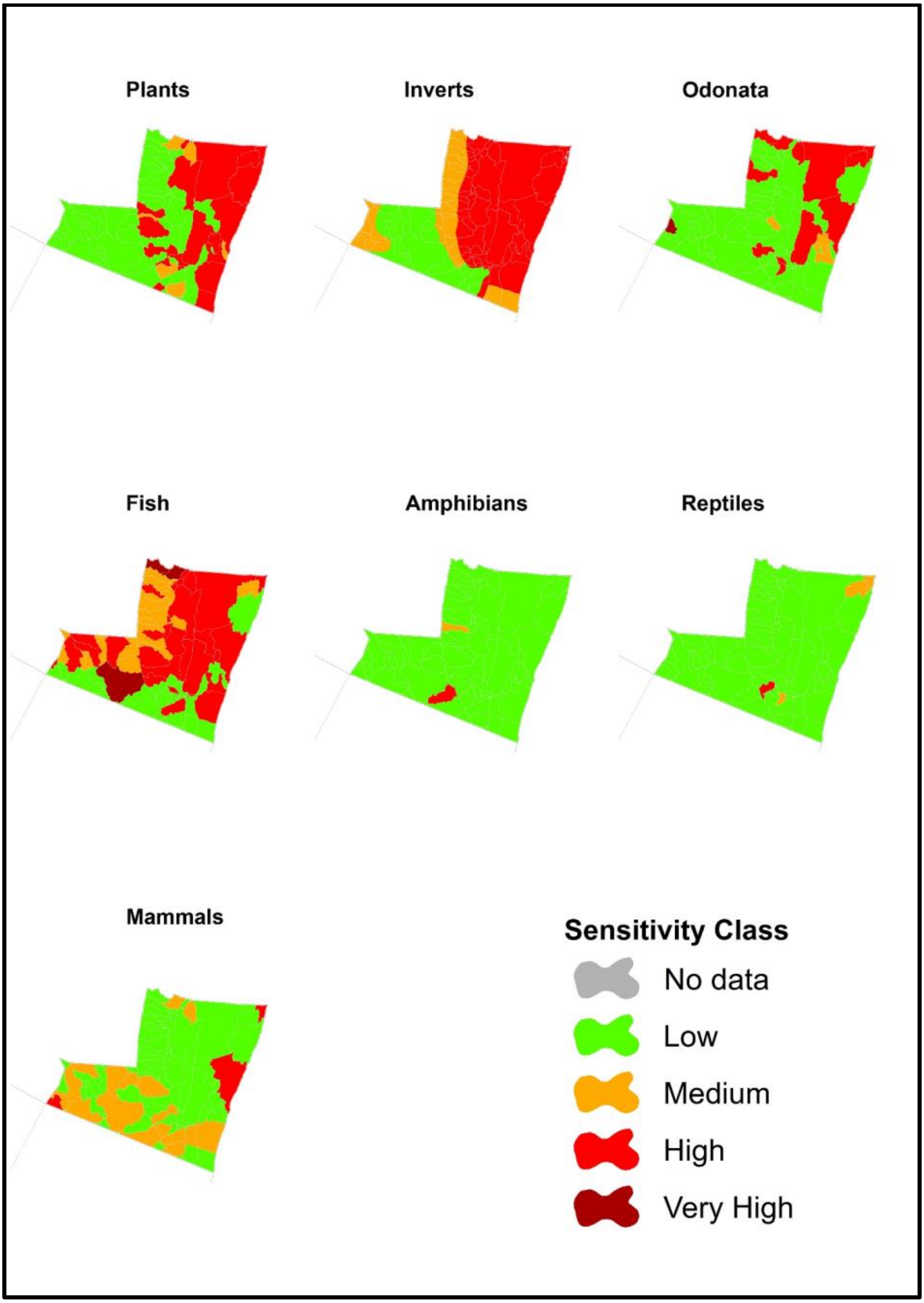

Figure 20: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 4 corridor in relation to sub-quaternary catchments

6.5.4 Freshwater ecosystems and biota (combined)

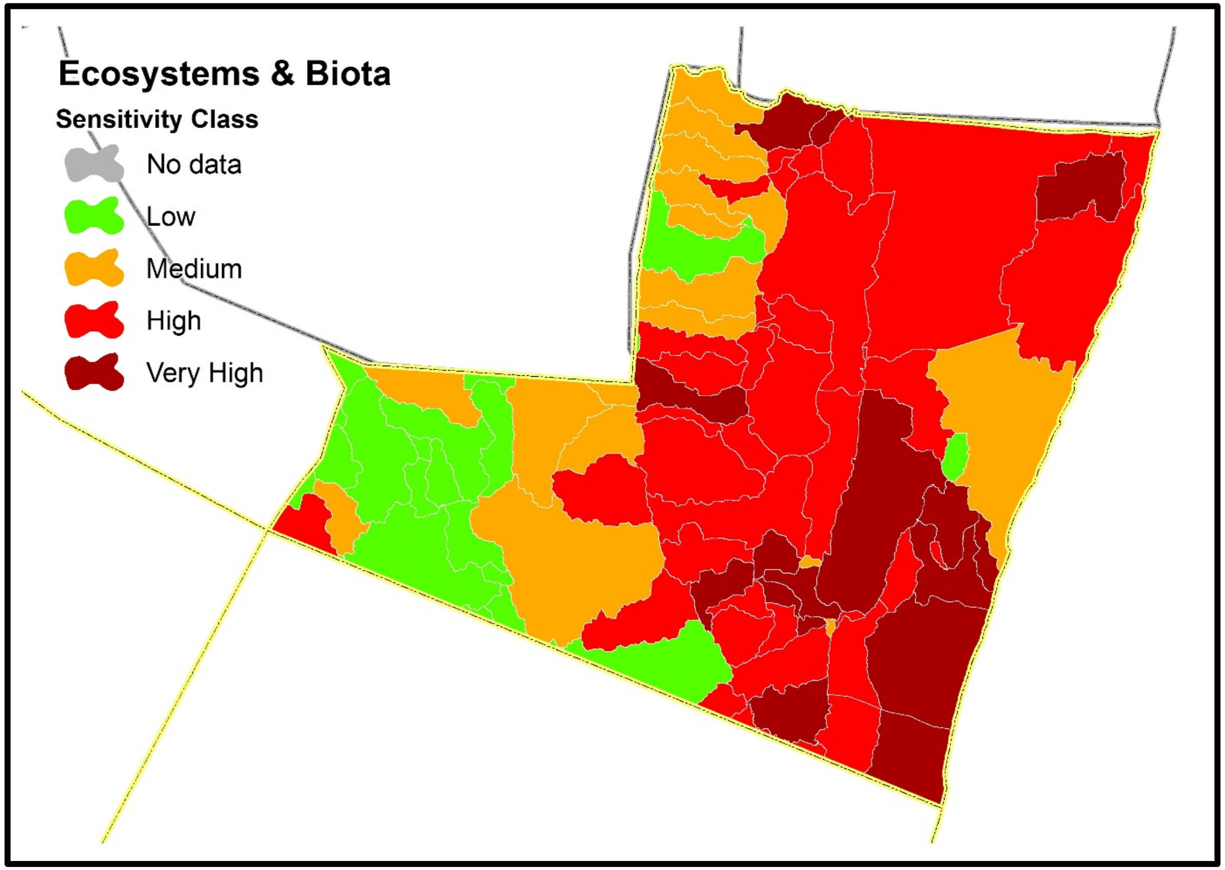

Figure 21: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 4 corridor.

6.6 Phase 5 Corridor

6.6.1 Rivers

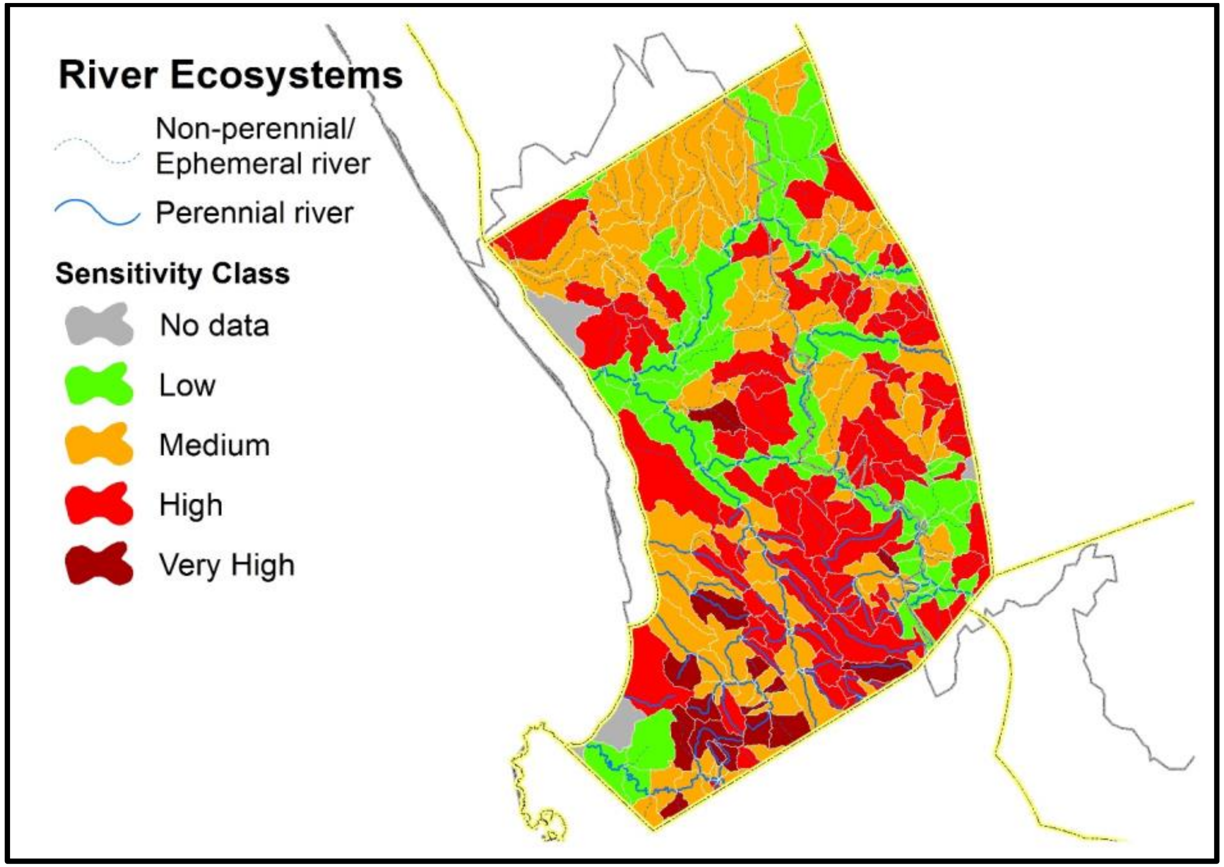

Figure 22: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 5 corridor using PES, EI and ES data from DWS (2014).

6.6.2 Wetlands

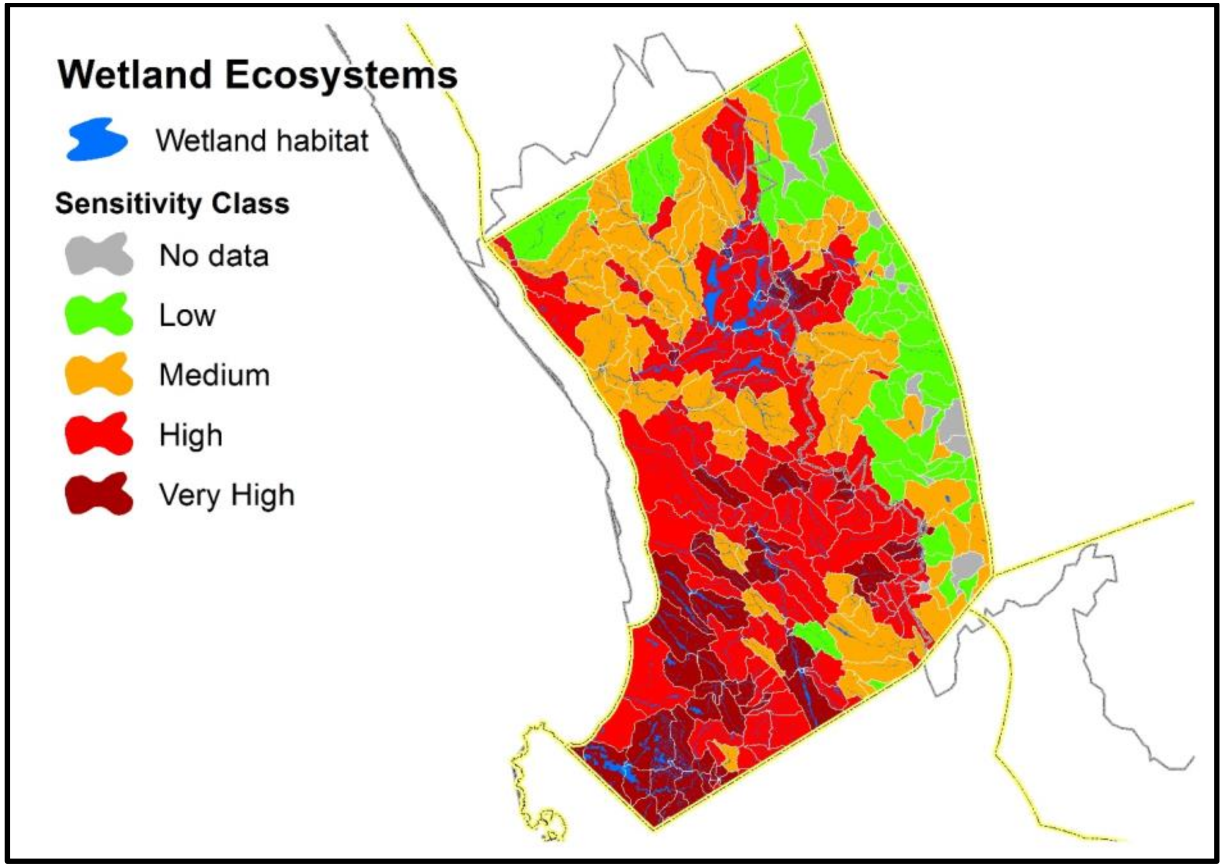

Figure 23: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 5 corridor.

6.6.3 Freshwater biota (fauna and flora)

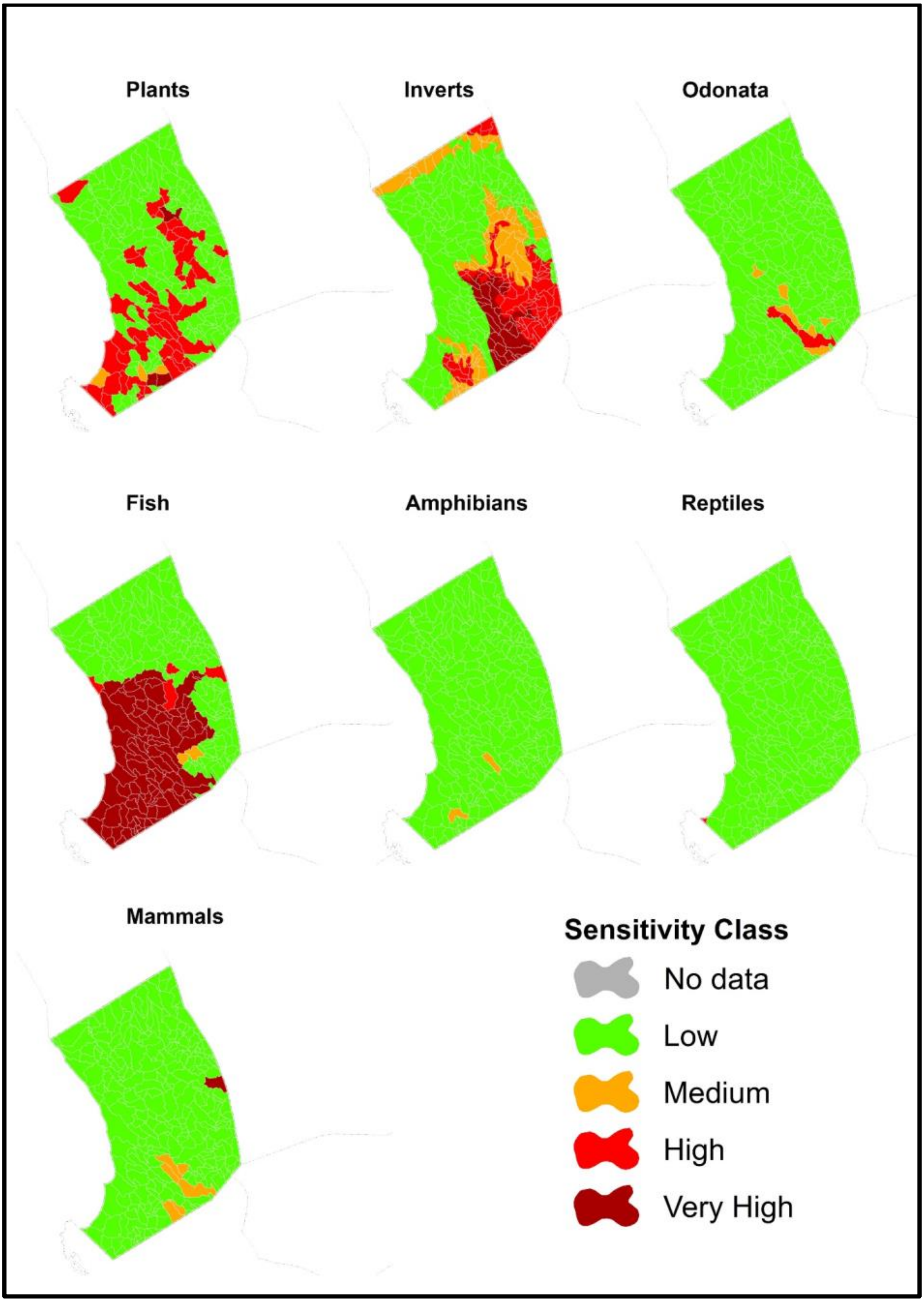

Figure 24: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 5 corridor in relation to sub-quaternary catchments

6.6.4 Freshwater ecosystems and biota (combined)

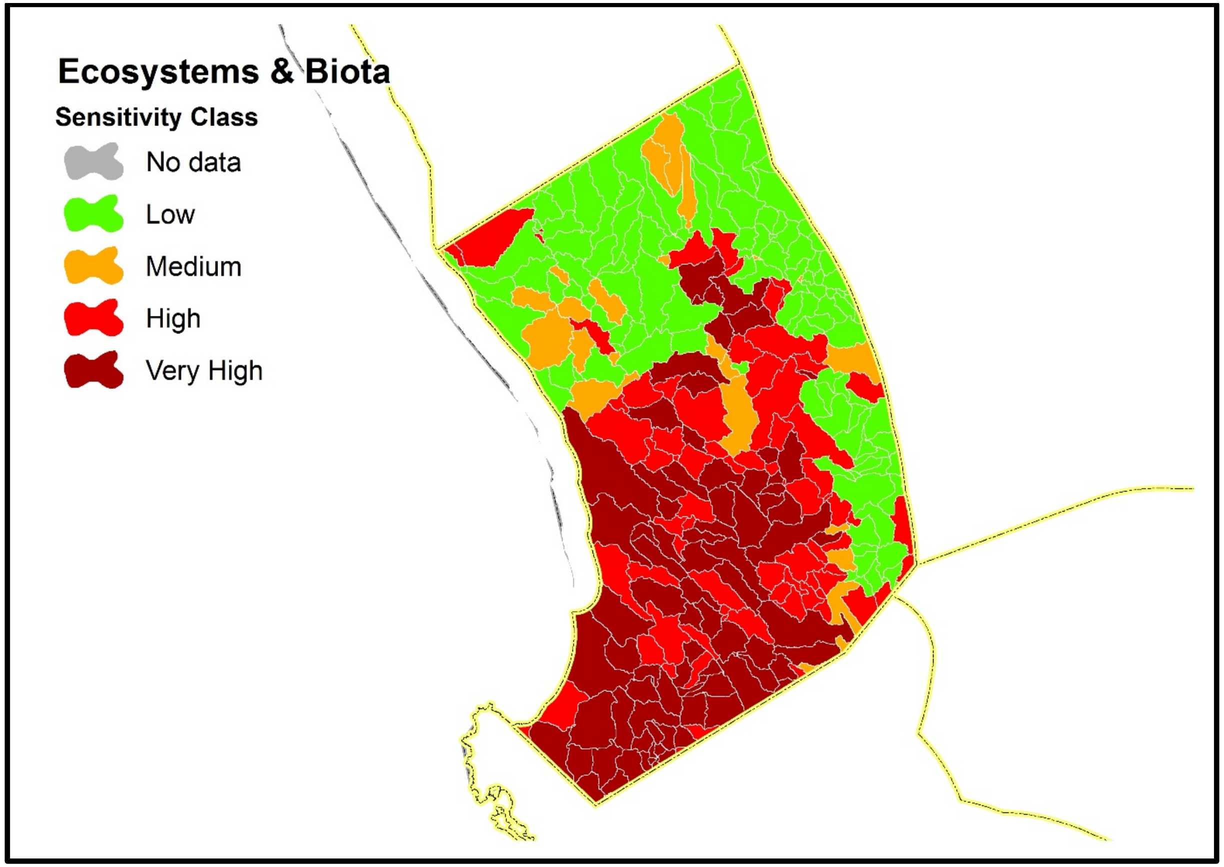

Figure 25: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 5 corridor.

6.7 Phase 6 Corridor

6.7.1 Rivers

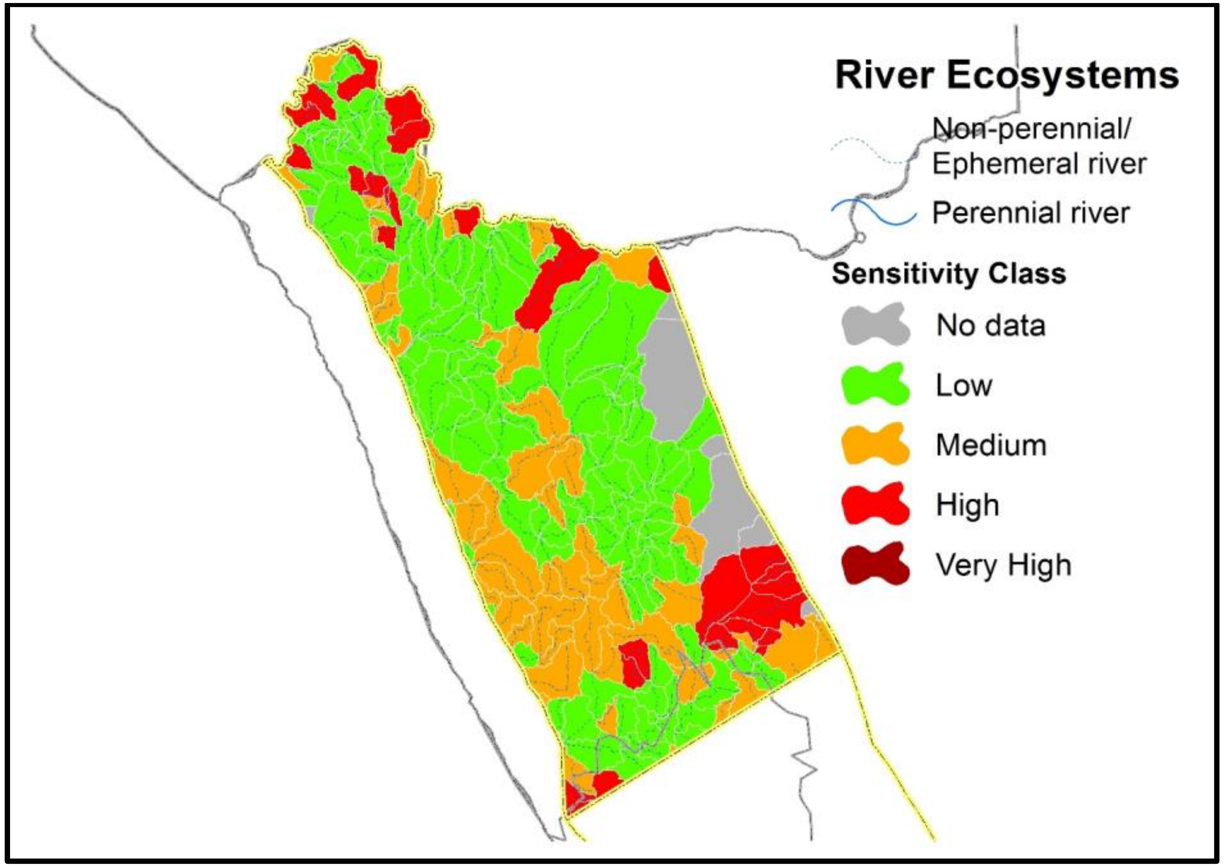

Figure 26: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 6 corridor using PES, EI and ES data from DWS (2014).

6.7.2 Wetlands

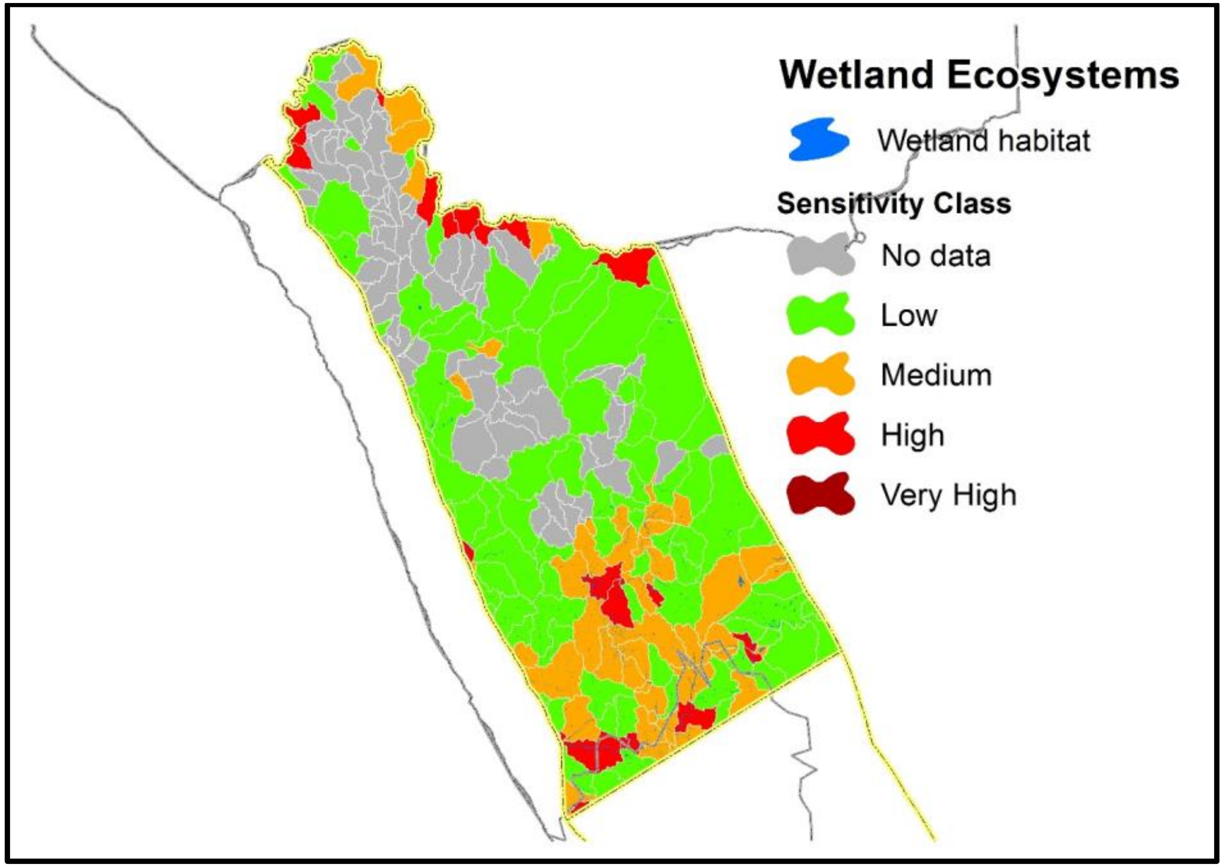

Figure 27: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 6 corridor.

6.7.3 Freshwater biota (fauna and flora)

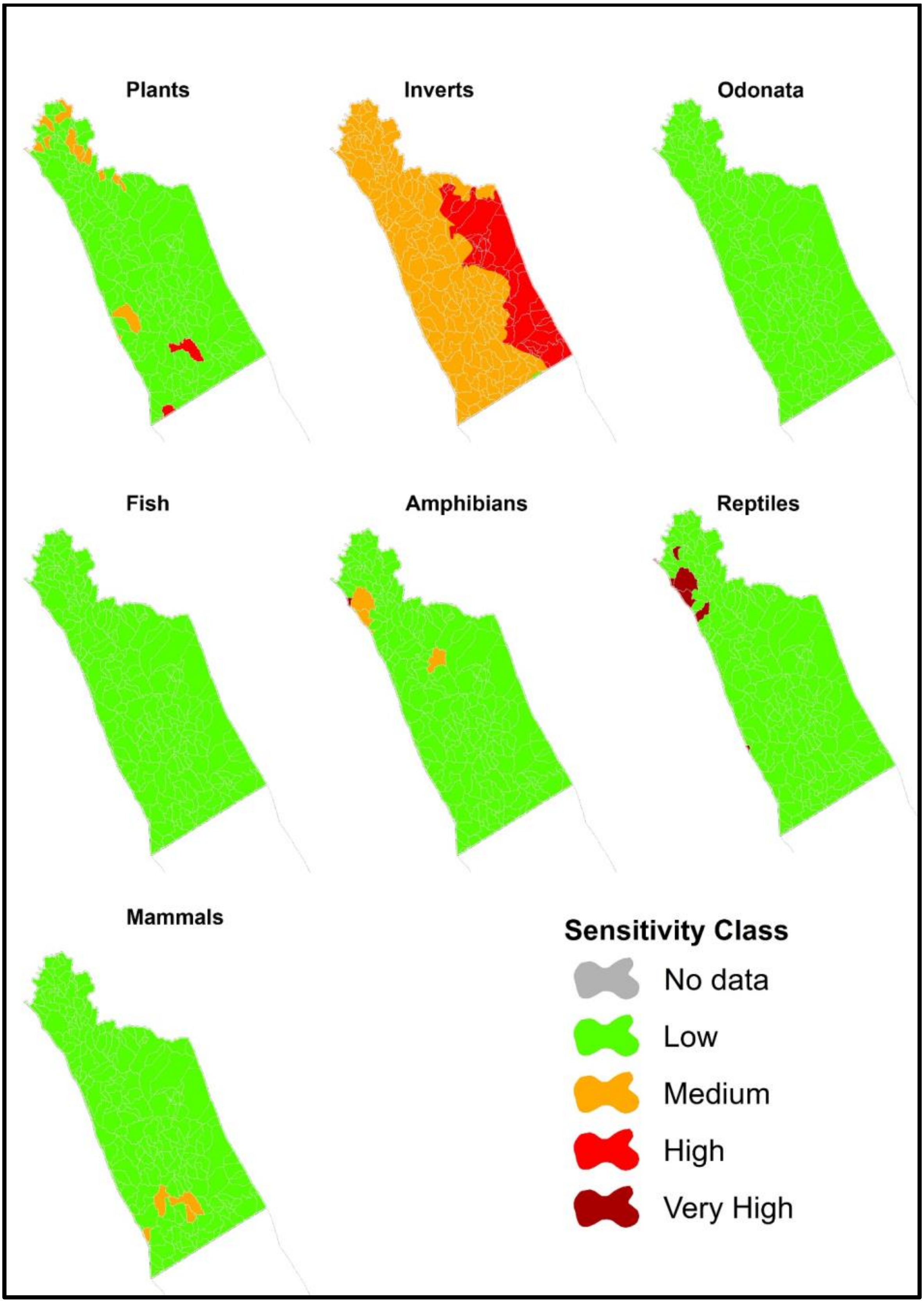

Figure 28: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 6 corridor in relation to sub-quaternary catchments

6.7.4 Freshwater ecosystems and biota (combined)

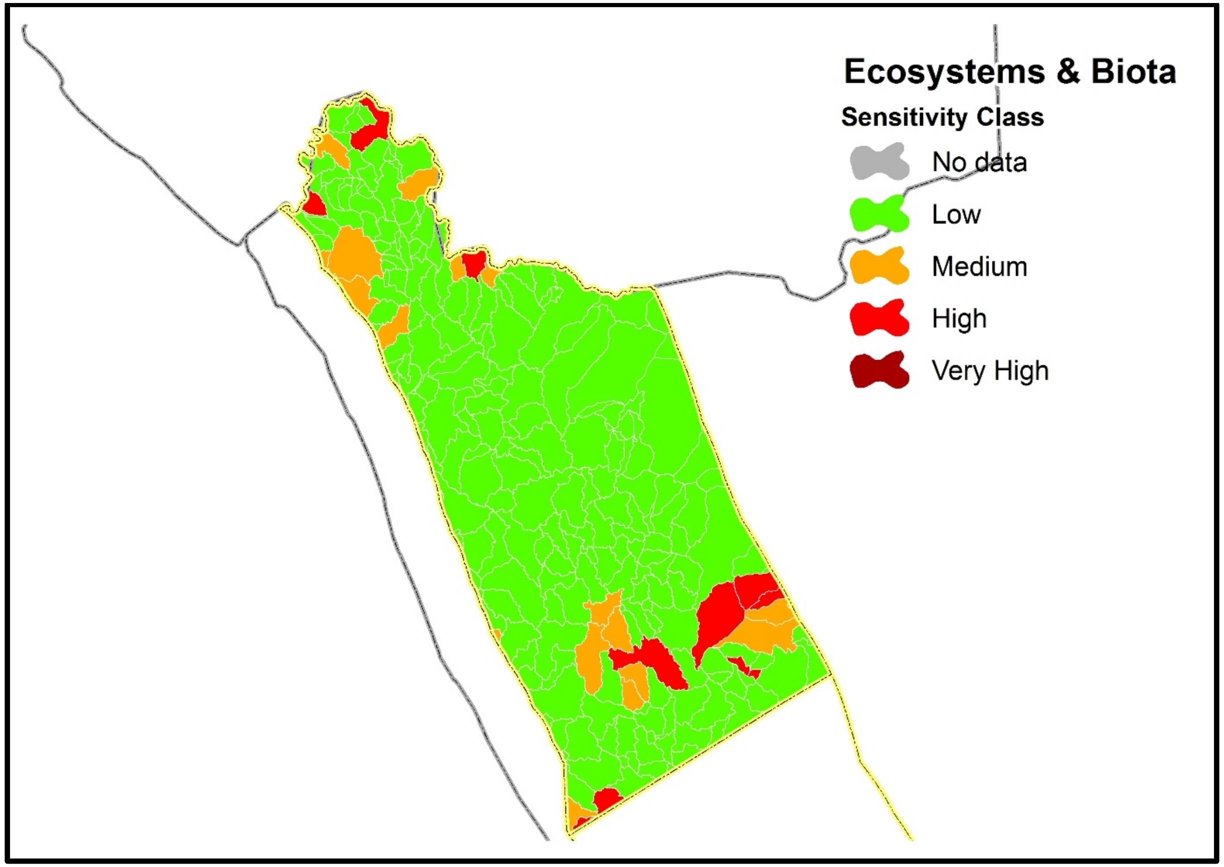

Figure 29: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 6 corridor.

6.8 Phase 7 Corridor

6.8.1 Rivers

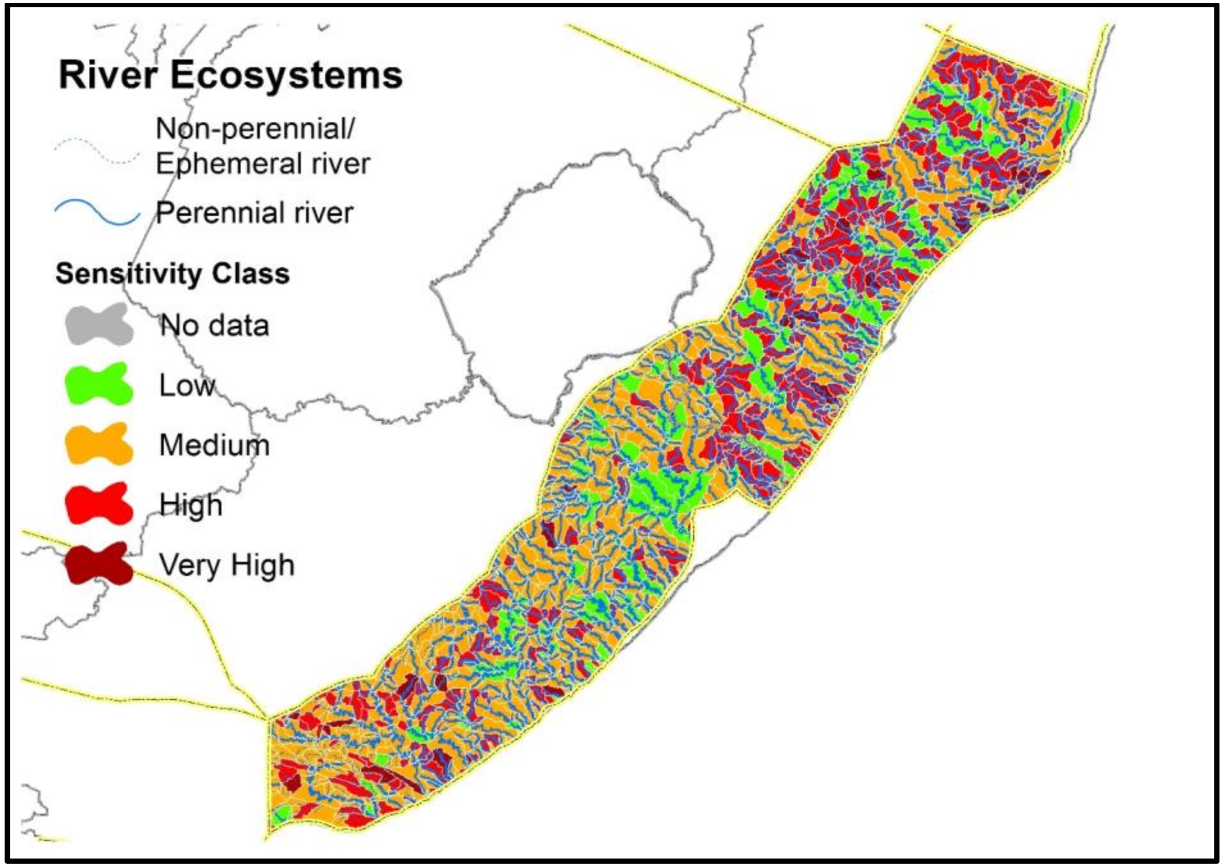

Figure 30: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 7 corridor using PES, EI and ES data from DWS (2014).

6.8.2 Wetlands

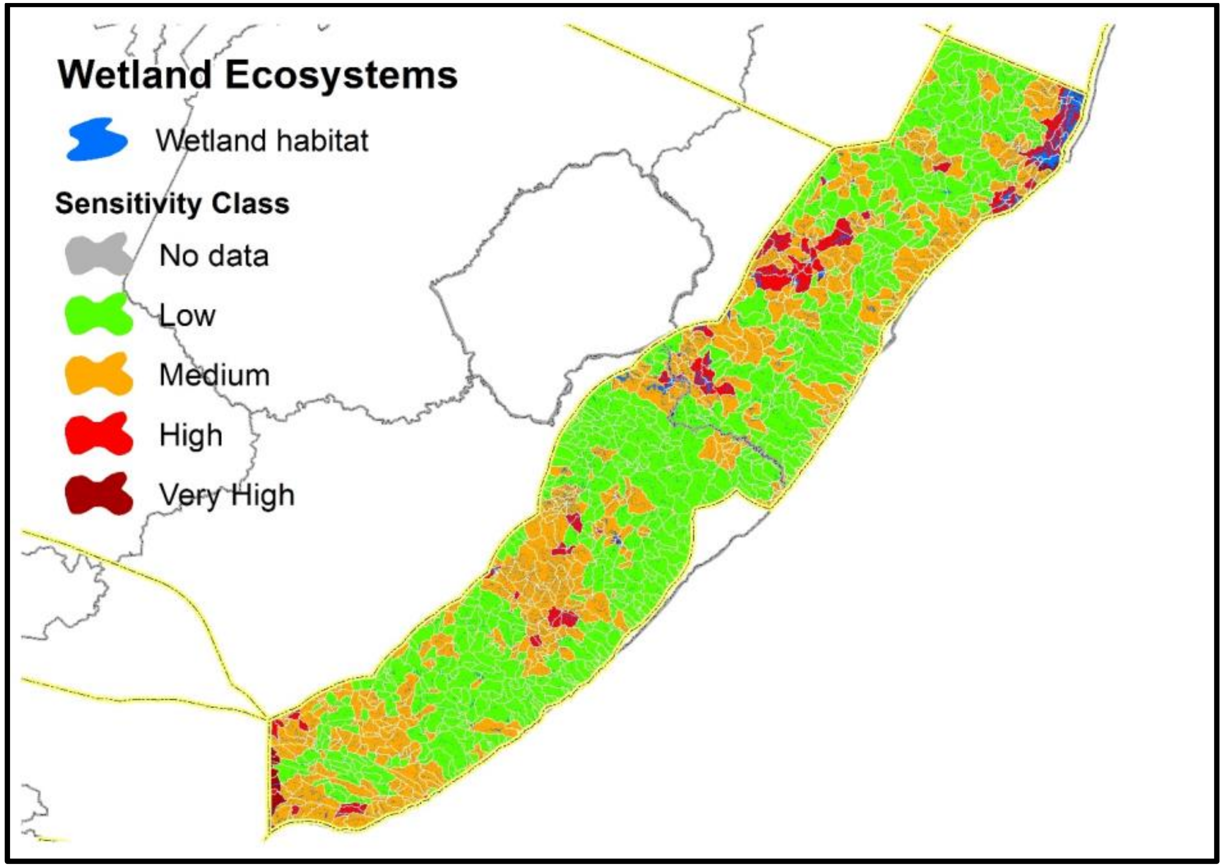

Figure 31: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 7 corridor.

6.8.3 Freshwater biota (fauna and flora)

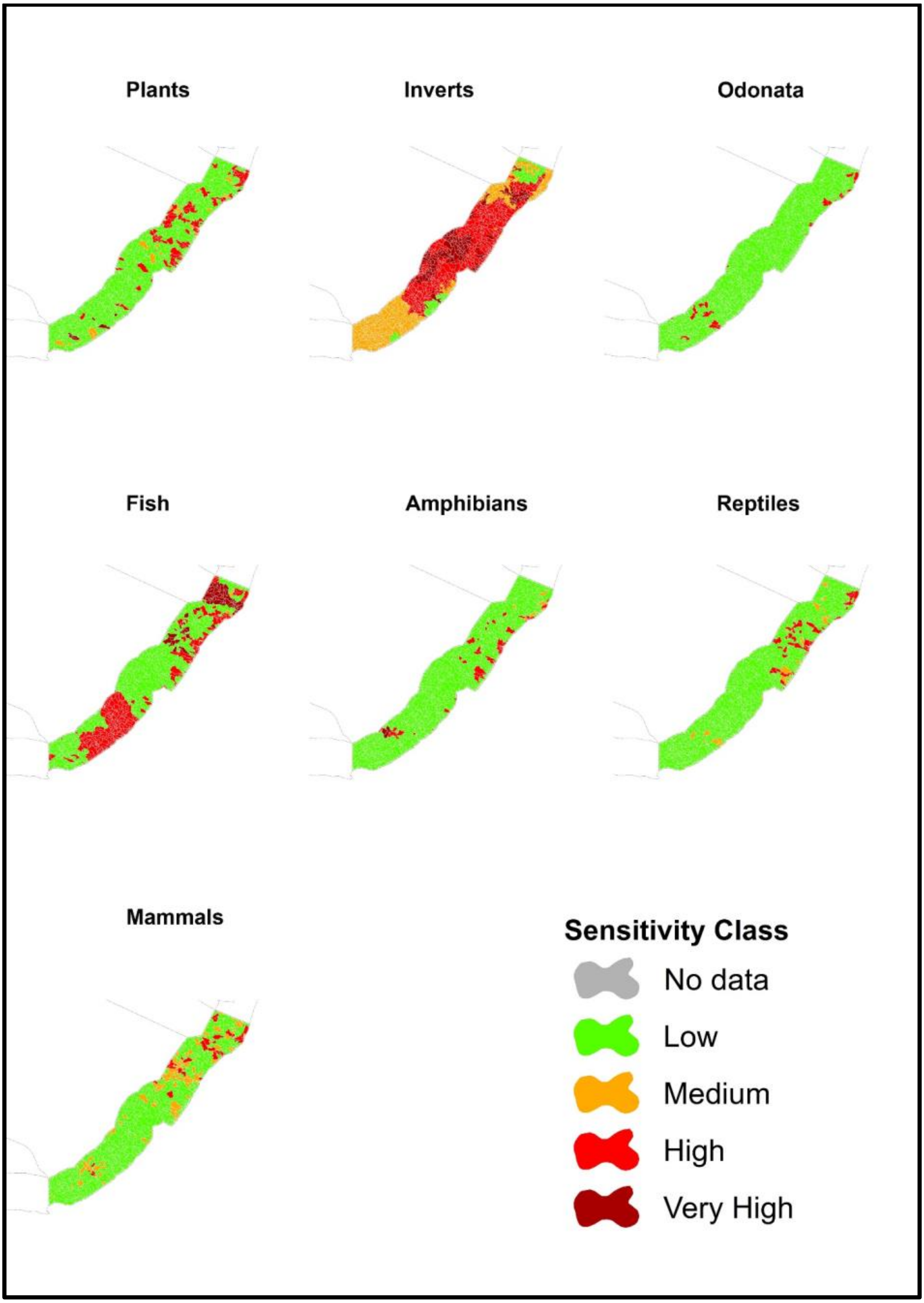

Figure 32: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 7 corridor in relation to sub-quaternary catchments

6.8.4 Freshwater ecosystems and biota (combined)

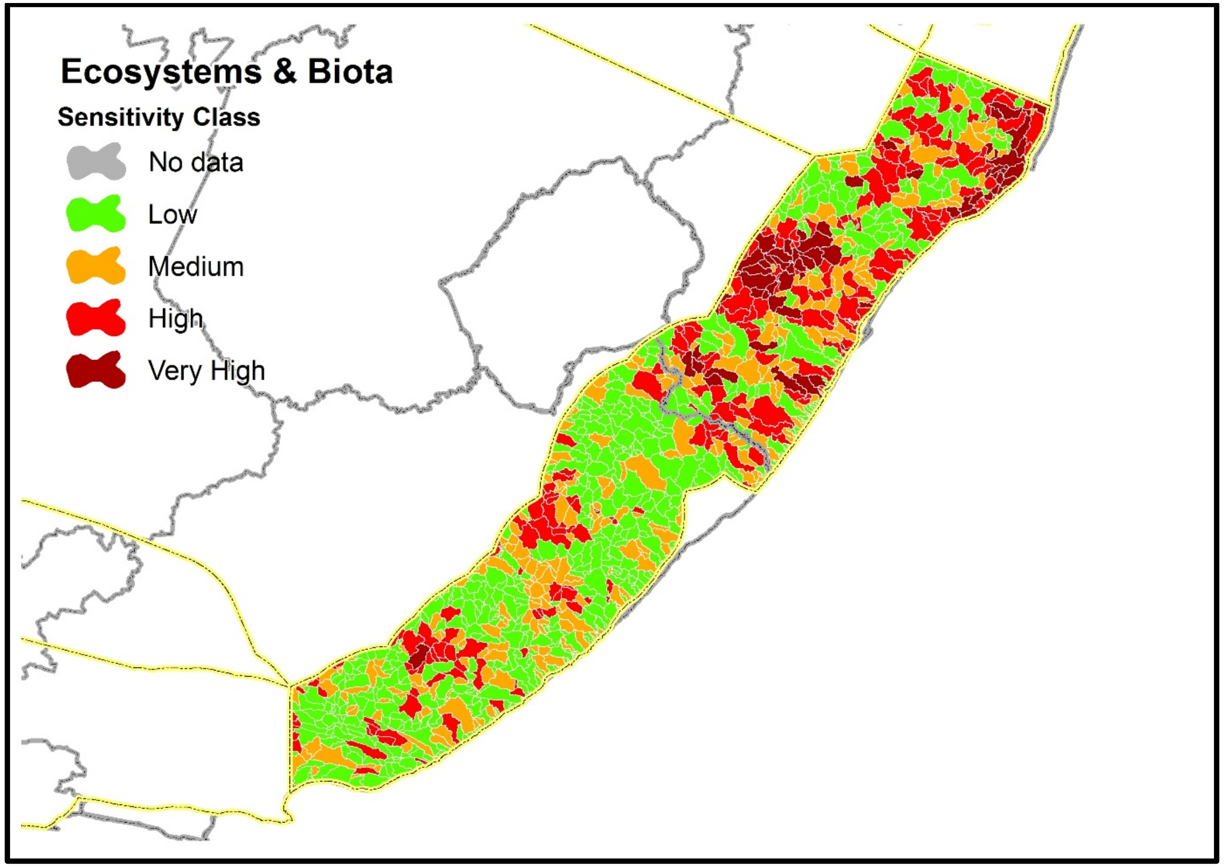

Figure 33: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 7 corridor.

6.9 Phase 8 Corridor

6.9.1 Rivers

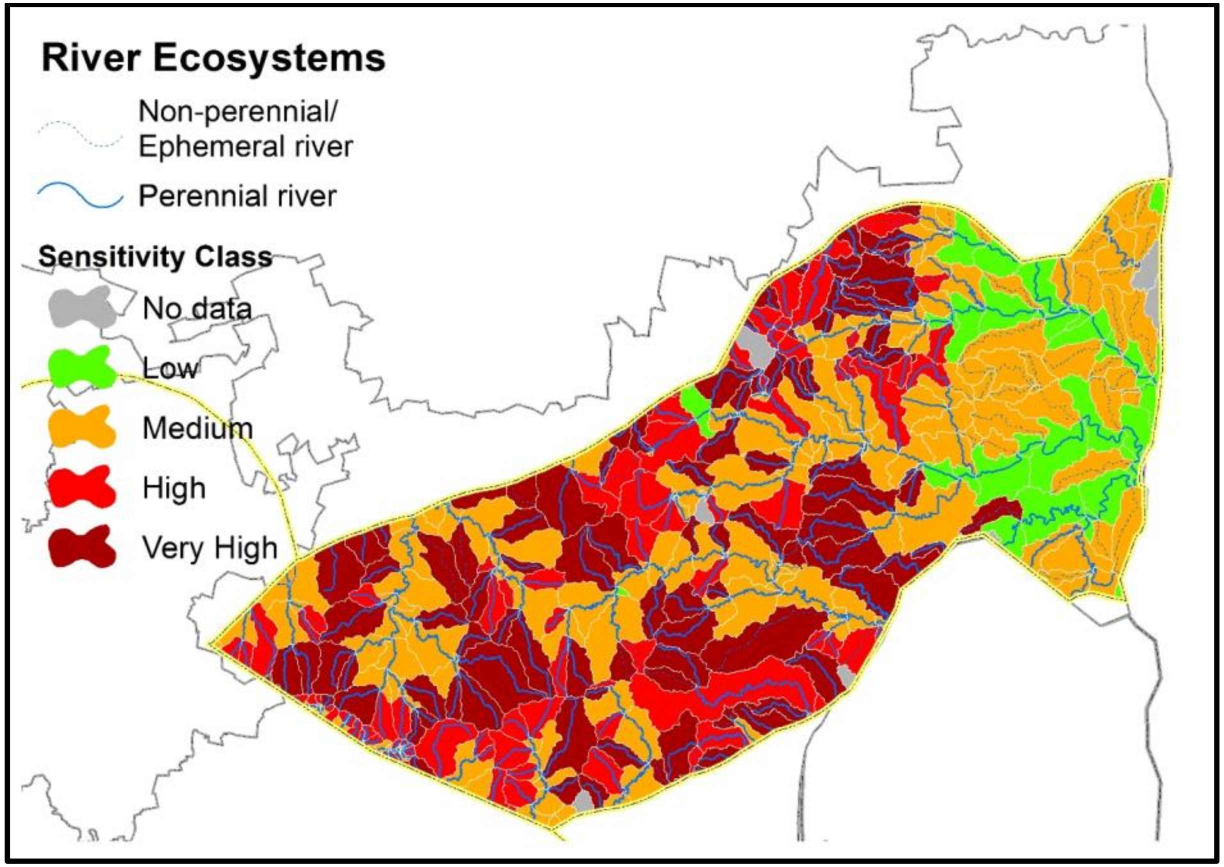

Figure 34: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline phase 8 corridor using PES, EI and ES data from DWS (2014).

6.9.2 Wetlands

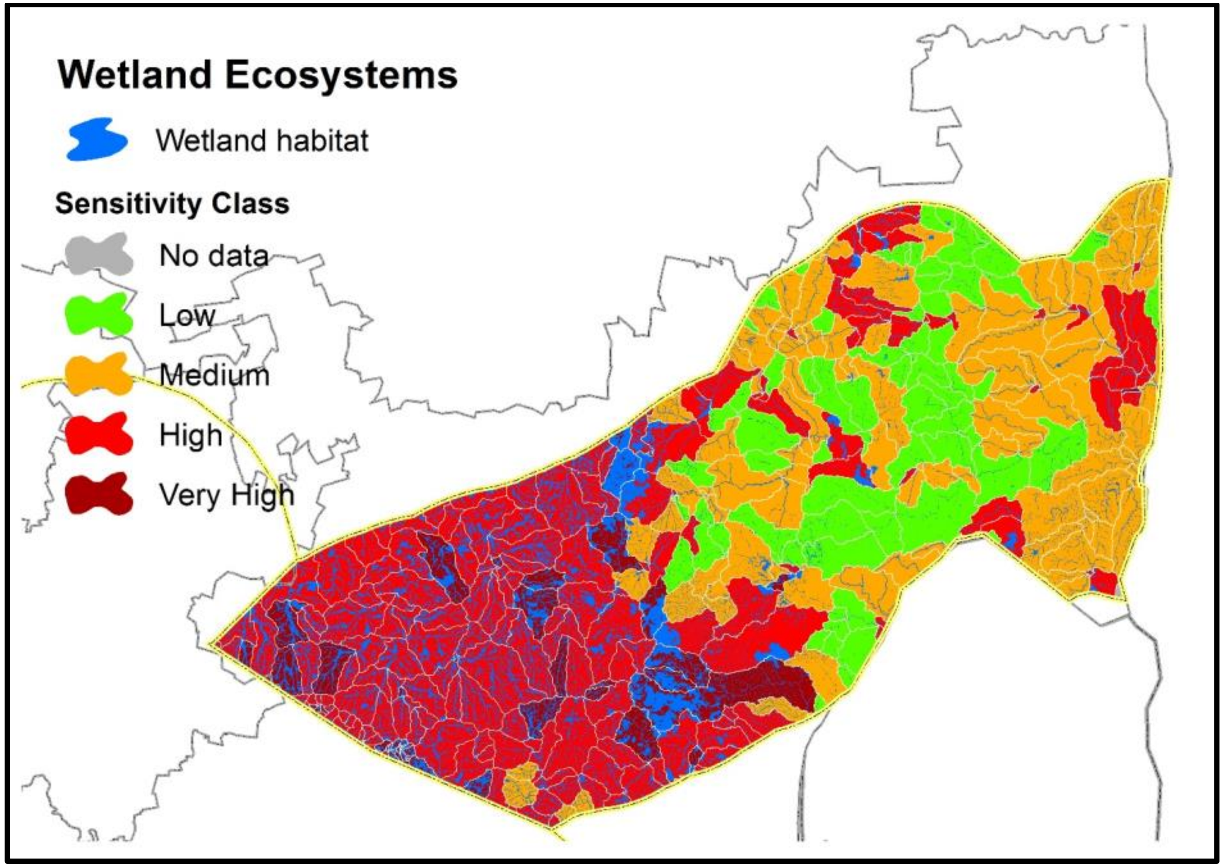

Figure 35: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline phase 8 corridor.

6.9.3 Freshwater biota (fauna and flora)

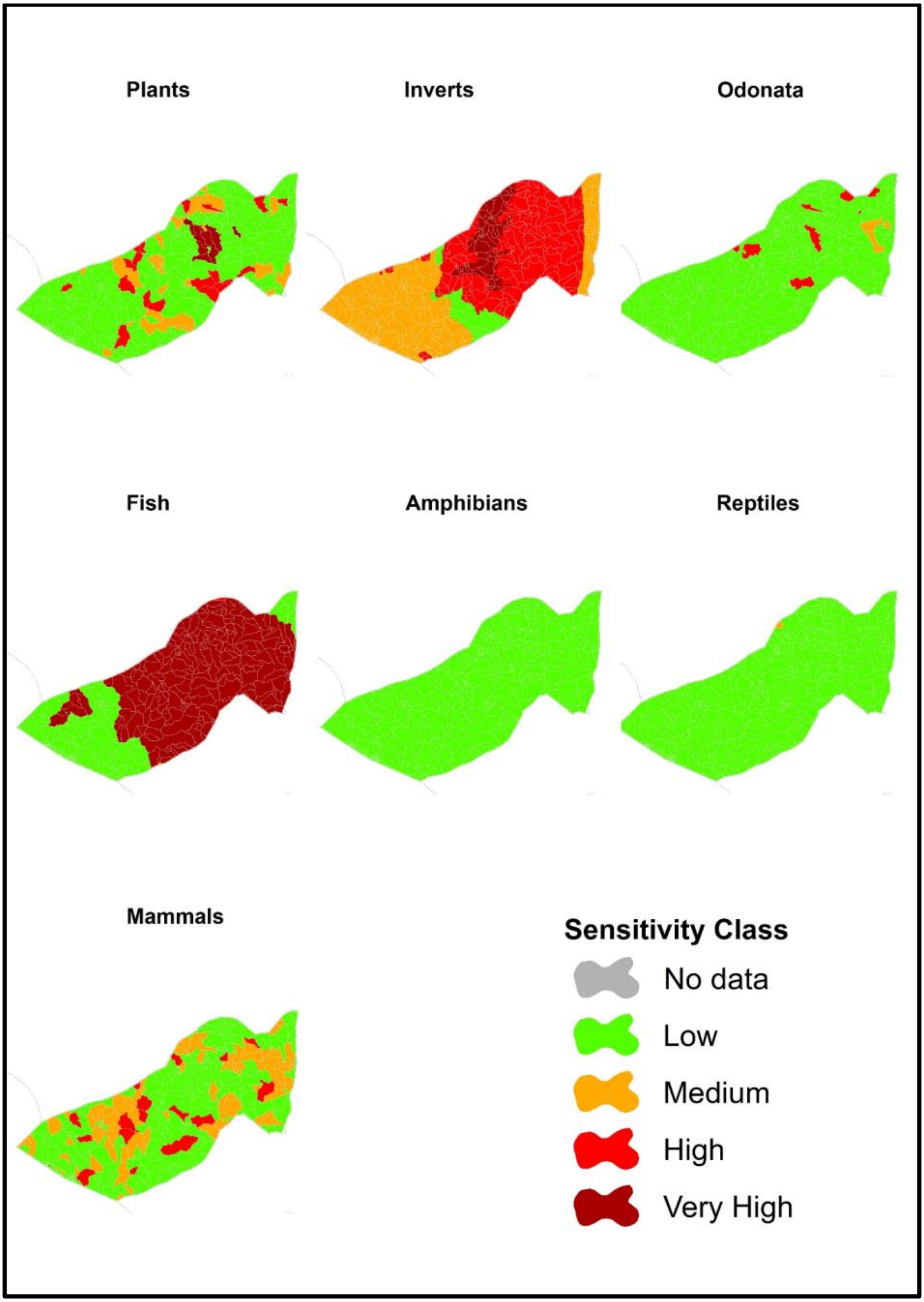

Figure 36: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline phase 8 corridor in relation to sub-quaternary catchments

6.9.4 Freshwater ecosystems and biota (combined)

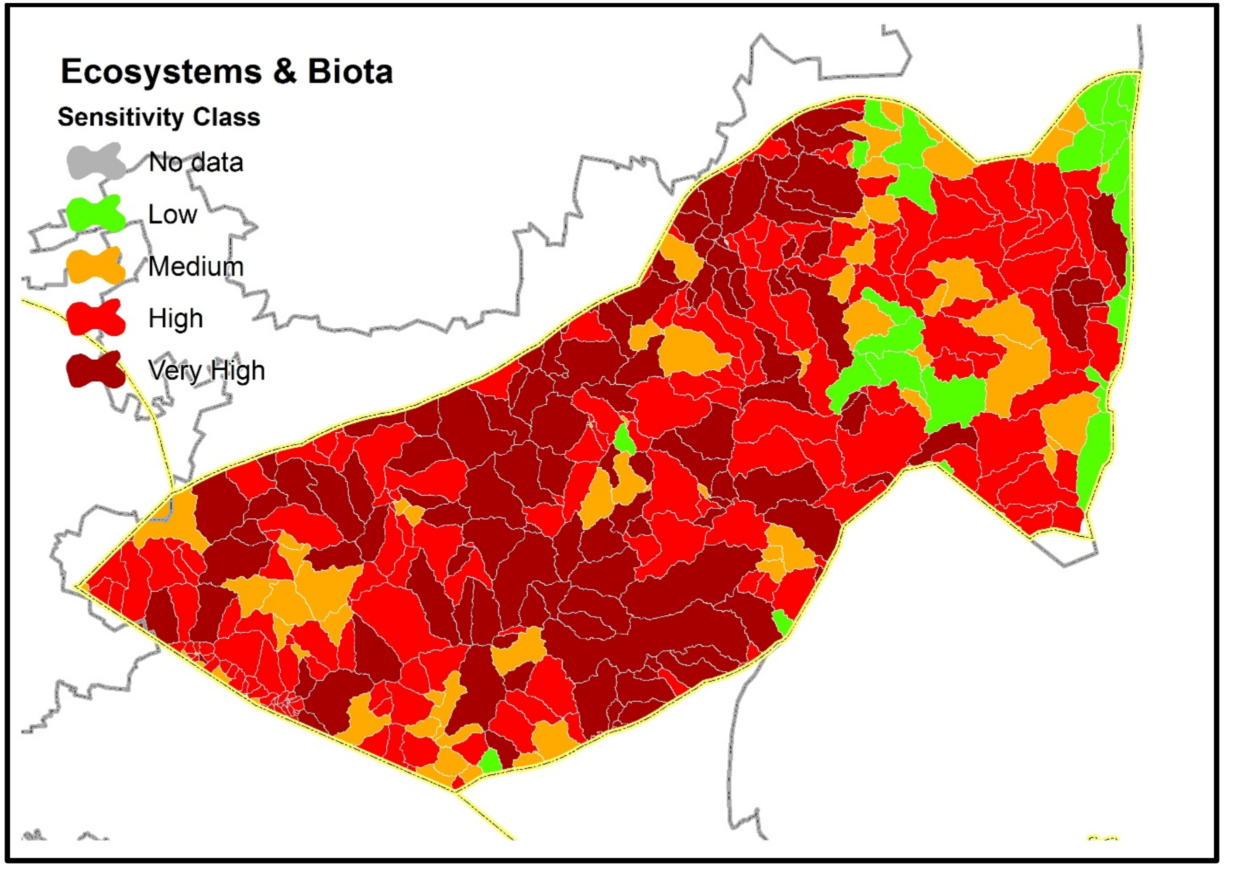

Figure 37: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline phase 8 corridor.

6.10 Inland Corridor

6.10.1 Rivers

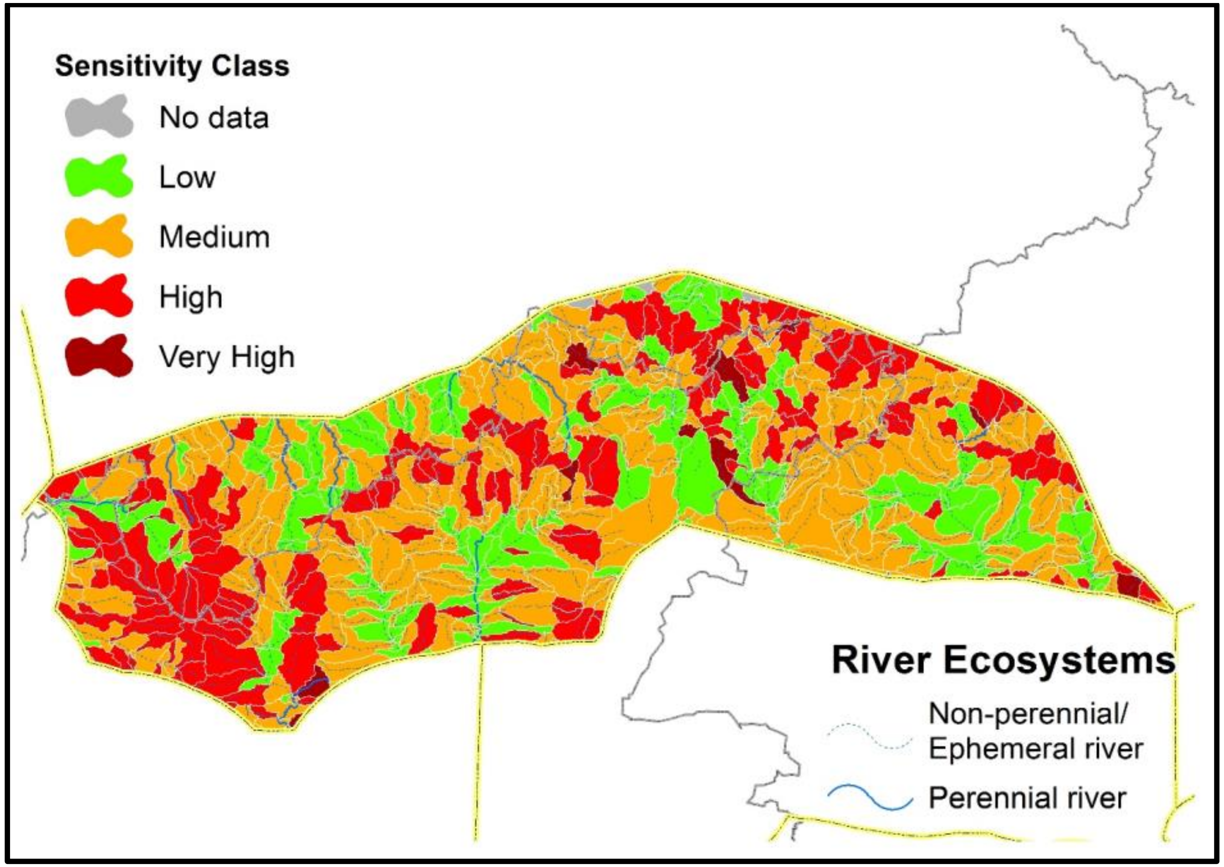

Figure 38: River threat status and sensitivity calculated for sub-quaternary catchments in the gas pipeline inland corridor using PES, EI and ES data from DWS (2014).

6.10.2 Wetlands

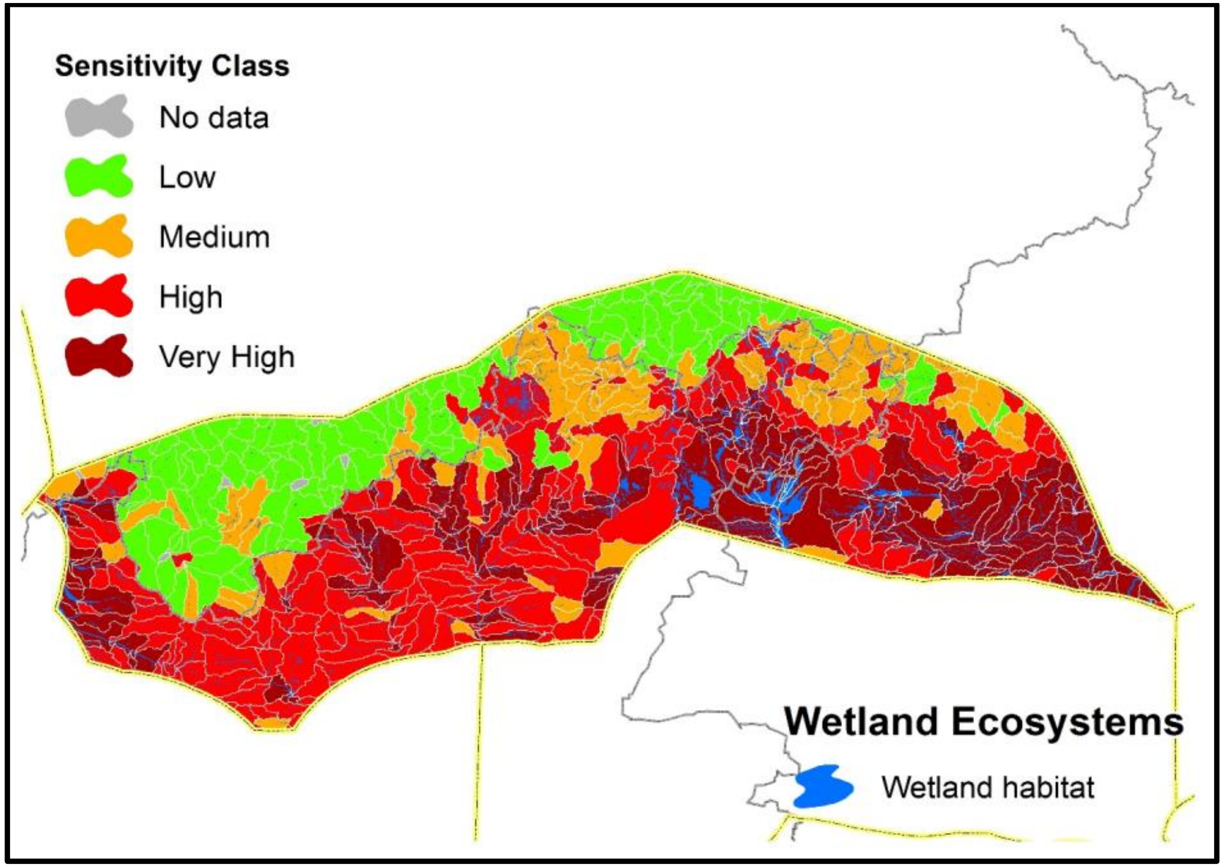

Figure 39: Wetland threat status and sensitivity calculated in relation to areas of sub-quaternary catchments in the gas pipeline inland corridor

6.10.3 Freshwater biota (fauna and flora)

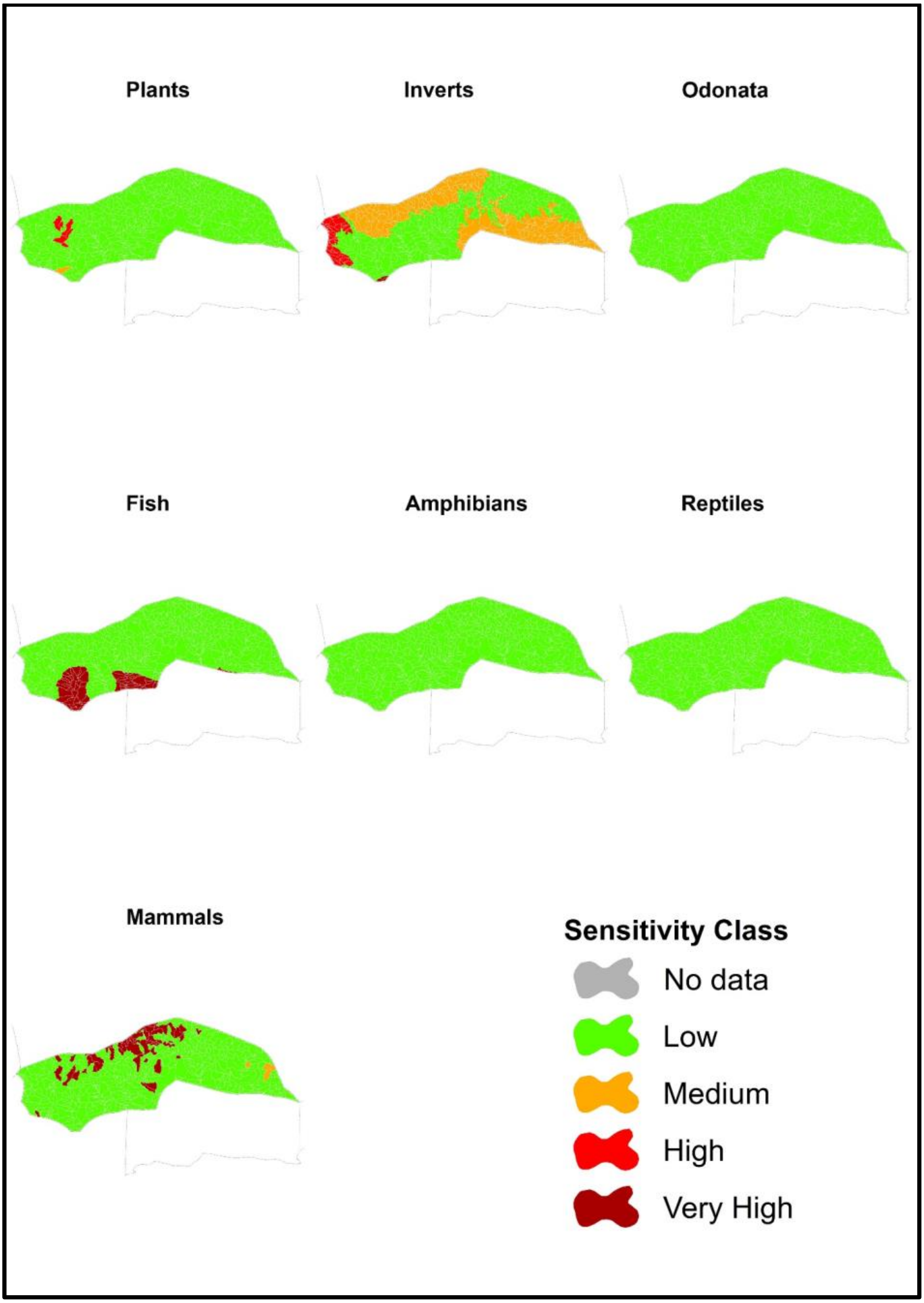

Figure 40: Threat and sensitivity status calculated for different freshwater taxonomic groups (flora and fauna) in the gas pipeline inland corridor in relation to sub-quaternary catchments

6.10.4 Freshwater ecosystems and biota (combined)

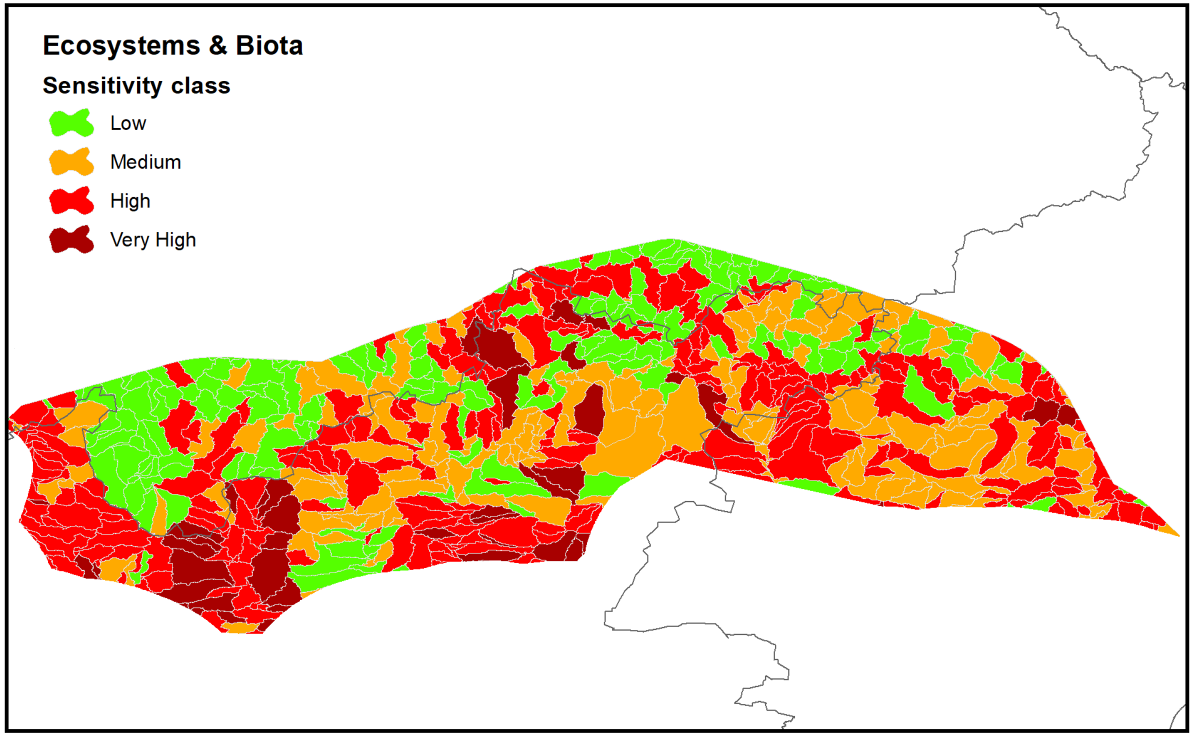

Figure 41: Integrated sensitivity and threat status map for freshwater ecosystems and biota in the gas pipeline inland corridor.

7 KEY POTENTIAL IMPACTS AND MITIGATION

The impacts associated with gas pipeline development range from those that are direct (e.g. excavation of trenches for pipelines and maintenance of vegetation within pipeline servitudes) to those that are more subtle (indirect) and which occur over longer timeframes (e.g. vegetation compositional changes from continued servitude maintenance, habitat fragmentation, and alien plant infestation). The majority of the impacts identified in this assessment are relevant to the scope of the present study, and have been contextualised here in relation to the following activities and their associated impacts to aquatic ecosystems and biota.

- **Developing access roads** – Development of new access roads to enable construction, as well as ongoing maintenance during the operational phase may result in the following impacts:
    - Direct loss of riparian and wetland vegetation (and associated buffers), including potentially sensitive/important freshwater ecosystems and/or habitat supporting species of conservation concern;
    - Fragmentation of freshwater ecosystems and flow patterns, resulting in an indirect loss of ecological patterns and processes such as species movement and dispersal, habitat connectivity, increased edge effects and disturbance, establishment of invasive alien vegetation, etc.;
    - Stormwater runoff resulting in increased flows within receiving aquatic environments, particularly in relation to runoff discharge points, which in turn has a number of indirect issues such as bank erosion and collapse, scouring and channel incision, headcut erosion, desiccation of 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 freshwater ecosystems to function properly;
    - Waste pollution and contamination of aquatic environments from foreign materials (e.g. fuels/hydrocarbons, cement, and building materials) being dumped and/or carried into aquatic environments;
    - Compaction of soils and creation of preferential flow paths with and adjacent to wetland and river habitats; and
    - Direct loss (i.e. fatality) of flora and fauna (including Threatened or other species of conservation concern) that inhabit wetland/river ecosystems and adjacent buffer/fringe habitats, including accidental road kills caused by increased traffic on both existing and new roads.
- **Vegetation clearing and grading** – The stripping/removal of vegetation and topsoil to prepare the right of way (ROW) for pipeline construction will result in similar impacts to the development of access roads (as above), but will differ in terms of extent, duration and intensity. Typical ROWs are between 30 to 50 metres wide, translating to roughly one hectare for every 200 to 300 metres of pipeline constructed. Thus, the total area of wetland and riparian vegetation that is removed will be based on the total length of pipeline that passes through these freshwater ecosystems and their associated buffer habitats.
- **Trenching and excavation** – Trenches to bury pipelines will also need to be excavated during the pipeline construction process. This will also include excavations for pigging stations, which will be positioned every 250 to 500 km (based on new technology). Trenching and excavations have the potential to cause direct mortality of fauna that inhabit freshwater and fringe habitats, in particular fossorial fauna (i.e. animals adapted to living underground), but also small fauna that are moving across the excavation path that then fall into trenches or excavation where they become trapped and eventually die.
- **Rehabilitation and maintenance** – Gas pipeline servitudes for accessing the pipeline and pigging stations will require ongoing vegetation management and clearing to maintain a strip of grass/herbaceous vegetation, with trees/shrubs removed in most cases.

In addition to the main activities and key impacts resulting from gas pipeline development and operation, other more specific impacts that may occur as a result include:

- **Habitat fragmentation** – one of the more concerning issues of linear developments such as gas pipelines, and the associated servitudes for ongoing maintenance, is the fragmentation of freshwater habitat and associated buffers, especially where areas are permanently impacted (e.g. through roads and pigging stations). This presents a potential serious issue particularly to freshwater fauna, and leads to populations becoming more isolated, resulting in a reduction of inter-population connectivity and compromised genetic viability. For example, inappropriately designed and constructed river crossings could prevent fish from moving/migrating freely within a river system. Habitat fragmentation also has the potential to exacerbate impacts to freshwater ecosystems, such as through altering micro-climatic conditions (e.g. fire, wind, desiccation, etc.). These alterations in turn affect the perimeter of wetland and riparian habitats resulting in edge effects and development of transitional habitats. This presents a favourable situation for invasive alien plants (IAPs) to establish, with knock-on effects for freshwater ecosystem and associated fauna and flora (as discussed in the following point).
- **Habitat alteration and knock-on effects caused by IAPs** – IAPs that already occur in an area are likely to invade newly disturbed areas, by gradual (or even rapid) encroachment into disturbed areas (e.g. ROWs, temporary construction camps, borrow pits, vehicle parking, pipeline stockpiles, etc.), transitional habitats, as well as areas 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. Secondary impacts (caused by IAPs) include, but are not limited to:
    - Competition with native plant species, especially when considering the severity of allelopathic influences caused by certain IAP (e.g. *Acacia mearnsii*);
    - Shading of banks and instream habitats, which in turn impacts on water temperatures and freshwater fauna and flora that are intolerant;
    - Shift in allochthonous and autochthonous organic compounds within wetland and river ecosystems;
    - Bank instability, erosion and collapse, with exacerbated deposition of sediments and debris; and
    - In more severe cases, reduced water availability due to excessive water consumption from most IAPs (in particular, deep-rooted tree species such as *Eucalyptus* spp.).
- **Mortality of fauna** – Earthworks and excavations would mainly affect fossorial fauna (i.e. animal adapted to living underground), as well as small, less-mobile fauna (e.g. amphibians, as well as freshwater obligate reptiles and shrews/rodents). Mortality of fauna from accidental collisions due to the movement of vehicles/machinery across the site would also be an issue for smaller, less mobile species of fauna. In addition there is the risk of fauna falling into and getting trapped within trenches and excavations, which may lead to further mortality cases. Lastly, illegal hunting/poaching could also present a significant impact during the construction phase whereby certain personnel/contractors engage in such activities.
- **Disturbance of fauna** – Certain fauna are more susceptible to impacts from increased noise, vibrations, dust and/or artificial lighting. Artificial lighting in and around construction camps and pipeline stockpiles may for example have a significant impact on normal life cycles of adult forms of aquatic macro-invertebrates, as well as increased mortality rate. Noise impacts will affect noise-sensitive mammals, particularly larger mammals such as Otter species and Servals. Noise and light impacts ultimately result in the displacement of fauna away from the noise impact area, but is expected to be temporary, and restricted to the construction phase.
- **Water quality impacts** – One of the main impacts that result from construction activities within and/or adjacent to rivers and wetlands is the increase in suspended solids and deposition of sediments causing habitat destruction due to sediment ‘smothering’, which in turn affects composition, feeding, reproduction, and wellbeing of aquatic biota. Other impacts that may also occur include accidental spills and vehicle leakages (e.g. fuels, oils, cement, etc.) that result in contamination of aquatic environments.

Overall, in this study impacts are characterised at the broadest scale in relation to the corridors as a means to identify preferred routings that will have the least possible impact on freshwater ecosystems and/or associated biota. Nevertheless, an inadequately positioned pipeline alignment through a particular corridor could potentially impact areas with severe consequences for freshwater biodiversity. Taking this into consideration, it is thus important to acknowledge impacts at a finer scale (i.e. sub-quaternary catchment) in order to identify preferred alignments/positions of gas pipelines within the proposed corridors. Lastly, data within the catchments at a site specific/habitat scale have been interrogated to guide the finer alignment of infrastructure, as well as inform the specialist assessments required and the mitigation measures.

Table 8 provides detail in terms of key impacts and possible effects on freshwater ecosystems and associated fauna and flora that are linked to gas pipeline phases and development activities. Mitigation measures are included to ensure that impacts are avoided where necessary and/or minimised in terms of mitigation hierarchy.

Table 8: Key potential impacts to freshwater ecosystems and associated fauna and flora by gas pipeline development, and their mitigation.

Project Phase	Activity	Key Impact	Possible Effect	Mitigation
Design phase	Placement of gas pipelines and pigging stations within ROWs, as well as construction camps, pipeline stockpiles, and access roads within or close to wetlands or rivers (including associated buffer habitat)	Loss of freshwater habitat through clearing/ infilling of wetlands and rivers and associated buffer habitat, potentially including threatened/ sensitive ecosystems.	Removal of wetland and riparian vegetation, instream habitat, as well as adjacent terrestrial buffer habitat, which could result in a loss of ecological functions and processes, freshwater biota (i.e. fauna and flora), and valuable ecosystem services.	Gas pipeline routing to avoid catchments with a very high sensitivity as far as possible, and try to avoid catchments with a medium to high sensitivity. However, where this is unavoidable, placement of pipeline infrastructure within these catchments (as well as catchments with a low sensitivity) should avoid freshwater ecosystems and associated buffers, which should be determined during route screening, validation and walk-throughs.
		Fragmentation of aquatic 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)	As far as possible, existing road networks should be used. Where this is not possible, avoid and/or minimise road crossings through wetlands and rivers as far as possible. Where this is not possible, ensure that crossings are designed 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, 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.
		Hydrological alteration largely through interrupted surface and/or subsurface water flows, as well as the concentration of water flows due to roads traversing wetlands or rivers.	Flow changes result in degradation of the ecological functioning of aquatic ecosystems that rely on a specific hydrological regime to maintain their integrity. This also leads to geomorphologic impacts within systems.	As far as possible, existing road networks should be used. Where this is not possible, avoid and/or minimise road crossings through wetlands and rivers as far as possible. Minimise the number of watercourse crossings for access roads. Ensure adequate watercourse crossings (i.e. culverts of the correct specification) are designed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible.
		Erosion caused by loss of	Alterations in moisture	Avoid clearing of sensitive indigenous vegetation as far as possible.

Project Phase	Activity	Key Impact	Possible Effect	Mitigation
		vegetation cover through site clearing and consequent sedimentation of aquatic ecosystems. Erosion is particularly a high risk in steep systems, and in drainage lines that lack channel features and are naturally adapted to lower energy runoff with dispersed surface flows (such as unchannelled valley-bottom wetlands).	availability and soil structure can promote the invasion of weedy and/or alien species at the expense of more natural vegetation and thus a loss of habitat integrity and/or biodiversity. Loss of vegetation altogether can lead to erosion and increased sedimentation and therefore loss or degradation of riverine/wetland habitats	Bank stabilisation measures (gabions, eco logs, geofabric, sediment fences) are required when wetland or watercourse banks steeper than 1:5 are denuded during construction. Appropriate rehabilitation procedures/measures should be planned.
Construction phase	Establishment of ROWs and construction of gas pipelines and pigging stations (including trenching/ excavations), as well as camps, pipeline stockpiles, and access roads within or close to wetlands or rivers (including associated buffer habitat)	Physical destruction or damage of freshwater ecosystems and adjacent fringe habitats by workers and machinery operating within or in close proximity to wetlands or drainage lines, and through the establishment of construction camps or temporary laydown areas within or in close proximity to wetlands or watercourses.	Loss of ecosystem services provided by these habitats, as well as mortality of fauna and flora directly through clearing and trenching/ excavation, as well as indirectly through poaching/hunting.	All wetlands and watercourses should generally be treated as "no-go" areas (as far as possible) 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). Construction camps, toilets, temporary laydown areas should be located outside of the recommended buffer areas around wetlands and watercourses and should be rehabilitated following construction. Ensure that a WUL is undertaken where developments will occur within 500 metres of a wetland or 100 metres from a river to authorise certain activities as per Section 21 of the National Water Act (Act No. 36 of 1998). Trenches/excavations should be backfilled and rehabilitated immediately after the pipes/pigging stations have been installed, and should be done concurrently as the pipeline construction process progresses along the ROW. Trenches/excavations that are open should be inspected daily by an ECO and plans put in place to rescue any vertebrate fauna that have become trapped within a

Project Phase	Activity	Key Impact	Possible Effect	Mitigation
				trench/excavation. Low fences that will prevent fauna from entering the ROW should be used especially in situations where trenches/excavations remain open for longer periods of time (i.e. a few weeks to several months). All construction activities (including establishment of construction camps, temporary lay-down areas, construction of haul roads and operation of heavy machinery, should ideally take place during the dry season to reduce potential impacts to freshwater ecosystems that are linked to rainfall-runoff.
	Stockpiling of materials and washing of equipment within or in close proximity to wetlands or watercourses	Pollution (water quality deterioration) of freshwater 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	Construction activities associated with the establishment of access roads through wetlands or watercourses (if unavoidable) should be restricted to a working area of ten metres in width either side of the road, and these working areas should be clearly demarcated. No vehicles, machinery, personnel, construction material, cement, fuel, oil or waste should be allowed outside of the demarcated working areas. Vehicles and machinery should not be washed within 30 metres of the edge of any wetland or watercourse.
	Construction of haul roads for movement of machinery and materials	Reduction in habitat quality through erosion and sedimentation of 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 watercourses.		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) should be used to minimise the transport of wind-blown dust. Any roads/crossings not needed after the construction process should be decommissioned and rehabilitated in accordance with detailed rehabilitation plans.
	Excavation of borrow pits for road construction	Excavation of borrow pits can act as pitfall traps for		Borrow pits should be located outside of the recommended buffer areas around wetlands and watercourses and should be

Project Phase	Activity	Key Impact	Possible Effect	Mitigation
		amphibians and other terrestrial species leading to unnecessary death of species.		rehabilitated following construction in accordance with detailed rehabilitation plans. Borrow pits should also be checked regularly by the on-site ECO to rescue any trapped vertebrate fauna.
	Operation of heavy machinery within or in close proximity to wetlands or other watercourses	Disturbance to and fatality of aquatic and semi-aquatic fauna, as a result of the noise and vibration from and movement of construction teams and their machinery working within or in close proximity to wetlands and rivers. Damage to vegetation from operating heavy machinery		No fuel storage, refuelling, vehicle maintenance or vehicle depots should be allowed within 30 metres of the edge of any wetlands, rivers 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. No effluents or polluted water should be discharged directly into any watercourse or wetland areas. If construction areas are to be pumped of water (e.g. after rainfall), this water should be pumped into an appropriate settlement area, and not allowed to flow straight into any watercourses or wetland areas. No spoil material, including stripped topsoil, should be temporarily stockpiled within 30 m of the edge of any wetland or drainage line. Freshwater 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, a 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 watercourses and in wetland areas, of not undertaking activities that could result in the pollution

Project Phase	Activity	Key Impact	Possible Effect	Mitigation
				of drainage lines 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 to monitor vegetation changes and potential site impacts occurring during construction phase
Operational Phase	Clearing or trimming of natural wetland or riparian vegetation to maintain the ROW, and access thereof.	Loss and/or reduction in habitat quality Growth stimulation of alien vegetation/ invasive species	Degradation of ecological integrity and changes to species community composition as well as habitat structure	Fixed point photography could be used to monitor long-term vegetation changes and potential site impacts. Avoid clearing vegetation (especially indigenous vegetation from high and very highly sensitive areas. Active removal of alien vegetation/spraying to be guided by an invasive alien plant control programme with long term monitoring.
	Application of herbicides	Pollution (water quality deterioration) of freshwater ecosystems and potential contamination of groundwater/subsurface drainage, which could also lead to bioaccumulation or poisoning of fauna and flora.		Avoid the use of herbicides in close proximity (close than 50 m) to wetlands or rivers and do not disturb riparian/or wetland buffer areas.

8 RISK ASSESSMENT

The following risk assessment (as presented in Table 9 below) was carried out for all of the identified impacts described in Section 7. For each impact the consequence (ranging from slight to extreme) of the impact affecting freshwater systems and/or biota was defined as a combination of three factors, namely: impact severity, spatial scale and duration. The probability is based on the likelihood of an impact occurring from extremely unlikely to very likely. The overall risk of a particular impact is based on the combined consequence of the impact and the probability/likelihood that the impact will occur, with each impact evaluated according to the four-tiered rating scale as used in the sensitivity mapping.

Table 9: Assessment of risk associated with impacts to freshwater ecosystems resulting from gas pipeline development with respect to the four-tiered sensitivity classes for freshwater attributes.

Direct Impact	Combined Sensitivity level	Without Mitigation			With Mitigation		
		Consequence	Probability	Risk	Consequence	Probability	Risk
Loss of freshwater habitat through clearing/ infilling of wetlands and rivers and associated buffer habitat, potentially including threatened/ sensitive ecosystems	Low	Moderate	Very likely	Low	Slight	Not likely	Very Low
	Medium	Substantial	Very likely	Moderate	Slight	Not likely	Very Low
	High	Severe	Very likely	High	Moderate	Not likely	Low
	Very High	Extreme	Very likely	Very High	Substantial	Not likely	Moderate
Fragmentation of aquatic habitat (mostly as a result of road construction)	Low	Slight	Likely	Very Low	Slight	Not likely	Very Low
	Medium	Moderate	Likely	Low	Slight	Not likely	Very Low
	High	Substantial	Likely	Moderate	Slight	Not likely	Very Low
	Very High	Severe	Likely	High	Moderate	Not likely	Low
Hydrological alteration largely through interrupted surface and/or subsurface water flows, as well as the concentration of water flows due to roads traversing wetlands or rivers	Low	Slight	Likely	Very Low	Slight	Not likely	Very Low
	Medium	Moderate	Likely	Low	Slight	Not likely	Very Low
	High	Substantial	Likely	Moderate	Moderate	Not likely	Low
	Very High	Substantial	Likely	Moderate	Substantial	Not likely	Moderate
Erosion caused by loss of vegetation cover through site clearing and consequent sedimentation of aquatic ecosystems	Low	Moderate	Very Likely	Low	Slight	Likely	Very Low
	Medium	Moderate	Very Likely	Low	Moderate	Likely	Low
	High	Substantial	Very Likely	Moderate	Substantial	Likely	Moderate
	Very High	Severe	Very Likely	High	Substantial	Likely	Moderate
Physical destruction or damage of freshwater ecosystems and adjacent fringe habitats by workers and machinery operating within or in close proximity to wetlands or drainage lines, and through the establishment of construction camps or	Low	Substantial	Very Likely	Moderate	Moderate	Likely	Low
	Medium	Substantial	Very Likely	Moderate	Substantial	Likely	Moderate
	High	Severe	Very Likely	High	Substantial	Likely	Moderate
	Very High	Extreme	Very Likely	Very High	Severe	Likely	High

Direct Impact	Combined Sensitivity level	Without Mitigation			With Mitigation		
		Consequence	Probability	Risk	Consequence	Probability	Risk
temporary laydown areas							
Pollution (water quality deterioration) of freshwater ecosystems through the runoff of contaminants such as fuel, oil, concrete, wash-water, sediment and sewage into these ecosystems	Low	Moderate	Likely	Low	Slight	Likely	Very Low
	Medium	Substantial	Likely	Moderate	Slight	Likely	Very Low
	High	Severe	Likely	High	Moderate	Likely	Low
	Very High	Extreme	Likely	High	Substantial	Likely	Moderate
Clearing or trimming of natural wetland or riparian vegetation leading to loss and/or reduction in habitat quality	Low	Moderate	Likely	Low	Slight	Likely	Very Low
	Medium	Moderate	Likely	Low	Slight	Likely	Very Low
	High	Substantial	Likely	Moderate	Moderate	Likely	Low
	Very High	Substantial	Likely	Moderate	Moderate	Likely	Low
Reduction in habitat quality through erosion and sedimentation of wetlands and rivers	Low	Moderate	Very Likely	Low	Slight	Likely	Very Low
	Medium	Moderate	Very Likely	Low	Slight	Likely	Very Low
	High	Substantial	Very Likely	Moderate	Moderate	Likely	Low
	Very High	Substantial	Very Likely	Moderate	Moderate	Likely	Low
Excessive dust generation from road construction and vehicle traffic/haulage leading to impact on surrounding vegetation health and suspended solids/sediment entering nearby watercourses	Low	Slight	Very Likely	Very low	Slight	Likely	Very Low
	Medium	Slight	Very Likely	Very Low	Slight	Likely	Very Low
	High	Moderate	Very Likely	Low	Moderate	Likely	Low
	Very High	Substantial	Very Likely	Moderate	Moderate	Likely	Low
Excavation of borrow pits for road construction acting as pitfall traps for amphibians and other terrestrial species leading to unnecessary death of species.	Low	Slight	Very Likely	Very Low	Slight	Likely	Very Low
	Medium	Substantial	Very Likely	Moderate	Slight	Likely	Very Low
	High	Severe	Very Likely	High	Moderate	Likely	Low
	Very High	Severe	Very Likely	High	Substantial	Likely	Moderate
Disturbance to and fatality of aquatic and semi-aquatic fauna, as a result	Low	Slight	Likely	Very Low	Slight	Not likely	Very Low
	Medium	Slight	Very Likely	Very Low	Slight	Not likely	Very Low

Direct Impact	Combined Sensitivity level	Without Mitigation			With Mitigation		
		Consequence	Probability	Risk	Consequence	Probability	Risk
of the noise and vibration from and movement of construction teams and their machinery working within or in close proximity to wetlands and rivers.	High	Moderate	Very Likely	Low	Slight	Not likely	Very Low
	Very High	Moderate	Very Likely	Low	Slight	Not likely	Very Low
Clearing, disturbance or trimming of natural wetland or riparian vegetation leading to stimulation of alien vegetation/invasive species	Low	Moderate	Likely	Low	Slight	Likely	Very Low
	Medium	Substantial	Very Likely	Moderate	Slight	Likely	Very Low
	High	Severe	Very Likely	High	Moderate	Likely	Low
	Very High	Extreme	Very Likely	Very High	Substantial	Likely	Moderate
Pollution (water quality deterioration) of freshwater ecosystems and potential contamination of groundwater/ subsurface drainage, which could also lead to bioaccumulation or poisoning of fauna and flora.	Low	Moderate	Likely	Low	Moderate	Not likely	Low
	Medium	Moderate	Very Likely	Low	Moderate	Not likely	Low
	High	Substantial	Very Likely	Moderate	Substantial	Not likely	Moderate
	Very High	Severe	Very Likely	High	Severe	Not likely	Moderate

9 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

This section provides “best practice” (or “good practice”) guidelines and management actions (including relevant standards and protocols) that cover the following development stages, and include practical, target-directed recommendations for monitoring of specified aspects raised in previous sections: During planning, construction, operations, rehabilitation. These guidelines and monitoring requirements must also take into consideration mitigation measures provided in Section 7.

9.1 Planning phase

The planning phase for gas pipeline development through firstly establishing preferred pipeline routings and alignments, and needs for ancillary infrastructure (e.g. access roads, water abstraction points, etc.) has the potential to greatly reduce impacts on freshwater ecosystems and associated fauna and flora through simply avoiding areas of very high sensitivity, and as far as possible avoiding areas of high sensitivity. In order to significantly reduce potential impacts on freshwater biodiversity, then sub-quaternary catchments classified with a very high or high sensitivity should be avoided. Where these areas cannot be avoided, then a detailed desktop investigation should be followed to determine whether the gas pipeline alignment and development footprint can avoid the actual freshwater ecosystems (i.e. wetland and river habitats) and associated buffers (see Section 6.1). This process should also be followed for all other sub-quaternary catchments (including medium and low sensitivities).

Where it is impossible to avoid freshwater ecosystems (i.e. wetland and river habitats) and associated buffers altogether, then it will be necessary to undertake more detailed specialist studies, impacts assessments, and if necessary investigate needs and opportunities for offsets. Preference should be given to position of gas pipelines within already disturbed/degraded areas (e.g. freshwater ecosystems and buffers that are already invaded by IAPs). 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, and in instances where it is provided that there are significant residual impacts due to the proposed development. Any freshwater ecosystems that will be affected by gas pipeline development must be subject to a project level assessment.

9.2 Construction phase

This phase may include the establishment of ROWs and construction of pipelines and pigging stations, and will thus include a number of impacts typical of construction activities, such as disturbance to wildlife through noise/light pollution, creation of dust, erosion and degradation/disturbance of habitats and vegetation (including areas for access via roads and servitudes and movement of heavy machinery), and bulldozing and vegetation/habitat clearing. Specific measures and actions required during the construction phase are presented in Section 7, but key to the process to include:

- Timing of construction activities to occur in the dry season as much 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 EMPr; and
- Environmental monitoring (or biomonitoring) required for pre-construction, during construction and post construction at strategically selected monitoring sites based on additional detail specified in Section 9.5 below.

9.3 Operations phase

This phase will predominantly include activities typical of routine maintenance, such as clearing/trimming of natural wetland or riparian vegetation (to maintain pipeline servitudes), as well as IAP control and application of herbicides. Specific measures to be considered are provided in in Section 9.1.

9.4 Rehabilitation and post closure

Rehabilitation and post-closure measures would be mostly required for ROWs within or in proximity to freshwater ecosystems, as well as for areas degraded by access routes, operation of vehicles/heavy machinery, and infestation of servitudes by IAPs. In general, the following processes/procedures as recommended by James and King (2010):

- Initiation – to assemble the rehabilitation project team/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 – a 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 freshwater 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, knock-on impacts to freshwater ecosystems caused during implementation (e.g. herbicide drift and contamination), etc.;
- 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, gabions/reno mattresses, etc.).

9.5 Monitoring requirements

Sites/areas where freshwater ecosystems are likely to be affected by gas pipeline development, according to the various phases of development (including rehabilitation), appropriate measures of monitoring should be considered, including:

- 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 Index of Habitat Integrity (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 operation 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.

10 GAPS IN KNOWLEDGE

The following gaps in knowledge are presented as follows in terms of influencing the freshwater assessment:

- This SEA study was developed using available spatial data covering freshwater habitats and species, and these datasets are not exhaustive across the entire study area. Species occurrence data in particular is only based on known records, and thus does not necessarily account for the true distribution of species. Furthermore, occurrence data for certain taxanomic groups is poorly represented, particularly in certain corridors (e.g. Odonata within the Phase 6 and Inland corridors, as well as in large parts of the Phase 3 and 7 corridors).
- Complete data of wetland habitat that includes characterisation of wetland condition and HGM units, was not available for the purpose of determining threat status of wetlands based on HGM type. The conservative approach that was adopted in based on the threat status derived for the broader-scale wetland vegetation groups.
- Species-level data and conservation assessments is limited for certain taxanomic groups, notably aquatic invertebrates. Thus, in the case of invertebrates (excluding Family: Odonata), only family-level data was used.
- This study does not make use of any ground-truthing and verification as a means to validate system importance and sensitivity, and therefore assumes that the data obtained is accurate and representative of the on-the-ground situation. The precautionary approach is to ensure that ground-truthing and infield assessments will be required once the gas pipeline alignments have been established (including alternatives), especially in the more sensitive areas. This will be particularly important to ensure that the extent/boundary of freshwater habitats (including the adjacent buffer zones), as well as the presence of conservation important species, is confirmed firstly, then avoided and/or appropriately managed.
- As with any large-scale project the likelihood for cumulative impacts developing are potentially great, especially when considering the knock-ons effects that gas development could have on other developments that in-turn also may impact on freshwater systems. This study obviously does not account for full extent of cumulative impacts linked both directly gas development (e.g. gas-to-power and storage facilities) and indirectly (through other developments that respond to the distribution of gas as a source of power.

11 CONCLUSIONS AND FURTHER RECOMMENDATIONS

Biodiversity impacts, unfortunately, are unavoidable when developing large-scale projects such as a national-scale network of gas pipelines. This is particularly the case when considering that these linear developments need to avoid human settlement (and other areas with anthropogenic significance, e.g. large/viable agricultural areas) as much as possible to prevent socio-economic impacts. Despite this, impacts to local and regional biodiversity assets can be substantially reduced through careful strategic level planning and design which consider areas of concern.

The sensitivity maps presented herein are based on specifically developed methods that enabled spatial integration of a broad suite of data depicting freshwater ecosystems and associated fauna and flora. Outputs include a series of four-tiered sensitivity maps that are intended to be used proactively in terms of planning gas pipeline development footprints, including servitude negotiations and potential land acquisitions, such that environmental impacts to freshwater ecosystems are minimised. The maps also indicate those areas where development is likely to be able to proceed with minimal risk and needs for EA.

The sensitivity maps and desktop analyses can also be used for any other planned development within the corridors that may impact freshwater ecosystems. Potential impacts and associated mitigation measures identified in this SEA are related specifically to gas pipeline development and are not generally applicable to other types of development.

Pipeline routing will need to include an integration of all specialist studies and GIS layers to develop something akin to a Marxan cost surface. It is assumed that a measure of slope will be factored in the routing optimisation, as it is applicable across a number of specialist fields. Specialist input will still be required to aid in the identification of the preferred option and refine the final pipeline route through the identified corridor/s based on more detailed desktop and infield assessments. Ultimately, pipeline alignment and development should avoid areas of very high sensitivity, and as far as possible avoid areas a high sensitivity. Where this is not possible, more site-specific specialist studies will need to be conducted to include further desktop verification with ground-truthing. Specific considerations for additional specialist studies include:

- Details for more sensitive areas, and
- Catchment-scale evaluation and oversight;
- Confirmation of occurrence of species conservation concern through range/habitat modelling and field surveys;
- Identify primary receivers, major impacts and most effective site-specific mitigation measures along with sensitivity specific mitigation measure; and
- Undertake pre-construction walk throughs.

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APPENDICES

Appendix 1: Selected flora used in the assessment of freshwater biota

Family	Species	Conservation status
Rutaceae	*Agathosma sedifolia*	EN
Fabaceae	*Albizia suluensis*	EN
Apiaceae	*Alepidea attenuata*	NT
Asphodelaceae	*Aloe simii*	CR
Aponogetonaceae	*Aponogeton angustifolius*	NT
Aponogetonaceae	*Aponogeton fugax*	EN
Asteraceae	*Arctotheca forbesiana*	VU
Apocynaceae	*Asclepias gordon-grayae*	EN
Apocynaceae	*Aspidonepsis cognata*	NT
Asteraceae	*Athanasia capitata*	EN
Salviniaceae	*Azolla pinnata subsp. africana*	NT
Plantaginaceae	*Bacopa monnieri*	NT
Plantaginaceae	*Callitriche bolusii*	DD
Cyperaceae	*Carex subinflata*	VU
Rhizophoraceae	*Cassipourea gummiflua var. verticillata*	VU
Cyperaceae	*Catabrosa drakensbergense*	VU
Rosaceae	*Cliffortia ericifolia*	EN
Rhamnaceae	*Colubrina nicholsonii*	VU
Asteraceae	*Cotula eckloniana*	VU
Asteraceae	*Cotula filifolia*	NT
Asteraceae	*Cotula myriophylloides*	CR
Asteraceae	*Cotula paludosa*	VU
Asteraceae	*Cotula pusilla*	VU
Crassulaceae	*Crassula tuberella*	NT
Amaryllidaceae	*Crinum campanulatum*	NT
Amaryllidaceae	*Crinum moorei*	VU
Tecophilaeaceae	*Cyanella aquatica*	EN
Cyperaceae	*Cyathocoma bachmannii*	VU
Cyperaceae	*Cyperus sensilis*	NT
Amaryllidaceae	*Cyrtanthus eucallus*	VU
Acanthaceae	*Dicliptera magaliesbergensis*	VU
Orchidaceae	*Disa cernua*	VU
Orchidaceae	*Disa extinctoria*	NT
Orchidaceae	*Disa flexuosa*	NT
Orchidaceae	*Disa scullyi*	EN
Orchidaceae	*Disa zuluensis*	EN
Aizoaceae	*Disphyma dunsdonii*	VU
Asteraceae	*Dymondia margaretae*	EN
Apocynaceae	*Ectadium virgatum*	NT
Restionaceae	*Elegia verreauxii*	VU
Cyperaceae	*Eleocharis schlechteri*	DD
Aizoaceae	*Erepsia brevipetala*	EN
Ericaceae	*Erica alexandri subsp. alexandri*	CR
Ericaceae	*Erica bakeri*	CR
Ericaceae	*Erica chrysocodon*	CR
Ericaceae	*Erica hansfordii*	CR
Ericaceae	*Erica heleogena*	CR
Ericaceae	*Erica margaritacea*	CR
Ericaceae	*Erica melanacme*	EN
Ericaceae	*Erica purgatoriensis*	VU

Family	Species	Conservation status
Ericaceae	*Erica riparia*	EN
Eriocaulaceae	*Eriocaulon mutatum var. angustisepalum*	VU
Eriocaulaceae	*Eriocaulon transvaalicum subsp. tofieldifolium*	VU
Hyacinthaceae	*Eucomis pallidiflora subsp. pole-evansii*	NT
Zygophyllaceae	*Fagonia rangei*	NT
Asteraceae	*Felicia westae*	EN
Cyperaceae	*Ficinia elatior*	VU
Cyperaceae	*Fimbristylis aphylla*	VU
Iridaceae	*Geissorhiza brehmii*	VU
Iridaceae	*Geissorhiza geminata*	EN
Geraniaceae	*Geranium ornithopodioides*	EN
Iridaceae	*Gladiolus paludosus*	VU
Thymelaeaceae	*Gnidia ornata*	VU
Amaryllidaceae	*Haemanthus nortieri*	EN
Hydrostachyaceae	*Hydrostachys polymorpha*	VU
Isoetaceae	*Isoetes capensis*	VU
Isoetaceae	*Isoetes eludens*	VU
Isoetaceae	*Isoetes stellenbossiensis*	NT
Isoetaceae	*Isoetes stephanseniae*	CR
Isoetaceae	*Isoetes wormaldii*	CR
Cyperaceae	*Isolepis venustula*	VU
Asphodelaceae	*Kniphofia flammula*	EN
Asphodelaceae	*Kniphofia latifolia*	EN
Asphodelaceae	*Kniphofia leucocephala*	CR
Hyacinthaceae	*Lachenalia bachmannii*	EN
Hyacinthaceae	*Lachenalia longituba*	VU
Hyacinthaceae	*Lachenalia salteri*	EN
Hydrocharitaceae	*Lagarosiphon cordofanus*	VU
Proteaceae	*Leucadendron conicum*	NT
Proteaceae	*Leucadendron corymbosum*	VU
Proteaceae	*Leucadendron floridum*	CR
Proteaceae	*Leucadendron laxum*	EN
Proteaceae	*Leucadendron levisanus*	CR
Proteaceae	*Leucadendron linifolium*	VU
Proteaceae	*Leucadendron macowanii*	CR
Proteaceae	*Leucadendron modestum*	EN
Proteaceae	*Leucospermum catherinae*	EN
Alismataceae	*Limnophyton obtusifolium*	NT
Plumbaginaceae	*Limonium anthericoides*	EN
Scrophulariaceae	*Lindernia monroi*	DD
Fabaceae	*Liparia angustifolia*	EN
Lobeliaceae	*Lobelia quadrisepala*	DD
Onagraceae	*Ludwigia leptocarpa*	NT
Asteracea	*Marasmodes sp. nov.*	CR
Marsileaceae	*Marsilea apposita*	DD
Marsileaceae	*Marsilea farinosa subsp. arrecta*	VU
Marsileaceae	*Marsilea fenestrata*	NT
Celastraceae	*Maytenus abbottii*	EN
Proteaceae	*Mimetes hirtus*	VU
Apocynaceae	*Mondia whitei*	EN
Iridaceae	*Moraea stagnalis*	VU
Najadaceae	*Najas setacea*	VU
Amaryllidaceae	*Nerine pancratioides*	NT
Lythraceae	*Nesaea crassicaulis*	NT
Lythraceae	*Nesaea wardii*	VU
Menyanthaceae	*Nymphoides forbesiana*	DD

Family	Species	Conservation status
Lamiaceae	*Ocimum reclinatum*	VU
Hydrocharitaceae	*Ottelia exserta*	NT
Hydrocharitaceae	*Ottelia ulvifolia*	NT
Oxalidaceae	*Oxalis davyana*	VU
Oxalidaceae	*Oxalis dines*	VU
Oxalidaceae	*Oxalis disticha*	NT
Oxalidaceae	*Oxalis natans*	CR
Oxalidaceae	*Oxalis uliginosa*	EN
Thymelaeaceae	*Passerina paludosa*	EN
Marsileaceae	*Pilularia bokkeveldensis*	CR
Marsileaceae	*Pilularia dracomontana*	Rare
Asteraceae	*Poecilolepis maritima*	VU
Potamogetonaceae	*Pseudalthenia aschersoniana*	CR
Fabaceae	*Psoralea alata*	VU
Fabaceae	*Psoralea angustifolia*	VU
Fabaceae	*Psoralea sp. nov.*	EN
Orchidaceae	*Pterygodium cruciferum*	EN
Orchidaceae	*Pterygodium microglossum*	EN
Arecaceae	*Raphia australis*	VU
Restionaceae	*Restio femineus*	EN
Restionaceae	*Restio paludosus*	VU
Restionaceae	*Restio sabulosus*	EN
Restionaceae	*Restio zuluensis*	VU
Iridaceae	*Romulea aquatica*	EN
Iridaceae	*Romulea multisulcata*	VU
Asteraceae	*Senecio cadiscus*	CR
Santalaceae	*Thesium polygaloides*	VU
Scrophulariaceae	*Torenia thouarsii*	VU
Lentibulariaceae	*Utricularia benjaminiana*	NT
Lentibulariaceae	*Utricularia cymbantha*	VU
Lentibulariaceae	*Utricularia foliosa*	VU
Menyanthaceae	*Villarsia goldblattiana*	VU
Campanulaceae	*Wahlenbergia pyrophila*	CR
Lemnaceae	*Wolffiella denticulata*	VU
Xyridaceae	*Xyris natalensis*	NT

Appendix 2: Selected fauna according the taxonomic groups used in the assessment of freshwater biota

Family	Species name	Common name	Conservation status
Dragonflies and Damselflies (Odonata)			
Coenagrionidae	*Aciagrion gracile*	Graceful Slim	VU
Coenagrionidae	*Agriocnemis gratiosa*	Gracious Wisp	VU
Gomphidae	*Ceratogomphus triceraticus*	Cape Thorntail	NT
Coenagrionidae	*Ceriagrion suave*	Sauve Citril	EN
Chlorocyphidae	*Chlorocypha consueta*	Ruby Jewel	CR
Synlestidae	*Chlorolestes apricans*	Amatola Malachite	EN
Libellulidae	*Diplacodes pumila*	Dwarf Percher	EN
Synlestidae	*Ecchlorolestes nylephtha*	Queen Malachite	NT
Synlestidae	*Ecchlorolestes peringueyi*	Rock Malachite	NT
Aeshnidae	*Gynacantha villosa*	Brown Duskhawker	VU
Corduliidae	*Hemicordulia africana*	African Emerald	NT
Lestidae	*Lestes dissimulans*	Cryptic Spreadwing	VU
Lestidae	*Lestes ictericus*	Tawny Spreadwing	VU
Lestidae	*Lestes uncifer*	Sickle Spreadwing	VU
Platycnemididae	*Metacnemis valida*	Blue Streamjack	EN
Libellulidae	*Olpogastra lugubris*	Bottletail	NT
Libellulidae	*Orthetrum robustum*	Robust Skimmer	NT
Libellulidae	*Orthetrum rubens*	Elusive Skimmer	EN
Libellulidae	*Parazyxomma flavicans*	Banded Duskdarter	VU
Corduliidae	*Phyllomacromia monoceros*	Sable Cruiser	NT
Coenagrionidae	*Proischnura polychromatica*	Mauve Bluet	EN
Platycnemididae	*Spesbona angusta*	Spesbona	EN
Corduliidae	*Syncordulia gracilis*	Yellow Presba	VU
Corduliidae	*Syncordulia legator*	Gilded Presba	VU
Corduliidae	*Syncordulia serendipator*	Rustic Presba	VU
Corduliidae	*Syncordulia venator*	Mahogany Presba	VU
Libellulidae	*Trithemis werneri*	Elegant Dropwing	NT
Fish			
Amphiliidae	*Amphilius natalensis*	*Natal Mountain Catfish*	DD
Poeciliidae	*Aplocheilichthys myaposae*	*Natal Topminnow*	NT
Austroglanididae	*Austroglanis barnardi*	*Barnard's Rock-catfish*	EN
Austroglanididae	*Austroglanis gilli*	*Clanwilliam Rock Catfish*	NT
Cyprinidae	*Barbus amatolicus*	*Amatola Barb*	VU
Cyprinidae	*Barbus eutaenia*	*Orangefin Barb*	DD
Cyprinidae	*Barbus sp. nov. 'Keiskamma'*		EN
Cyprinidae	*Barbus sp. nov. 'South Africa'*		NT
Cyprinidae	*Barbus sp. nov. 'Waterberg'*	*Waterberg Shortfin Barb*	NT
Cichlidae	*Chetia brevis*	*Orange-fringed River Bream*	EN
Mochokidae	*Chiloglanis bifurcus*	*Incomati Suckermouth*	CR
Cyprinidae	*Engraulicypris gariepenus*		NT
Cyprinidae	*Enteromius brevipinnis*	*Shortfin Barb*	NT
Cyprinidae	*Enteromius motebensis*	*Marico Barb*	NT
Cyprinidae	*Enteromius treurensis*	*Treur River Barb*	CR
Cyprinidae	*Enteromius trevelyani*	*Border Barb*	EN
Galaxiidae	*Galaxias sp. nov. 'Breede'*		EN
Galaxiidae	*Galaxias sp. Nov. 'Goukou'*		VU
Galaxiidae	*Galaxias sp. Nov. 'Heuningnes'*		EN
Galaxiidae	*Galaxias sp. nov. 'Riviersonderend'*		VU
Galaxiidae	*Galaxias sp. nov. 'Verlorenvlei'*		EN
Kneriidae	*Kneria sp. nov. 'South Africa'*	*Southern Kneria 'South Africa'*	EN

Family	Species name	Common name	Conservation status
Cyprinidae	*Labeo rubromaculatus*	*Tugela Labeo*	VU
Cyprinidae	*Labeo seeberi*	Clanwilliam Sandfish	EN
Cyprinidae	*Labeobarbus kimberleyensis*	*Largemouth Yellowfish*	NT
Cyprinidae	*Labeobarbus nelspruitensis*	*Incomati Chiselmouth*	NT
Cyprinidae	*Labeobarbus seeberi*	*Clanwilliam Yellowfish*	NT
Mormyridae	*Marcusenius caudisquamatus*		EN
Cichlidae	*Oreochromis mossambicus*	Mozambique Tilapia	VU
Cyprinidae	*Pseudobarbus afer*	Eastern Cape Redfin	EN
Cyprinidae	*Pseudobarbus asper*	Smallscale Redfin	EN
Cyprinidae	*Pseudobarbus burchelli*	Barrydale Redfin	CR
Cyprinidae	*Pseudobarbus burgi*		EN
Cyprinidae	*Pseudobarbus calidus*	Clanwilliam Redfin	NT
Cyprinidae	*Pseudobarbus capensis*	Berg-Breede River Whitefish	EN
Cyprinidae	*Pseudobarbus erubescens*	Twee River Redfin	CR
Cyprinidae	*Pseudobarbus phlegethon*	*Fiery Redfin*	EN
Cyprinidae	*Pseudobarbus senticeps*		CR
Cyprinidae	*Pseudobarbus serra*	*Clanwilliam Sawfi*	NT
Cyprinidae	*Pseudobarbus skeltoni*	*Giant Redfin*	EN
Cyprinidae	*Pseudobarbus sp. nov. 'doring'*	*Doring Fiery Redfin*	CR
Cyprinidae	*Pseudobarbus sp. nov. 'heuningnes'*		CR
Cyprinidae	*Pseudobarbus swartzi*	*Gamtoos River Redfin*	EN
Cyprinidae	*Pseudobarbus tenuis*	*Slender Redfin*	NT
Cyprinidae	*Pseudobarbus verloreni*		EN
Anabantidae	*Sandelia bainsii*	*Eastern Cape Rocky*	EN
Anabantidae	*Sandelia capensis*	*Cape Kurper*	DD
Cichlidae	*Serranochromis meridianus*	*Lowveld Largemouth*	EN
Gobiidae	*Silhouettea sibayi*	*Sibayi Goby*	EN
Amphibians			
Hyperoliidae	*Afrixalus knysnae*	Knysna Leaf-folding Frog	EN
Pyxicephalidae	*Anhydrophryne ngongoniensis*	Mistbelt Chirping Frog	EN
Pyxicephalidae	*Anhydrophryne rattrayi*	Hogsback Chirping Frog	VU
Pyxicephalidae	*Arthroleptella landdrosia*	Landdros Moss Frog	NT
Pyxicephalidae	*Arthroleptella lightfooti*	Lightfoot’s Moss Frog	NT
Pyxicephalidae	*Arthroleptella rugosa*	Rough Moss Frog	CR
Pyxicephalidae	*Arthroleptella subvoce*	Northern Moss Frog	CR
Brevicipitidae	*Breviceps bagginsi*	Bilbo's Rain Frog	NT
Brevicipitidae	*Breviceps branchi*	Branch's Rain Frog	DD
Brevicipitidae	*Breviceps gibbosus*	Cape Rain Frog	NT
Brevicipitidae	*Breviceps macrops*	Desert Rain Frog	NT
Pyxicephalidae	*Cacosternum capense*	Cape Dainty Frog	NT
Pyxicephalidae	*Cacosternum platys*	Smooth Dainty Frog	NT
Pyxicephalidae	*Cacosternum thorini*	Hogsback Caco	EN
Bufonidae	*Capensibufo deceptus*	Deception Peak Mountain Toadlet	DD
Bufonidae	*Capensibufo magistratus*	Landdroskop Mountain Toadlet	DD
Bufonidae	*Capensibufo rosei*	Rose’s Mountain Toadlet	CR
Bufonidae	*Capensibufo selenophos*	Moonlight Mountain Toadlet	DD
Heleophrynidae	*Heleophryne hewitti*	Hewitt’s Ghost Frog	EN
Heleophrynidae	*Heleophryne rosei*	Table Mountain Ghost Frog	CR
Hemisotidae	*Hemisus guttatus*	Spotted Shovel-nosed Frog	NT
Hyperoliidae	*Hyperolius pickersgilli*	Pickersgill's Reed Frog	EN
Arthroleptidae	*Leptopelis xenodactylus*	Long-toed Tree Frog	EN
Pyxicephalidae	*Microbatrachella capensis*	Micro Frog	CR
Pyxicephalidae	*Natalobatrachus bonebergi*	Kloof Frog	EN
Pyxicephalidae	*Poyntonia paludicola*	Montane Marsh Frog	NT
Bufonidae	*Sclerophrys pantherina*	Western Leopard Toad	EN
Bufonidae	*Vandijkophrynus amatolicus*	Amathole Toad	CR

Family	Species name	Common name	Conservation status
Pipidae	*Xenopus gilli*	Cape Platanna	EN
Reptiles (freshwater obligates)			
Chamaeleondidae	*Bradypodion melanocephalum*	KwaZulu Dwarf Chamaeleon	VU
Chamaeleondidae	*Bradypodion pumilum*	Cape Dwarf Chamaeleon	VU
Lamprophiidae	*Macrelaps microlepidotus*	KwaZulu-Natal Black Snake	NT
Lamprophiidae	*Montaspis gilvomaculata*	Cream-spotted Mountain Snake	DD
Gekkonidae	*Pachydactylus rangei*	Namib Web-footed Gecko	CR
Pelomedusidae	*Pelusios rhodesianus*	Variable Hinged Terrapin	VU
Mammals (freshwater obligates)			
Carnivora	*Aonyx capensis*	Cape Clawless Otter	NT
Carnivora	*Leptailurus serval*	Serval	NT
Carnivora	*Hydrictis maculicollis*	Spotted-necked Otter	VU
Eulipotyphla	*Crocidura mariquensis*	Swamp Musk Shrew	VU
Eulipotyphla	*Myosorex sclateri*	Sclater's Forest Shrew	VU
Lagomorpha	*Bunolagus monticularis*	Riverine Rabbit	CR
Rodentia	*Dasymys capensis*	Cape Marsh Rat	VU
Rodentia	*Dasymys incomtus*		NT
Rodentia	*Dasymys robertsii*		VU
Rodentia	*Otomys auratus*	Vlei Rat	NT
Rodentia	*Otomys laminatus*	Laminate Vlei Rat	NT

Appendix 3: Peer Review and Specialist Response Sheet

Peer Reviewer: Duncan Hay, Catherine Pringle, and Leo Quayle, Institute of Natural Resources

EXPERT REVIEW AND SPECIALIST RESPONSES: Freshwater - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Kate Pringle	9	20		and therefore requires	Corrected
Kate Pringle	9	24		obtaining EA is not are	Corrected
Kate Pringle	12	4		and builds on	Corrected
Kate Pringle	12	14		Why does the freshwater assessment identify caves, geology and roosts?	Changed as per comments for EGI. The report now mentions freshwater features. Note the EGI Report Responses to Peer Reviewer notes the following: This was a generic sentence copied from CSIR template. It has been reworded to relate to freshwater features such as waterfalls, spray zones etc.
Kate Pringle	13	1		Further the above - should this not be further to the above?	Corrected
Kate Pringle	13	11		I think it would be good to mention that the species information relates to freshwater-dependent species and not all plants, butterflies and reptiles	Changed
Kate Pringle	16	9		EI and ES should be written in full	Corrected
Kate Pringle	16	10		DWS should be written in full	DWS has already been abbreviated in Section 3 on Page 12.
Kate Pringle	16	28		It is unclear why stream order has been included in determining river sensitivity. Could you provide additional justification for this?	Higher stream order usually represents smaller, faster flowing, lower volume rivers higher in the catchment which are more sensitive to impacts.
Kate Pringle	17		Table 1	I would suggest that Ramsar sites be included in the very high sensitivity class	The reason why Ramsar sites were given a "high" sensitivity and not given a very high sensitivity is because they are protected to some extent. We feel that highly sensitive systems outside of protected areas and other conservation areas are more sensitive as they are more likely to be impacted by development.

EXPERT REVIEW AND SPECIALIST RESPONSES: Freshwater - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Kate Pringle	18	35		You indicate that 141 freshwater plants were selected for analysis as these were categorised as Threatened, Near Threatened or data deficient. Presumably this is the total number of plants in SA in these categories? From this, you then selected 4129 point localities of these plants occurring in the study area? If this is what you have done, then why does the total number of plants in these categories in SA differ between the EGI and Gas report (141 vs 160)? In addition, I would expect the total number of points to be higher in the gas report than the EGI report as it covers a much greater extent (4129 vs 6700). I have picked up a similar issue with the dragonflies, freshwater fish, amphibians, reptiles and mammals. If this is an error, then you may need to re-run your sensitivity analyses. Also please clarify if all selected species occur in the study area or only a portion of those selected from the SA dataset?	The discrepancy has come from earlier report versions. The initial EGI report referred to the total number of species and points that occur within all corridors (both EGI and Gas). Attempts have been made to correct these so that data was specific to either the Gas or EGI corridors. These have now been corrected. Also, selected species occur with the study area (in this case the Gas corridors).
Kate Pringle	19	16		(Gas) - is this meant to be included in the text?	Removed
Kate Pringle	20	19		You indicate that 49 species were selected for the study. You then indicate that point localities for 30 of these were obtained from GBIF and the other 22 from the IUCN data. This totals 52 not 49?	Corrected
Kate Pringle	21	19		You indicate that the data was obtained from Child et al 2016. In the EGI report you list the sources as Bates. Please clarify which is correct and amend one or both reports.	Corrected to Child et al 2016 in the EGI Report.
Kate Pringle	22	9		In order to reduce not reduced	Corrected
Kate Pringle	27-28		Table 2	The numbers of point locations in this table for dragonflies, freshwater fish, amphibians, reptiles, and mammals do not match the number given in the text on pages 18-21.	Corrected and standardised for both reports. These discrepancy stems from previous analyses where total numbers for the entire area covering both EGI and Gas was used.

EXPERT REVIEW AND SPECIALIST RESPONSES: Freshwater - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Kate Pringle	30		Table 4	The relevant acts, strategies and policies are a bit muddled in this table. I would reorder the national instruments so that NEMA appears first as the framework legislation followed by the various specific environmental management acts (SEMAs) e.g. National Water Act. I would also then list the associated instruments, policies and strategies under the relevant act e.g. the EIA regs under NEMA and the RQOs under the National Water Act.	I disagree, the table has been ordered as per CSIR suggestions and flow from international instruments/legislation down to provincial/regional legislation
Kate Pringle	37		Table 4	Is it necessary to list all the extended power ordinances?	These are not power ordinances but conservation ordinances relevant to freshwater. We just wanted to be thorough.
Kate Pringle	38		Table 4	You have not included provincial legislation for Mpumalanga, Gauteng and Free State.	These provinces do not have separate provincial legislation relevant to freshwater systems/pollution - this national legislation applies in these provinces
Kate Pringle	39	1		I think this chapter should start with an introductory paragraph rather than just a table.	Edited
Kate Pringle	39		Table 5	"The rivers are generally in poor condition" - I might reword this as 50% are in good or fair and 50% are poor or critical.	Reworded
Kate Pringle	41		Table 5	Does Addo fall into both Phase 2 and Phase 7?	Yes, it does
Kate Pringle	42		Table 5	Key impacts - presumably the urbanisation is impacting water quality? Maybe be explicit about this.	Reworded
Kate Pringle	42		Table 5	EOO and AOO should be written in full	EOO and AOO have already been abbreviated in Phase 1 on Page 41.
Kate Pringle	43		Table 5	(Turner and de Villers, 2017).	Corrected
Kate Pringle	44		Table 5	Phase 4: smaller number of rivers	Corrected
Kate Pringle	47-48		Table 5	Acacia karoo should be in italics	Corrected
Kate Pringle			Table 5	Should specific mention not be made of the relevant free flowing rivers?	Have added these in
Kate Pringle	100-101			Have birds been considered elsewhere? There are several key wetland species such as cranes which may be significantly impacted.	A separate study covers the assessment of impacts on avifauna.
Kate Pringle	101			I think you should include a specific section on water quality which covers sedimentation, spills, impacts on groundwater etc.	Added some text to this effect

EXPERT REVIEW AND SPECIALIST RESPONSES: Freshwater - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Kate Pringle	109			Could you provide a bit more detail on how the different elements were integrated to arrive at a risk category?	Based on the agreed risk assessment approach. Note from the CSIR: The Risk Assessment approach and methodology has been standardised across all specialist studies in terms of consequence vs. probability to calculate risk. The approach will be detailed in the SEA Report and Integrated Biodiversity Chapter.
Kate Pringle	118			This section seems a little out of place here. I think it may fit better at the end of Section 6.	Agreed and moved
Kate Pringle	120	13		HGM should be written in full	HGM has already been abbreviated in Section 4.2 on Page 24.
Kate Pringle	121	3		Remove "as to develop" so that it reads "such as a national-scale"	Corrected
Kate Pringle	121	8		the last sentence may be better as "...planning and design which consider areas of concern"	Corrected
Kate Pringle	121	26		be required to aid in	Corrected
Kate Pringle	123	14		Reference requires a date after the authors	Corrected and Included
Kate Pringle	124	15-18		Line spacing issue	Corrected
Kate Pringle				This report must consider Strategic Water Source Areas and Strategic Groundwater Areas. These areas must be incorporated as a sensitivity value = 4. They are critically important and must be avoided at all costs.	Note from the CSIR: Strategic Water Source Areas (SWSAs) - Surface and Groundwater (Dataset: Council for Scientific and Industrial Research (CSIR), April 2018) has been considered in the Environmental Sensitivity Analysis used to optimise the location of the corridors. It has been rated with a HIGH Sensitivity. This will be captured in the Environmental Sensitivity Map in the SEA Report, as well as in the Integrated Biodiversity Assessment Chapter.

EXPERT REVIEW AND SPECIALIST RESPONSES: Freshwater - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Kate Pringle				Many wetland resources are groundwater driven. Has groundwater been considered elsewhere? If not, this is a major oversight that must be addressed. If the groundwater has been addressed elsewhere, it would be helpful to cross-reference.	Note from the Project Team: The Gas Pipeline will be constructed below ground at a depth of about 2 m. Based on feedback from the engineers, this is not considered deep enough to impact significantly on groundwater resources and deep aquifers. The specialists believe that the consideration of groundwater is not a major concern as aquatic systems are not driven significantly by groundwater resources, and the impacts from gas pipelines will be minor (and non-existent for EGI). However, this assumes that we are referring to (deeper) groundwater and not subsurface flows. Nevertheless, the following impact has been assessed in the Freshwater Gas Report: *Pollution (water quality deterioration) of freshwater ecosystems and potential contamination of groundwater/ subsurface drainage, which could also lead to bioaccumulation or poisoning of fauna and flora.*
Kate Pringle				Have estuaries been considered elsewhere?	Estuaries are not considered in the Freshwater Assessment but are the subject of a separate dedicated specialist assessment.

Strategic Environmental Assessment for the Development of a Phased Gas Pipeline Network in South Africa

Appendix C.1.8

Biodiversity and Ecological Impacts - Avifauna

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

AVIFAUNA

Contributing Authors	Chris van Rooyen[1] Albert Froneman[1]

[1] Chris van Rooyen Consulting

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FIGURES

ABBREVIATIONS AND ACRONYMS

SEA	Strategic Environmental Assessment
IBA	Important Bird Area
SABAP1	Southern African Bird Atlas Project 1
SABAP2	Southern African Bird Atlas Project 2
EWT	Endangered Wildlife Trust
NT	Near threatened
VU	Vulnerable
EN	Endangered
CR	Critically Endangered
SANBI	South African National Biodiversity Institute
QDGC	Quarter Degree Grid Cell
BLSA	Birdlife South Africa
IFC	International Finance Corporation

1 SUMMARY

The table below provides a summary of the most important findings of the study, as well as an overall suitability rating for each Gas Pipeline Corridor Phase.

Corridor Phase	Overall Suitability	Comment
Phase Inland	High	Mortality: Very low risk for Red Data species is anticipated. Displacement due to disturbance: Low to very low risk for Red Data species is anticipated. Depending on where the alignment is located, the impact could be moderate on tree and powerline nesting Martial Eagles. Displacement due to habitat destruction: Very low risk for Red Data species is anticipated.
Phase 1	Medium - high	Mortality: Moderate to very low risk for Red Data species is anticipated. Depending on where the alignment is located, the impact on Martial Eagle could be moderate, and substantial in the case of Damara Terns breeding at De Mond in the De Hoop Nature Reserve. Displacement due to disturbance: Moderate to very low risk for Red Data species is anticipated. Depending on where the alignment is situated, impact on the Cape Vulture colony at Potberg and the Damara Terns breeding at De Mond in the De Hoop Nature Reserve could be substantial. Displacement due to habitat destruction: Very low risk for Red Data species is anticipated.
Phase 2	Medium - high	Mortality: Low to very low risk for Red Data species is anticipated. Depending on where the alignment is located, the impact on Martial Eagle could be moderate. Displacement due to disturbance: Low to very low risk for Red Data species is anticipated. Depending on where the alignment is situated, the impact on Martial Eagles could be moderate. Displacement due to habitat destruction: Very low risk for Red Data species is anticipated.
Phase 3	Medium	Mortality: Moderate to very low risk for Red Data species anticipated. Depending on where the alignment is located, impact on Wattled Crane, forest specialists e.g. Eastern Bronze-naped Pigeon, and tree nesting vultures could be substantial. Rudd's Lark and Botha's lark could also be substantially impacted in grassland habitat. Displacement due to disturbance: Moderate to low risk for Red Data species is anticipated. Depending on where the alignment is located, impact on forest specialists e.g. Eastern Bronze-naped Pigeon, and vultures, both tree nesting and cliff-nesting (Cape Vultures in the Magaliesberg) could be substantial. Disturbance of breeding Wattled Cranes in wetlands could also be substantial. Rudd's Lark and Botha's lark could also be substantially impacted in grassland habitat. Displacement due to habitat destruction: Low to very low risk for Red Data species is anticipated. Depending on where the alignment is located, impact on forest specialists e.g. Eastern Bronze-naped Pigeon, and tree nesting vultures could be moderate. Rudd's Lark and Botha's lark could also be moderately impacted in grassland habitat.
Phase 4	Medium	Mortality: Moderate to very low risk for Red Data species anticipated. Depending on where the alignment is located, impact on tree nesting raptors and vultures could be substantial. Displacement due to disturbance: Moderate to very low risk for Red Data species anticipated. Depending on where the alignment is located, the impact on large eagles, vultures and Pink-backed Pelicans could be substantial. Displacement due to habitat destruction: Low to very low risk for Red Data species is anticipated. Depending on where the alignment is located, impact on forest specialists e.g. Eastern Bronze-naped Pigeon, and tree nesting vultures could be moderate.

Corridor Phase	Overall Suitability	Comment
Phase 5	High	Mortality: Very low risk for Red Data species is anticipated. Displacement due to disturbance: Low to very low impact risk for Red data species is envisaged. Depending on where the alignment is located, the impact on powerline nesting raptors, especially Martial Eagle, could be moderate. Displacement due to habitat destruction: Very low risk for Red Data species is anticipated
Phase 6	High	Mortality: Very low risk for Red Data species is anticipated. Displacement due to disturbance: Low to very low impact risk for Red data species is envisaged. Depending on where the alignment is located, the impact on powerline nesting raptors, especially Martial Eagle, could be moderate. Displacement due to habitat destruction: Very low risk for Red Data species is anticipated.
Phase 7	Medium	Mortality: Moderate to very low risk for Red Data species anticipated. Depending where the alignment is situated, impact could be substantial on Damara Tern, Southern Ground Hornbill, forest species, tree nesting large eagles and vultures and Wattled Crane. Displacement due to disturbance: Moderate to very low risk for Red Data species. Depending where the alignment is situated, impact could be substantial on Damara Tern, Southern Ground Hornbill, forest species, tree nesting large eagles and vultures, Blue Swallows and Wattled Crane. Displacement due to habitat destruction: Moderate to very low risk for Red Data species. Depending on where the alignment is situated, impact could be moderate on forest species and tree nesting large eagles and vultures, but substantial for Blue Swallow.
Phase 8	Medium	Mortality: High to very low risk for Red Data species anticipated. Depending on where the alignment is located, impacts could be substantial for large raptors and vultures and Southern Ground Hornbill. Severe impacts are possible in the case of White-winged Flufftail. Displacement due to disturbance: High to very low risk for Red Data species anticipated. Depending on where the alignment is located, impacts could be substantial for large raptors and vultures and Southern Ground Hornbill. Severe in the case of White-winged Flufftail and Wattled Crane. Displacement due to habitat destruction: Depending where the alignment is situated, impact could be moderate on tree nesting large eagles and vultures

2 INTRODUCTION

The focus of this report is on activities associated with construction and operation of gas pipelines and related facilities that have the potential to affect avifauna, particularly Red Data species. Examples of related facilities are pigging stations and block valves, and other infrastructure required for the operation of the gas transmission line. The actual sourcing of gas and the activities associated with the distribution of the gas or use of the gas by third parties is not included in the scope of this SEA. Distribution (branch lines to industrial areas and reticulation offtake points) and reticulation (lines to homes and small industry) pipelines, with pressures less than 15 bar, are also not considered in this SEA Process.

Generally, gas infrastructure is divided into small- and large-diameter pipelines. Large pipelines (>508 mm; 20 in), require larger equipment and more space for construction, emphasizing the need for detailed considerations during the planning stages (Stantec, 2013). For purposes of this report a construction servitude of 50m (25m either side of the centre line) was assumed (Refer to Part 2 of the SEA Report for a Project Description).

Operational activities on gas pipeline servitudes are generally limited to maintenance and monitoring programs and as such have fewer operational interactions with avifauna. Operational activities are mostly related to integrity management, vegetation management and daily operational activities at compressor or pump stations[1]. These activities pose some risk to avifauna depending on the timing, extent and duration of work activities. Generally operational activities are localized, and the risk of direct mortality and displacement due to disturbance and habitat destruction is much less than what exists for construction-related activities.

While the envisaged impacts on avifauna are linked to and overlap with some of the other disciplines e.g. terrestrial ecology, estuaries and freshwater, there are also important differences, in that the mobility of birds means they can sometimes (although not in the case of nestlings or eggs) avoid an impact by moving out of an impacted area. Also, in the case of avifauna, transformed habitats can be very important, e.g. the mosaic of pastures and cultivation in the Overberg Wheatbelt (Phase 1) is crucial habitat for the threatened Blue Crane.

3 PROJECT SCOPE

3.1 Terms of reference

The terms of reference for this report are as follows:

- Review of existing literature to compile a baseline description applicable to each corridor phase;
- Compilation of a shortlist of bird species that are sensitive to gas pipeline infrastructure that are likely to occur in each corridor phase;
- Identification of avifaunal sensitivity features (e.g. habitat classes, roosts and colonies etc.) within each corridor phase;
- Development of an approach for classing each sensitivity feature in each corridor phase according to a four-tiered sensitivity rating system i.e. Very High, High, Medium or Low;
- Assessment of the proposed corridor phases in terms of the potential impacts associated with the construction and operation of gas pipelines on priority species and their habitats;
- Description of proposed management actions to enhance benefits and avoid/reduce/offset negative impacts in each corridor phase;
- Based on the findings of the assessment, the compilation of a four-tiered sensitivity map related to potential impact on avifauna in each corridor phase;

[1] Compressor stations are not included in the scope of work as the initial pipeline phases will, most likely, be built without compressor stations. Compressor stations form part of future expansions of the pipelines and will be located near the pigging stations.

- Provision of input into the pre-construction site specific environmental assessment protocol (Decision-Support Tools) for each corridor phase i.e. the additional information and level of assessment which is required in each sensitivity category before an authorisation with respect to avifauna should be considered.

Note that this Specialist Assessment Report was peer reviewed prior to release to stakeholders for review. The report was updated, as required, following the peer review findings. A copy of the peer review report and responses from the Specialist Team is included in Appendix A of this report.

3.2 Data Sources

Below is a detailed list and description of all data sources on which the assessment is based, and from which sensitive features/criteria are extracted (Table 1).

Table 1: Data sources on which the avifauna assessment is based.

Data title	Source and date of publication	Data Description
The Southern African Bird Atlas 1 (SABAP1)	Animal Demography Unit, University of Cape Town, 1997.	The Southern African Bird Atlas Project (SABAP) was conducted between 1987 and 1991.Because a new bird atlas was started in southern Africa in 2007, the earlier project is now referred to as SABAP1. SABAP1 covered six countries: Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe. At the time, Mozambique was engulfed in a civil war, and had to be excluded. The resolution for SABAP1 was the quarter degree grid cell (QDGC), 15 minutes of latitude by 15 minutes of longitude, 27.4 km north-south and about 25 km east-west, an area of about 700 km^2. Fieldwork was conducted mainly in the five-year period 1987–1991, but the project coordinators included all suitable data collected from 1980–1987. In some areas, particularly those that were remote and inaccessible, data collection continued until 1993. Fieldwork was undertaken mainly by birders, and most of it was done on a volunteer basis. Fieldwork consisted of compiling bird lists for the QDGCs. All the checklists were fully captured into a database. The final dataset consisted of 147 605 checklists, containing a total of 7.3 million records of bird distribution. Of the total 3973 QDGCs, only 88 had no checklists (2.2% of the total).
The Southern African Bird Atlas 2 (SABAP2)	Animal Demography Unit, University of Cape Town, 1 July 2007 to present, ongoing. Accessed in March 2018.	SABAP2 is the follow-up project to the Southern African Bird Atlas Project (for which the acronym was SABAP, and which is now referred to as SABAP1). This first bird atlas project took place from 1987-1991. The second bird atlas project started on 1 July 2007 and plans to run indefinitely. The current project is a joint venture between the Animal Demography Unit at the University of Cape Town, BirdLife South Africa and the South African National Biodiversity Institute (SANBI). The project aims to map the distribution and relative abundance of birds in southern Africa and the atlas area includes South Africa, Lesotho and Swaziland. SABAP2 was launched in Namibia in May 2012. The field work for this project is done by more than one thousand five hundred volunteer birders. The unit of data collection is the pentad, five minutes

Data title	Source and date of publication	Data Description
		of latitude by five minutes of longitude, squares with sides of roughly 9km. At the end of June 2017, the SABAP2 database contained more than 189,000 checklists. The milestone of 10 million records of bird distribution in the SABAP2 database was less than 300,000 records away. Nine million records were reached on 29 December 2016, eight months after reaching 8 million on 14 April 2016, which in turn was eight months after reaching seven million on 22 August 2015, and 10 months after the six million record milestone. More than 78% of the original SABAP2 atlas area (i.e. South Africa, Lesotho and Swaziland) has at least one checklist at this stage in the project's development. More than 36% of pentads have four or more lists.
2013 - 2014 South African National Land-Cover Dataset	DEA February 2015 (https://egis.environment.gov.za/)	The 2013-14 South African National Land-cover dataset produced by GEOTERRAIMAGE as a commercial data product has been generated from digital, multi-seasonal Landsat 8 multispectral imagery, acquired between April 2013 and March 2014. The data set was procured by the Department of Environmental Affairs for public use. In excess of 600 Landsat images were used to generate the land-cover information, based on an average of 8 different seasonal image acquisition dates, within each of the 76 x image frames required to cover South Africa. The land-cover dataset, which covers the whole of South Africa, is presented in a map-corrected, raster format, based on 30x30m cells equivalent to the image resolution of the source Landsat 8 multi-spectral imagery. The dataset contains 72 x land cover / use information classes, covering a wide range of natural and man-made landscape characteristics. Each data cell contains a single code representing the dominant land-cover class (by area) within that 30x30m unit, as determined from analysis of the multi-date imagery acquired over that image frame. The original land-cover dataset was processed in UTM (north) / WGS84 map projection format based on the Landsat 8 standard map projection format as provided by the USGS3. The final product is available in UTM35 (north) and (south), WGS84 map projections and Geographic Coordinates, WGS84.
The biomes of South Africa as contained in the National Vegetation Map of South Africa (2012)	The Vegetation Map of South Africa, Lesotho and Swaziland by Mucina and Rutherford (eds.), 2006, with the spatial product updated in 2012.	The descriptions of vegetation types are given for each biome and include a general introduction to each biome, details about how each vegetation type relates to previously published vegetation maps, distribution, vegetation and landscape features, geology and soils, climate, important taxa, biogeographically important taxa, endemic taxa, conservation, and remarks.
The crane, raptor and vulture nest databases of the Endangered Wildlife Trust (EWT)	Endangered Wildlife Trust, accessed February 2018	Data on crane, vulture and raptor nests collected by the various programmes of the EWT. Absence of records does not imply absence of the species within an area, but simply that this area may not have been surveyed. All recorded nesting sites were included, no verification of current status of nests were conducted.

Data title	Source and date of publication	Data Description
National vulture restaurant database	VulPro, March 2017 http://www.vulpro.com/	The register contains a georeferenced list of vulture restaurants throughout South Africa as compiled by VulPro. All recorded vulture restaurants were included; no verification of current status of vulture restaurants was conducted.
List of eagle nests on Eskom transmission lines in the Karoo	Endangered Wildlife Trust, 2006	The dataset contains a georeferenced list of Tawny Eagle, Martial Eagle and Verreaux's Eagle nests on transmission lines in the Karoo as at 2006. All recorded nesting sites were included, no verification of current status of nests were conducted.
Information on the locality of Red Data nests	Unpublished data from pre-construction monitoring at renewable energy projects from 2010 - 2018, obtained from various avifaunal specialists.	Nests of various raptors, including Verreaux's Eagle, Martial Eagle, Tawny Eagle, African Crowned Eagle, Wattled Crane, White-backed Vulture collected in the course of pre-construction monitoring at proposed renewable energy projects in the Western, Northern, and Eastern Cape, and KZN.
The national register of Cape Vulture colonies	VulPro and Endangered Wildlife Trust, 2018	The dataset contains a georeferenced list of Cape Vulture colonies, as well as the results of the 2013 aerial survey of Cape Vulture colonies conducted by Eskom, EWT and Birdlife South Africa (BLSA) in the former Transkei, Eastern Cape.
A map of Blue Swallow breeding areas	Ezemvelo KZN Wildlife, March 2018	The KZN Mistbelt Grassland Important Bird Area (IBA) which incorporates all the known patches of grassland where Blue Swallows are known to nest and forage, plus additional nests sites outside the IBA. No verification of current status of nests was conducted.
Information on potential nesting areas of Southern Ground Hornbills.	Mabula Ground Hornbill Project, March 2018.	The data consists of a list of pentads where the species was sighted in Kwa-Zulu-Natal, Mpumalanga and the Eastern Cape. Data was provided in pentad format. The assumption was made that the species would be breeding within the pentad.
Information on various Red Data species nests obtained from the Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa.	Wind and Solar SEA, Phase 1, CSIR, 2015	The data comprise nest localities of Black Harrier, Martial Eagle, Verreaux's Eagle, Blue Crane, Lanner Falcon, in the 8 solar and wind focus areas where they overlap with the gas pipeline corridor phases.
Information on the localities of Southern Bald Ibis breeding colonies.	BirdLife South Africa 2015	The data comprises nest localities of Southern Bald Ibis collected by Dr. Kate Henderson as part of her PhD studies.
KNP Buffer Aug2017v2	Kruger National Park Management Plan 2018 – 2028	Buffer zone proposed in the latest management plan for the Kruger National Park.
Areas earmarked for formal conservation as part of the National Protected Areas Expansion Strategy (NPAES)	Priority areas for protected area expansion, 2016 (including updated Northern Cape priorities) Department of Environmental Affairs (DEA)	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.
Database of national estuaries	SANBI, Biodiversity GIS, 2012 http://bgis.sanbi.org/	Estuarine systems along the South African coastline
Conservation Areas	SA conservation area database-Q2 2017 (DEA); Provincial game farm data https://egis.environment.gov.za/	Biosphere reserves Botanical gardens Ramsar Sites (not already protected) Game farms, private reserves and hunting areas

Data title	Source and date of publication	Data Description
Protected Areas	South African Protected Areas Database (SAPAD) - Q3, 2017, South African National Parks (SANParks) and Provincial https://egis.environment.gov.za	Marine Protected Areas National Parks Nature Reserves Protected Environments Forest Nature Reserve Forest Wilderness Area Special Nature Reserve
Important Bird and Biodiversity Areas of South Africa	BirdLife South Africa, 2015	National inventory of the Important Bird or Biodiversity Areas of South Africa, compiled by BirdLife South Africa.
A list of potential Bush Blackcap, Spotted Ground-Thrush and Orange Ground-Thrush breeding habitat.	BirdLife South Africa, 2018	The results of a modelling exercise undertaken by BirdLife South Africa to identify critical breeding habitat for three key forest – dwelling Red Data species.
Bearded Vulture nest sites in KwaZulu – Natal	Maloti-Drakensberg Vulture Project, Dr. Sonja Krűger, Ezemvelo KZN Wildlife, 2013.	The results of nest surveys conducted from 2000 - 2012
Yellow-breasted Pipit core distribution mapping	BirdLife South Africa, 2018	Map of core distribution/breeding areas based on the modelling of key aspects of the species' biology.
Rudd's Lark core distribution mapping	BirdLife South Africa, 2018	Map of core distribution/breeding areas based on the modelling of key aspects of the species' biology.
Botha's Lark core distribution mapping	BirdLife South Africa, 2018	Map of core distribution/breeding areas based on the modelling of key aspects of the species' biology.
White-winged Flufftail confirmed sightings 2000 – 2014	BirdLife South Africa, 2018	A list of wetlands where this critically endangered species has been recorded in South Africa which includes the locality where the first breeding for the region has recently been confirmed.
Red Data nest localities in the Western Cape	CapeNature, 2018	A list of nest localities of Black Harrier, Blue Crane, Verreaux's Eagle.

3.3 Assumptions and limitations

3.3.1 Assumptions

- It is assumed that the data layers used are reasonably accurate. Field verification will have to take place on a site by site basis linked to development proposals.
- Important Bird Areas were automatically classified as High Sensitivity, on the basis that those areas have already gone through an extensive rating process by BirdLife South Africa before being designated Important Bird Area status.
- Sections of Protected Areas overlapping with an Important Bird Area were automatically elevated to a Very High sensitive level, on the assumption that those areas are likely to be of crucial importance to avifauna.
- Note that although compressor/pump stations are not part of the Scope of Work of this SEA, they have been included in this assessment for completeness.

3.3.2 Limitations

- Due to the relatively coarse resolution of a QDGC (25 x 27.4km) sometimes species were recorded within a QDGC which contains more than one biome, e.g. in the Corridor Phase 1, Southern Black Korhaan was recorded in some of the QDGCs which contains both Forest (where it is unlikely to occur) and Fynbos (where it will most likely occur). In such an instance professional judgment was used to assess the potential for a species to occur in a given habitat class and it was taken into account in the risk rating process.

- Only existing published and unpublished datasets used with limited desktop verification.
- Some avifaunal specialists did not respond to data requests.
- The recommendations put forward here should be seen as generic and not replacing the project-specific recommendations which will be generated for an individual project that requires a form of Environmental Authorisation level of assessment.
- Due to the wide scope of the assessment, it is not possible to determine limits of acceptable change with a great deal of accuracy for each species in each corridor phase. For that, accurate data on population figures is required, as well as comprehensive data on the biology of each species, in order to model the effect of the envisaged impacts on the population. Information on that level is lacking for the majority of the species. Modelling impact at population level is a complicated process which falls outside the scope of this project.

3.4 Relevant Regulations and Legislation

Below is a detailed list and description of relevant regulatory instruments associated with the field of expertise at international, national scale, as well as provincial scale (Table 2).

Table 2: International, national and provincial regulatory instruments relevant to avifauna.

Instrument	Key objective
International Instruments	
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.
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	Aims to conserve terrestrial, marine and avian migratory species throughout their range.
The Agreement on the Conservation of African- Eurasian Migratory Waterbirds, or African- Eurasian Waterbird Agreement (AEWA)	Intergovernmental treaty dedicated to the conservation of migratory waterbirds and their habitats across Africa, Europe, the Middle East, Central Asia, Greenland and the Canadian Archipelago.
International Finance Corporation (IFC) Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	To protect and conserve biodiversity. To maintain the benefits from ecosystem services. To promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities.
Convention on Biological Diversity (1993) including the CBD's Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets	The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.
National Instruments	
National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)	The National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) provides for listing threatened or protected ecosystems, in one of four categories: critically endangered (CR), endangered (EN), vulnerable (VU) or protected. Activity 12 in Listing Notice 3 (Government Notice R324 of 7 April 2017) relates to clearance of 300 m^2 or more of vegetation within any critically endangered or endangered ecosystem listed in terms of section 52 of the NEMBA or prior to the publication of such a list, within an area that has been identified as critically endangered in the National Spatial Biodiversity Assessment 2004
National Environmental Management: Protected Areas Act, 2003. (Act 57 of 2003)	To provide for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes; for the establishment of a national register of all national, provincial and local protected areas; for the management of those areas in

Instrument	Key objective
	accordance with national norms and standards; for intergovernmental co-operation and public consultation in matters concerning protected areas; and for matters in connection therewith.
National Environmental Management Act,1998 (Act 107 of 1998), as amended	Promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.
Environment Conservation Act, 1989 (Act 73 of 1989)	To provide for the effective protection and controlled utilization of the environment and for matters incidental thereto.
National Water Act, 1998 (Act 36 of 1998)	Part 3, The Reserve: The ecological reserve relates to the water required to protect the aquatic ecosystems of the water resource.
Provincial Instruments	
KwaZulu Nature Conservation Act, 1992 (Act 29 of 1992) still in force	Provides for the protection of fauna and flora in those areas that formed part of the former KwaZulu.
Natal Nature Conservation Ordinance 15 of 1974 (still in force)	Provides for the protection of fauna and flora in those areas that form part of the former Natal province.
Western Cape Nature Conservation Board Act, 1998 (Act 15 of 1998)	To provide for the establishment, powers, functions and funding of the Western Cape Nature Conservation Board and the establishment, funding a control of a Western Cape Nature Conservation Fund, and to provide for matters incidental thereto. The object of the board shall be, (a) promote and ensure nature conservation and related matter in the Province.
Western Cape Nature Conservation Laws Amendment Act, 2000. (Act 3 of 2000)	To provide for the amendment of various laws on nature conservation in order to transfer the administration of the provisions of those laws to the Western Cape Nature Conservation Board; to amend the Western Cape Nature Conservation Board Act, 1998 to provide for a new definition of Department and the deletion of a definition; to provide for an increase in the number of members of the Board; to provide for additional powers of the Board; to amend the provisions regarding the appointment and secondment of persons to the Board; and to provide for matters incidental thereto.
Northern Cape Nature Conservation Act, 2009 (Act 10 of 2009).	To provide for the sustainable utilization of wild animals, aquatic biota and plants: to provide for the implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora; to provide for offences and penalties for contravention of the Act: to provide for the issuing of permits and other authorisations: and provide for the matter connected therewith.
Bophuthatswana Nature Conservation Act, 1973 (Act 3 of 1973; still in force)	To provide for the protection of game and fish, the conservation of flora and fauna and the destruction of vermin in the former Bophuthatswana.
Free State Nature Conservation Ordinance, 1969 (Act 8 of 1969)	To provide for the conservation of fauna and flora and the hunting of animals causing damage and for matters incidental thereto.
Ciskei Nature Conservation, 1987 (Act 10 of 1987, still in force)	To consolidate and amend the laws relating to the conservation, management and protection of fauna, flora, fish and the habitats generally, to provide for the establishment and management of nature reserves, hiking trails, water catchment areas and a coastal conservation area, to provide for matter relating to the sea and the seashore and the provide for the incidental matters.
Transvaal Nature Conservation Ordinance No 12 of 1983 as amended (still in force)	Provides for the protection of fauna and flora in the North-West and Gauteng Provinces (former Transvaal Province).
Mpumalanga Nature Conservation Act Of 1998	Provides for the protection of fauna and flora in the Mpumalanga Province.
Cape Nature Conservation Ordinance, No. 19 of 1974 (still in force)	Provides for the protection of fauna and flora in parts of the North-West Province and the Eastern Cape (former Cape Province).

4 KEY ENVIRONMENTAL ATTRIBUTES AND SENSITIVITIES OF THE CORRIDOR PHASES

4.1 Description of corridor phases

The point of departure was the delineation of a corridor phase according to the biomes that are contained in the phase and then extracting the Red Data species recorded by SABAP 2 within that biome[2]. It is generally accepted that vegetation structure, rather than the actual plant species, influences bird species distribution and abundance (Harrison et al., 1997). The description of the biomes largely follows the classification system used in the Atlas of Southern African Birds (SABAP1)) (Harrison et al. 1997) supplemented with material from Mucina and Rutherford (2006). The criteria used by the SABAP1 authors to amalgamate botanically defined vegetation units, or to keep them separate were: (1) the existence of clear differences in vegetation structure, likely to be relevant to birds; and (2) the results of published community studies on bird/vegetation associations.

The biome descriptions used in this report are as follows:

- Fynbos: Fynbos is dominated by low shrubs and has two major vegetation divisions: fynbos proper characterised by restioid, ericoid and proteoid components; and renosterveld, dominated by *Asteraceae*, specifically Renosterbos *Elytropappus rhinocerotis*, with geophytes and some grasses.
- Succulent Karoo: The Succulent Karoo falls within the winter rain-fall region in the far west, and is characterised by succulent shrubs, particularly *Mesembryanthemaceae* and a particular paucity of grass cover and trees, except in the Little Karoo of the Western Cape Province, where tree cover is relatively well developed.
- Nama Karoo: The Nama Karoo vegetation largely comprises low shrubs and grasses; peak rainfall occurs in summer. Trees, e.g. *Vachellia karoo* and aline species such as Mesquite *Prosopis glandulosa* are mainly restricted to water courses where fairly luxuriant stands can develop especially in the Eastern Cape Province. In comparison to the Succulent Karoo, the Nama Karoo has a higher proportion of grass and tree cover.
- Savanna: Savanna is defined here as having a grassy understorey and a distinct woody upper storey of trees and tall shrubs. Tree cover can range from sparse to almost closed-canopy cover. The relatively arid fine-leaved, typically *Vachellia*-dominated woodland types typically occur in the drier western regions, while the mesic, pre-dominantly broadleaved woodlands typically occur in the more mesic eastern regions.
- Grassland: The dominant vegetation comprises grasses, with geophytes and herbs also well-represented. These grasslands are maintained largely by a combination of relatively high summer rainfall, frequent fires, frost and grazing, which preclude the presence of shrubs and trees. Sweet grasslands are found in lower rainfall areas, are taller and less dense, have a lower fibre content and retain nutrients in the leaves during winter. Sour grasslands occur in higher rainfall regions and are characterized by being shorter and denser in structure, having a high fibre content and a tendency to withdraw nutrients to the roots during winter.
- Desert: The dominant vegetation comprises grassland dominated by “white grasses”, some spinescent (*Stipograstis* species) on flats with additional shrubs and herbs in the drainage lines or on more gravelly or loamy soil next to mountains. Hills and mountains are dominated by bare outcrops with very sparse shrubby vegetation in crevices, sometimes with localised grassland areas.
- Albany Thicket: The vegetation of this biome comprises dense, woody, semi-succulent and thorny vegetation of an average height of 2-3m, relatively impenetrable with a poorly developed grass cover. There is a wide range of growth forms and a high diversity of plant species which is a

[2] It should be noted that due to the relatively coarse resolution of a QDGC (25 x 27.4km) sometimes species were recorded within a QDGC which contains more than one biome, e.g. in the Corridor Phase 1, Southern Black Korhaan was recorded in some of the QDGCs which contains both Forest (where it is unlikely to occur) and Fynbos (where it will most likely occur). In such an instance professional judgment was used to assess the potential for a species to occur in a given habitat class, and it was taken into account in the risk rating process.

reflection of the transitional nature of thicket vegetation, being an interface between the various types of forest, shrublands, karoo and grasslands.

- Indian Ocean Coastal Belt/East Coast Littoral: This is a mosaic of coastal forest, sand forest, coastal thicket, coastal grasslands and mangroves. It is typically moist and tropical to sub-tropical.
- Azonal vegetation: This refers to distinctive vegetation types not restricted to a specific biome but occurring across several biomes. In azonal vegetation special substrate (special soil types or bedrocks) and/or hydrogeological conditions (waterlogging, flooding, tidal influence) exert an overriding influence on floristic composition, structure and dynamics over macroclimate. Azonal vegetation are mostly found in freshwater wetlands, alluvial zones, salt pans, estuaries, seashores, and dunes.

Figure 1 provides an overview of the various biomes within South Africa, as well as the proposed gas pipeline corridors.

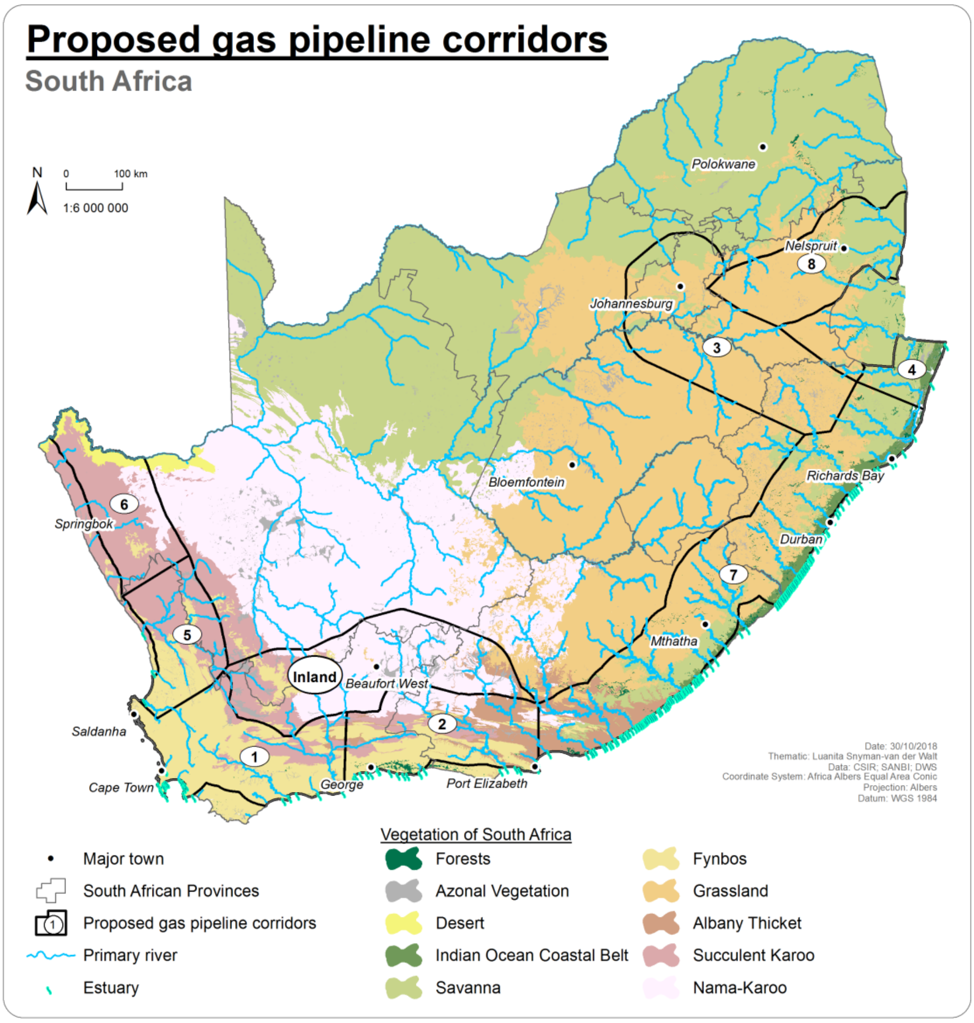

Figure 1: Overview of the Biomes within South Africa and the Proposed Gas Pipeline Corridors

Table 3: Environmental description of the proposed gas pipeline corridors.

Corridor Phase	Brief description
Inland	*The Inland corridor phase contains five biomes, as well as Azonal vegetation. These are:* • *Fynbos* • *Succulent Karoo* • *Nama Karoo* • *Albany Thicket* • *Grassland* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 133 QDGCs. Biomes where the species is most likely to be encountered is listed below.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Species	Status	Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Grassland	Azonal
African Finfoot	VU						x
African Marsh-Harrier	EN	x				x	x
African Rock Pipit	NT	x	x	x		x	
Black Harrier	EN	x	x	x		x	
Black Stork	VU		x	x			x
Blue Crane	NT	x	x	x		x	x
Caspian Tern	VU						x
European Roller	NT				x	x	
Greater Flamingo	NT	x	x	x			x
Karoo Korhaan	NT	x	x	x			
Knysna Woodpecker	NT				x		
Kori Bustard	NT		x	x		x	
Lanner Falcon	VU	x	x	x	x	x	x
Lesser Flamingo	NT	x	x	x			x
Ludwig's Bustard	EN	x	x	x		x	
Maccoa Duck	NT						x
Martial Eagle	EN		x	x	x	x	
Red-footed Falcon	NT			x		x	
Secretary bird	NT	x	x	x		x	
Southern Black Korhaan	VU	x	x				
Tawny Eagle	EN			x		x	
Verreaux's Eagle	VU	x	x	x			
Burchell's Courser	VU		x	x		x	x
Cape Rock-jumper	NT	x					
Denham's Bustard	VU					x	
Marabou Stork	NT	Vagrant					
Protea Seedeater	NT	x					
Sclater's Lark	NT		x	x			
Yellow-billed Stork	EN						x
Abdim's Stork	NT					x	
Half-collared Kingfisher	NT						x

Corridor Phase	Brief description

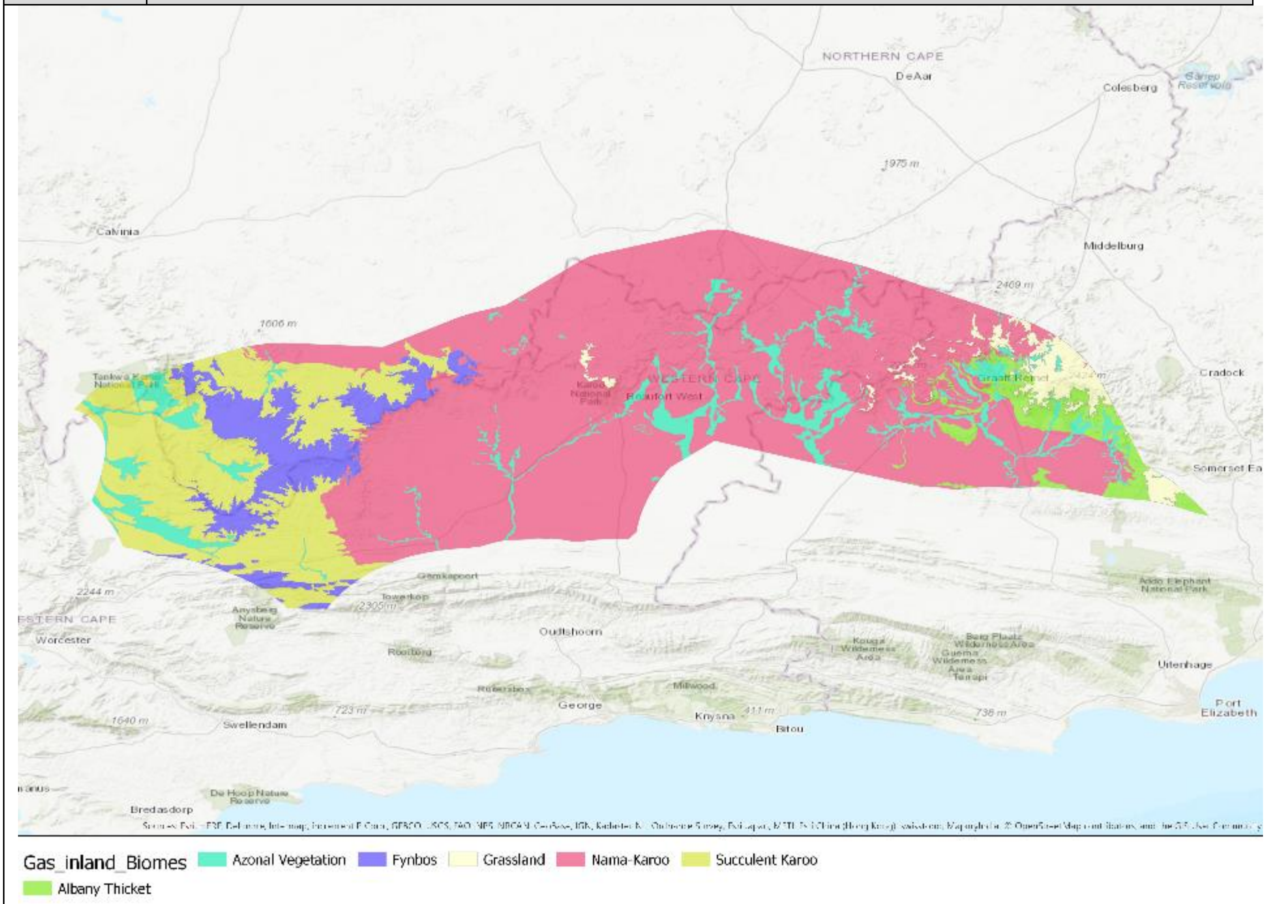

Figure 2: Biomes of the Inland Phase Corridor.

Corridor Phase	Brief description
Phase 1	*Corridor Phase 1 contains five biomes, as well as Azonal vegetation. These are:* • *Albany Thicket* • *Forests* • *Fynbos* • *Nama-Karoo* • *Succulent Karoo.* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 105 QDGCs. Biomes where the species is most likely to be encountered is listed below.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Species	Status	Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Forest	Azonal
African Marsh-Harrier	EN	x					x
Agulhas Long-billed Lark	NT	x					
Black Harrier	EN	x	x	x			
Black Stork	VU	x	x	x			x

Corridor Phase	Brief description							
	Blue Crane	NT	x	x				x
	Caspian Tern	VU						x
	European Roller	NT	x			x		
	Greater Flamingo	NT	x	x	x			x
	Karoo Korhaan	NT	x	x	x			
	Knysna Woodpecker	NT				x	x	
	Kori Bustard	NT		x	x			
	Lanner Falcon	VU	x	x	x	x	x	x
	Lesser Flamingo	NT	x	x	x			x
	Ludwig's Bustard	EN	x	x	x			
	Maccoa Duck	NT						x
	Martial Eagle	EN	x	x	x	x		
	Red-footed Falcon	NT						
	Secretarybird	NT	x	x	x			
	Southern Black Korhaan	VU	x	x				
	Tawny Eagle	EN						
	Verreaux's Eagle	VU	x	x	x			
	Burchell's Courser	VU						
	Cape Rock-jumper	NT	x					
	Denham's Bustard	VU	x					
	Marabou Stork	NT	Vagrant					
	Protea Seedeater	NT	x					
	Sclater's Lark	NT						
	Yellow-billed Stork	EN						
	Abdim's Stork	NT						
	Half-collared Kingfisher	NT						x
	African Rock Pipit	NT	x	x	x			
	Eurasian Curlew	NT						x
	Greater Painted-snipe	NT						x
	Hottentot Buttonquail	EN	x					
	Knysna Warbler	VU				x	x	
	Striped Flufftail	VU	x					
	African Crowned Eagle	VU					x	
	Burchell's Courser	VU		x	x			x
	Cape Vulture	EN	x					
	Chestnut-banded Plover	NT						x
	Damara Tern	CR						x
	Great White Pelican	VU						x
	Black-winged Pratincole	NT	Vagrant					

Corridor Phase	Brief description

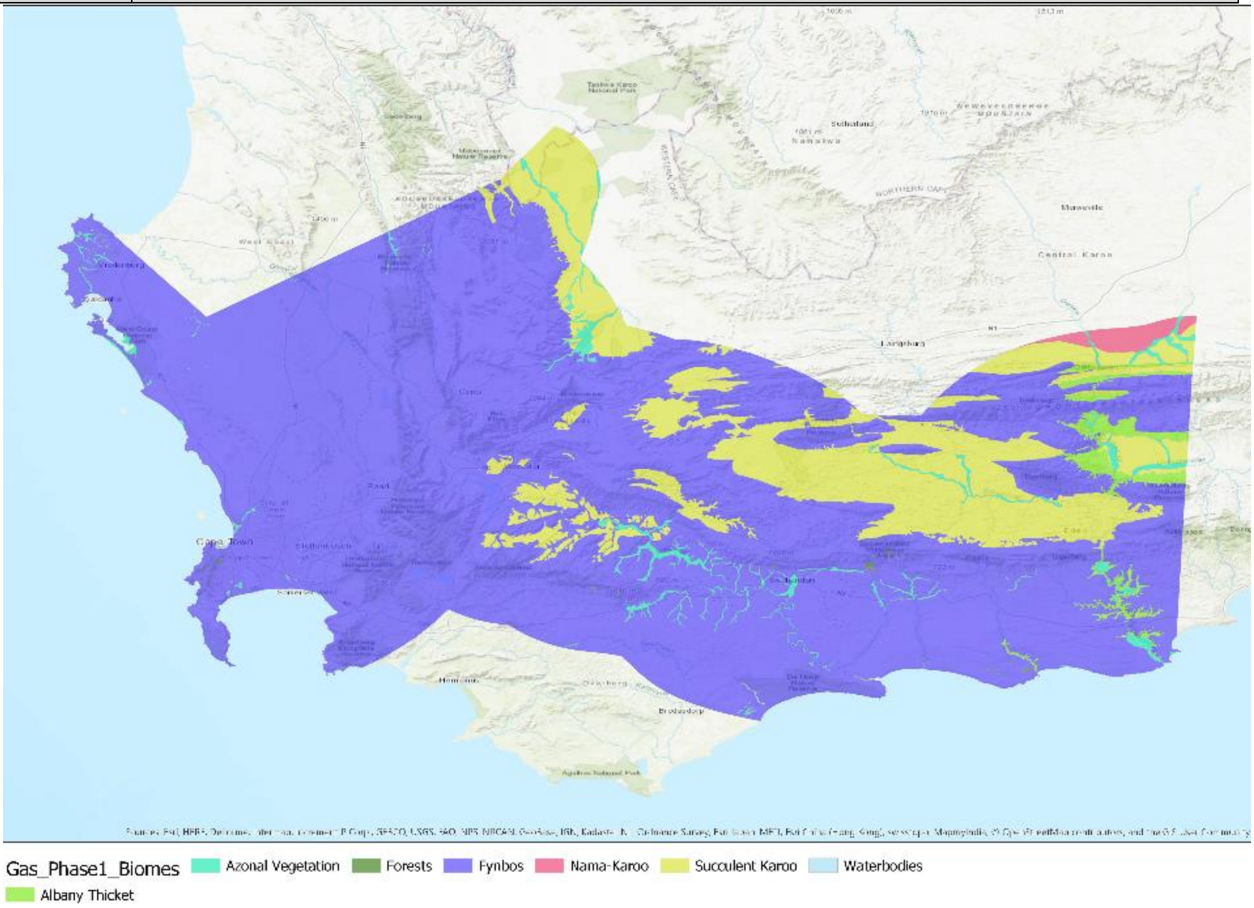

Figure 3: Biomes of the Phase 1 Corridor.

Corridor Phase	Brief description
Phase 2	*Corridor Phase 2 contains six biomes, as well as Azonal vegetation. These are:* • *Albany Thicket* • *Forests* • *Fynbos* • *Grassland* • *Nama-Karoo* • *Succulent Karoo* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 88 QDGCs.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Corridor Phase	Brief description

Species	Status	Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Grassland	Forest	Azonal
African Marsh-Harrier	EN	x				x		x
Agulhas Long-billed Lark	NT	x						
Black Harrier	EN	x	x	x		x		
Black Stork	VU	x	x	x	x			x
Blue Crane	NT	x	x	x		x		x
Caspian Tern	VU							x
European Roller	NT	x			x			
Greater Flamingo	NT	x	x	x				x
Karoo Korhaan	NT	x	x	x				
Knysna Woodpecker	NT				x		x	
Kori Bustard	NT		x	x		x		
Lanner Falcon	VU	x	x	x	x	x	x	x
Lesser Flamingo	NT	x	x	x				x
Ludwig's Bustard	EN		x	x				
Maccoa Duck	NT							x
Martial Eagle	EN	x	x	x	x	x		
Red-footed Falcon	NT			x		x		
Secretary bird	NT	x	x	x		x		
Southern Black Korhaan	VU	x	x					
Verreaux's Eagle	VU	x	x	x				
Cape Rock-jumper	NT	x						
Denham's Bustard	VU	x				x		
Protea Seedeater	NT	x						
Sclater's Lark	NT		x	x				
Half-collared Kingfisher	NT							x
African Rock Pipit	NT	x	x	x	x			
Eurasian Curlew	NT							x
Greater Painted-snipe	NT							x
Hottentot Buttonquail	EN	x						
Knysna Warbler	VU				x		x	
Striped Flufftail	VU	x						
African Crowned Eagle	VU						x	
Burchell's Courser	VU		x	x				x
Cape Vulture	EN	x						
Chestnut-banded Plover	NT							x
Damara Tern	CR							x
Great White Pelican	VU							x
African Finfoot	VU							x
African Grass-Owl	VU	x				x		
Grey Crowned Crane	EN					x		x
Pallid Harrier	NT					x		
White-bellied Korhaan	VU	x				x		
Black-winged Pratincole	NT	Vagrant						

Corridor Phase	Brief description

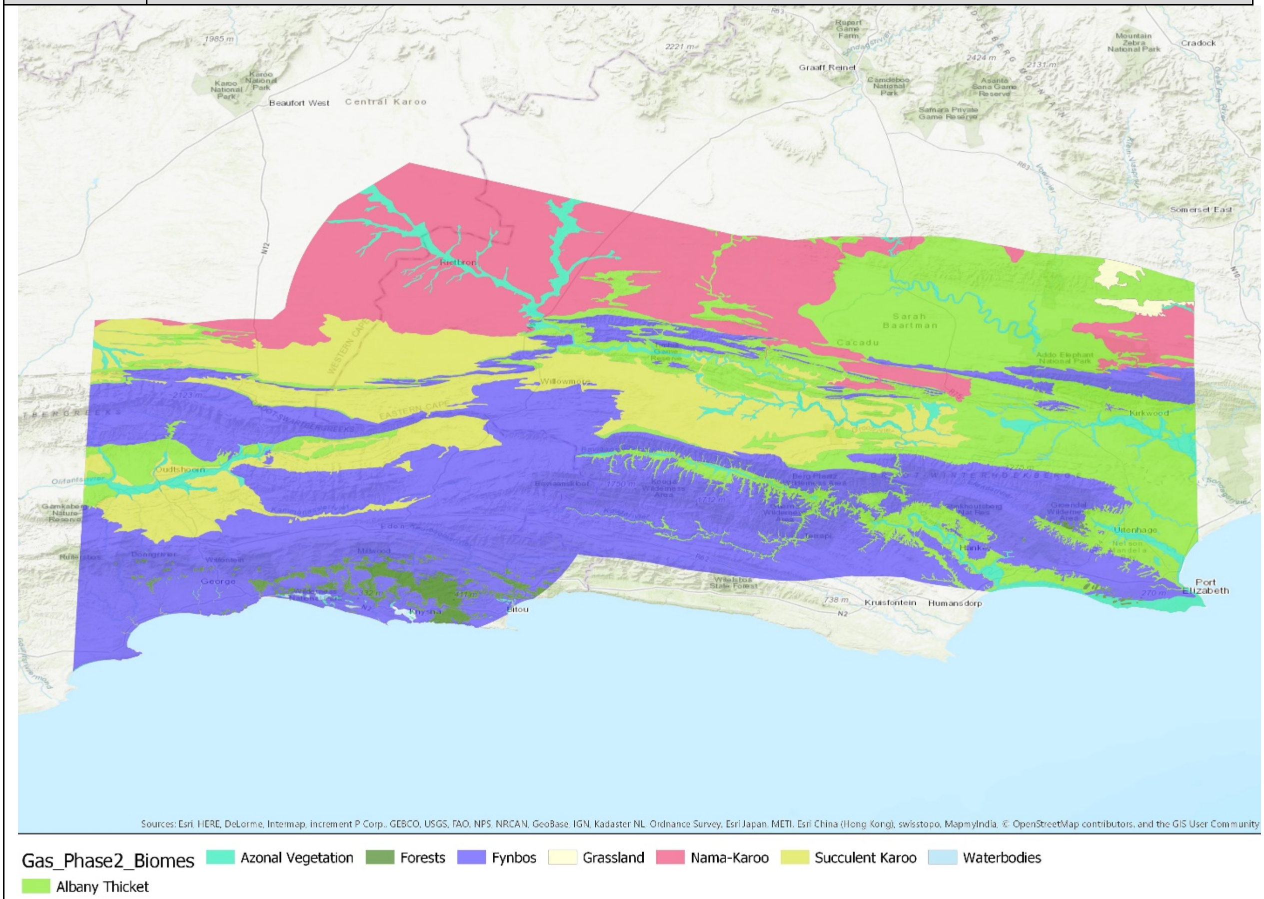

Figure 4: Biomes of the Phase 2 Corridor.

Corridor Phase	Brief description
Phase 3	*Corridor Phase 3 contains three biomes, as well as Azonal vegetation. These are:* • *Forests* • *Grassland* • *Savanna* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 136 QDGCs.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Species	Status	Savanna	Grassland	Forest	Azonal
African Marsh-Harrier	EN	x	x		x
Abdim's Stork	NT	x	x		x
Black Harrier	EN		x		
Black Stork	VU		x		x
Blue Crane	NT		x		x
Caspian Tern	VU				x

Corridor Phase	Brief description					
	European Roller	NT	x			
	Greater Flamingo	NT	x	x		x
	Black-rumped Buttonquail	VU		x		
	Black-winged Pratincole	NT	x	x		x
	Botha's Lark	EN		x		
	Lanner Falcon	VU	x	x	x	x
	Lesser Flamingo	NT	x	x		x
	Bush Blackcap	VU			x	
	Maccoa Duck	NT				x
	Martial Eagle	EN	x	x	x	x
	Red-footed Falcon	NT		x		
	Secretary bird	NT	x	x		
	Lappet-faced Vulture	EN	x			
	Verreaux's Eagle	VU	x	x		
	Marabou Stork	NT	x			x
	Denham's Bustard	VU		x		
	Orange Ground-Thrush	NT			x	
	Pink-backed Pelican	VU				x
	Half-collared Kingfisher	NT				x
	African Rock Pipit	NT	x	x		
	Eurasian Curlew	NT				x
	Greater Painted-snipe	NT				x
	Rudd's Lark	EN		x		
	Saddle-billed Stork	EN				x
	Short-tailed Pipit	VU		x		
	Southern Bald Ibis	VU		x		
	Burchell's Courser	VU		x		
	Cape Vulture	EN	x	x		
	Chestnut-banded Plover	NT				x
	Southern Ground-Hornbill	EN	x			
	Tawny Eagle	EN	x			
	Wattled Crane	CR		x		x
	African Grass-Owl	VU		x		x
	Grey Crowned Crane	EN		x		x
	Pallid Harrier	NT		x		
	White-bellied Korhaan	VU	x	x		
	White-backed Vulture	CR	x			
	Yellow-billed Stork	EN				x
	Yellow-breasted Pipit	VU		x		
	Eastern Bronze-naped Pigeon	EN			x	
	Yellow-throated Sandgrouse	NT	x	x		

Corridor Phase	Brief description

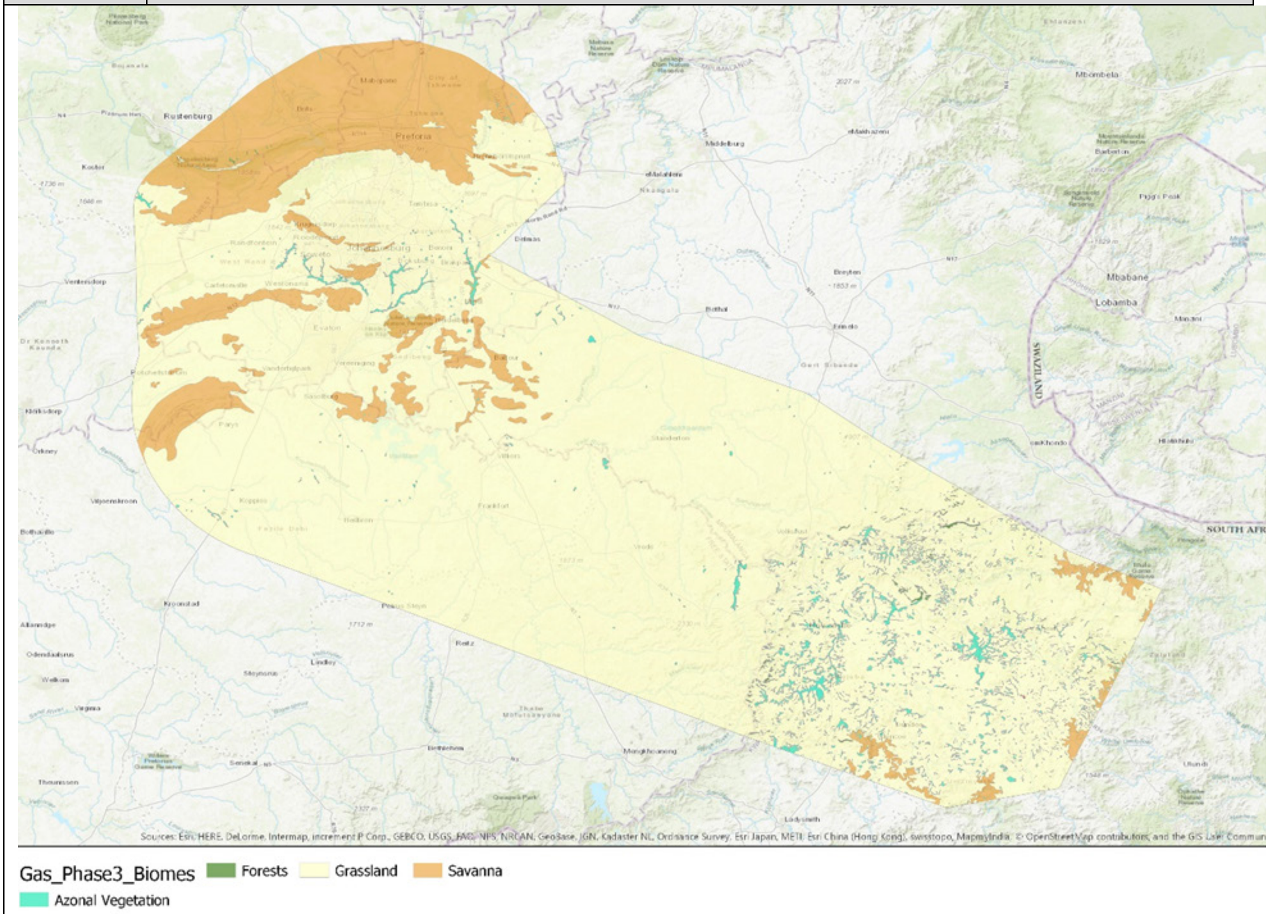

Figure 5: Biomes of the Phase 3 Corridor.

Corridor Phase	Brief description
Phase 4	*Corridor Phase 4 contains four biomes, as well as Azonal vegetation. These are* • *Forests* • *Grassland* • *Indian Ocean Coastal Belt* • *Savanna* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 26 QDGCs.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Species	Status	Savanna	Grassland	Forest	Indian Ocean Coastal Belt	Azonal
African Marsh-Harrier	EN	x	x		x	x
Abdim's Stork	NT		x			x
Black Harrier	EN		x			
Black Stork	VU	x	x		x	x
Blue Crane	NT		x		x	x
Caspian Tern	VU					x
European Roller	NT	x			x	
Greater Flamingo	NT				x	x
Black-rumped Buttonquail	VU	x			x	
Black-winged Pratincole	NT		x			
Botha's Lark	EN		x			
Lanner Falcon	VU	x	x	x	x	x
Lesser Flamingo	NT				x	x
Bush Blackcap	VU			x		
Maccoa Duck	NT					x
Martial Eagle	EN	x	x		x	
Red-footed Falcon	NT		x			
Secretary bird	NT	x	x			
Lappet-faced Vulture	EN	x				
Verreaux's Eagle	VU	x	x			
Marabou Stork	NT	x			x	x
Denham's Bustard	VU		x		x	
Orange Ground-Thrush	NT			x		
Pink-backed Pelican	VU					x
Half-collared Kingfisher	NT					x
African Rock Pipit	NT	x	x			
Eurasian Curlew	NT					x
Greater Painted-snipe	NT					x
Rudd's Lark	EN		x			
Saddle-billed Stork	EN					x
Short-tailed Pipit	VU		x			
Southern Bald Ibis	VU		x			
Burchell's Courser	VU		x			
Cape Vulture	EN	x				
Chestnut-banded Plover	NT					x
Southern Ground-Hornbill	EN	x			x	
Tawny Eagle	EN	x				
Wattled Crane	CR		x			x
African Grass-Owl	VU		x			x

Corridor Phase	Brief description

Grey Crowned Crane	EN		x		x	x
Pallid Harrier	NT		x		x	
White-bellied Korhaan	VU	x	x		x	
White-backed Vulture	CR	x				
Yellow-billed Stork	EN					x
Yellow-breasted Pipit	VU		x			
Eastern Bronze-naped Pigeon	EN			x		
African Broadbill	VU			x		
African Crowned Eagle	VU			x		
African Finfoot	VU					x
African Pygmy-Goose	VU					x
Bateleur	EN	x				
Great White Pelican	VU					x
Hooded Vulture	CR	x				
Lemon-breasted Canary	NT				x	
Lesser Jacana	VU					x
Mangrove Kingfisher	EN				x	
Neergaard's Sunbird	VU				x	
Pel's Fishing-Owl	EN					x
Rosy-throated Longclaw	NT				x	
Southern Banded Snake-Eagle	CR				x	
Swamp Nightjar	VU				x	
White-headed Vulture	CR	x				

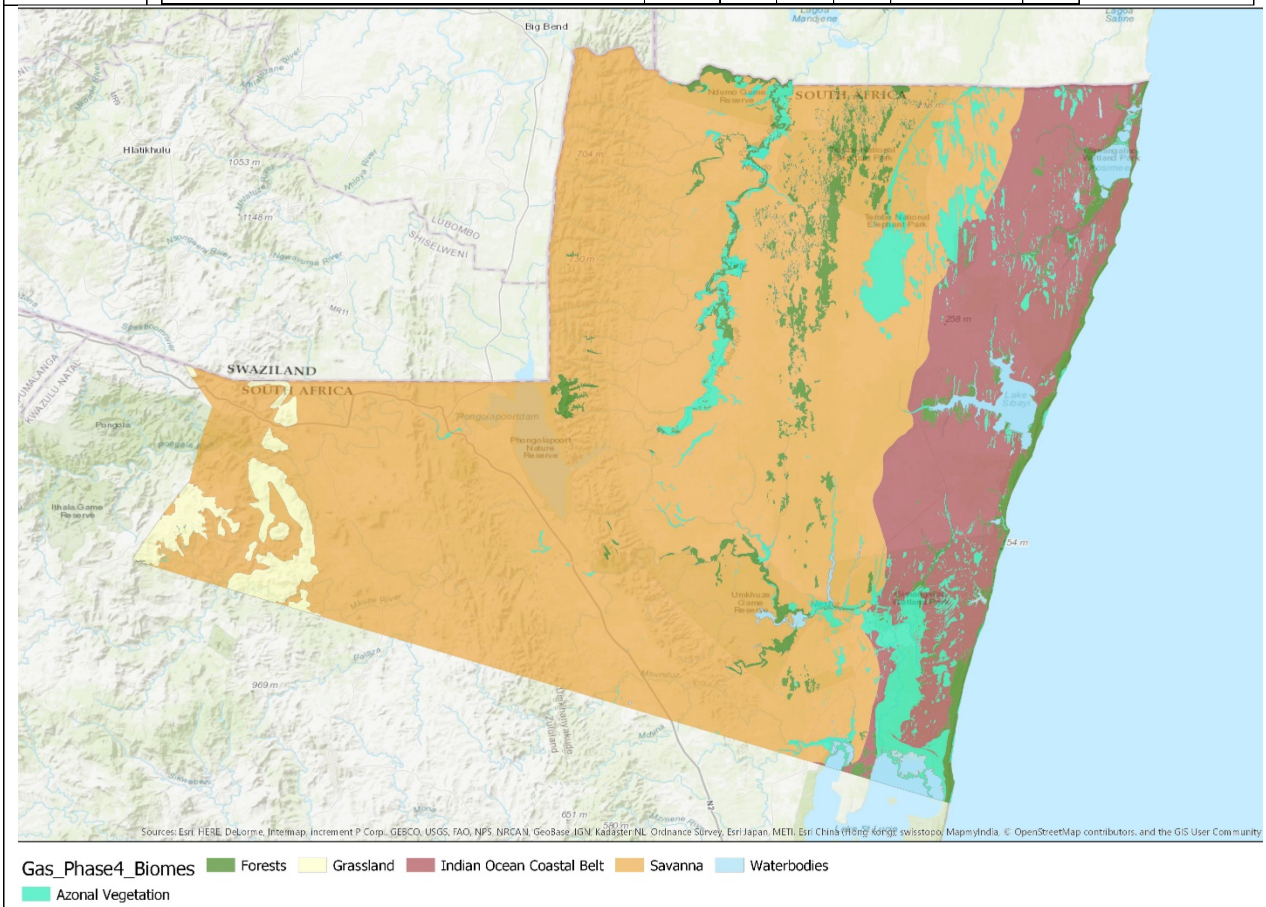

Figure 6: Biomes of the Phase 4 Corridor.

Corridor Phase	Brief description
Phase 5	*Corridor Phase 5 contains 2 biomes, as well as Azonal vegetation. These are* • *Fynbos* • *Succulent Karoo* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 66 QDGCs.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Species	Status	Fynbos	Succulent Karoo	Azonal
African Marsh-Harrier	EN	x		x
Black Harrier	EN	x	x	
Black Stork	VU	x	x	x
Blue Crane	NT	x	x	x
Caspian Tern	VU			x
European Roller	NT	x		
Greater Flamingo	NT	x	x	x
Karoo Korhaan	NT	x	x	
Lanner Falcon	VU	x	x	x
Lesser Flamingo	NT	x	x	x
Ludwig's Bustard	EN	x	x	
Maccoa Duck	NT			x
Martial Eagle	EN	x	x	
Secretary bird	NT	x	x	
Southern Black Korhaan	VU	x	x	
Verreaux's Eagle	VU	x	x	
Burchell's Courser	VU		x	x
Cape Rock-jumper	NT	x		
Protea Seedeater	NT	x		
Yellow-billed Stork	EN			x
Eurasian Curlew	NT			x
Burchell's Courser	VU		x	x
Chestnut-banded Plover	NT			x
Great White Pelican	VU			x
Red Lark	VU		x	

Corridor Phase	Brief description

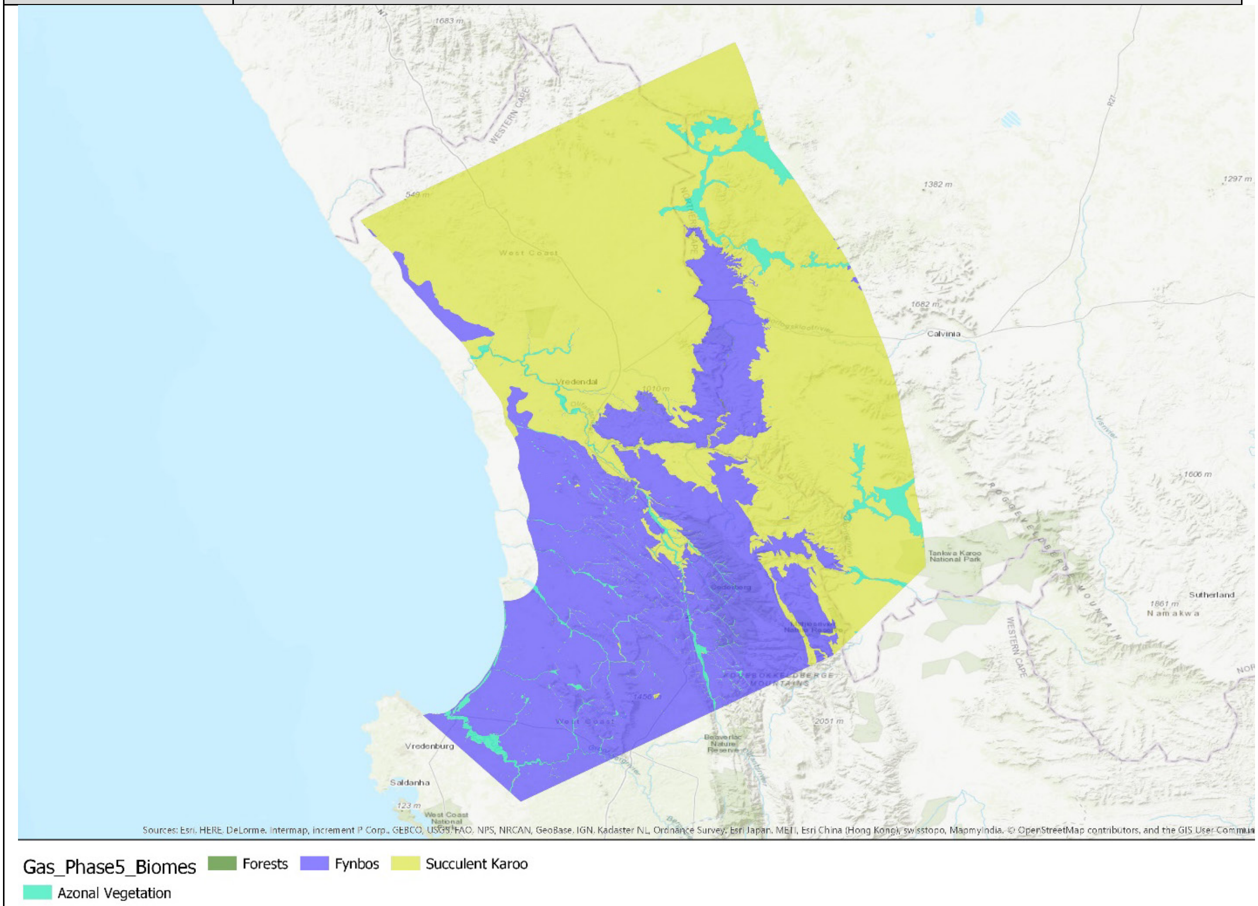

Figure 7: Biomes of the Phase 5 Corridor.

<table>
<tr><th>Corridor Phase</th><th>Brief description</th></tr>
<tr><td>Phase 6</td><td>
Corridor Phase 6 contains 4 biomes, as well as Azonal vegetation. These are

Desert
Fynbos
Nama-Karoo
Succulent Karoo

The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 71 QDGCs.

NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered

<table>
<tr><th>Species</th><th>Status</th><th>Fynbos</th><th>Succulent Karoo</th><th>Nama Karoo</th><th>Desert</th><th>Azonal</th></tr>
<tr><td>African Marsh-Harrier</td><td>EN</td><td>x</td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>Black Harrier</td><td>EN</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>Black Stork</td><td>VU</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Blue Crane</td><td>NT</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>Caspian Tern</td><td>VU</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>Greater Flamingo</td><td>NT</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Karoo Korhaan</td><td>NT</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>Lanner Falcon</td><td>VU</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Lesser Flamingo</td><td>NT</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Ludwig's Bustard</td><td>EN</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>Maccoa Duck</td><td>NT</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>Martial Eagle</td><td>EN</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>Secretarybird</td><td>NT</td><td>x</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>Southern Black Korhaan</td><td>VU</td><td>x</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Verreaux's Eagle</td><td>VU</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>Burchell's Courser</td><td>VU</td><td></td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Chestnut-banded Plover</td><td>NT</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>Great White Pelican</td><td>VU</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>Red Lark</td><td>VU</td><td></td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>Barlow's Lark</td><td>VU</td><td></td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>Kori Bustard</td><td>NT</td><td></td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Sclater's Lark</td><td>NT</td><td></td><td>x</td><td></td><td></td><td></td></tr>
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Corridor Phase	Brief description

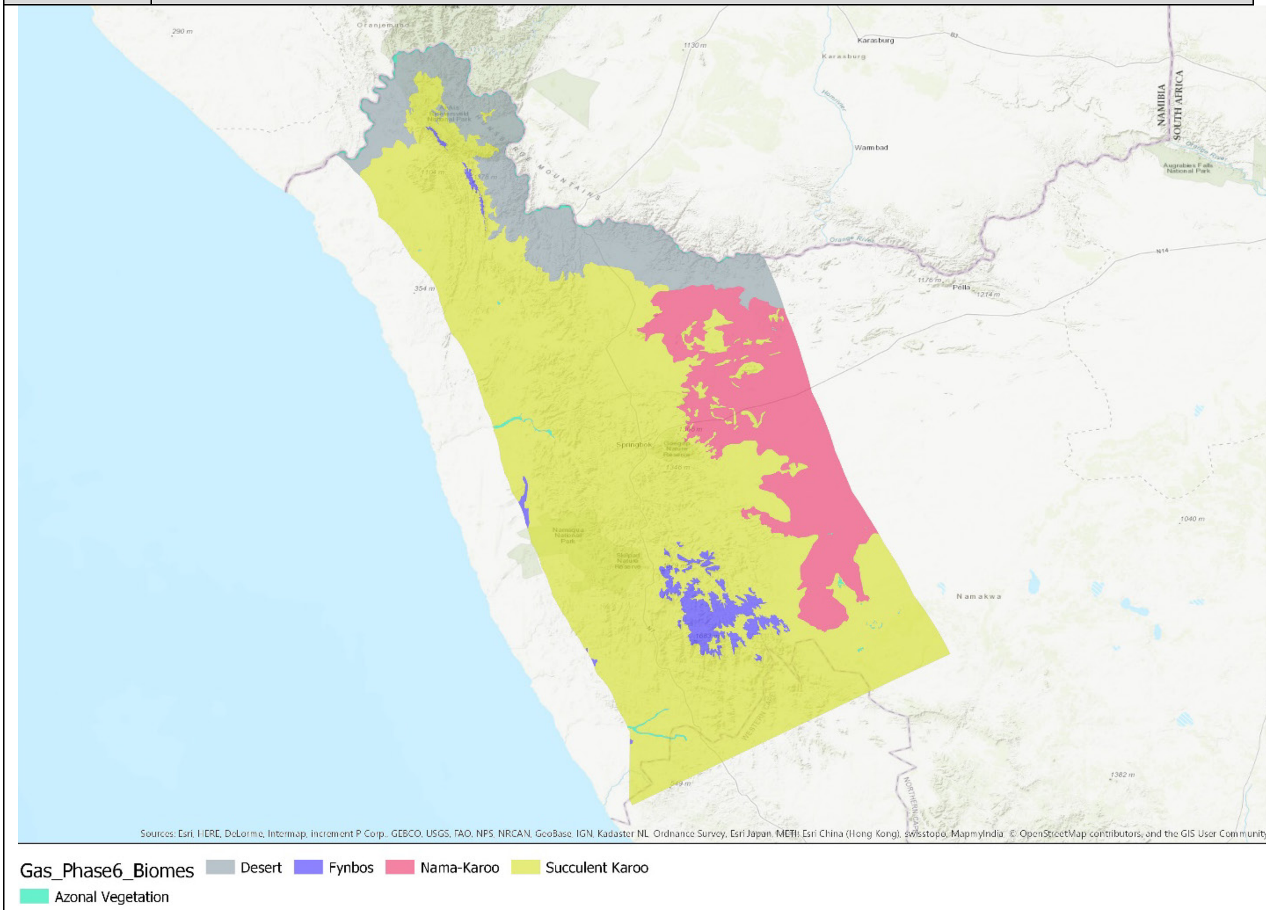

Figure 8: Biomes of the Phase 6 Corridor.

Corridor Phase	Brief description
Phase 7	*Corridor Phase 7 contains 7 biomes, as well as Azonal vegetation. These are:*

- *Albany Thicket*
- *Forests*
- *Fynbos*
- *Grassland*
- *Indian Ocean Coastal Belt*
- *Nama-Karoo*
- *Savanna*

The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 220 QDGCs.:

NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered

Species	Status	Albany Thicket	Savanna	Grassland	Nama Karoo	Forest	Indian Ocean Coastal Belt	Fynbos	Azonal
Cape Parrot	EN					x			
Abdim's Stork	NT		x	x					x
Black Harrier	EN			x	x			x	
Black Stork	VU		x	x	x		x	x	x
Blue Crane	NT			x	x		x	x	x
Caspian Tern	VU								x
European Roller	NT		x				x		
Greater Flamingo	NT				x		x		x
Black-rumped Buttonquail	VU		x	x			x		
Damara Tern	CR								x
Karoo Korhaan	NT				x			x	
Lanner Falcon	VU	x	x	x	x		x	x	x
Lesser Flamingo	NT				x		x		x
Bush Blackcap	VU					x			
Maccoa Duck	NT								x
Martial Eagle	EN	x	x	x	x		x	x	
Red-footed Falcon	NT			x	x				
Secretary bird	NT		x	x	x		x	x	
Lappet-faced Vulture	EN		x						
Verreaux's Eagle	VU		x	x	x			x	
Marabou Stork	NT		x						x
Denham's Bustard	VU		x	x			x		
Orange Ground-Thrush	NT					x			
Pink-backed Pelican	VU						x		x
Half-collared Kingfisher	NT								x
African Rock Pipit	NT				x				
Eurasian Curlew	NT								x
Greater Painted-snipe	NT								x
Knysna Warbler	VU	x				x			
Saddle-billed Stork	EN								x
Short-tailed Pipit	VU			x					
Southern Bald Ibis	VU			x					
Burchell's Courser	VU				x				x
Cape Vulture	EN		x	x					
Chestnut-banded Plover	NT								x
Southern Ground-Hornbill	EN		x						

Corridor Phase	Brief description									
	Tawny Eagle	EN		x						
	Wattled Crane	CR			x					x
	African Grass-Owl	VU			x			x		
	Grey Crowned Crane	EN			x			x		x
	Pallid Harrier	NT			x					
	White-bellied Korhaan	VU		x	x				x	
	White-backed Vulture	CR		x						
	Yellow-billed Stork	EN								x
	Yellow-breasted Pipit	VU			x					
	Eastern Bronze-naped Pigeon	EN					x			
	Knysna Woodpecker	NT	x				x			
	African Crowned Eagle	VU					x			
	African Finfoot	VU								x
	African Pygmy-Goose	VU								x
	Bateleur	EN		x						
	Great White Pelican	VU								x
	Kori Bustard	NT		x		x				
	Lemon-breasted Canary	NT						x		
	Lesser Jacana	VU								x
	Mangrove Kingfisher	EN						x		x
	Neergaard's Sunbird	VU						x		
	Ludwig's Bustard	EN				x				
	Rosy-throated Longclaw	NT						x		
	Southern Banded Snake-Eagle	CR						x		
	Swamp Nightjar	VU						x		
	White-headed Vulture	CR		x						
	Southern Black Korhaan	VU							x	
	Striped Flufftail	VU			x					
	White-backed Night-Heron	VU								x
	African Broadbill	VU					x			
	Bat Hawk	EN		x						
	Bearded Vulture	CR			x					
	Blue Swallow	CR			x					
	Green Barbet	EN					x			
	Mountain Pipit	NT			x					
	Spotted Ground-Thrush	EN					x			
	White-headed Vulture	CR		x						

Corridor Phase	Brief description

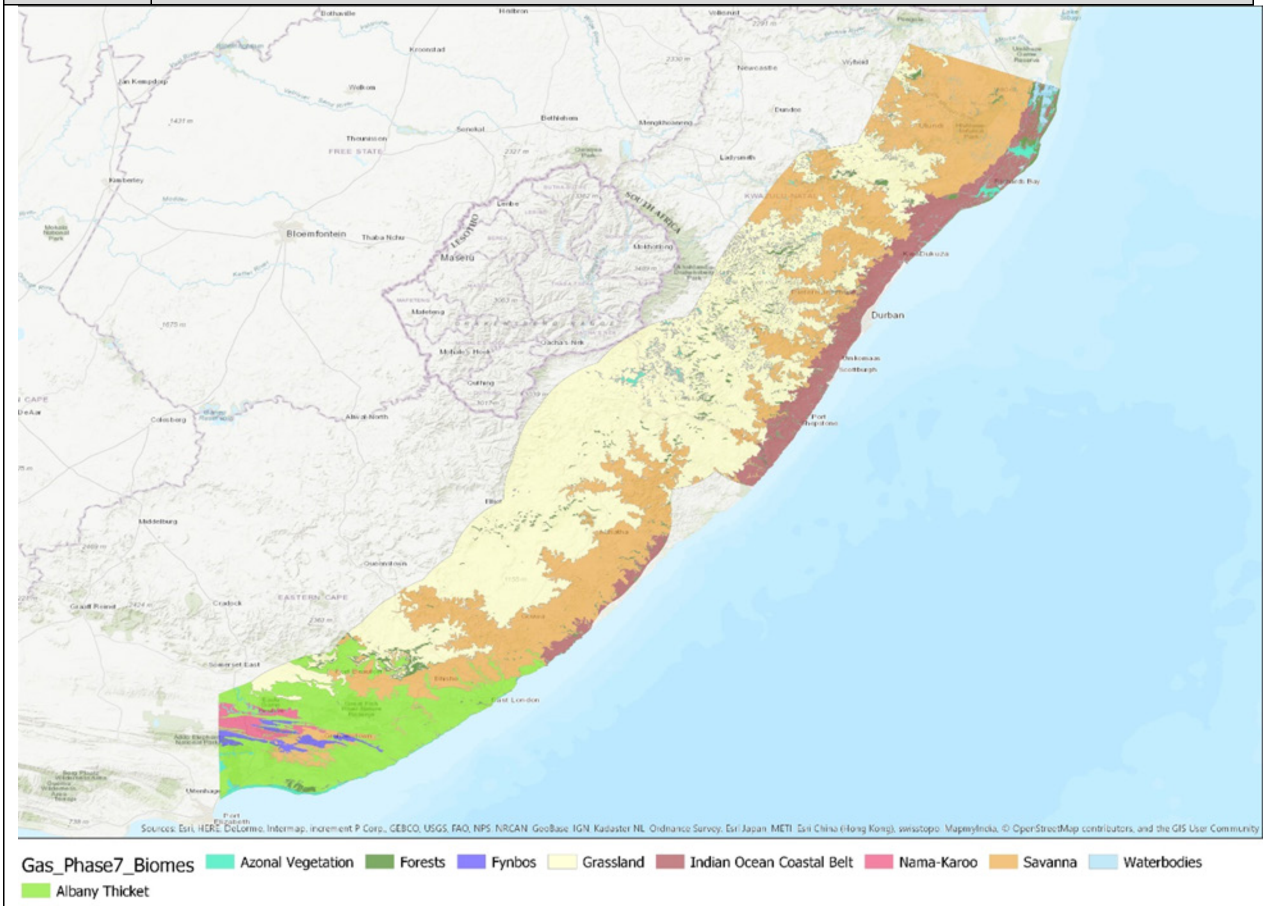

Figure 9: Biomes of the Phase 7 Corridor.

Corridor Phase	Brief description
Phase 8	*Corridor Phase 8 contains 3 biomes, as well as Azonal vegetation. These are:* • *Forests* • *Grassland* • *Savanna* *The following Red Data species were identified and rated for potential impacts in each biome, extracted from a total of 80 QDGCs.* *NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered*

Species	Status	Savanna	Grassland	Forest	Azonal
Abdim's Stork	NT	x	x		x
Black Harrier	EN		x		
Black Stork	VU	x	x		x
Blue Crane	NT		x		x
Caspian Tern	VU				x
European Roller	NT	x			
Greater Flamingo	NT		x		x
Black-rumped Buttonquail	VU	x	x		
Lanner Falcon	VU	x	x		x
Lesser Flamingo	NT		x		x
Bush Blackcap	VU			x	
Maccoa Duck	NT				x
Martial Eagle	EN	x	x		
Red-footed Falcon	NT		x		
Secretary bird	NT	x	x		
Lappet-faced Vulture	EN	x			
Verreaux's Eagle	VU	x	x		
Marabou Stork	NT	x			x
Denham's Bustard	VU		x		
Orange Ground-Thrush	NT			x	
Pink-backed Pelican	VU				x
Half-collared Kingfisher	NT				x
Greater Painted-snipe	NT				x
Saddle-billed Stork	EN				x
Short-tailed Pipit	VU		x		
Southern Bald Ibis	VU		x		
Cape Vulture	EN	x	x		
Chestnut-banded Plover	NT				x
Southern Ground-Hornbill	EN	x			
Tawny Eagle	EN	x			
Wattled Crane	CR		x		x
African Grass-Owl	VU		x		
Grey Crowned Crane	EN		x		x
Pallid Harrier	NT		x		
White-bellied Korhaan	VU	x	x		
White-backed Vulture	CR	x			
Yellow-billed Stork	EN				x
Yellow-breasted Pipit	VU		x		
African Crowned Eagle	VU			x	
African Finfoot	VU				x
African Pygmy-Goose	VU				x

Corridor Phase	Brief description

Bateleur	EN	x			
Kori Bustard	NT	x			
Lesser Jacana	VU				x
White-backed Night-Heron	VU				x
Bat Hawk	EN	x			
Blue Swallow	CR		x		
White-headed Vulture	CR	x			
African Marsh-Harrier	EN		x		x
Black-winged Pratincole	NT		x		x
Hooded Vulture	CR	x			
White-winged Flufftail	CR		x		x

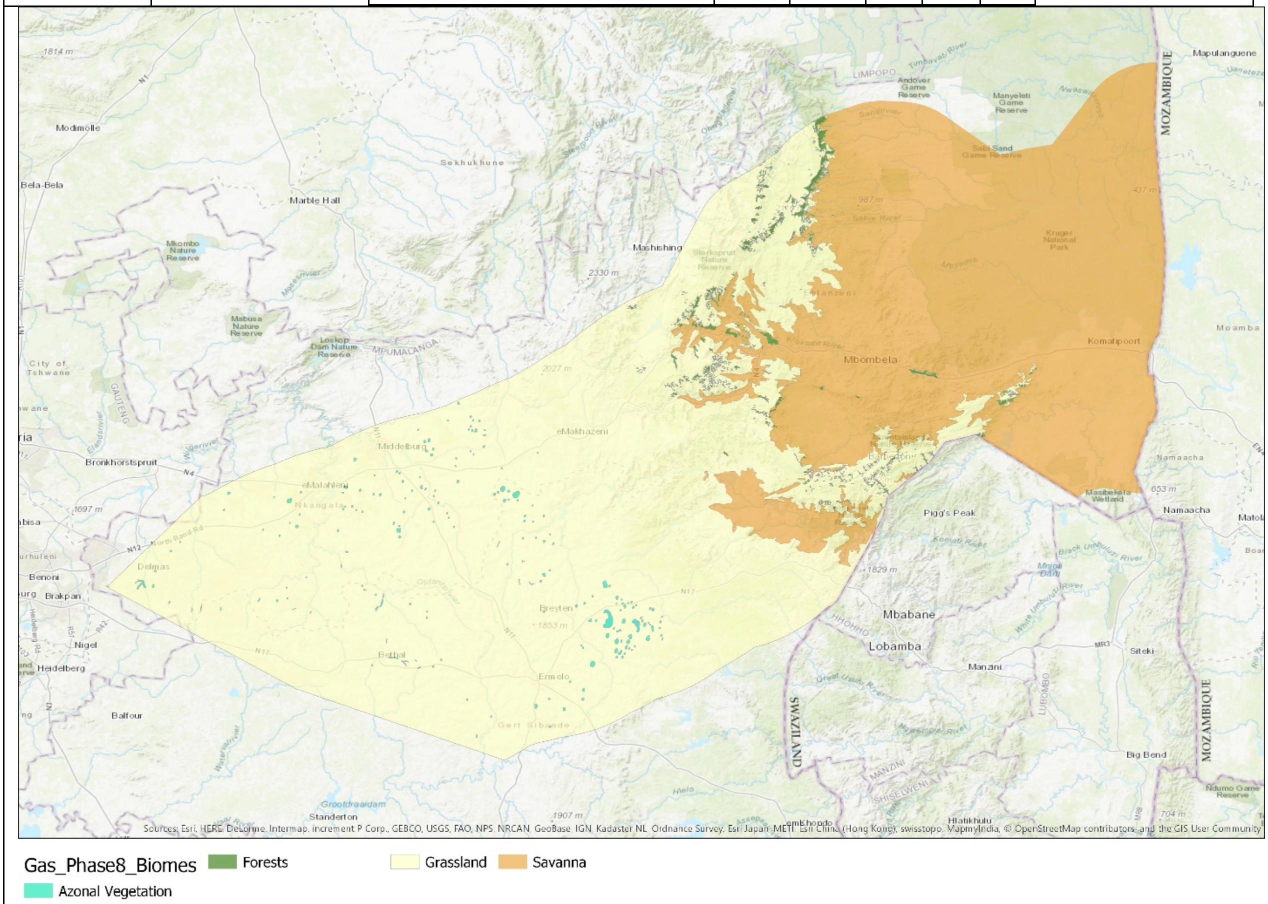

Figure 10: Biomes of the Phase 8 (Rompco) Corridor.

4.2 Feature Sensitivity Mapping

4.2.1 Identification of feature sensitivity criteria

The basic point of departure for the definition of avifaunal feature sensitivity classes (habitat classes) was the 2013 - 2014 South African National Land-Cover Dataset. This was supplemented with information on specific features (sensitivity features) where available, e.g. Important Bird Areas (IBAs), South African Protected Areas, known nests sites of Red Data species, and vulture colonies (refer to Section 3.3) (Table 4). The potential negative impacts on avifauna by the proposed gas pipeline were summarised as[3]:

- Direct mortality due to the destruction of nests in the construction servitude;
- Displacement due to disturbance during the construction of the pipeline and associated infrastructure; and
- Displacement of breeding individuals through habitat transformation[4].

The probability of the impacts occurring in a specific habitat class for a specific species was rated for all Red Data species with a SABAP2 reporting rate of >5%, to arrive at a species-specific probability score, within each habitat class, within each biome, within each corridor phase. Probabilities for the respective impacts occurring were rated according to the below scale:

- 0 = probability of the impact occurring is < 20%
- 1 = probability of the impact occurring is 20 – 50%
- 2 = probability of the impact occurring is 51 - 80%
- 3 = probability of the impact occurring is >80%

The species-specific probability score was multiplied by a weighted Red Data status score for each priority species to arrive at a species-specific habitat sensitivity score for each species, for each habitat class. The Red Data status was assigned weighted scores according to the below scale:

- Near threatened = 2
- Vulnerable = 4
- Endangered = 8
- Critically endangered = 16

An aggregated habitat sensitivity score for each habitat class within each biome, within each corridor phase was calculated as the sum of all the species-specific probability scores for that particular habitat class:

- Low = 0; Medium = 1-11; High = 12 – 22; Very High = 23 – 33

[3] See Section 5 for a more detailed exposition of potential impacts on avifauna.
[4] Although the 50 m wide construction servitude will be revegetated through a process of vegetation rehabilitation and natural colonisation, a 10 m wide servitude will remain to provide access for maintenance. In the case of access roads, the transformation will be permanent. However, where possible, shallow rooted plants/crops can be allowed to re-grow in the 10 m wide servitude. No service road is planned to be built along the pipeline.

Table 4: Description and sources of data used for the avifauna sensitivity analysis.

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
Wetlands and waterbodies: Water permanent	South African National Land-Cover Dataset, 2013/14	Areas of open, surface water, that are detectable on all image dates used in the Landsat 8 based water modelling processes. Permanent water extent typically refers to the minimum water extent, which occurs throughout the 2013-14 assessment period. Includes both natural and man-made water features.	All
Wetlands and waterbodies: Water seasonal	South African National Land-Cover Dataset, 2013/14	Areas of open, surface water, that are detectable on one or more, but not all image dates used in the Landsat 8 based water modelling processes. Seasonal water extent typically refers to the maximum water extent, which may only occur for a limited time within the 2013-14 assessment period. Includes both natural and man-made water features.	All
Wetlands and waterbodies: Wetlands	South African National Land-Cover Dataset, 2013/14	Wetland areas that are primarily vegetated on a seasonal or permanent basis. Defined on the basis of seasonal image identifiable surface vegetation patterns (not subsurface soil characteristics. The vegetation can be either rooted or floating. Wetlands may be either daily (i.e. coastal), temporarily, seasonal or permanently wet and/or saturated. Vegetation is predominately herbaceous. Includes but not limited to wetlands associated with seeps/springs, marshes, floodplains, lakes/pans, swamps, estuaries, and some riparian areas. Wetlands associated with riparian zones represent image identified vegetation along the edges of watercourses that show similar spectral characteristics to nearby wetland vegetation. Excludes Mangrove swamps. Permanent or seasonal open water areas within the wetlands are classified separately (Appendix C.1.7 of the Gas Pipeline SEA Report). Seasonal wetland occurrences within commercially cultivated field boundaries are not shown, although they have been retained within subsistence level cultivation fields.	All
Indigenous Forest	South African National Land-Cover Dataset, 2013/14	Natural / semi-natural indigenous forest, dominated by tall trees, where tree canopy heights are typically > ± 5m and tree canopy densities are typically > ± 75 %, often with multiple understory vegetation canopies.	All
Thicket/dense bush	South African National Land-Cover Dataset, 2013/14	Natural / semi-natural tree and / or bush dominated areas, where typically canopy heights are between 2 - 5 m, and canopy density is typically > ± 75%, but may include localised sparser areas down to ± 60%. Includes dense bush, thicket, closed woodland, tall, dense shrubs, scrub forest and mangrove swamps. Can include self-seeded bush encroachment areas if sufficient canopy density exists.	All

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
Woodland/open bush	South African National Land-Cover Dataset, 2013/14	Natural / semi-natural tree and / or bush dominated areas, where typically canopy heights are between ± 2 - 5 m, and canopy densities typically between 40 - 75%, but may include localised sparser areas down to ± 15 - 20 %. Includes sparse – open bushland and woodland, including transitional wooded grassland areas. Can include self-seeded bush encroachment areas if canopy density is within indicated range. In the arid western regions (i.e. Northern Cape), this cover class may be associated with a transitional bush / shrub cover that is lower than typical Open Bush / Woodland cover but higher and/or more dense than typical Low Shrub cover.	All
Grassland	South African National Land-Cover Dataset, 2013/14	Natural / semi-natural grass dominated areas, where typically the tree and / or bush canopy densities are typically < ± 20 %, but may include localised denser areas up to ± 40 %, (regardless of canopy heights). Includes open grassland, and sparse bushland and woodland areas, including transitional wooded grasslands. May include planted pasture (i.e. grazing) if not irrigated. Irrigated pastures will typically be classified as cultivated, and urban parks and golf courses etc. under urban.	All
Shrubland fynbos	South African National Land-Cover Dataset, 2013/14	Natural / semi-natural low shrub dominated areas, typically with < ± 2m canopy height, specifically associated with the Fynbos Biome. Includes a range of canopy densities encompassing sparse to dense canopy covers. Very sparse covers may be associated with the bare ground class. Note that taller tree / bush / shrub communities within this vegetation type are typically classified separately as one of the other tree or bush dominated cover classes.	All
Low shrubland	South African National Land-Cover Dataset, 2013/14	Natural / semi-natural low shrub dominated areas, typically with ≤ 2m canopy height. Includes a range of canopy densities encompassing sparse to dense canopy covers. Very sparse covers may be associated with the bare ground class. Typically associated with low, woody shrub, karoo-type vegetation communities, although can also represent locally degraded vegetation areas where there is a significantly reduced vegetation cover in comparison to surrounding, less impacted vegetation cover, including long-term wildfire scars in some mountainous areas in the western Cape. Note that taller tree / bush / shrub communities within this vegetation type are typically classified separately as one of the other tree or bush dominated cover classes.	All
Cultivated commercial fields rainfed	South African National Land-Cover Dataset, 2013/14	Cultivated lands used primarily for the production of rain-fed, annual crops for commercial markets. Typically represented by large field units, often in dense local or regional clusters. In most cases the defined cultivated extent represents the actual cultivated or potentially extent.	All

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
Cultivated commercial pivots	South African National Land-Cover Dataset, 2013/14	Cultivated lands used primarily for the production of centre pivot irrigated, annual crops for commercial markets. In most cases the defined cultivated extent represents the actual cultivated or potentially extent.	All
Cultivate orchards and vines	South African National Land-Cover Dataset, 2013/14	Cultivated lands used primarily for the production of both rain-fed and irrigated permanent crops for commercial markets. Includes both tree, shrub and non-woody crops, such as citrus, tea, coffee, grapes, lavender and pineapples etc. In most cases the defined cultivated extent represents the actual cultivated or potentially extent.	All
Cultivated subsistence	South African National Land-Cover Dataset, 2013/14	Cultivated lands used primarily for the production of rain-fed, annual crops for local markets and / or home use. Typically represented by small field units, often in dense local or regional clusters. The defined area may include intra-field areas of non-cultivated land, which may be degraded or use-impacted, if the individual field units are too small to be defined as separate features.	All
Cultivated sugar cane	South African National Land-Cover Dataset, 2013/14	Commercial, pivot irrigated fields that appear to be used continuously for growing sugarcane on the majority of multi-date Landsat images used in the 2013-14 analysis period. Also includes commercial and semi-commercial / emerging farmer status, non-pivot fields, that appear to be used continuously for growing sugarcane on the majority of multi-date Landsat images used in the 2013-14 analysis period.	3,4,7
Plantations	South African National Land-Cover Dataset, 2013/14	Planted forestry plantations used for growing commercial timber tree species. The class represents mature tree stands which have approximately 70% or greater tree canopy closure (regardless of canopy height), on all the multi-date Landsat images in the 2013-14 analysis period. The class includes spatially smaller woodlots and windbreaks with the same cover characteristics. It also includes young tree stands that have approximately 40 - 70% tree canopy closure (regardless of canopy height), clear-felled stands and spatially smaller woodlots and windbreaks with the same cover characteristics.	All
Industrial	South African National Land-Cover Dataset, 2013/14	Mining activity footprint, based on pure, non-vegetated, bare ground surfaces. Includes extraction pits, tailings, waste dumps and associated surface infrastructure such as roads and buildings (unless otherwise indicated), for both active and abandoned mining activities. Class may include open cast pits, sand mines, quarries and borrow pits etc. also includes mining activity footprint, based on semi-bare ground surfaces, which may be sparsely vegetated. Includes extraction pits, tailings, waste dumps and associated surface infrastructure such as roads and buildings (unless otherwise indicated) and surrounding dust-impacted areas, for both active and abandoned mining activities. Water bodies inside mining areas which	All

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
		represent permanent and non-permanent water extents are also included. Areas containing buildings and large surface infrastructure associated with the extraction, processing or administration of the associated mining area are also included.	
Bare	South African National Land-Cover Dataset, 2013/14	Non-vegetated donga and gully features, typically associated with significant natural or man-induced erosion activities along or in association with stream and flow lines. The mapped extent of the dongas and gullies is represented by bare ground conditions in all or the majority of the multi-date Landsat images used in the land-cover modelling. Note that these erosion features are significantly better represented both spatially and numerically in the wetter, more lush regions of the country where the non-vegetated erosion surface is significantly different from the surrounding vegetation cover (i.e. bushveld and grassland regions). In general, sparsely vegetated sheet eroded areas and degraded areas with significantly reduced local vegetation cover are not included in this class but will be represented by local areas of low shrub or bare ground. Also included are bare, non-vegetated ground, with little or very sparse vegetation cover (i.e. typically < ± 5 - 10 % vegetation cover), occurring as a result of either natural or man-induced processes. Includes but not limited to natural rock exposures, dry river beds, dry pans, coastal dunes and beaches, sand and rocky desert areas, very sparse low shrublands and grasslands, surface (sheet) erosion areas, severely degraded areas, and major road networks etc. May also include long-term wildfire scars in some mountainous areas in the western Cape.	All
Urban	South African National Land-Cover Dataset, 2013/14	Areas containing the following: • high density buildings and other built-up structures associated with mainly non-residential, commercial, administrative, health, religious or transport (i.e. train station) activities; • buildings and other built-up structures associated with mainly non-residential, industrial and manufacturing activities, including power stations; • high density buildings and other built-up structures typically associated with informal, often non-regulated, residential housing; • variable density buildings and other built-up structures typically associated with formal, regulated, residential housing; • buildings, other built-up structures and open sports areas typically areas associated with schools and school sports grounds. • Areas containing a low density mix of buildings, other built-up structures	All

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
		within open areas, which may or may not be cultivated, that are representative of both formally declared agricultural holdings, and similar small holdings / small farms, typically located on the periphery of urban areas. • Areas containing a low density mix of buildings, other built-up structures associated with golf courses. The class includes both residential golf estates and non-residential golf courses, and typically represents the border extent of the entire estate or course. • Areas containing high density buildings and other built-up structures typically associated with formal, regulated, residential housing associated with townships and "RDP" type housing developments. • Areas containing variable density structures typically associated with rural villages, including both traditional and modern building formats. • Areas containing variable densities of buildings other built-up structures, or no structures at all, that are not clearly identifiable as one of the other Built-Up classes. May include runways, major infrastructure development sites, holiday chalets, roads, car parks, cemeteries etc.	
Drainage lines	National Freshwater Ecosystem Priority Areas Project (NFEPA), 2011	• The National Freshwater Ecosystem Priority Areas (NFEPA) project identifies a national network of freshwater conservation areas and explores institutional mechanisms for their implementation.	All
Areas earmarked for formal conservation as part of the National Protected Areas Expansion Strategy (NPAES)	Priority areas for protected area expansion, 2016 (including updated Northern Cape priorities) Department of Environmental Affairs (DEA)	• Maps of the most important areas for protected area expansion in South Africa.	All
Conservation Areas	SA conservation area database-Q2 2017 (DEA); Provincial game farm data	• Biosphere reserves, Botanical gardens, Ramsar Sites (not already protected), Game farms, private reserves and hunting areas.	All
Protected Areas	South African Protected Areas Database (SAPAD) - Q3, 2017, South African National Parks (SANParks) and Provincial	• Marine Protected Areas, National Parks, Nature Reserves, Protected Environments, Forest Nature Reserve, Forest Wilderness Area, Special Nature Reserve	All
Wetlands and waterbodies: Estuaries	Database of national estuaries, SANBI, Biodiversity GIS, 2012	• Estuarine systems along the South African coastline	1,2,4,5,7
Important Bird and Biodiversity Areas of South Africa	BirdLife South Africa, 2015	• National inventory of the Important Bird on Biodiversity Areas of South Africa, compiled by BirdLife South Africa.	All
Nest sites, roosts and colonies of Red Data species	• The crane and raptor nest databases of the Endangered Wildlife Trust (EWT); 2018 • The Endangered Wildlife Trust's database of	• Nest sites of Martial Eagle, Verreaux's Eagle, Tawny Eagle, Bateleur, White-backed Vulture, Lappet-faced Vulture, Black Harrier, Lanner Falcon, Blue Crane, Wattled Crane, Grey Crowned Crane. • Martial Eagle, Verreaux's Eagle and Tawny Eagle nests on transmission	4,7,8

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
	eagles nesting on transmission lines in the Karoo; 2006	lines in the Karoo.	Inland, 5
	• A map of Blue Swallow breeding areas obtained from Ezemvelo KZN Wildlife; 2018	• Blue Swallow breeding areas in KwaZulu-Natal	7
	• Information on the locality of various Red Data raptor nests and Cape Vulture roosts in the Northern, Eastern Cape, and Western Cape. Received from various avifaunal specialists working on renewable energy projects, 2010 – 2018.	• Nest localities of Martial Eagle, Verreaux's Eagle, Tawny Eagle and Black Harrier (roosts included) at renewable energy development sites. Also includes a number of Cape Vulture roosts.	Inland, 1,2,3,4,5,6,7
	• Information on potential nesting areas of Southern Ground Hornbills, Mabula Ground Hornbill Project, 2018.	• Potential nest areas of Southern Ground Hornbill.	3,4,7,8
	• Information on various Red Data species nests and vulture colonies obtained from the Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa, 2015.	• The data comprise nest localities of Black Harrier, Martial Eagle, Verreaux's Eagle, Blue Crane, Lanner Falcon, in the 8 solar and wind focus areas that overlap with the gas pipeline corridor phases.	Inland,1,6,7
	• Information on the locality of Southern Bald Ibis breeding colonies, Birdlife South Africa, 2015.	• Information from Dr. Kate Henderson's PhD on the locality of Southern Bald Ibis roost and colonies.	3,4,7,8
	• National vulture restaurant database obtained from VulPro in March 2017	• A register of all known vulture restaurants.	1,3,4,7,8
	• The results of the 2013 aerial survey of Cape Vulture colonies conducted by Eskom, EWT and Birdlife South Africa (BLSA) in the former Transkei, Eastern Cape.	• List of Cape Vulture colonies in the former Transkei, Eastern Cape, collected via an aerial survey in 2013.	7
	• The national register of vulture Cape Vulture colonies obtained from VulPro in May 2015.	• List of all known Cape Vulture colonies compiled by VulPro.	1,3,4,7,8
	• A list of potential Bush Blackcap, Spotted Ground-Thrush and Orange Ground-Thrush breeding sites. BirdLife South Africa, 2018.	• The results of a modelling exercise undertaken by BirdLife South Africa to identify critical habitat for three key forest – dwelling Red Data species.	3,4,7,8
	• Bearded Vulture nest sites in KwaZulu – Natal, obtained from Dr. Sonja Krűger at Ezemvelo KZN Wildlife.	• The results of nest surveys conducted from 2000 – 2012.	7
	• White-winged Flufftail confirmed sightings 2000 – 2014	• A list of wetlands where this critically endangered species has been recorded in South Africa which includes the locality where the first breeding for the region has recently been confirmed.	3,7,8

Sensitivity Feature Class (Habitat class)	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors Phases
	• Information on various Red Data species nests obtained from Ezemvelo KZN Wildlife	• Nests localities of Bateleur, Black Stork, African Crowned Eagle, Lappet-faced Vulture, Marabou Stork, Martial Eagle, Secretary bird, Tawny Eagle, White-backed Vulture and White-headed Vulture.	4, 7

Below are all feature types considered in the sensitivity analysis and the rating given to each feature and buffered area, where applicable (Table 5). Details on each individual feature ratings are available on request in spreadsheet format.

Table 5: Avifauna sensitivity features and ratings.

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
Inland	Albany Thicket	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	High	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Inland	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	High	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	High	
		Plantations	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Inland	Fynbos	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	High	
		Cultivated orchards	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	High	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Inland	Grassland	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Inland	Nama-Karoo	Bare	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	High	
		Cultivated orchards	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Inland	Succulent Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	High	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	
		Woodland/Open bush	Medium	
Phase 1	Albany Thicket	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 1	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	
		Grassland	High	
		Industrial	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Woodland/Open bush	Medium	
Phase 1	Forests	Bare	Low	
		Cultivated commercial fields rainfed	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 1	Fynbos	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	High	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Medium	
		Low shrubland	High	
		Plantations	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 1	Nama-Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Medium	
		Low shrubland	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 1	Succulent Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 2	Albany Thicket	Bare	Medium	
		Cultivated commercial fields rainfed	High	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 2	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	High	
		Plantations	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 2	Forests	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 2	Fynbos	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	High	
		Industrial	Low	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 2	Grassland	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Low shrubland	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 2	Nama-Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	High	
		Cultivated commercial pivots	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 2	Succulent Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 3	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Very high	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
Phase 3	Forests	Bare	Low	
		Cultivated commercial fields rainfed	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 3	Grassland	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Medium	
Phase 3	Indian Ocean Coastal Belt	Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Medium	200m
Phase 3	Savanna	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	High	
Phase 4	Azonal Vegetation	Bare	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Grassland	High	
		Indigenous Forest	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	High	
Phase 4	Forests	Bare	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 4	Grassland	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	High	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 4	Indian Ocean Coastal Belt	Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	High	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	High	
Phase 4	Savanna	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	High	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Very high	
Phase 5	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated subsistence	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 5	Forests	Bare	Low	
		Cultivated commercial fields rainfed	Low	
		Cultivated orchards	Low	
		Grassland	Low	
		Low shrubland	Low	
		Shrubland fynbos	Low	
		Thicket /Dense bush	Low	
		Wetlands and waterbodies (200m buffer)	Low	200m
		Woodland/Open bush	Low	
Phase 5	Fynbos	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	High	
		Plantations	Medium	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 5	Succulent Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 6	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated orchards	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Medium	
		Low shrubland	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 6	Desert	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated orchards	Medium	
		Cultivated vines	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 6	Fynbos	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 6	Nama-Karoo	Bare	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 6	Succulent Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 7	Albany Thicket	Bare	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 7	Azonal Vegetation	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Medium	
Phase 7	Forests	Bare	Low	
		Cultivated commercial fields rainfed	Low	
		Cultivated orchards	Medium	
		Cultivated subsistence	Low	
		Cultivated sugar cane	Low	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	High	
		Industrial	Low	
		Low shrubland	Low	
		Plantations	Medium	
		Shrubland fynbos	Low	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Medium	200m
		Woodland/Open bush	Medium	
Phase 7	Fynbos	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 7	Grassland	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Very high	
		Indigenous Forest	High	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Medium	
Phase 7	Indian Ocean Coastal Belt	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	High	60m
		Grassland	High	
		Indigenous Forest	High	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Medium	
Phase 7	Nama-Karoo	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Industrial	Medium	
		Low shrubland	High	
		Shrubland fynbos	High	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	High	200m
		Woodland/Open bush	Medium	
Phase 7	Savanna	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	Medium	
		Industrial	Low	
		Low shrubland	Medium	
		Plantations	Medium	
		Shrubland fynbos	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
		Woodland/Open bush	Very high	
Phase 8	Azonal Vegetation	Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Very high	200m
Phase 8	Forests	Bare	Low	
		Cultivated commercial fields rainfed	Low	
		Cultivated orchards	Low	
		Cultivated subsistence	Low	
		Cultivated sugar cane	Low	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	High	
		Low shrubland	Low	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Low	200m
		Wetlands and waterbodies (200m buffer)	Low	200m
		Woodland/Open bush	Medium	
Phase 8	Grassland	Bare	Medium	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	Medium	
		Indigenous Forest	High	
		Industrial	Medium	
		Low shrubland	Low	
		Plantations	Medium	
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Medium	200m
		Wetlands and waterbodies (200m buffer)	Low	200m
		Woodland/Open bush	Very high	
Phase 8	Savanna	Bare	High	
		Cultivated commercial fields rainfed	Medium	
		Cultivated commercial pivots	Medium	
		Cultivated orchards	Medium	
		Cultivated subsistence	Medium	
		Cultivated sugar cane	Medium	
		Drainage lines 60m buff	Medium	60m
		Grassland	High	
		Indigenous Forest	High	
		Industrial	Medium	
		Low shrubland	Low	
		Plantations	Medium	

Corridor Phase	Biome	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
		Thicket /Dense bush	Medium	
		Urban (200m buffer)	Medium	200m
		Wetlands and waterbodies (200m buffer)	Low	200m
		Woodland/Open bush	Very high	
All phases	All biomes	Areas earmarked for formal conservation as part of the National Protected Areas Expansion Strategy (NPAES)	High	
		Conservation Areas	High (Elevated to Very high if overlapping with IBA)	
		Protected Areas	High (Elevated to Very high if overlapping with IBA)	
		Estuaries	High (Elevated to Very high if overlapping with IBA)	
		Nest sites, roosts and colonies of Red Data species	Very high	2km (3km for Black Harrier)
		Important Bird and Biodiversity Areas of South Africa	High	

4.3 Feature maps

4.3.1 Phase Inland

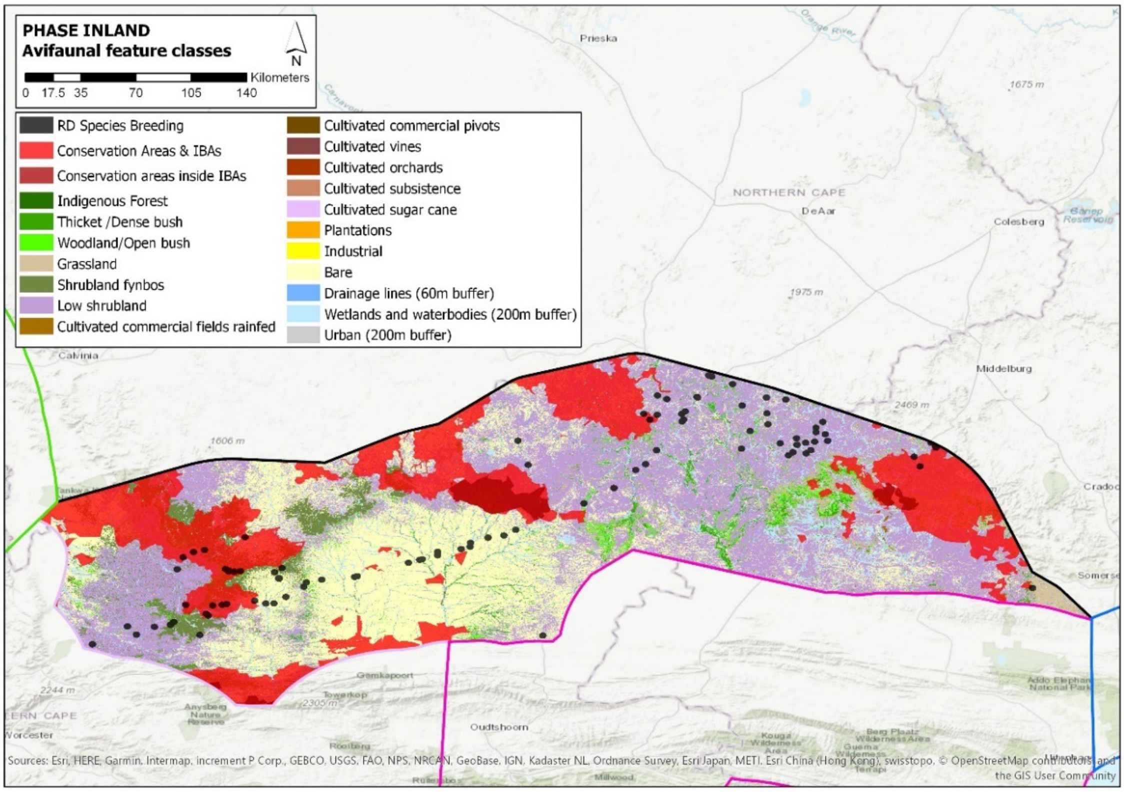

Figure 11: Sensitive environmental features of importance to avifauna in the Inland Phase Corridor.

4.3.2 Phase 1

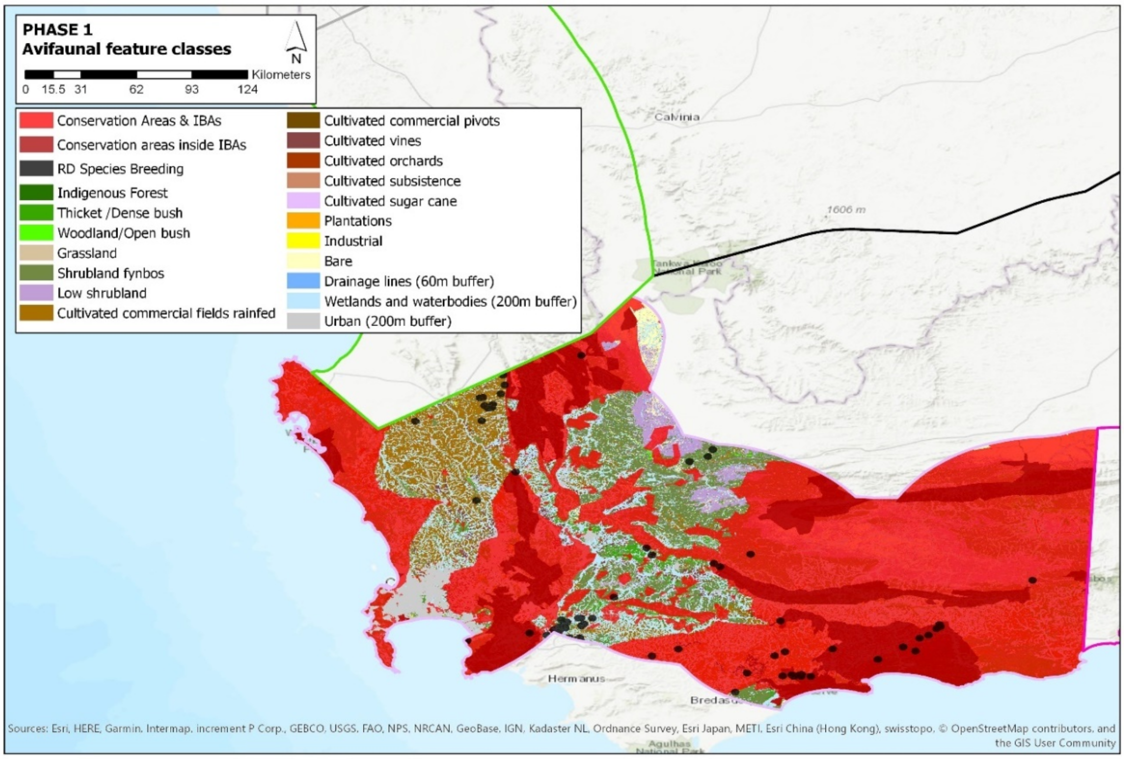

Figure 12: Sensitive environmental features of importance to avifauna in the Phase 1 Corridor.

4.3.3 Phase 2

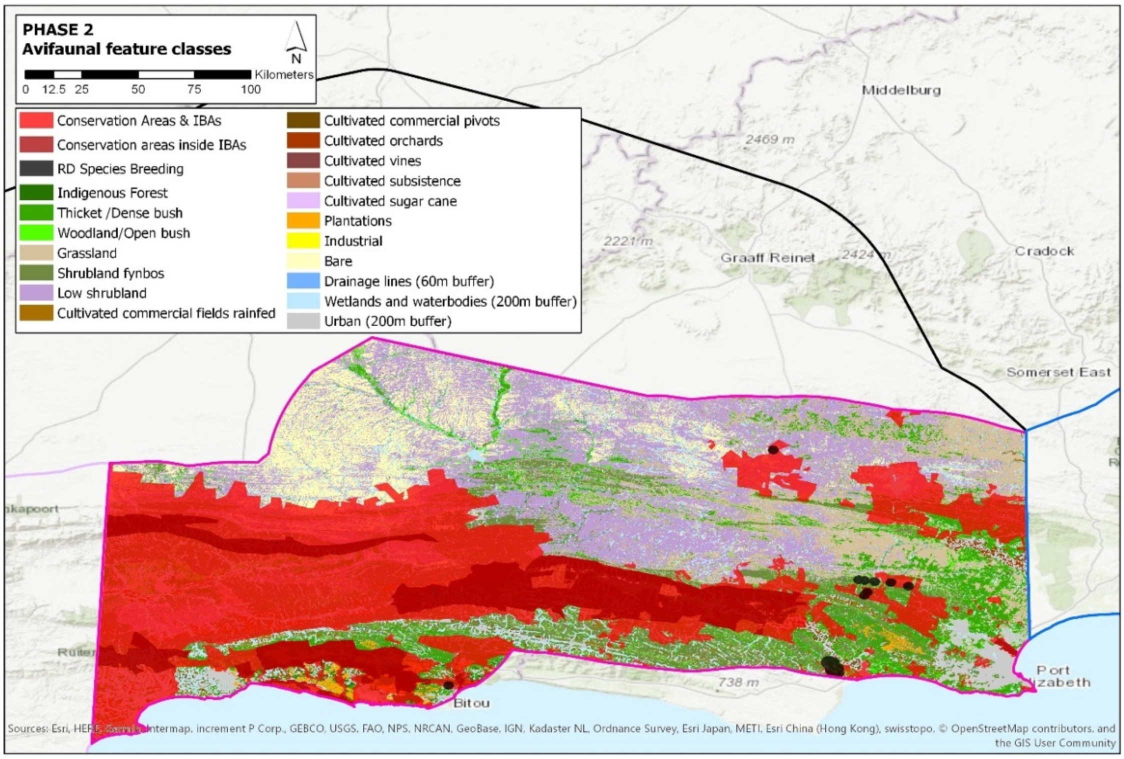

Figure 13: Sensitive environmental features of importance to avifauna in the Phase 2 Corridor.

4.3.4 Phase 3

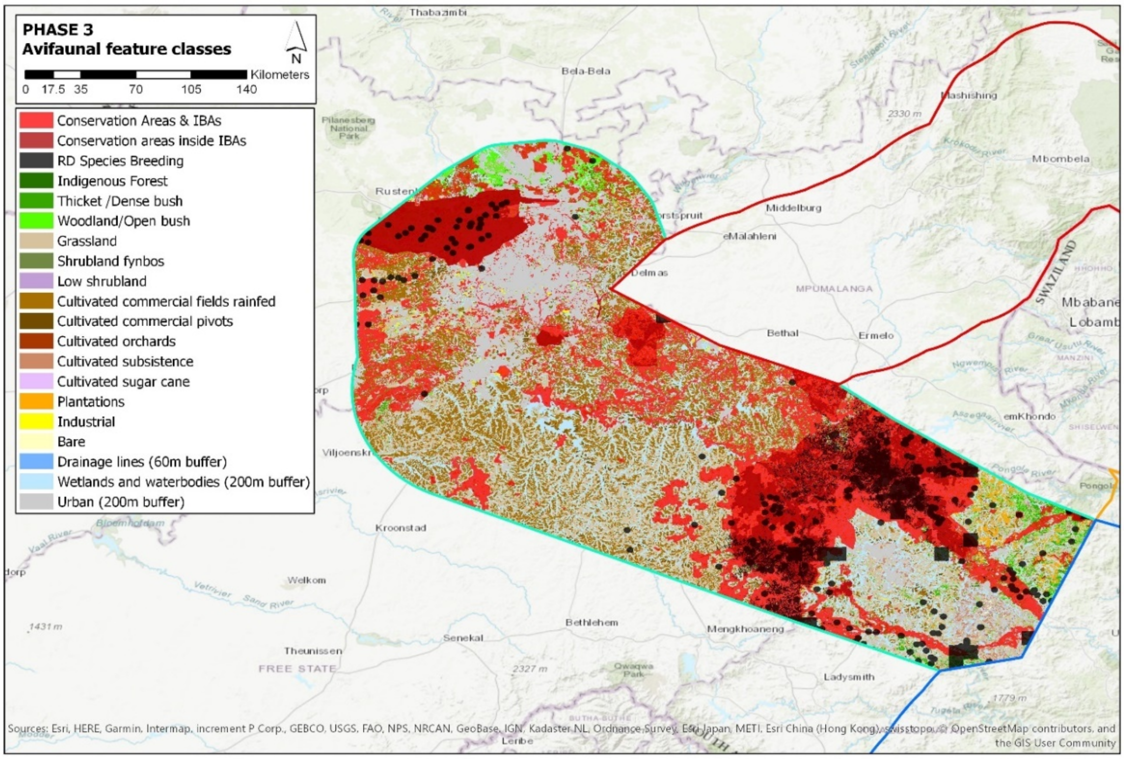

Figure 14: Sensitive environmental features of importance to avifauna in the Phase 3 Corridor

4.3.5 Phase 4

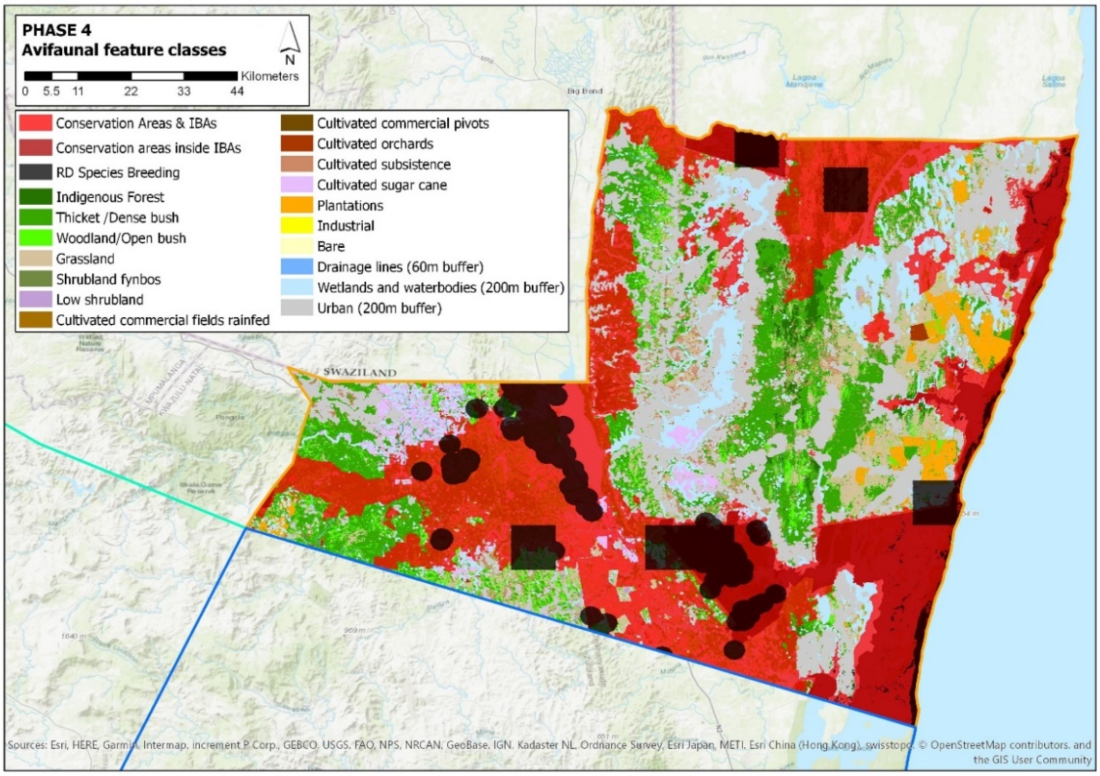

Figure 15: Sensitive environmental features of importance to avifauna in the Phase 4 Corridor

4.3.6 Phase 5

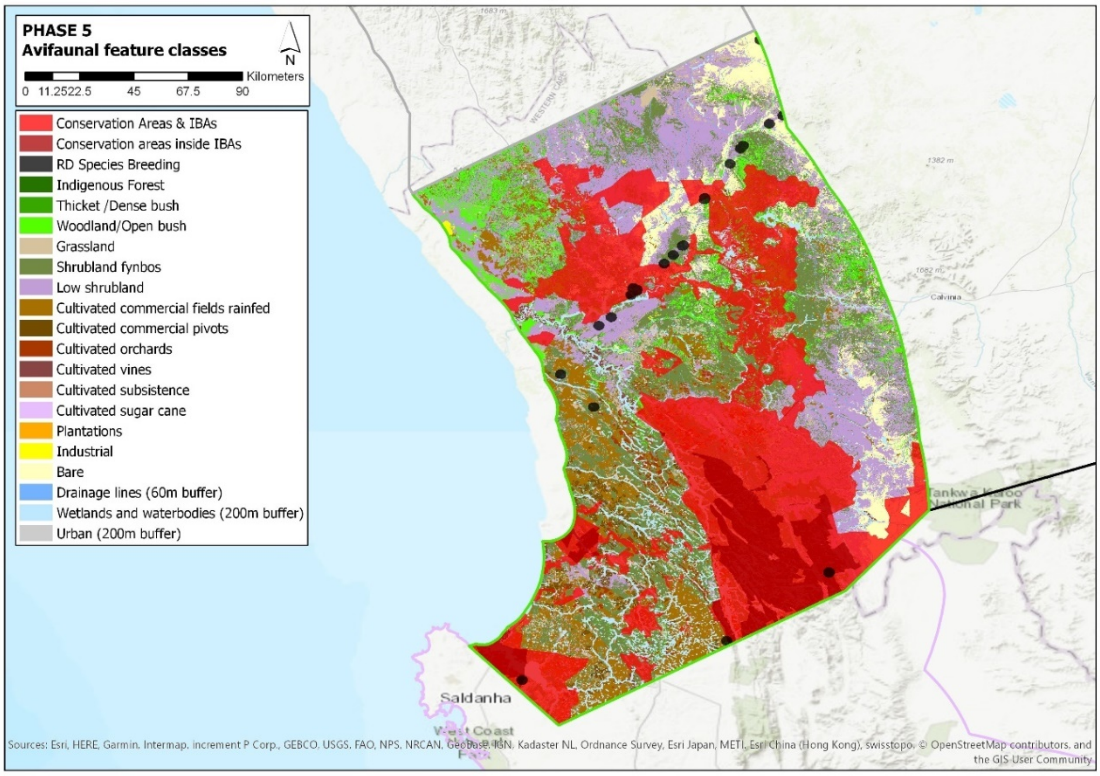

Figure 16: Sensitive environmental features of importance to avifauna in the Phase 5 Corridor

4.3.7 Phase 6

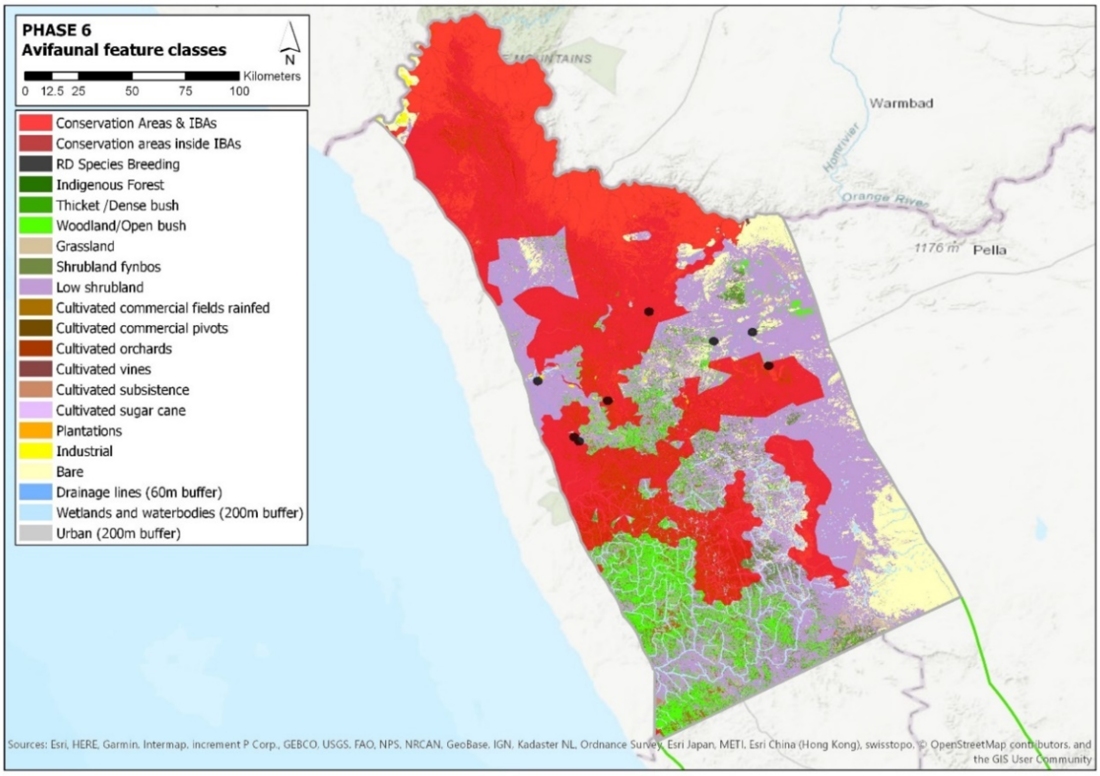

Figure 17: Sensitive environmental features of importance to avifauna in the Phase 6 Corridor.

4.3.8 Phase 7

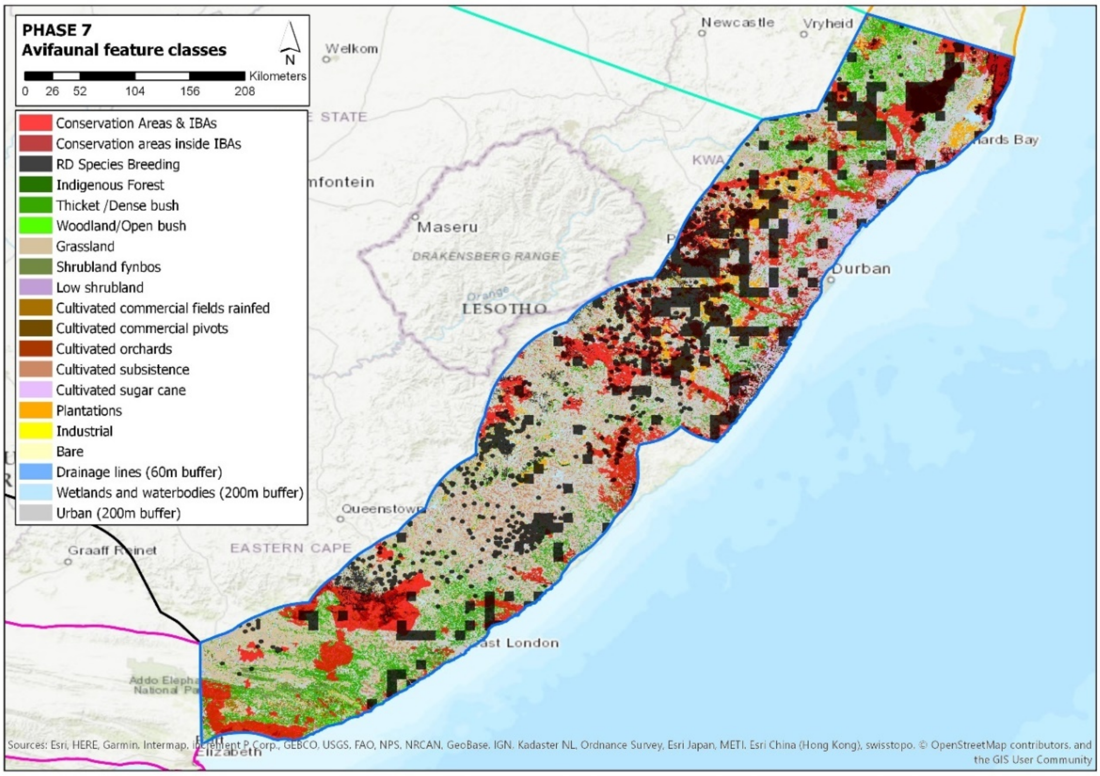

Figure 18: Sensitive environmental features of importance to avifauna in the Phase 7 Corridor.

4.3.9 Phase 8

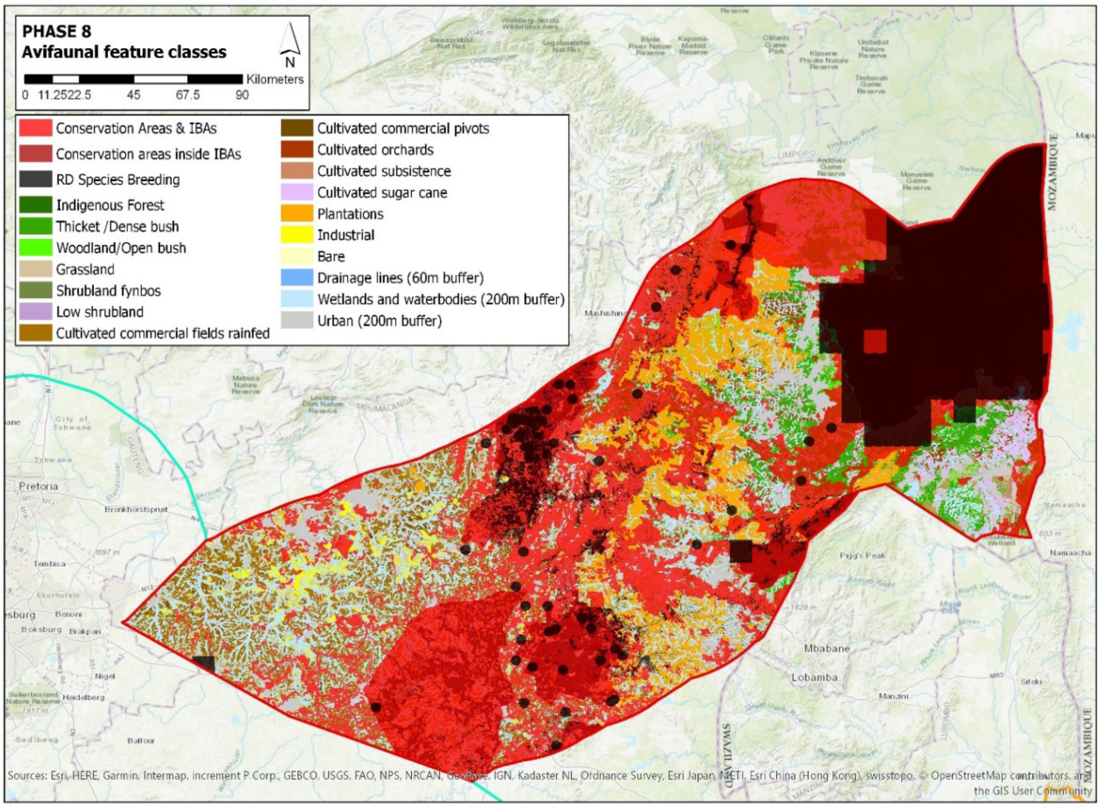

Figure 19: Sensitive environmental features of importance to avifauna in the Phase 8 Corridor.

4.4 Four- Tier Sensitivity Mapping

4.4.1 Phase Inland

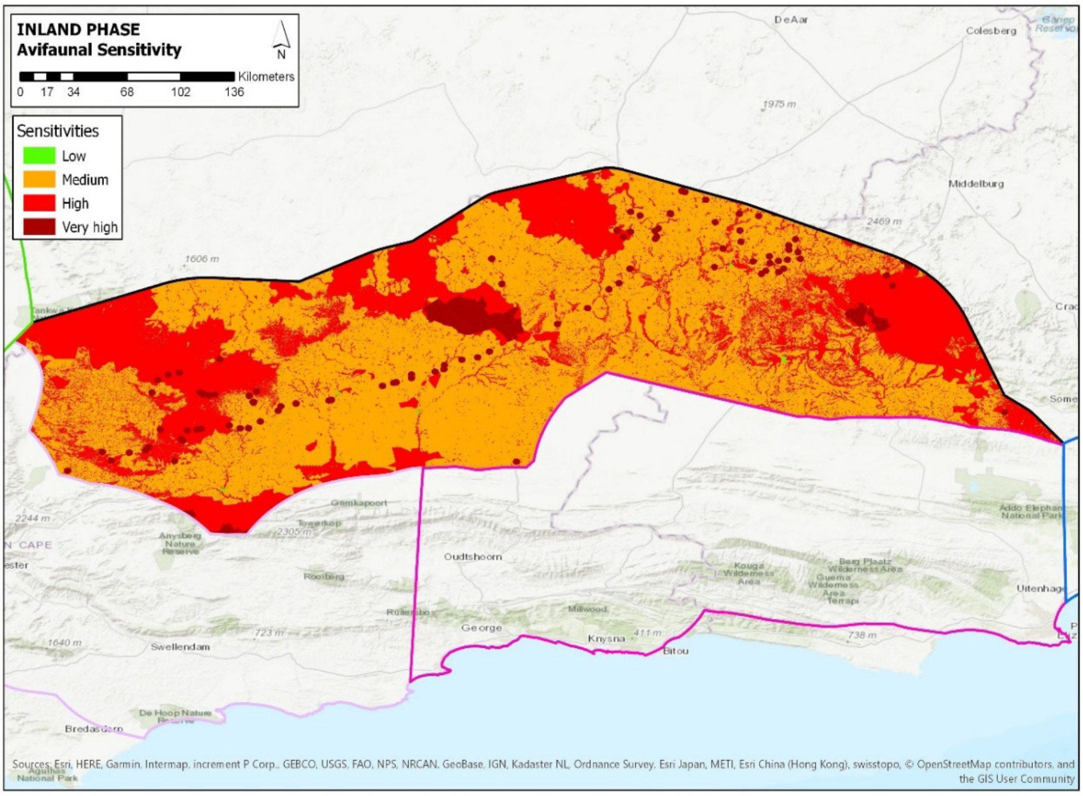

Figure 20: Avifauna sensitivity map for the Inland Phase Corridor.

4.4.2 Phase 1

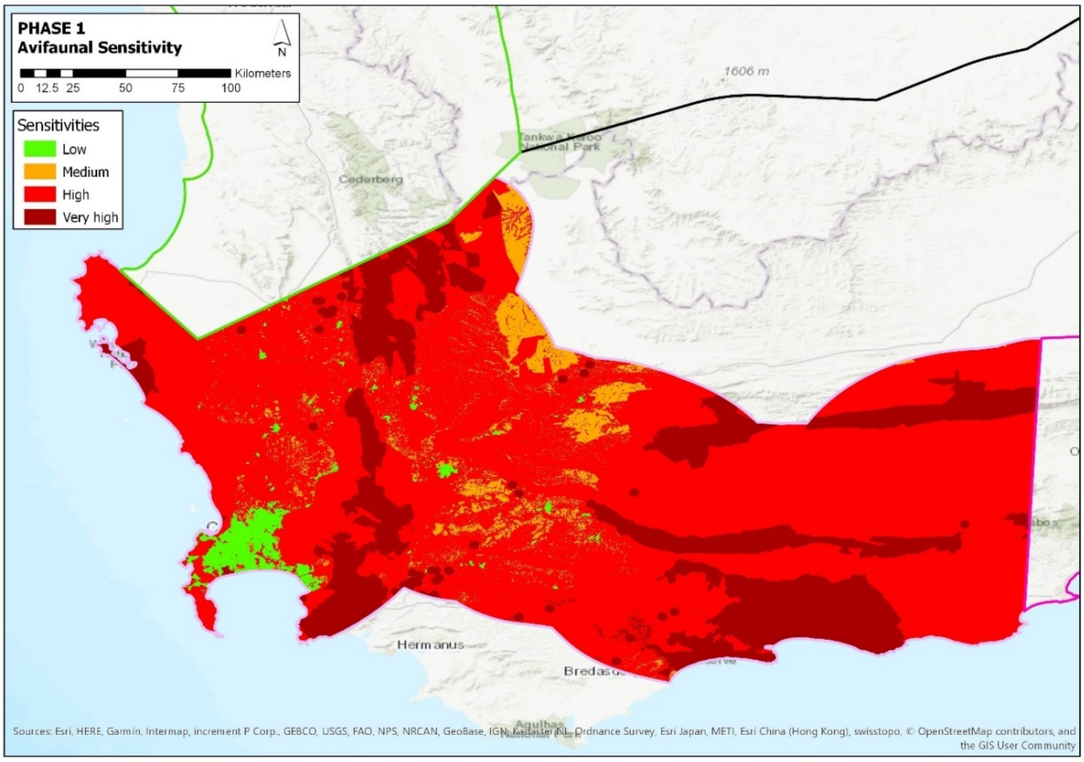

Figure 21: Avifauna sensitivity map for the Phase 1 Corridor.

4.4.3 Phase 2

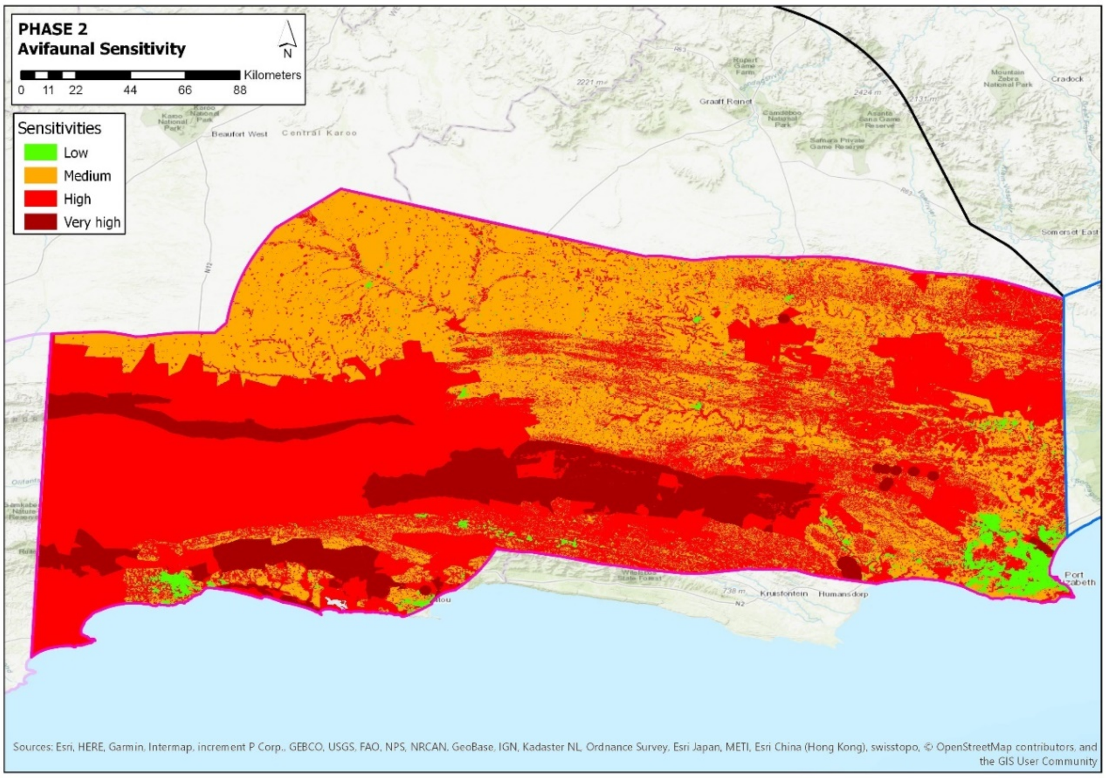

Figure 22: Avifauna sensitivity map for the Phase 2 Corridor.

4.4.4 Phase 3

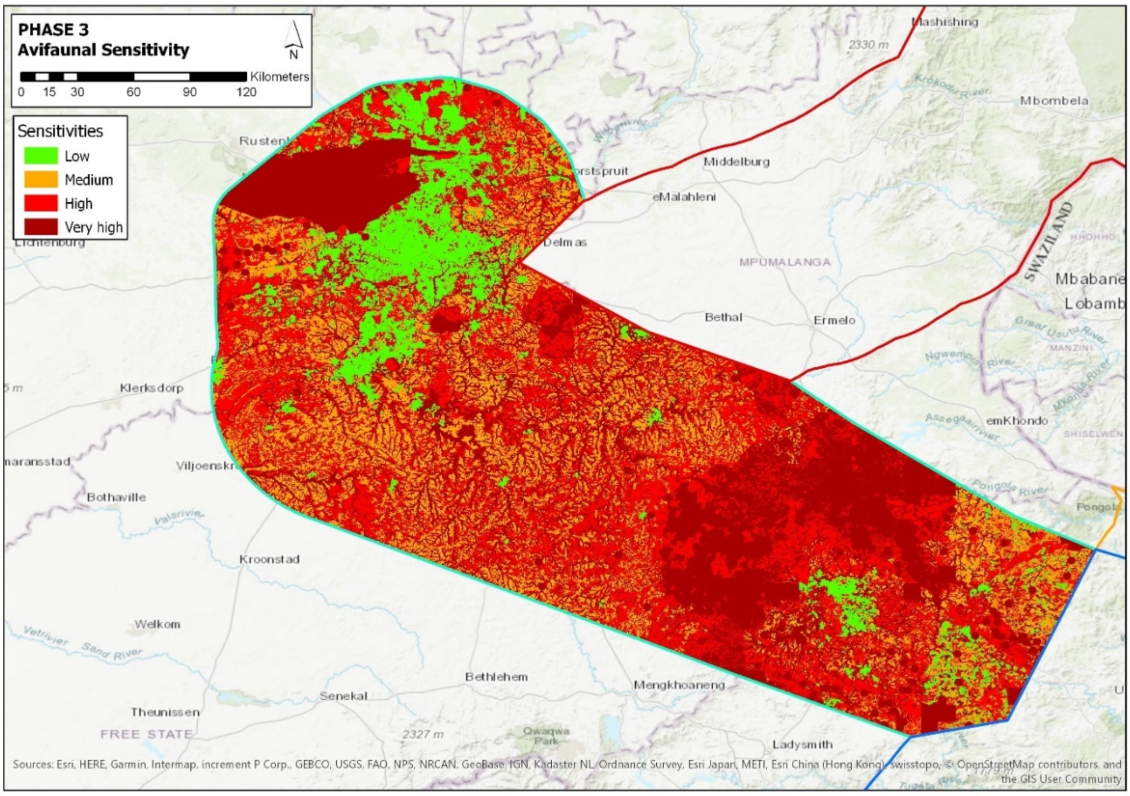

Figure 23: Avifauna sensitivity map for the Phase 3 Corridor.

4.4.5 Phase 4

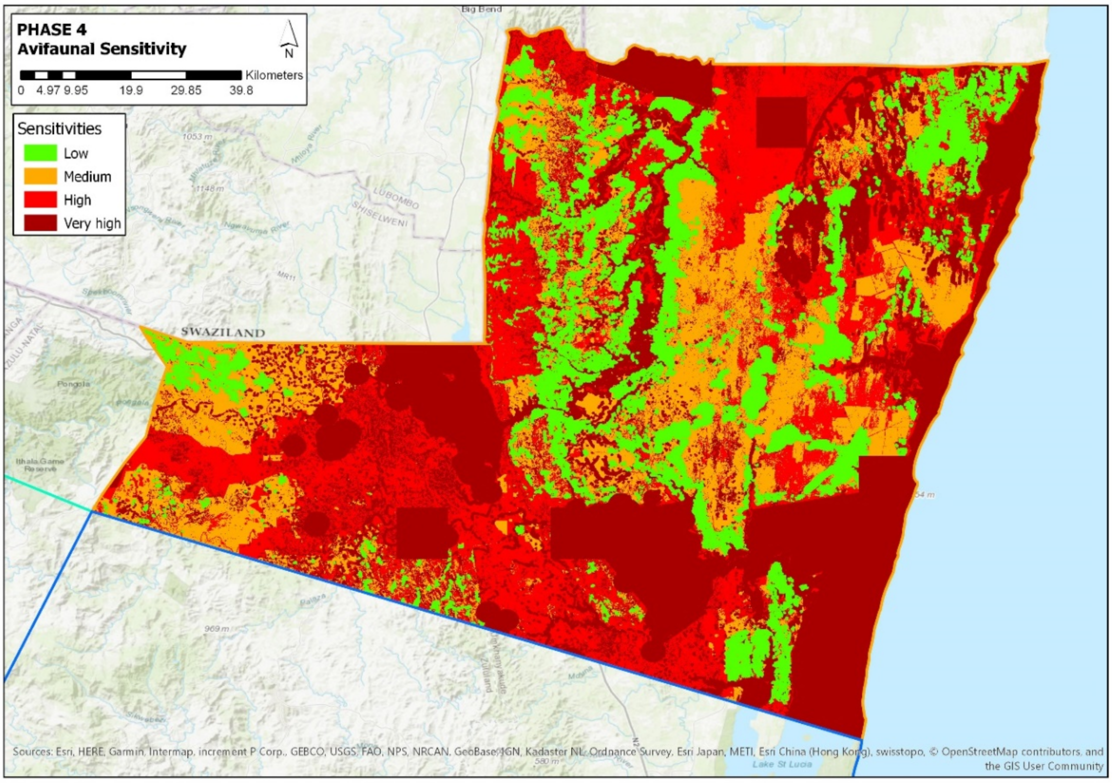

Figure 24: Avifauna sensitivity map for the Phase 4 Corridor.

4.4.6 Phase 5

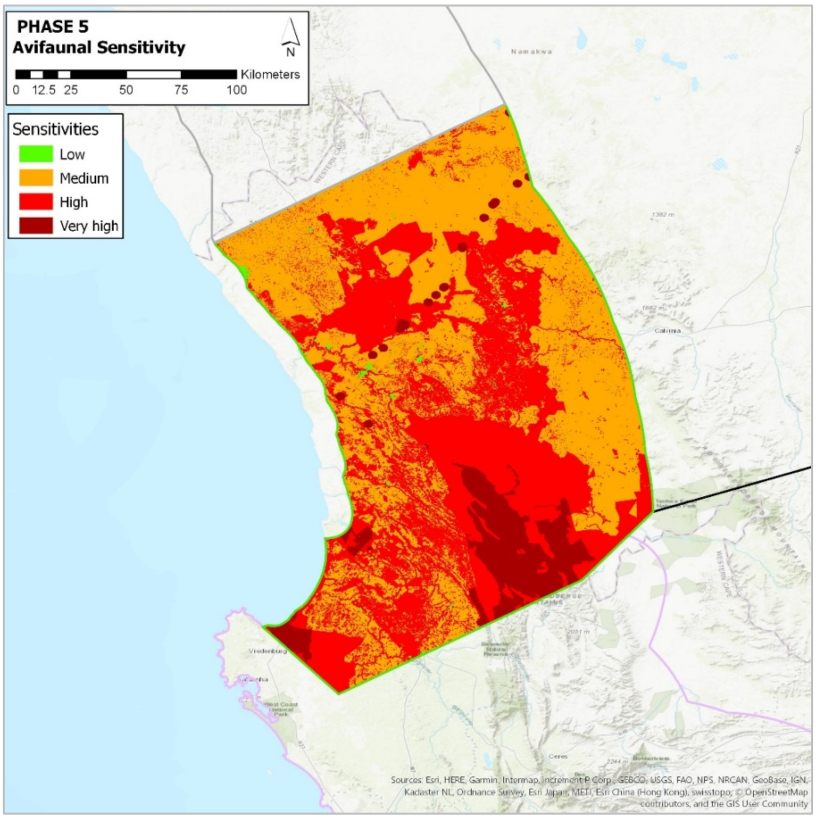

Figure 25: Avifauna sensitivity map for the Phase 5 Corridor.

4.4.7 Phase 6

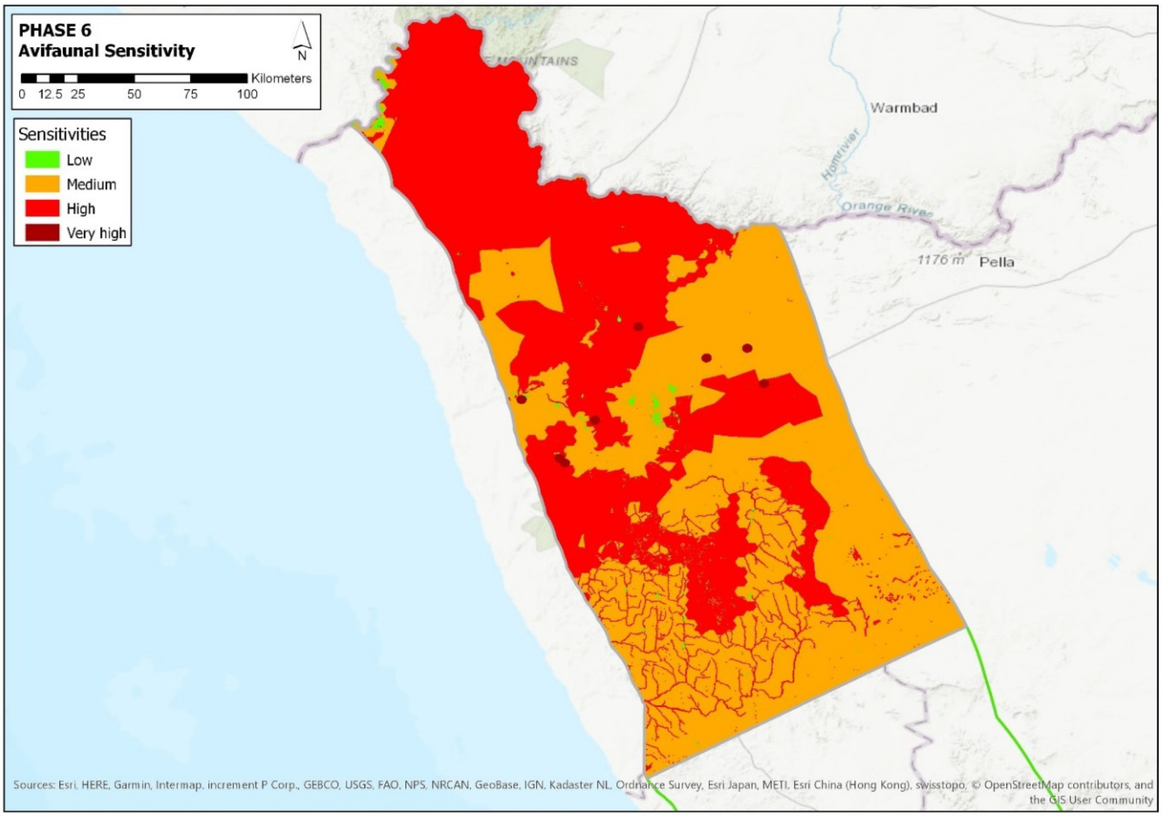

Figure 26: Avifauna sensitivity map for the Phase 6 Corridor.

4.4.8 Phase 7

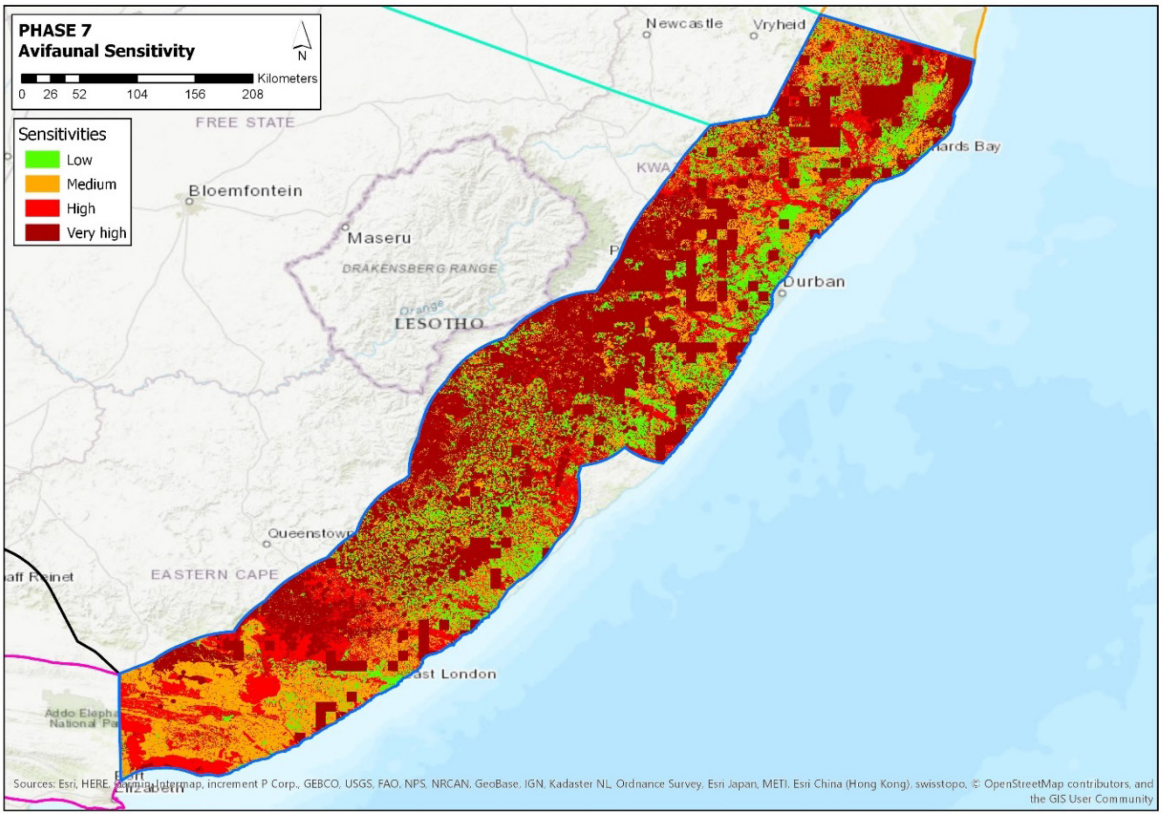

Figure 27: Avifauna sensitivity map for the Phase 7 Corridor.

4.4.9 Phase 8

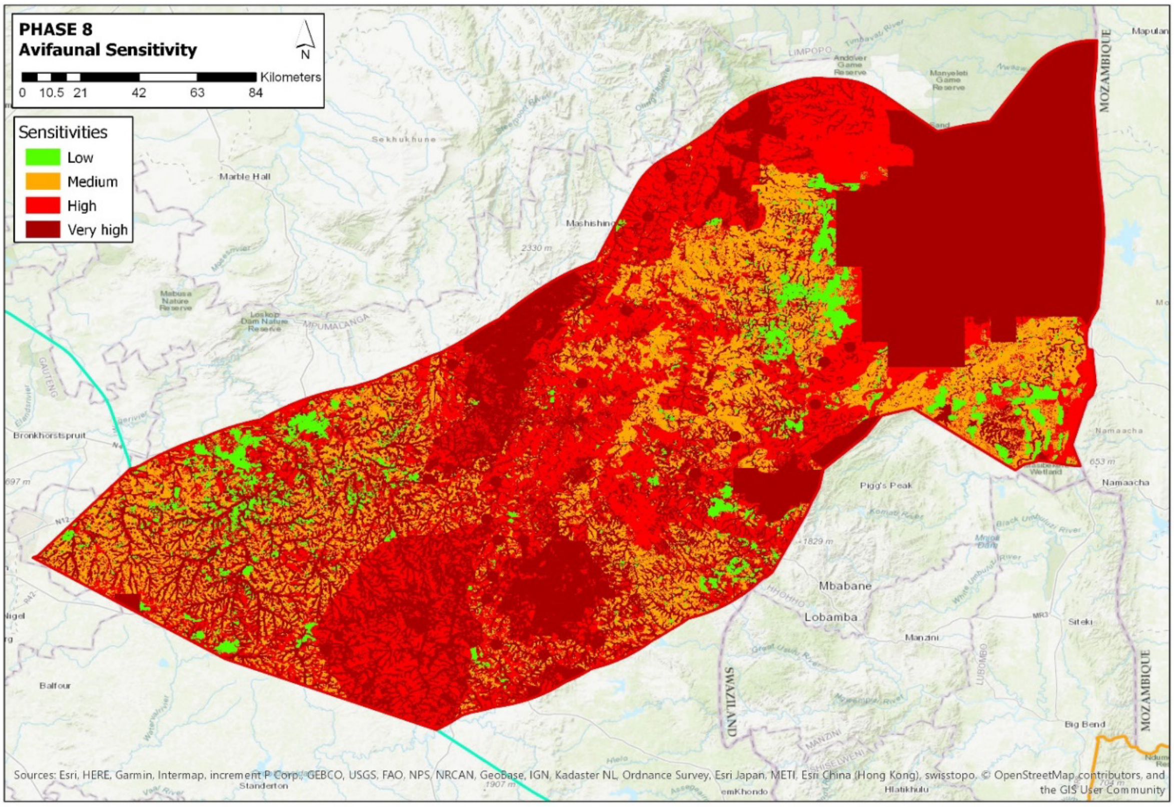

Figure 28: Avifauna sensitivity map for the Phase 8 Corridor.

5 KEY POTENTIAL IMPACTS AND THEIR MITIGATION

Table 6 list the most important potential impacts on Red Data avifauna associated with the construction of gas pipelines and associated infrastructure, with proposed generic mitigation measures (adapted from Stantec (2013)):

Table 6: Potential impacts on Red Data avifauna associated with the construction of gas pipelines and associated infrastructure and suggested mitigation measures[5].

Planning and Construction Phase: Pipeline						
Stage	Activity Summary description	Activity	Potential impact on avifauna: Direct mortality through the destruction of active nests in the construction servitude	Potential impact on avifauna: Displacement due to sensory disturbance during construction activities	Potential impact on avifauna: Displacement due to habitat destruction	Mitigation
Planning	Identification of potential pipeline assessment corridors	• Identify technically feasible assessment corridor alternatives for assessment.	N/A	N/A	N/A	• Avoidance of Very High and High sensitivity areas as much as possible. If these areas cannot be avoided, the Mitigation Hierarchy must be followed (as prescribed by IFC Performance Standards) and there is a high likelihood of a biodiversity offset being required.
Servitude Preparation	Preparation of the pipeline servitude for installation of pipe, topsoil conservation and grading.	• Removal of vegetation • Use of temporary workspace for soil and spoil salvage	x	x	x	• Nest surveys by a suitably qualified avifaunal specialist to identify all active nests in the servitude and immediately adjacent areas prior to the commencement of the servitude clearing. • On discovery of a nest, the avifaunal specialist must be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures would need to be implemented, the nature of which will depend on the

[5] Each project should have a set of project specific recommendations emanating from the bird impact assessment study which was conducted during the Project Specific Assessment Phase of the project, the level of which should have been determined by the sensitivity rating of the area where the proposed pipeline is situated. The recommendations put forward here should be seen as generic and not replacing the project specific recommendations.

<table>
<tr><th colspan="7">Planning and Construction Phase: Pipeline</th></tr>
<tr><th rowspan="2">Stage</th><th rowspan="2">Activity Summary description</th><th rowspan="2">Activity</th><th colspan="3">Potential impact on avifauna</th><th rowspan="2">Mitigation</th></tr>
<tr><th>Direct mortality through the destruction of active nests in the construction servitude</th><th>Displacement due to sensory disturbance during construction activities</th><th>Displacement due to habitat destruction</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>conservation status of the species and the location of the nest. Each case will have to be dealt with on an ad hoc basis but could include the following:
o Removal of the eggs and/or chicks to rehabilitation facility if the nest will be destroyed.
o If the nest falls outside the actual pipeline servitude, the timing of construction activities to avoid the disturbance of the breeding birds.</td></tr>
<tr><td>• Restrict activity to the servitude width.
• Ensure that no access is allowed to property/habitat beyond the servitude.
• Make maximum use of existing access roads to prevent the unnecessary construction of new roads.</td></tr>
<tr><td></td><td>Stringing pipe, welding, trenching, lowering-in, and backfill</td><td>• Sequential staging of pipeline activities cumulating with installation of the pipe
• Involves heavy equipment such as tracked backhoes; side booms, pipe trucks, welders (mechanized and non-mechanized)
• Progresses quickly over the length of the pipeline right-of-way (on average 3-4 km/day)</td><td></td><td>x</td><td></td><td>• Restrict activity to the servitude width.
• Ensure that no access is allowed to property/habitat beyond the servitude.
• Implement noise and dust reduction measures according to industry best practices.</td></tr>
</table>

Planning and Construction Phase: Pipeline

Stage	Activity Summary description	Activity	Potential impact on avifauna: Direct mortality through the destruction of active nests in the construction servitude	Potential impact on avifauna: Displacement due to sensory disturbance during construction activities	Potential impact on avifauna: Displacement due to habitat destruction	Mitigation
Pipeline Installation	Rehabilitation	• Low vehicle and people intensity work • Seeding of the pipeline right–of-way • Ground application using all-terrain vehicles, agricultural equipment, seed drills etc. • Aerial application using helicopter and/or fixed wing aircraft • Specialized reclamation in some areas (water crossings) • Minimal people and equipment on site		x		• Restrict activity to the servitude width • Ensure that no access is allowed to property/habitat beyond the servitude • Keep people and equipment to a minimum to execute the on-site work. • Ensure that a rehabilitation expert is consulted to manage the process in order to recreate the natural environment as best as possible.

Construction Phase: Compressor/Pump Stations, Pigging Stations and Block Valves

Stage	Activity Summary description	Activity	Potential impact on avifauna: Direct mortality through the destruction of active nests	Potential impact on avifauna: Displacement due to sensory disturbance	Potential impact on avifauna: Displacement due to habitat destruction	Mitigation
Site Preparation	Involves removing of vegetation cover, topsoil conservation and grading	• Clearing of vegetation, topsoil conservation and grading	x	x	x	• Nest surveys conducted by a suitably qualified avifaunal specialist to identify all active nests in the construction footprint and immediately adjacent areas prior to the commencement of the servitude clearing.

Construction Phase: Compressor/Pump Stations, Pigging Stations and Block Valves						
Stage	Activity Summary description	Activity	Potential impact on avifauna			Mitigation
			Direct mortality through the destruction of active nests	Displacement due to sensory disturbance	Displacement due to habitat destruction	
						• On discovery of a nest, the avifaunal specialist should be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures would need to be implemented, the nature of which will depend on the conservation status of the species and the location of the nest. Each case will have to be dealt with on an ad hoc basis but could include the following: ○ Removal of the eggs and/or chicks to rehabilitation facility if the nest will be destroyed. ○ If the nest falls outside the actual pipeline servitude, the timing of construction activities should be structured so as to avoid the disturbance of the breeding birds.
Associated Infrastructure construction	Construction of compressor station / pump station/meter stations, Pigging Stations and Block Valves	• Involves construction of foundations and buildings, installation of pumps and or compressor units and pigging stations and block valves. Installation of yard piping. Fencing of facility.		x		• Restrict activity to the servitude width. • Ensure that no access is allowed to property/habitat beyond the servitude. • Make maximum use of existing access roads to prevent the unnecessary construction of new roads.
Construction of permanent access roads to facility sites	-	• Vegetation removal and topsoil conservation, and grading to create road bed, and gravelling of	x	x	x	• Nest surveys to be conducted by a suitably qualified avifaunal specialist to identify all active nests in the servitude and immediately adjacent areas prior to the commencement of the servitude clearing.

Construction Phase: Compressor/Pump Stations, Pigging Stations and Block Valves						
Stage	Activity Summary description	Activity	Potential impact on avifauna			Mitigation
			Direct mortality through the destruction of active nests	Displacement due to sensory disturbance	Displacement due to habitat destruction	
		access road.				• On discovery of a nest, the avifaunal specialist should be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures would need to be implemented, the nature of which will depend on the conservation status of the specie and the location of the nest. Each case will have to be dealt with on an ad hoc basis but could include the following: ○ Removal of the eggs and/or chicks to rehabilitation facility if the nest will be destroyed. ○ If the nest falls outside the actual pipeline servitude, the timing of construction activities to avoid the disturbance of the breeding birds. ○ Restrict activity to the servitude width. ○ Ensure that no access is allowed to property beyond the servitude. ○ Make maximum use of existing access roads to prevent the unnecessary construction of new roads.

Operation Phase: Pipeline						
			Potential impact on avifauna			
Stage	Activity Summary description	Activity	Direct mortality through the destruction of active nests	Displacement due to sensory disturbance	Displacement due to habitat destruction	Mitigation
Aerial and Ground Surveillance - Line Patrol	Aerial and ground surveillance activities to: • identify any potential 3rd party incursions onto their servitudes • identify areas of servitude instability that could potential affect the integrity of the pipeline • to identify areas where there is potential surface erosion • to comply the requirements of permits and approvals	• Aerial line patrol – varies in frequency depending on location • Walking/driving the pipeline servitude. Occurs typically at least once every 3 years.		x		• Avoid flying below 500m above ground to limit sensory disturbance to nesting birds. • Consider the use of drones for aerial inspections to limit the disturbance factor. • Schedule ground-based programs to occur outside of breeding window. • When conducting ground-based programs (walking or driving) stay near ditchline to limit disturbance to breeding birds • Plan once-off pass through vs "in and out' to limit potential disturbance to birds.
Pipeline repairs	Similar to pipeline construction but on a very site-specific basis. Involves vegetation removal (topsoil stripping), trenching, replacing/repairing pipe, backfill, and reclamation	• Removing vegetation through topsoil stripping • Trenching • Pipe removal and replacement • Backfilling • Reclamation	x	x	x	• If feasible, schedule repairs outside breeding window • Restrict activity to the servitude width • Ensure that no access is allowed to property/habitat outside the servitude • Implement noise and dust reduction measures according to best practices • If activity occurs within breeding window, conduct nesting surveys • Temporary removal of a nestlings and/or eggs by a qualified avifaunal rehabilitation expert for the duration of the repair activities could be an option to explore.

6 RISK ASSESSMENT OF EACH IMPACT WITHIN EACH PROPOSED CORRIDOR PHASE, AND DIFFERENT SENSITIVITY CLASSES IN EACH STUDY AREA

6.1 Consequence levels

The table below provides a description of the consequence levels used in the rating process.

Table 7: Consequence levels used in the risk assessment.

Consequence level Impact ↓	Slight	Moderate	Substantial	Severe	Extreme
Mortality of Red Data species due to destruction of nests in the 50m construction servitude, or within the compressor/pump station, block valves and pigging stations footprint, or during pipeline repairs in the operational phase.	Negligible impact on current reproductive output within Corridor Phase, i.e. it is hardly affected. Impact is temporary.	Notable impact on current reproductive output within the Corridor Phase, reproductive output is notably reduced for some species. Impact is temporary.	Substantial impact on current reproductive output within the Corridor Phase, i.e. reproductive output is significantly reduced for some species. Impact may be permanent in the case of some species.	Severe impact on current reproductive output within the Corridor Phase, i.e. reproductive output is severely reduced for some species. Impact may be permanent in the case of some species.	Extreme impact on current reproductive output within the Corridor Phase, i.e. reproductive output is almost completely terminated for some species. Impact is permanent.
Displacement of Red Data species due to sensory disturbance during the construction phase of the pipeline and the compressor/pump stations, block valves and pigging stations or during pipeline repairs in the operational phase.	Negligible impact on life cycles within Corridor Phase, i.e. they are hardly affected. Displacement is temporary. Breeding is slightly affected.	Notable impact on life cycles within the Corridor Phase. Breeding activity is notably reduced for some species. Displacement is temporary.	Substantial impact on life cycles within the Corridor Phase. Breeding activity is significantly reduced for some species. Displacement may be permanent in the case of some species.	Severe impact on life cycles within the Corridor Phase. Breeding activity is severely reduced for some species. Displacement may be permanent in the case of some species.	Extreme impact on life cycles within the Corridor Phase. Breeding activity ceases almost completely. Displacement is permanent.
Displacement of Red Data species due to habitat destruction within the 50m construction servitude, or within the compressor/pump station footprint, block valves and pigging stations or during pipeline repairs in the operational phase.	Negligible impact on abundance within Corridor Phase, i.e. populations are hardly affected. Impact is temporary.	Notable impact on abundance within the Corridor Phase. Impact is temporary.	Substantial impact on abundance within the Corridor Phase. Displacement is temporary but may be permanent for some species.	Severe impact on abundance within the Corridor Phase. Displacement is temporary but may be permanent for some species.	Extreme impact on abundance within the Corridor Phase. Displacement is permanent.

6.2 Risk assessment results

Table 8: Assessment of the risk of gas pipeline construction and operation to avifauna in the proposed gas pipeline corridors.

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
Mortality of Red Data species due to destruction of nests in the 50m construction servitude, or within the compressor/pump station, block valves and pigging stations footprint, or during pipeline repairs in the operational phase.	Phase Inland	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo. • Key ground nesting species i.e. Black Harrier, Blue Crane, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, Burchell's Courser, Sclater's Lark.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 1	Very high sensitivity area	Moderate to substantial (especially in the case of Martial Eagle and Damara Tern)	Likely	Moderate negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo. • Key ground nesting species i.e. Agulhas Long-billed Lark, Black Harrier, Blue Crane, Denham's Bustard, Hottentot Buttonquail, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, Burchell's Courser, Damara Tern. • Key tree nesting species: Martial Eagle • Depending on where the alignment is located, the impact on Martial Eagle could be moderate, and substantial in the case of Damara Terns breeding at De Mond in the De Hoop Nature Reserve.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 2	Very high sensitivity area	Moderate (especially in the case of Martial Eagle)	Likely	Low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo and Albany Thicket. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black Harrier,
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	Blue Crane, Denham's Bustard, Hottentot Buttonquail, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, White-bellied Korhaan, Agulhas Long-billed Lark, Burchell's Courser, Sclater's Lark. • Key tree nesting species: Martial Eagle • Depending on where the alignment is located, the impact on Martial Eagle could be moderate.
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 3	Very high sensitivity area	Substantial	Likely	Moderate negative	Slight	Not likely	Very low negative	• Primary biomes: Grassland, Forest and Savanna. • Keys tree nesting species i.e. African Crowned Eagle, Bush Blackcap, Orange Ground-Thrush Eastern Bronze-naped Pigeon, Lappet-faced Vulture, Martial Eagle, Secretary bird, Southern Ground-Hornbill, Tawny Eagle, White-backed Vulture. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black-rumped Buttonquail, Blue Crane, Botha's Lark, Burchell's Courser, Denham's Bustard, Grey Crowned Crane, Rudd's Lark, Short-tailed Pipit, Wattled Crane (wetlands), White-bellied Korhaan, Yellow-breasted Pipit, Yellow-throated Sandgrouse. • Depending on where the alignment is located, impact on forest specialists e.g.
		High sensitivity area	Moderate	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight (moderate for some species in some habitat classes e.g. Eastern Bronze-naped Pigeon)	Likely	Low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									Eastern Bronze-naped Pigeon, and tree nesting vultures could be substantial. Rudd's Lark and Botha's Lark could also be substantially impacted in grasslands.
	Phase 4	Very high sensitivity area	Substantial (especially for nesting vultures and large raptors)	Likely	Moderate negative	Slight	Not likely	Very low	• Primary biomes: Savanna, Forest, Indian Ocean Coastal Belt, Azonal • Key tree nesting species i.e. African Broadbill, African Crowned Eagle, African Pygmy-Goose, Bateleur, Hooded Vulture, Lappet-faced Vulture, Lemon-breasted Canary, Martial Eagle, Pel's Fishing-Owl, Saddle-billed Stork, Secretary bird, Southern Ground-Hornbill, Tawny Eagle, White-backed Vulture, White-headed Vulture, African Broadbill, African Crowned Eagle, Neergaard's Sunbird, Southern Banded Snake-Eagle, Pink-backed Pelican. • Key nesting ground nesting species i.e. African Marsh-Harrier, Rosy-throated Longclaw, Swamp Nightjar. • Depending on where the alignment is located, the impact on large eagles and vultures could be substantial
		High sensitivity area	Moderate	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight (substantial for some species and habitat classes e.g. Southern Banded Snake – Eagle)	Not likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 5	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo. • Key ground nesting species i.e. African Marsh-Harrier, Black Harrier, Blue Crane, Karoo
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium	Slight	Likely	Very low	Slight	Not likely	Very low	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
		sensitivity area			negative			negative	Korhaan, Ludwig's Bustard, Southern Black Korhaan, Red Lark, Burchell's Courser. • Key tree nesting species i.e. Martial Eagle, Secretary bird. • Slight impact on Red Data species anticipated.
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 6	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Succulent Karoo, Nama Karoo, Desert. • Key ground nesting species i.e. Barlow's Lark, Black Harrier, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Red Lark, Southern Black Korhaan, Burchell's Courser, Sclater's Lark. • Key tree nesting species i.e. Martial Eagle, Secretary bird. • Slight impact on Red Data species anticipated.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 7	Very high sensitivity area	Substantial (especially for Damara Tern, Southern Ground Hornbill, forest species, tree nesting large eagles and vultures.	Likely	Moderate	Slight	Not likely	Very low negative	• Primary biomes: Savanna, Grassland, Indian Ocean Coastal Belt. • Key tree nesting species i.e. African Crowned Eagle, African Finfoot, African Pygmy-Goose, Bush Blackcap, Cape Parrot, Half-collared Kingfisher, Mangrove Kingfisher, Martial Eagle, Orange Ground-Thrush, Secretary bird, Southern Ground-Hornbill, White-backed Night-Heron, Yellow-billed Stork, African Broadbill, Bat Hawk, Bateleur, Eastern Bronze-naped Pigeon, Green Barbet, Lappet-faced Vulture, Lemon-breasted Canary,
		High sensitivity area	Moderate (especially for forest species e.g. Cape Parrot)	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	Neergaard's Sunbird, Saddle-billed Stork, Southern Banded Snake-Eagle, Spotted Ground-Thrush, Tawny Eagle, White-backed Vulture, White-headed Vulture. • Key ground nesting species i.e. African Marsh-Harrier, Blue Crane, Damara Tern, Denham's Bustard, Grey Crowned Crane, Kori Bustard, Striped Flufftail, White-bellied Korhaan, Yellow-breasted Pipit, African Grass-Owl, Black-rumped Buttonquail, Blue Swallow, Rosy-throated Longclaw, Short-tailed Pipit, Swamp Nightjar, Wattled Crane (wetlands). • Depending where the alignment is situated, impact could be substantial on Damara Tern, Southern Ground Hornbill, forest species, tree nesting large eagles and vultures.
	Phase 8	Very high sensitivity area	Substantial to severe (substantial for large raptors and vultures and Southern Ground Hornbill. Severe in the case of White-winged	Likely	High negative	Slight	Not likely	Very low negative	• Primary biomes: Savanna, Forest, Grassland. • Key tree nesting species i.e. African Crowned Eagle, African Finfoot, Bush Blackcap, Half-collared Kingfisher, Secretary bird, Yellow-billed Stork, Bateleur, Hooded Vulture, Lappet-faced Vulture, Martial Eagle, Saddle-billed Stork, Southern Ground-Hornbill, Tawny Eagle, White-backed

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
			Flufftail).						Night-Heron, White-backed Vulture, White-headed Vulture, African Pygmy-Goose, Bat Hawk. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black-rumped Buttonquail, Blue Crane, Denham's Bustard, Grey Crowned Craned, Wattled Crane, White-bellied Korhaan, Blue Swallow, Short-tailed Pipit, Yellow-breasted Pipit, White-winged Flufftail, Kori Bustard. • Depending on where the alignment is located, impacts could be substantial for large raptors and vultures and Southern Ground Hornbill. Severe in the case of White-winged Flufftail.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
Displacement of Red Data species due to sensory disturbance during the construction phase of the pipeline and the compressor/pump stations, block valves and pigging stations , or during pipeline repairs in the operational phase.	Inland Phase	Very high sensitivity area	Moderate (especially in the case of Martial Eagle)	Likely	Low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo. • Key ground nesting species i.e. Black Harrier, Blue Crane, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, Burchell's Courser, Sclater's Lark. • Key tree and/or powerline nesting species: Martial Eagle, Secretary bird. • Depending on where the line is situated, the impact could be moderate tree and powerline nesting Martial Eagles.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 1	Very high sensitivity area	Substantial (especially for	Likely	Moderate negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
			Cape Vulture and Damara Tern)						and Albany Thicket. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black Harrier, Blue Crane, Denham's Bustard, Hottentot Buttonquail, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, White-bellied Korhaan, Agulhas Long-billed Lark, Burchell's Courser, Sclater's Lark and Damara Tern. • Key cliff-nesting species i.e. Cape Vulture • Key wetland and waterbody species: Greater Flamingo, Lesser Flamingo, Great White Pelican. • Depending on where the alignment is situated, impact on the Cape Vulture colony at Potberg and the Damara Terns breeding at De Mond in the De Hoop Nature Reserve could be substantial.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 2	Very high sensitivity area	Moderate (especially in the case of Martial Eagles)	Likely	Low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo and Albany Thicket. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black Harrier, Blue Crane, Denham's Bustard, Hottentot Buttonquail, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, White-bellied Korhaan, Agulhas Long-billed Lark, Burchell's Courser,
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									Sclater's Lark. • Key tree nesting species: Martial Eagle • Key wetland and waterbody species: Greater Flamingo, Lesser Flamingo. • Depending on where the alignment is situated, the impact om Martial Eagles could be moderate.
	Phase 3	Very high sensitivity area	Substantial	Likely	Moderate negative	Slight	Not likely	Very low negative	• Primary biomes: Grassland, Forest and Savanna. • Key tree nesting species i.e. African Crowned Eagle, Bush Blackcap, Orange Ground-Thrush Eastern Bronze-naped Pigeon, Lappet-faced Vulture, Martial Eagle, Secretary bird, Southern Ground-Hornbill, Tawny Eagle, White-backed Vulture. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black-rumped Buttonquail, Blue Crane, Botha's Lark, Burchell's Courser, Denham's Bustard, Grey Crowned Crane, Rudd's Lark, Short-tailed Pipit, White-bellied Korhaan, Yellow-breasted Pipit, Yellow-throated Sandgrouse, Wattled Crane (wetlands). • Key cliff-nesting species: Cape Vulture • Key wetlands and waterbody species: Greater Flamingo, Lesser Flamingo, Wattled
		High sensitivity area	Moderate	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight (moderate for some species in some habitat classes e.g. Eastern Bronze-naped Pigeon)	Likely	Low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									Crane. • Depending on where the alignment is located, impact on forest specialists e.g. Eastern Bronze-naped Pigeon, and vultures, both tree nesting and cliff-nesting (Cape Vultures in the Magaliesberg) could be substantial. Disturbance of breeding Wattled Cranes in wetlands, and Rudd's Lark and Botha's Lark in grasslands could also be substantial.
	Phase 4	Very high sensitivity area	Substantial (especially for nesting vultures and large raptors, and Pink-backed Pelicans)	Likely	Moderate negative	Slight	Not likely	Very low	• Primary biomes: Savanna, Forest, Indian Ocean Coastal Belt, Azonal • Key tree nesting species i.e. African Broadbill, African Crowned Eagle, African Pygmy-Goose, Bateleur, Hooded Vulture, Lappet-faced Vulture, Lemon-breasted Canary, Martial Eagle, Pel's Fishing-Owl, Saddle-billed Stork, Secretary bird, Southern Ground-Hornbill, Tawny Eagle, White-backed Vulture, White-headed Vulture, African Broadbill, African Crowned Eagle, Neergaard's Sunbird, Southern Banded Snake-Eagle, Pink-backed Pelican. • Key ground nesting species i.e. African Marsh-Harrier, Rosy-throated Longclaw, Swamp Nightjar. • Key wetland species: Great White Pelican, Greater Flamingo, Lesser Flamingo,
		High sensitivity area	Moderate	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight (substantial for some species and habitat classes e.g. Southern Banded Snake – Eagle)	Not likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									Pink-backed Pelican. • Depending on where the alignment is located, the impact on large eagles, vultures and Pink-backed Pelicans could be substantial.
	Phase 5	Very high sensitivity area	Moderate	Likely	Low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo. • Key ground nesting species i.e. African Marsh-Harrier, Black Harrier, Blue Crane, Karoo Korhaan, Ludwig's Bustard, Southern Black Korhaan, Red Lark, Burchell's Courser. • Key tree and/or powerline nesting species i.e. Martial Eagle, Secretary bird, Lanner Falcon, Verreaux's Eagle. • Key wetland species: Lesser Flamingo, Greater Flamingo. • Depending on where the alignment is located, the impact on powerline nesting raptors, especially Martial Eagle could be moderate.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 6	Very high sensitivity area	Moderate	Likely	Low negative	Slight	Not likely	Very low negative	• Primary biomes: Succulent Karoo, Nama Karoo, Desert. • Key ground nesting species i.e. Barlow's Lark, Black Harrier, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Red Lark, Southern Black Korhaan, Burchell's Courser, Sclater's Lark. • Key tree and/or powerline nesting species i.e. Martial Eagle, Verreaux's Eagle, Secretary bird.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									• Key wetland species: Lesser Flamingo, Greater Flamingo. • Depending on where the alignment is located, the impact on powerline nesting raptors, especially Martial Eagle, could be moderate
	Phase 7	Very high sensitivity area	Substantial (especially for Damara Tern, Southern Ground Hornbill, forest species, tree nesting large eagles and vultures, and Wattled Crane.	Likely	Moderate	Slight	Not likely	Very low negative	• Primary biomes: Savanna, Grassland, Indian Ocean Coastal Belt. • Key tree nesting species i.e. African Crowned Eagle, African Finfoot, African Pygmy-Goose, Bush Blackcap, Cape Parrot, Half-collared Kingfisher, Mangrove Kingfisher, Martial Eagle, Orange Ground-Thrush, Secretary bird, Southern Ground-Hornbill, White-backed Night-Heron, Yellow-billed Stork, African Broadbill, Bat Hawk, Bateleur, Eastern Bronze-naped Pigeon, Green Barbet, Lappet-faced Vulture, Lemon-breasted Canary, Neergaard's Sunbird, Saddle-billed Stork, Southern Banded Snake-Eagle, Spotted Ground-Thrush, Tawny Eagle, White-backed Vulture, White-headed Vulture. • Key ground nesting species i.e. African Marsh-Harrier, Blue Crane, Damara Tern, Denham's Bustard, Grey Crowned Crane, Kori Bustard, Striped Flufftail, White-bellied Korhaan, Yellow-breasted Pipit, African Grass-Owl, Black-
		High sensitivity area	Moderate (especially for forest species e.g. Cape Parrot)	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									rumped Buttonquail, Blue Swallow, Rosy-throated Longclaw, Short-tailed Pipit, Swamp Nightjar, Wattled Crane. • Key wetland and waterbody species: Greater Flamingo, Lesser Flamingo, Pink-backed Pelican, Wattled Crane. • Depending where the alignment is situated, impact could be substantial on Damara Tern, Southern Ground Hornbill, forest species, tree nesting large eagles and vultures, Blue Swallows and Wattled Crane.
	Phase 8	Very high sensitivity area	Substantial to severe (substantial for large raptors and vultures and Southern Ground Hornbill. Severe in the case of White-winged Flufftail and Wattled Crane).	Likely	High negative	Slight	Not likely	Very low negative	• Primary biomes: Savanna, Forest, Grassland. • Key tree nesting species i.e. African Crowned Eagle, African Finfoot, Bush Blackcap, Half-collared Kingfisher, Secretary bird, Yellow-billed Stork, Bateleur, Hooded Vulture, Lappet-faced Vulture, Martial Eagle, Saddle-billed Stork, Southern Ground-Hornbill, Tawny Eagle, White-backed Night-Heron, White-backed Vulture, White-headed Vulture, African Pygmy-Goose, Bat Hawk. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black-rumped Buttonquail, Blue Crane, Denham's Bustard, Grey Crowned Craned, Wattled
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity	Slight	Likely	Very low	Slight	Not likely	Very low	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
		area			negative			negative	Crane, White-bellied Korhaan, Blue Swallow, Short-tailed Pipit, Yellow-breasted Pipit, White-winged Flufftail, Kori Bustard. • Depending on where the alignment is located, impacts could be substantial for large raptors and vultures and Southern Ground Hornbill. Severe in the case of White-winged Flufftail and Wattled Crane.
Displacement of Red Data species due to habitat destruction within the 50m construction servitude, or within the compressor/pump station, block valves and pigging stations footprint, or during pipeline repairs in the operational phase.	Phase Inland	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo. • Key ground nesting species i.e. Black Harrier, Blue Crane, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, Burchell's Courser, Sclater's Lark.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 1	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo. • Key ground nesting species i.e. Agulhas Long-billed Lark, Black Harrier, Blue Crane, Denham's Bustard, Hottentot Buttonquail, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, Burchell's Courser, Damara Tern. • Key tree nesting species: Martial Eagle
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 2	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo, Nama Karoo and Albany Thicket. • Key ground nesting species i.e.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	African Grass-Owl, African Marsh-Harrier, Black Harrier, Blue Crane, Denham's Bustard, Hottentot Buttonquail, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Southern Black Korhaan, White-bellied Korhaan, Agulhas Long-billed Lark, Burchell's Courser, Sclater's Lark. • Key tree nesting species: Martial Eagle
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 3	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Grassland, Forest and Savanna. • Keys tree nesting species i.e. African Crowned Eagle, Bush Blackcap, Orange Ground-Thrush Eastern Bronze-naped Pigeon, Lappet-faced Vulture, Martial Eagle, Secretary bird, Southern Ground-Hornbill, Tawny Eagle, White-backed Vulture. • Key ground nesting species i.e. African Grass-Owl, African Marsh-Harrier, Black-rumped Buttonquail, Blue Crane, Botha's Lark, Burchell's Courser, Denham's Bustard, Grey Crowned Crane, Rudd's Lark, Short-tailed Pipit, Wattled Crane (wetlands), White-bellied Korhaan, Yellow-breasted Pipit, Yellow-throated Sandgrouse. • Depending on where the alignment is located, impact on forest specialists e.g. Eastern Bronze-naped Pigeon, and tree nesting vultures could
		High sensitivity area	Moderate for tree nesting vultures and raptors	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Moderate for some species in forest habitat classes e.g. Eastern Bronze-naped Pigeon	Likely	Low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									be moderate. Rudd's Lark and Botha's Lark could also be moderately impacted in grasslands.
	Phase 4	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Savanna, Forest, Indian Ocean Coastal Belt, Azonal • Key tree nesting species i.e. African Broadbill, African Crowned Eagle, African Pygmy-Goose, Bateleur, Hooded Vulture, Lappet-faced Vulture, Lemon-breasted Canary, Martial Eagle, Pel's Fishing-Owl, Saddle-billed Stork, Secretary bird, Southern Ground-Hornbill, Tawny Eagle, White-backed Vulture, White-headed Vulture, African Broadbill, African Crowned Eagle, Neergaard's Sunbird, Southern Banded Snake-Eagle, Pink-backed Pelican. • Key nesting ground nesting species i.e. African Marsh-Harrier, Rosy-throated Longclaw, Swamp Nightjar. • Depending on where the alignment is located, the impact on large eagles and vultures could be moderate.
		High sensitivity area	Moderate for tree nesting vultures and raptors	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Moderate for some species in forest habitat classes e.g. Eastern Bronze-naped Pigeon	Likely	Low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 5	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Fynbos, Succulent Karoo. • Key ground nesting species i.e. African Marsh-Harrier, Black Harrier, Blue Crane, Karoo Korhaan, Ludwig's Bustard, Southern Black Korhaan, Red Lark, Burchell's Courser.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity	Slight	Likely	Very low	Slight	Not likely	Very low	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
		area			negative			negative	• Key tree nesting species i.e. Martial Eagle, Secretary bird.
	Phase 6	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Primary biomes: Succulent Karoo, Nama Karoo, Desert. • Key ground nesting species i.e. Barlow's Lark, Black Harrier, Karoo Korhaan, Kori Bustard, Ludwig's Bustard, Red Lark, Southern Black Korhaan, Burchell's Courser, Sclater's Lark. • Key tree nesting species i.e. Martial Eagle, Secretary bird.
		High sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
	Phase 7	Very high sensitivity area	Substantial for Blue Swallow.	Likely	Moderate negative	Slight	Not likely	Very low negative	• Primary biomes: Savanna, Grassland, Indian Ocean Coastal Belt. • Key tree nesting species i.e. African Crowned Eagle, African Finfoot, African Pygmy-Goose, Bush Blackcap, Cape Parrot, Half-collared Kingfisher, Mangrove Kingfisher, Martial Eagle, Orange Ground-Thrush, Secretary bird, Southern Ground-Hornbill, White-backed Night-Heron, Yellow-billed Stork, African Broadbill, Bat Hawk, Bateleur, Eastern Bronze-naped Pigeon, Green Barbet, Lappet-faced Vulture, Lemon-breasted Canary, Neergaard's Sunbird, Saddle-billed Stork, Southern Banded Snake-Eagle, Spotted Ground-Thrush, Tawny Eagle, White-backed Vulture, White-headed Vulture. • Key ground nesting species i.e. African Marsh-Harrier, Blue
		High sensitivity area	Moderate for tree nesting vultures and raptors	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Substantial for Blue Swallow. Moderate for some species in forest habitat classes e.g. Eastern Bronze-naped Pigeon	Likely	Moderate negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Not likely	Very low negative	Slight	Not likely	Very low negative	

Impact	Study area	Sensitivity	Without mitigation			With mitigation			Comments
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk	
									Crane, Damara Tern, Denham's Bustard, Grey Crowned Crane, Kori Bustard, Striped Flufftail, White-bellied Korhaan, Yellow-breasted Pipit, African Grass-Owl, Black-rumped Buttonquail, Blue Swallow, Rosy-throated Longclaw, Short-tailed Pipit, Swamp Nightjar, Wattled Crane (wetlands). • Depending where the alignment is situated, impact could be moderate on forest species and tree nesting large eagles and vultures, but substantial for Blue Swallow.
	Phase 8	Very high sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	• Depending where the alignment is situated, impact could be moderate on tree nesting large eagles and vultures.
		High sensitivity area	Moderate on tree nesting vultures and eagles	Likely	Low negative	Slight	Not likely	Very low negative	
		Medium sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	
		Low sensitivity area	Slight	Likely	Very low negative	Slight	Not likely	Very low negative	

6.3 Limits of Acceptable Change: Avifauna

Due to the wide scope of the assessment, it is not possible to determine limits of acceptable change with a great deal of accuracy for each species in each corridor phase. For that, accurate data on population figures is required, as well as comprehensive data on the biology of each species, in order to model the effect of the envisaged impacts on the population. Information on that level is lacking for the majority of the species. Modelling impact at population level is a complicated process which falls outside the scope of this project. However, the impact of pipeline developments on avifauna is likely to be less severe than for example renewable energy, powerline developments or urban developments, due to its limited footprint, compared to other types of developments.

7 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS: AVIFAUNA

Table 9 provides a framework for the investigation, assessment and mitigation of pipeline developments on avifauna.

7.1 Planning phase

Table 9: Planning phase framework for the investigation, assessment and mitigation of pipeline developments on avifauna.

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
Planning	The identification of potential pipeline assessment corridors as part of the Project Specific Assessment.	• Identify technically feasible assessment corridor alternatives for assessment.	• A suitably qualified avifaunal specialist should be appointed to conduct an avifaunal impact assessment study. The specialist should proceed as follows: o The centre line of each assessment corridor must be determined. o A 2km buffer zone must be drawn around the centre line of each assessment corridor. o The sum total area of each habitat sensitivity class in the assessment corridor must be calculated, based on the four-tier avifaunal sensitivity map. o The procedure to follow for the avifaunal assessment of each assessment corridor alternative must be determined, based on the majority sensitivity class in the corridor. Depending on the representation of sensitivity classes in the corridor, this may be a combination of procedures. • Nest surveys to be conducted in Very High sensitivity and High sensitivity areas. • The specialist must make a recommendation on whether the project/gas pipeline section may proceed or not, based on the anticipated impacts on Red Data avifauna, and must identify a preferred corridor which will have the least impact on Red Data avifauna, i.e. one which **avoids** Very High and High sensitive areas as much as possible.

7.2 Construction phase

Table 10: Construction phase framework for the investigation, assessment and mitigation of pipeline developments on avifauna.

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
Pipeline Servitude Preparation	Preparation of the pipeline servitude for installation of pipe, topsoil conservation and grading.	• Removal of vegetation • Use of temporary workspace for soil and spoil salvage	If a feasible corridor alternative is identified and authorisation or similar is obtained to proceed with the project, the procedure is as follows: • If need be, nest surveys should be conducted by a suitably qualified avifaunal specialist to identify all active Red Data nests in the servitude and immediately adjacent areas prior to the commencement of the servitude clearing. Due to the length of time between the authorisation (or similar) of the project and the commencement of construction activities, the nest surveys (if any) conducted during the planning phase will have to be repeated. This is usually only applicable in Very High and High sensitivity areas but depending on the circumstances of each project and the professional opinion of the specialist, this may have to be extended to Medium and Low sensitivity areas as well. The width of the corridor to be surveyed will be determined by the species which are likely to breed there. • Should a nest be discovered, the avifaunal specialist should be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures would need to be implemented, the nature of which will depend on the Red Data conservation status of the species and the location of the nest. Each case will have to be dealt with on an ad hoc basis but could include the following: ○ The eggs and/or chicks must be removed to a rehabilitation facility if the nest will be destroyed. ○ If the nest falls outside the actual pipeline servitude, the construction activities must be timed to avoid the disturbance of the breeding birds. • Activities must be restricted to the servitude width. • No access must be allowed to property/habitat beyond the servitude. • Maximum use must be made of existing access roads to prevent the unnecessary construction of new roads.
Pipeline Installation	Stringing pipe, welding, trenching, lowering-in, and backfill	• Sequential staging of pipeline activities cumulating with installation of the pipe • Involves heavy equipment such as tracked backhoes; side booms, pipe trucks, welders (mechanized and non-mechanized) • Progresses quickly over the length of	• Activities must be restricted to the servitude width. • No access must be allowed to property/habitat beyond the servitude. • Maximum use must be made of existing access roads to prevent the unnecessary construction of new roads.

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
		the pipeline right-of-way (on average 3-4 km/day)	
	Rehabilitation	• Low vehicle and people intensity work • Seeding of the pipeline right–of-way • Ground application using all-terrain vehicles, agricultural equipment, seed drills etc. • Aerial application using helicopter and/or fixed wing aircraft • Specialized reclamation in some areas (water crossings) • Minimal people and equipment on site	• Activities must be restricted to the servitude width as far as is practical possible. • No access must be allowed to property/habitat beyond the servitude. • Maximum use must be made of existing access roads to prevent the unnecessary construction of new roads. • People and equipment must be restricted to a minimum to execute the on-site work. • A suitably qualified rehabilitation expert must be appointed to manage the process in order to recreate the natural environment as best as possible.
Pump/ compressor station, block valves and pigging stations site Preparation	Involves removing of vegetation cover, topsoil conservation and grading	• Clearing of vegetation, topsoil conservation and grading	• Nest surveys should be conducted by a suitably qualified avifaunal specialist to identify all active nests in the construction footprint and immediately adjacent areas prior to the commencement of the site clearing. • Should a nest be discovered, the avifaunal specialist should be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures would need to be implemented, the nature of which will depend on the conservation status of the species and the location of the nest. Each case will have to be dealt with on an ad hoc basis but could include the following: o Removal of the eggs and/or chicks to rehabilitation facility if the nest will be destroyed. • If the nest falls outside the actual site footprint, the timing of construction activities should be scheduled in order to avoid the disturbance of the breeding birds.
Facility construction	Construction of compressor station / pump station/meter stations, Pigging Stations and Block Valves	• Involves construction of foundations and buildings, installation of pumps and/or compressor units, and block valves and pigging stations. Installation of yard piping. Fencing of facility	• Activities must be restricted to the footprint. • No access must be allowed to property beyond the footprint. • Maximum use must be made of existing access roads to prevent the unnecessary construction of new roads.
Construction of permanent access roads to facility sites	-	• Vegetation removal and topsoil conservation, and grading to create road bed, and gravelling of access road	• Nest surveys should be conducted by a suitably qualified avifaunal specialist to identify all active nests in the servitude and immediately adjacent areas prior to the commencement of the servitude clearing. • Should a nest be discovered, the avifaunal specialist should be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
			would need to be implemented, the nature of which will depend on the conservation status of the species and the location of the nest. Each case will have to be dealt with on an ad hoc basis but could include the following: o Removal of the eggs and/or chicks to rehabilitation facility if the nest will be destroyed. o If the nest falls outside the actual pipeline servitude, the timing of construction activities must be scheduled in order to avoid the disturbance of the breeding birds. • Activities must be restricted to the servitude width. • No access must be allowed to property beyond the servitude. • Maximum use must be made of existing access roads to prevent the unnecessary construction of new roads.

7.3 Operations phase

Table 11: Operations phase framework for the investigation, assessment and mitigation of pipeline developments on avifauna.

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
Aerial and Ground Surveillance - Line Patrol	Aerial and ground surveillance activities to: • identify any potential 3rd party incursions onto their servitudes • identify areas of servitude instability that could potential affect the integrity of the pipeline • to identify areas where there is potential surface erosion • to comply the requirements of permits and approvals	• Aerial line patrol – varies in frequency depending on location • Walking/driving the pipeline servitude. Occurs typically at least once every 3 years.	• Flying below 500m above ground should be avoided to limit sensory disturbance to nesting birds • Consider the use of drones for aerial inspections to limit the disturbance factor. • Ground-based programs should be scheduled to occur outside of breeding window. • When conducting ground-based programs (walking or driving) stay near ditchline to limit disturbance to breeding birds • Once-off pass through should be planned vs "in and out' to limit potential disturbance to birds.
Pipeline repairs	Similar to pipeline construction but on a very site-specific basis. Involves vegetation removal (topsoil stripping), trenching, replacing/repairing pipe, backfill, and reclamation	• Removing vegetation through topsoil stripping • Trenching • Pipe removal and replacement	• If feasible, repairs should be scheduled outside the breeding window • Activity should be restricted to the servitude width • No access should be allowed to property/habitat

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
		• Backfilling • Reclamation	outside the servitude • Noise and dust reduction measures must be implemented according to best practices • If activity occurs within breeding window, nesting surveys should be conducted. • Temporary removal of a nestlings and/or eggs for the duration of the repair activities could be an option to explore.

7.4 Rehabilitation and post closure

Table 12: Rehabilitation and post closure framework for the investigation, assessment and mitigation of pipeline developments on avifauna.

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
Rehabilitation and post closure	Rehabilitation	• Low vehicle and people intensity work • Appropriate seeding of the pipeline right–of-way • Ground application using all-terrain vehicles, agricultural equipment, seed drills etc. • Aerial application using helicopter and/or fixed wing aircraft • Specialized reclamation in some areas (water crossings) • Minimal people and equipment on site	• A suitably qualified rehabilitation expert must be appointed to manage the process in order to recreate the natural environment as best as possible.

7.5 Monitoring requirements

Table 13: Avifauna monitoring requirements for pipeline developments.

Stage	Activity Summary description	Activity	Suggested best practices for the assessment and mitigation of impacts on avifauna
Post closure	Monitoring	• None	• Depending on the sensitivity of the site, post-construction monitoring may be required for a specific period to compare pre- and post-construction populations of avifauna, to assess the longer-term impact of the pipeline.

8 GAPS IN KNOWLEDGE

The potential impact of pipeline developments on avifauna in South Africa is not as well studied as for example the impacts of powerline networks or wind energy. The reasons for that could be that the impacts on avifauna may on average not be as significant as those associated with powerlines and wind energy.

Areas where the lack of knowledge is a constraint are the following:

- It is unclear how some Red Data species will react to the disturbance associated with the construction of pipelines and associated infrastructure - more scientifically verifiable knowledge of the disturbance thresholds of these species would improve predictive capabilities.
- The population sizes of many Red Data species are not well known. The impact of nestling mortality on the population is therefore difficult to assess.

9 REFERENCES

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APPENDIX A – PEER REVIEW AND SPECIALIST RESPONSE SHEET

Peer Reviewer: Jonathan Booth and Robin Colyn, Birdlife South Africa

EXPERT REVIEW AND SPECIALIST RESPONSES: Avifauna - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
R.Colyn	7-8	11	Table 1	With reference to SABAP2 data used: "More than 36% of pentads have four or more lists." Were pentads with four or more cards submitted only used for analyses? Were full protocol and incidental records utilised? My reasoning here is that with range restricted, elusive and low density species it would be imperative to use all available data to represent them on these landscape level scales.	All pentads where data was collected were used irrespective of the number of lists. When SABAP2 data was lacking, it was supplemented with SABAP1 data.
R.Colyn	29	9-18		"The probability of the impacts occurring in a specific habitat class for a specific species was 9 rated for all Red Data species with a SABAP2 reporting rate of >5%" I see the need for a reporting rate cutoff to remove any vagrant or stochatically recorded species that aren't necessarily representative of the specific pentad/s. However, my concern is that range restricted and elusive species might inherently be even less adequately represented than they already sometimes are within SABAP2 data given their detection probability. It might not be a feasible task, but could all SABAP2 data not be used for Red Data species listed are South African endemics? Or alternatively, those SA endemics known to yield low detection probabilities and as such are poorly represented within SABAP2 data?	Where available, actual species data were used to augment the SABAP2 data and in so doing alleviates this concern to some degree e.g. Yellow-breasted Pipit, Barlows Lark, Botha's Lark. The problem with rating impacts for all species, irrespective of their reporting rate, is that it can skew the ratings heavily if many of the species with reporting rates of <5% are Red Data species. This could result in some habitat classes being assigned very high risk ratings due to the presence of these species in the SABAP2 database, while the chances of actually encountering them are negligible. While we take the point that in some cases the low reporting rate is due to other factors than actual scarcity, we believe that in the majority of cases it reflects actual low numbers on the ground. It is also important to bear in mind that this assessment does not replace the project specific bird specialist study, which will still be required, and will include field surveys in all instances except in the case of Very Low sensitivity areas.
J. Booth	10	29		"Some avifaunal specialists did not respond to data requests" - has this resulted in any significant gaps in data? Would it be beneficial if the authors were allowed more time to collect possible missing data in order to increase the level of confidence in their results?	It will never be possible to include all available data from all specialist sources and it is envisaged that such information gaps will be addressed during the site specific assessments to be conducted. See point 11 (second last point) below.

EXPERT REVIEW AND SPECIALIST RESPONSES: Avifauna - Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
J. Booth	11	1 - 3		BirdLife South Africa strongly supports this statement; given inherent SEA limitations, the SEA must not preclude a full EIA (and not just a Basic Assessment) taking place at the individual project level.	The level of investigation will not be determined by the legal procedure (BA or EIA) but by the habitat sensitivity level.
J. Booth	11	17 - 18	Table 2	Consider inclusion of the IFC Performance Standards. Performance Standard 6 is of particular relevance.	This was added as recommended.
J. Booth	41	6	Table 5	Could the authors describe how various buffer distances were calculated / what informed the buffer distances?	Buffer distances were defined based on our professional judgment of the extent of the potential impact of the gas infrastructure on avifauna within the defined habitat classes - i.e. drainage lines were deemed less sensitive (60m buffer) than wetlands and waterbodies (200m buffer).
J. Booth	66	3	Table 6	For Very High and High Sensitivity Class: Provincial conservation authorities and any regional conservation NGO's (e.g. Wilderness Foundation and Nature's Valley Trust in the Eastern Cape; Wildlands Conservation Trust in KwaZulu-Natal) should also be notified of any development proposals.	This was added as recommended.
J. Booth	66	3	Table 6	For Very High and High Sensitivity Class: In addition to the stated Implementation and Additional Assessments at Project Level - BirdLife South Africa recommends that the Mitigation Hierarchy, as described in the IFC Performance Standards, is also followed when considering development in these areas.	This was added as recommended.
J. Booth	67		Table 7	Under Row 2 of Table 7 (Stage = Planning), we recommend the following text in the Mitigation Cell: "Avoidance of Very High and High sensitivity areas as much as possible. If these areas cannot be avoided, the Mitigation Hierarchy must be followed (as prescribed by IFC Performance Standards) and there is a high likeliness of a Biodiversity Offset being required."	This was added as recommended.

Strategic Environmental Assessment for the Development of a Phased Gas Pipeline Network in South Africa

Appendix C.1.9

Biodiversity and Ecological Impacts - Bats

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

BATS

Contributing Authors	Kate MacEwan[1,2]

[1] Inkululeko Wildlife Services (Pty) Ltd
[2] South African Bat Assessment Association Panel

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FIGURES

ABBREVIATIONS AND ACRONYMS

AoO	Area of Occupancy
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
EWT	Endangered Wildlife Trust
EoO	Extent of Occurrence
IWS	Inkululeko Wildlife Services
NEMA	National Environmental Management Act
SABAA	South African Bat Assessment Association
SABAAP	South African Bat Assessment Association Panel
SANBI	South African National Biodiversity Institute
SEA	Strategic Environmental Assessment
WEF	Wind Energy Facility

SUMMARY

A Strategic Environmental Assessment (SEA) methodology is being adopted to identify and pre-assess suitable gas routing corridors. Inkululeko Wildlife Services (IWS) were appointed as the bat specialist to provide input into high level strategic mapping, provide guidance on the site specific assessment requirements that should be followed in each of the four sensitivity tiers, and provide input into some of the high level potential impacts relevant to bats and the gas routing corridors. This high level assessment is deemed suitable for an SEA study of this nature and where necessary, future site-specific investigations and appropriate specialist studies will provide more detail.

Terrestrial ecoregions, geology, known bat roosts, vegetation, irrigated agricultural areas, urban areas, eroded areas, wetlands, rivers, dams and extent of occurrence of conservation important bat species were selected as features relevant to bats. These features were mapped per corridor and then each feature or feature sub-class was assigned a sensitivity class and where appropriate, a buffer. The feature maps and sensitivity maps for each of the corridors are provided in this report.

Very High sensitivity areas were considered as such due to very high roosting and/ or foraging potential and/ or due to very high bat activity levels and/ or potential occurrence of Vulnerable, Data Deficient or Endangered species. These areas are probably unsuited to development from a bat perspective owing to the very high bat importance. High sensitivity areas were considered to have high roosting and/ or foraging potential and/ or due to high bat activity levels. These areas are potentially unsuited to development from a bat perspective owing to the high bat importance. Medium sensitivity areas were considered to have moderate roosting and/ or foraging potential and/ or due to moderate bat activity levels and/ or due to unknown bat activity levels and/ or potential occurrence of Near-threatened or Rare species. These areas are potentially more suitable for development from a bat perspective, but potential on-site sensitivities must be fully investigated and effective mitigation options clearly identified. Low sensitivity areas were considered to have low roosting and/ or foraging potential and/ or due to low bat activity levels and no known occurrence of conservation important species. These areas are probably the most suitable for development compared with the Medium to Very High sensitivity areas.

The potential impacts to bats by the gas pipeline developments during the construction phase (and possibly during the operational phase if maintenance or repair on the pipeline is required) could include roost disturbance and foraging habitat loss associated with clearing the right of way, and sensory disturbance due to increased levels of noise and dust associated with heavy vehicles and other machinery, and sedimentation of water bodies and wetlands. Measures to avoid and minimize impacts would include, in the planning phase, staying away from Very High and High sensitivity areas. Where required, based on the Decision-Making Tools (e.g. in areas of verified Very High and High sensitivity based on the recommendation of the general faunal ecologist), Bat Assessments, including field work, must be performed to inform whether the project would have adverse effects on bats and to make informed mitigation recommendations. Such recommendations could be micro-siting to avoid key roosts or foraging habitat, avoiding construction in certain seasons, keeping the development footprint to a minimum, dust prevention and prevention of sedimentation runoff into water bodies, etc.

1 INTRODUCTION

A Strategic Environmental Assessment (SEA) methodology is being adopted to identify and pre-assess suitable gas routing corridors. The Council for Scientific and Industrial Research (CSIR) (in collaboration with the South African National Biodiversity Institute (SANBI)) were appointed by the Department of Environmental Affairs (DEA) to undertake the Phased Gas Pipeline Network SEA. As such, the CSIR appointed Inkululeko Wildlife Services (IWS) as an independent, suitably qualified bat (order Chiroptera) specialist to provide expert high level bat input on the impacts of the development of a gas pipeline network.

Bats (Order: Chiroptera), the second most diverse mammal group on the planet, provide vital ecosystem services. They warrant consideration and protection at the very least due to their economic value, although tourism and biodiversity heritage value is also very important. Insectivorous bats are known to eat up to their body weight in insects daily; much of their prey considered pests. They thus act as vital pest-control agents, and their value has been estimated at $1bn in global savings in the agricultural industry (Kalka et al., 2008; Kunz et al., 2011; Maine and Boyles, 2015). Gonsalves et al. (2013) found that they have also proven to be effective at controlling mosquitoes carrying the Malaria parasite, a disease which ravages the African continent and is spread over many parts of South Africa. Fruit and nectar-eating bats are known to act as vectors for seed dispersal and pollination of 528 plant species - both important agricultural crops and naturally occurring species (Fleming et al., 2009). Cave-dwelling bats play important roles in nutrient cycling via the production of guano, a vital input of energy in most cave systems (IUCN SSC, 2014). Bats are thus important keystone species for most ecosystems and act as a good indicator of ecosystem health.

Although there are no publicly available studies investigating the impacts of gas pipeline development on bats, potentially adverse effects can be inferred based on other human-induced landscape-level changes (Hein, 2012). Potential impacts on bats include:

- The clearance of vegetation can cause destruction of roosting and foraging habitat.
- The digging of trenches during construction and maintenance activities during operation creates noise and vibrations that could displace local bats. This is particularly significant if there are species of conservation importance roosting within less than 200 m of the development activities.
- Indirect impacts during the construction and maintenance phases would include increased dust in the air and sedimentation in wetlands, rivers or open water bodies.
- It is unlikely that any potential gas leaks will have any significant impact on bats.

Bats are already nationally and globally under severe pressure due to disease, roost disturbance, habitat decline (IUCN SSC, 2014) and wind energy (Arnett and Baerwald, 2013; MacEwan, 2016). Therefore, there is public outcry in the USA where energy companies want to run large natural gas pipelines through and near roosting areas for severely threatened bat species.

2 SCOPE OF THIS STRATEGIC ISSUE

- Attend a briefing session at the beginning of the specialist assessment process and a multi-author team workshop to discuss the first draft report (V1).
- Provide a brief report and/or GIS files of key bat features for the gas pipeline corridor features.
- Provide input into the key features mapping from a bat perspective.
- Provide bat input into the environmental four tier sensitivity map.
- Develop/verify the approach for classing each sensitivity feature according to a four-tiered sensitivity rating system.
- Identify any gaps in information and based on the findings of the assessment.

3 APPROACH AND METHODOLOGY

As per the terms of reference supplied, the current high level study was based on a brief desktop review and high level strategic mapping.

3.1 Desktop Review

- Analysis of IWS collected bat call data from over 25 Wind Energy facility (WEF) Monitoring Studies within the various Terrestrial Ecoregions to determine an average annual bat activity level per Ecoregion for comparative analysis;
- Based on several years of experience and literature reviews, assessment of environmental parameters relevant to bat ecology and their distributions;
- A list of bat species of conservation importance was compiled for each of the nine gas corridor phases.

3.2 Spatial Data Analysis

Whilst various environmental parameters and spatial data sources were considered for the bat sensitivity spatial mapping exercise, only those parameters considered important for bats, as either important for roosting or foraging or of conservation significance were selected and used. The relevant sensitive environmental spatial layers were selected on the maps and buffered according to defendable criteria. This is further explained in Sections 4 and 5.

3.3 Impact characterisation

Whilst a detailed impact assessment was not undertaken, this report does discuss some of the potential impacts relevant to bats and gas pipeline development and does provide guidance on the site specific assessment requirements that should be followed in each of the four sensitivity tiers. This high level assessment is deemed suitable for an SEA study of this nature and where necessary the specialist studies will provide more detail.

4 FEATURE SENSITIVITY MAPPING

4.1 Feature identification, description and data sources

Table 1: Data sources used in this assessment.

Sensitivity Feature Class	Source and Date of Publication	Data Description and Processing	Relevant Corridor
Terrestrial Ecoregions	Terrestrial Ecoregions. 2009. The Nature Conservancy, Arlington, VA. Available at http://maps.tnc.org/gis_data.html	The terrestrial ecoregions (Olson et al., 2001) were clipped to the South African Borders, Swaziland and Lesotho Borders. From numerous monitoring assessments, IWS has calculated average bat passes per hour for the seven of the ecoregions to gain an understanding of the bat activity levels in each.	All
Geology	Council for Geosciences SA, 1997	Geology wr90 shapefile and Geology_Geoscience shapefile. Limited metadata are available but date of creation is 1997. Four main lithologies were selected as relevant to bats in terms of roosting potential: Limestone, Dolomite, Arenite and Sedimentary and Extrusive rock	All
Bat Roosts	Database from a collection of scientists, collated by the CSIR in 2017 and desktop	A few of the points were removed, as IWS knows them to not be true bat roost locations. Some points were	All

Sensitivity Feature Class	Source and Date of Publication	Data Description and Processing	Relevant Corridor
	refined by IWS in 2018. Main sources were: Bats KZN database, IWS database, Herselman and Norton (1985), Wingate (1983), Rautenbach (1982), David Jacobs database, Animalia database	moved, as the projection had put them in the ocean. Due to mainly construction phase impacts being the concern for bats, a minimum 500 m radial buffer was placed on each roost, irrespective of size or species.	
Vegetation	2013 – 2014 South African National Land-Cover Dataset. Created by GeoterraImage for the DEA, Pretoria. Version 05, February 2015. Available at https://egis.environment.gov.za/data_egis/data_download/current or http://bgis.sanbi.org/Projects/Detail/44	The following land cover classes were used: thicket/dense bush, plantations and indigenous forest (LC classes 4, 5, 32 and 33). For detailed descriptions of these classes please see Appendix A in http://www.geoterraimage.com/uploads/GTI%202013-14%20SA%20LANDCOVER%20REPORT%20-%20CONTENTS%20vs%2005%20DEA%20OPEN%20ACCESS%20vs2b.pdf Forests, plantations and thick bush provide refuge for several species of bats.	All
Irrigated Agricultural Areas	2013 – 2014 South African National Land-Cover Dataset. Created by GeoterraImage for the DEA, Pretoria. Version 05, February 2015. Available at https://egis.environment.gov.za/data_egis/data_download/current or http://bgis.sanbi.org/Projects/Detail/44	The following land cover classes were used: Vines, Subsistence cultivation, Pineapple agriculture, sugarcane plantations, commercial fields, and commercial pivots (LC classes 16-31). For detailed descriptions of these classes please see Appendix A in http://www.geoterraimage.com/uploads/GTI%202013-14%20SA%20LANDCOVER%20REPORT%20-%20CONTENTS%20vs%2005%20DEA%20OPEN%20ACCESS%20vs2b.pdf	All
Built-up and disturbed areas	2013 – 2014 South African National Land-Cover Dataset. Created by Geoterra Image for the DEA, Pretoria. Version 05, February 2015. Available at https://egis.environment.gov.za/data_egis/data_download/current or http://bgis.sanbi.org/Projects/Detail/44	The following land cover classes were used: Commercial, Industrial, Informal Settlements, Residential Areas, Schools and Sports Grounds, Smallholdings, Gold Courses, Townships, Villages and other built-up areas (LC classes 42-72), as well as erosion and dongas (LC class 40). For detailed descriptions of these classes please see Appendix A in http://www.geoterraimage.com/uploads/GTI%202013-14%20SA%20LANDCOVER%20REPORT%20-%20CONTENTS%20vs%2005%20DEA%20OPEN%20ACCESS%20vs2b.pdf.	All
Wetlands and Dams	Wetlands = National Freshwater Ecosystem Priority Areas (NFEPA). CSIR. July 2011. Dams = dams500g_wgs84 shapefile. Dept. Water and Sanitation.	Wetlands and dams provide drinking and foraging opportunities for bats.	All
Main Rivers	Rivers = wriall500_primary shapefile. Dept. Water and Sanitation	There is strong support for the importance of rivers and riparian areas for bats (Serra-Cobo et al., 2000; Akasaka et al., 2009; Hagen & Sabo, 2012).	All
Bat species occurrence data	Database from a collection of scientists and organisations. Collated by SANBI and the EWT in 2016 for use in the National Bat Red Data listings.	Extent of Occurrences (EoOs) were compiled for conservation important and certain high-risk bat species using the Child et al. (2016) species point data. These are simply points where one or more individuals from a particular species were confirmed from museum and scientific records. Because bats travel extensive distances nightly and some seasonally, these points are an under-estimation of the area each individual will occupy in their lifetime. Therefore, an arbitrary 50 km radius was placed around each confirmed point record to buffer for some or all of the potential movement or habitat spread. Then, a best fit polygon (the tightest possible polygon) was drawn around these radii to create an EoO for each relevant species. This is deemed as the maximum known extent that each species occurs in. However, the process did not exclude areas within the polygon where the bats are unlikely to occur due to disturbance or unfavourable habitat, i.e. the polygons	All except Phase 2

Sensitivity Feature Class	Source and Date of Publication	Data Description and Processing	Relevant Corridor
		did not represent the true area of occupancy (AoO). AoO is defined as the area within its EoO which is occupied by a taxon, excluding cases of vagrancy. In other words, the AoO is a more refined EoO that takes the detailed life history of each species into account. An AoO reflects the fact that a taxon will not usually occur throughout its entire EoO because the entire area may contain unsuitable or unoccupied habitats. To compile more AoOs per species is a significant task, beyond the scope of this SEA.	

4.2 Bat species of conservation importance relevant to the corridors

The following bat species of Conservation Importance are found within the proposed gas pipeline corridors.

Table 2: Red Data bat species that occur in the proposed gas pipeline corridors which are sensitive to development (LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered).

Species Name	Common Name	Conservation Status (Child et al, 2016)	Corridor Phase
Cistugo seabrae	Angolan Hairy Bat	NT (Jacobs et al., 2016a)	6
Cloeotis percivali	Short-eared Trident Bat	EN (Balona et al., 2016)	3, 4, 7, 8
Kerivoula argentata	Damara Woolly Bat	NT (Monadjem et al., 2016a)	3, 4, 7, 8
Laephotis namibensis	Namib Long-eared Bat	VU (Jacobs et al., 2016b)	1, 5, 6
Laephotis wintoni	De Winton's Long-eared Bat	VU (Avenant et al., 2016)	7
Miniopterus inflatus	Greater long-fingered bat	NT (Richards et al. 2016a)	3, 4, 7, 8
Neoromicia rendalli	Rendall's serotine	LC (Monadjem et al., 2016b) Rare in SA	4, 7
Otomops martiensseni	Large-eared free-tailed Bat	NT (Richards et al., 2016b)	3, 4, 7, 8
Rhinolophus blasii	Peak-saddle Horseshoe Bat	NT (Jacobs et al., 2016c)	3, 4, 7, 8
Rhinolophus cohenae	Cohen's Horseshoe Bat	VU (Cohen et al., 2016)	8
Rhinolophus denti	Dent's Horseshoe Bat	NT (Schoeman et al., 2016)	3
Rhinolophus smithersi	Smither's Horseshoe Bat	NT (Taylor et al., 2016)	8
Rhinolophus swinnyi	Swinny's Horseshoe Bat	VU (Jacobs et al., 2016d)	3, 4, 7, 8
Scotoecus albofuscus	Thomas' House Bat	NT (Richards et al., 2016c)	4, 7
Scotophilus nigrita	Giant Yellow House Bat	NT (Fernsby et al., 2016)	3, 4, 7, 8
Taphozous perforatus	Egyptian Tomb Bat	NT (Richards et al., 2016d)	3, 4, 7, 8

4.3 Bat feature and sensitivity maps

The following features have been mapped and then in a separate series of maps assigned varying sensitivities according to their bat importance. Where appropriate, buffers with a specific sensitivity have been assigned. The exact bat roost points have remained confidential in order to protect the roosts.

Table 3: Sensitivities assigned to features.

Feature Class	Feature Sub-class	Feature Sub-class Sensitivity	Buffer Distance	Buffer Sensitivity
Ecoregions	KwaZulu-Cape Coastal Forest Mosaic	Very High	None	None
	Maputuland Coastal Forest Mosaic	Very High	None	None
	Maputuland-Pondoland Bushlands and Thickets	Medium	None	None
	Lowland Fynbos and Renosterveld	Medium	None	None
	Knysna-Amatole Montane Forests	High	None	None
	Albany thicket	Medium	None	None
	Nama Karoo	Low	None	None
	Drakensberg Montane Grasslands, Woodlands and Forest	Medium	None	None
	Drakensberg Alti-Montane Grasslands, Woodlands and Forest	Medium	None	None
	Highveld Grassland	Low	None	None
	Kalahari Acacia-Baikiaea Woodlands	Medium	None	None
	Southern African Bushveld	Medium	None	None
	Southern African Mangroves	Low	None	None
	Zambesian and Mopane Woodlands	Medium	None	None
	Succulent Karoo	Low	None	None
Geology	Limestone	Very High	200 m	Very High
	Dolomite	Very High	200 m	Very High
	Arenite	Medium	200 m	High
	Sedimentary and Extrusive Rock	Medium	200 m	Medium
Bat Roosts	Bat Roost Points	Very High	500 m	Very High
Land Cover: Vegetation	Indigenous Forest: Very High	Very High	200 m	Very High
	Plantations / Woodlands: Mature	Medium	200 m	Medium
	Plantations / Woodlands: Young	Medium	200 m	Medium
	Thicket/ Dense Bush	Medium	200 m	Medium

Feature Class	Feature Sub-class	Feature Sub-class Sensitivity	Buffer Distance	Buffer Sensitivity
Irrigated Agricultural Areas	All irrigated crops	Medium	None	None
Land Cover: Urban Built-up Areas	Urban Areas	Medium	None	None
	Disturbed Land (Eroded)	Low	None	None
Wetlands	All Wetlands	Very High	200m	High
Rivers	Major Perennial Rivers	Very High	200m	Very High
Dams	Farm Dams and Natural Dams	Very High	200m	High
EoO is defined as the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy (IUCN, 2012). Only species, where their EoO overlaps with the Gas corridors were included.	*Cistugo seabrae*	Medium	No additional buffer on the EoO but there is a 50 km buffer on the individual record points	
	Cloeotis percivali	High		
	Kerivoula argentata	Medium		
	Laephotis namibensis	Medium		
	Laephotis wintoni	Medium		
	Miniopterus inflatus	Medium		
	Neoromicia rendalli	Medium		
	Otomops martiensseni	Medium		
	Rhinolophus blasii	Medium		
	Rhinolophus cohenae	High		
	Rhinolophus denti	Medium		
	Rhinolophus swinnyi	Medium		
	Scotoecus albofuscus	Medium		
	Scotophilus nigrita	Medium		
	Taphozous perforates	Medium		

5 FEATURE MAPS AND FOUR-TIERED SENSITIVITY MAPS

The bat feature and sensitivity maps constructed for each of the proposed gas pipeline corridors, using the criteria specified in Section 4.3 above, are presented in Figure 1 to Figure 18. Note, bat roosts are not indicated in the feature maps, but have been considered in this assessment and buffered by a distance of 500 m.

5.1 Phase 1

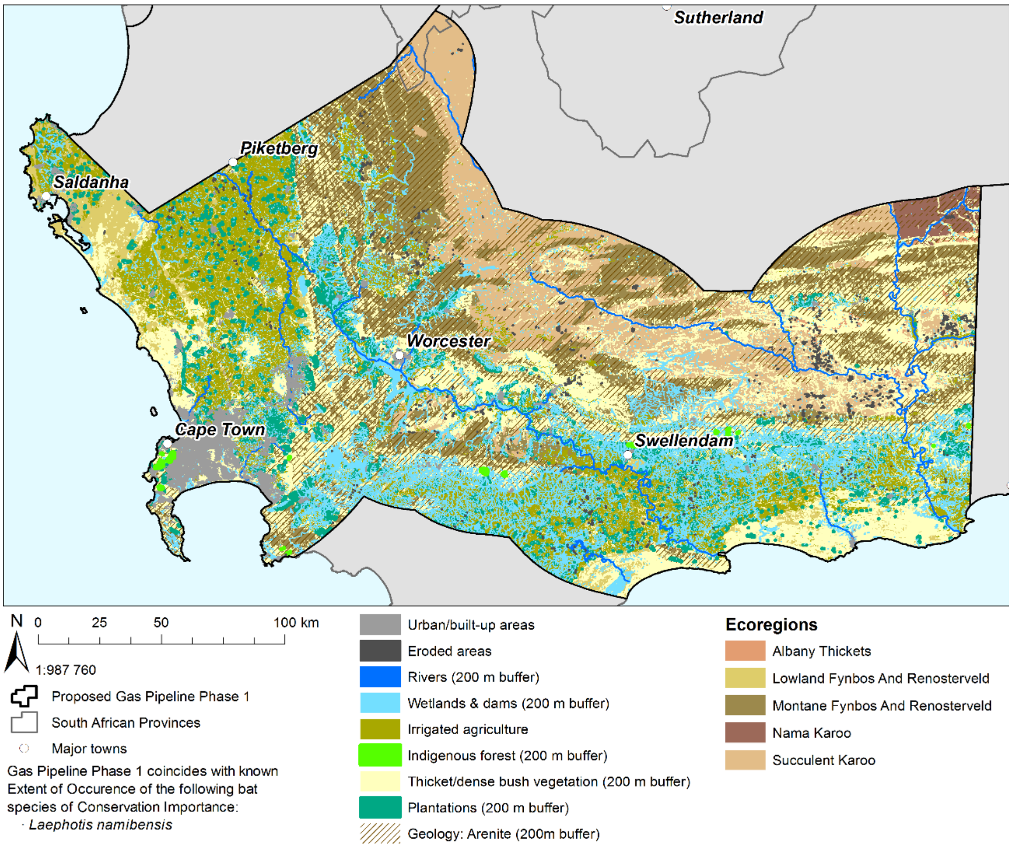

Figure 1: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 1 gas pipeline corridor.

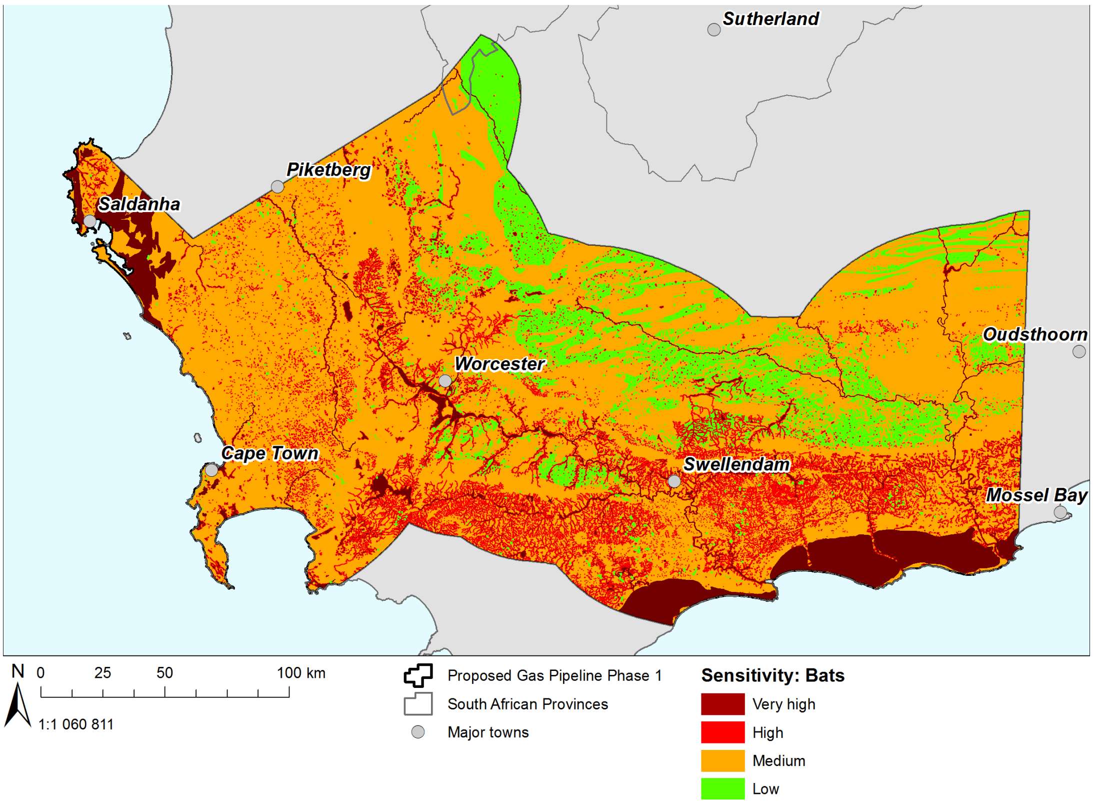

Figure 2: Bat sensitivity map for the proposed Phase 1 gas pipeline corridor.

5.2 Phase 2

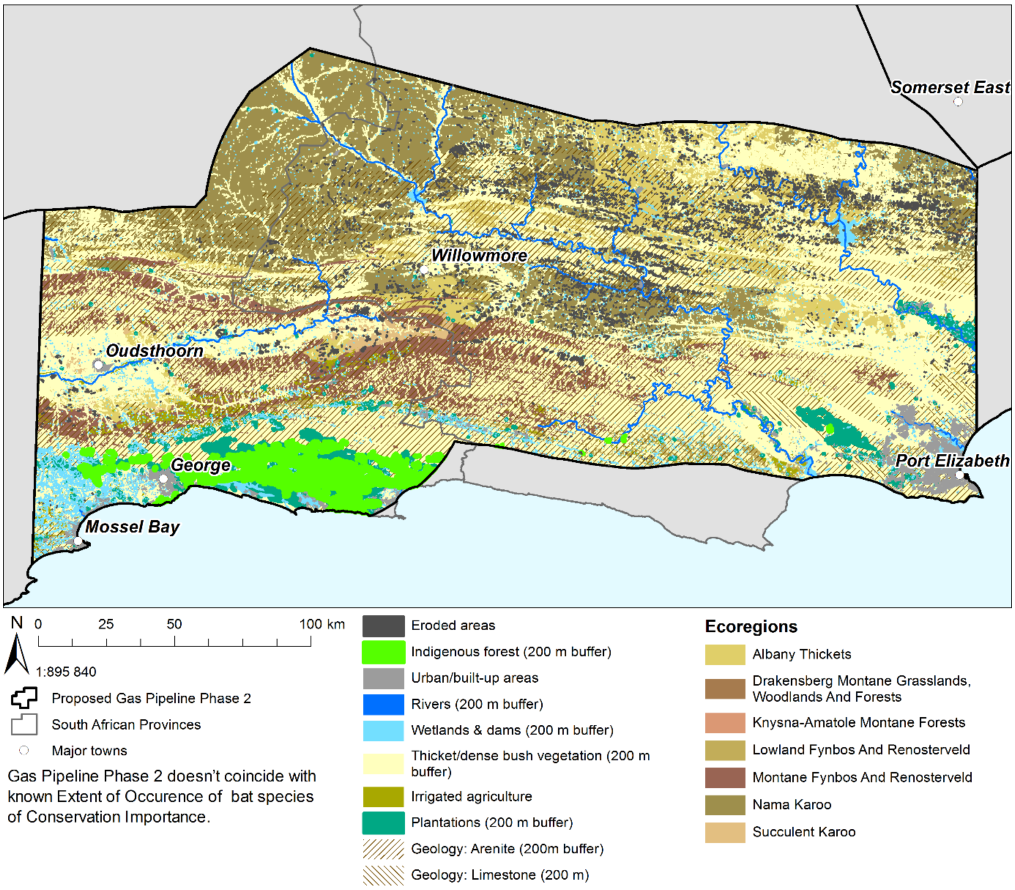

Figure 3: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 2 gas pipeline corridor.

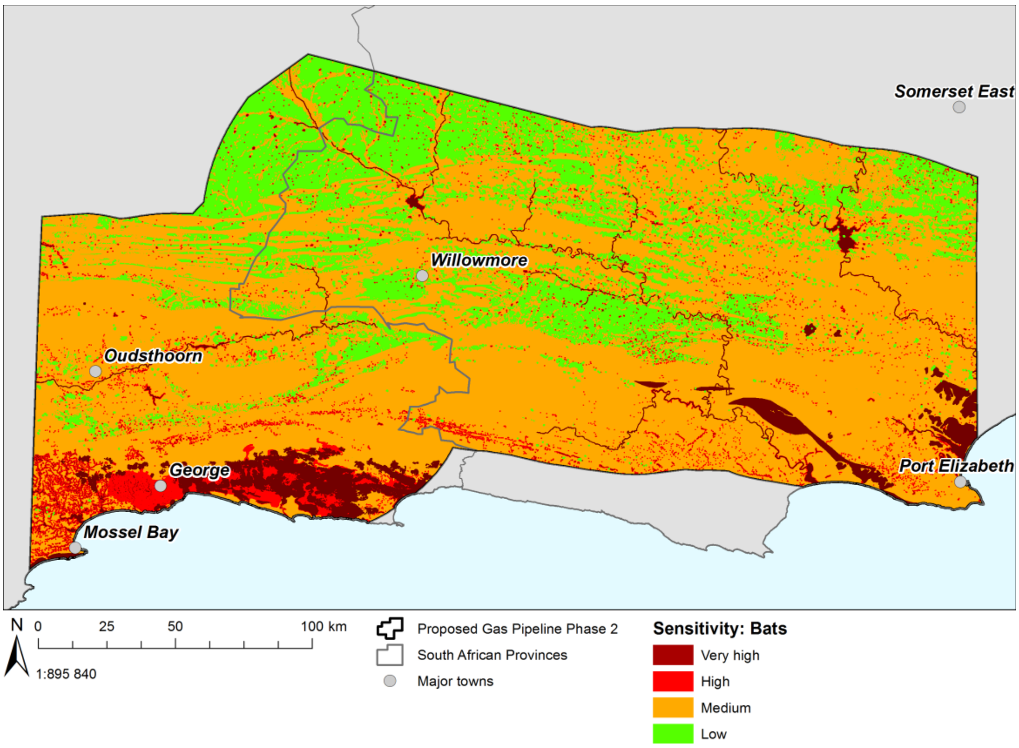

Figure 4: Bat sensitivity map for the proposed Phase 2 gas pipeline corridor.

5.3 Phase 3

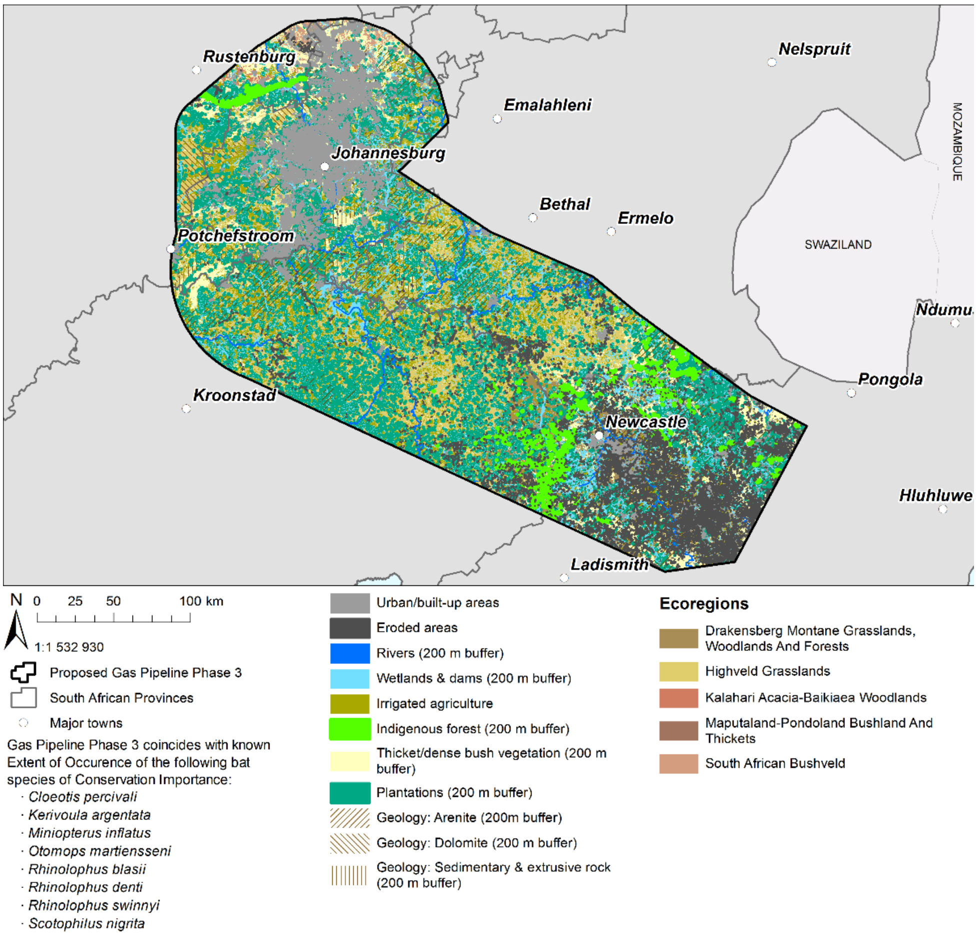

Figure 5: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 3 gas pipeline corridor.

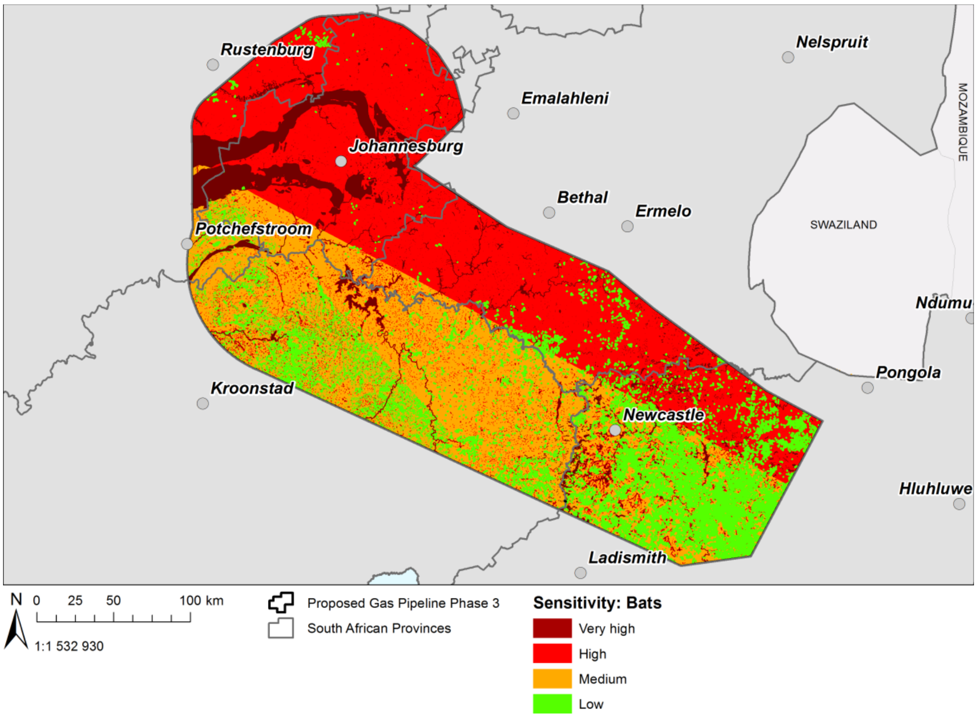

Figure 6: Bat sensitivity map for the proposed Phase 3 gas pipeline corridor.

5.4 Phase 4

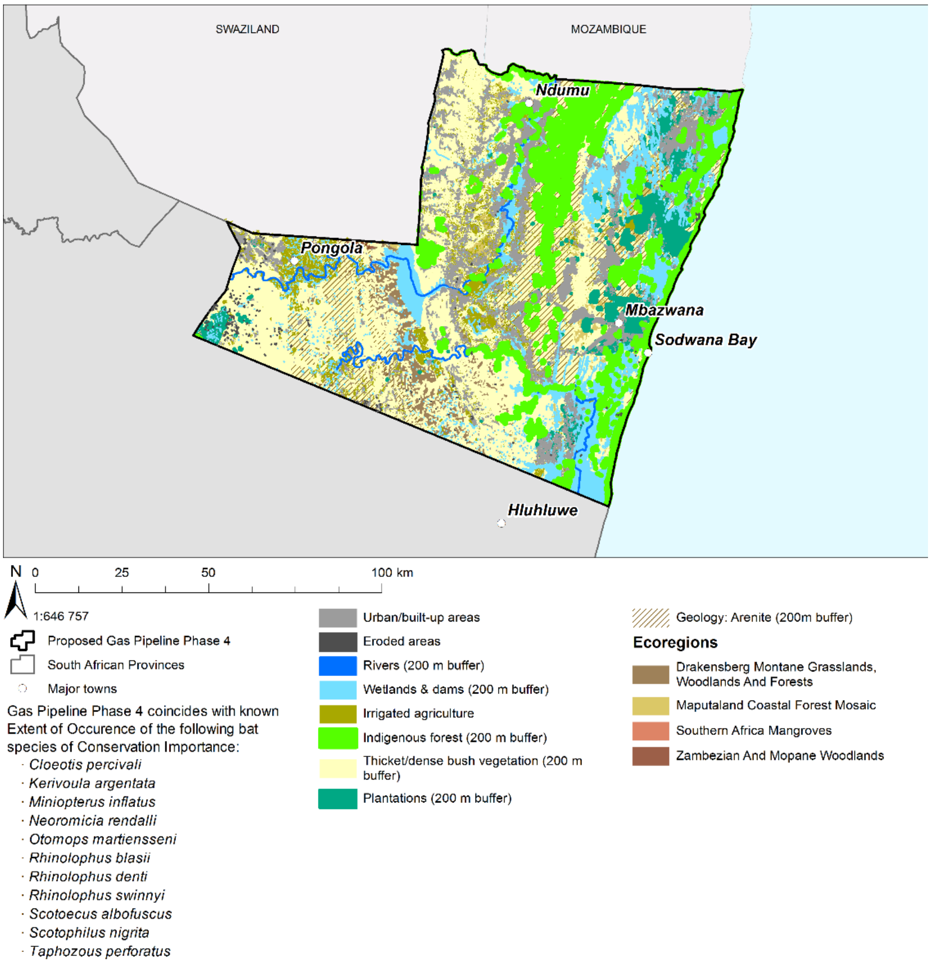

Figure 7: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 4 gas pipeline corridor.

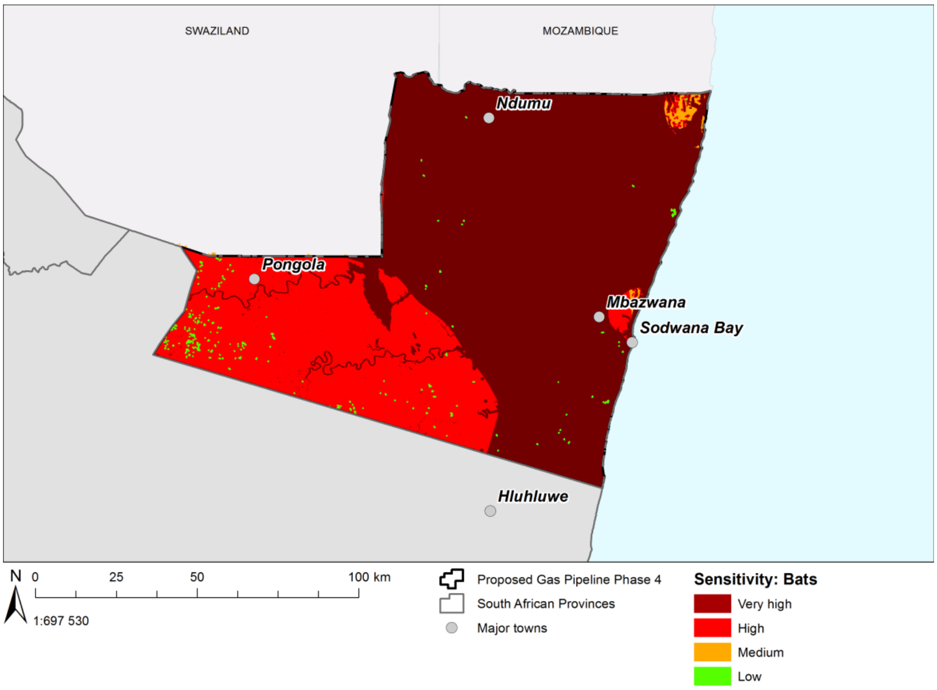

Figure 8: Bat sensitivity map for the proposed Phase 4 gas pipeline corridor.

5.5 Phase 5

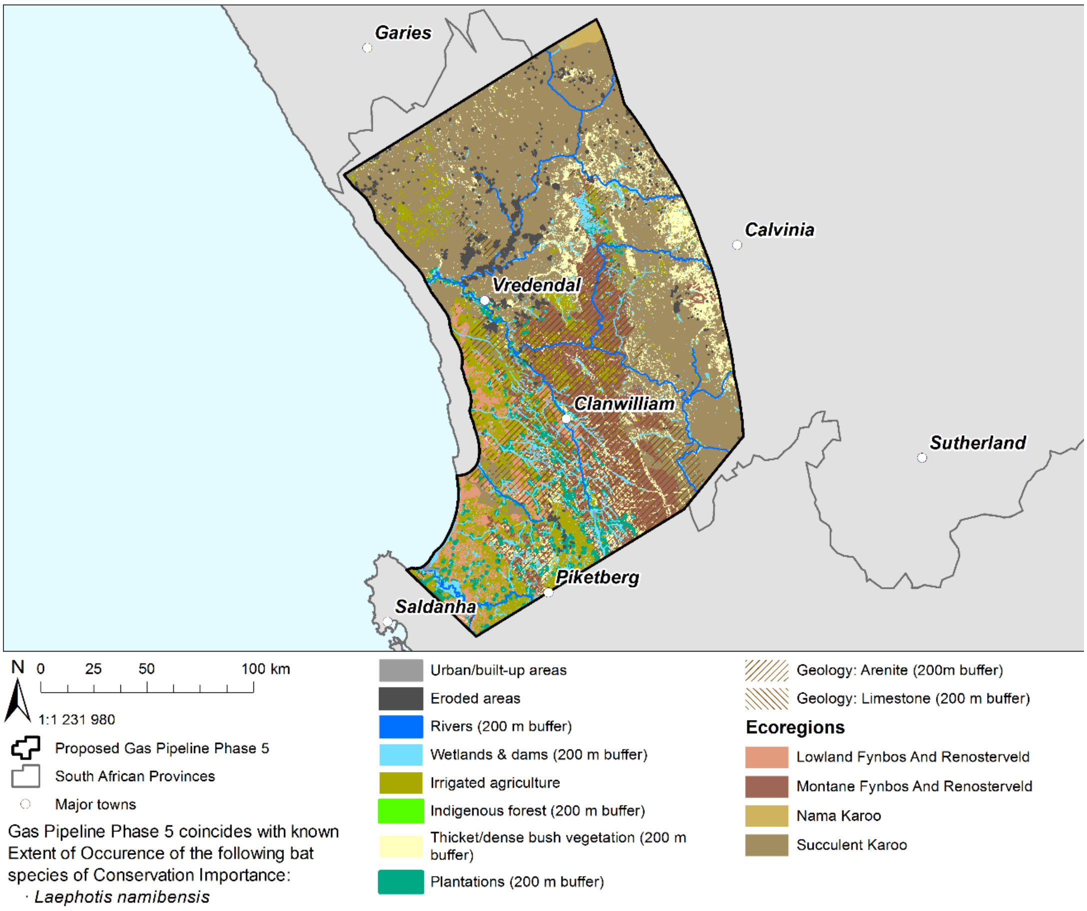

Figure 9: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 5 gas pipeline corridor.

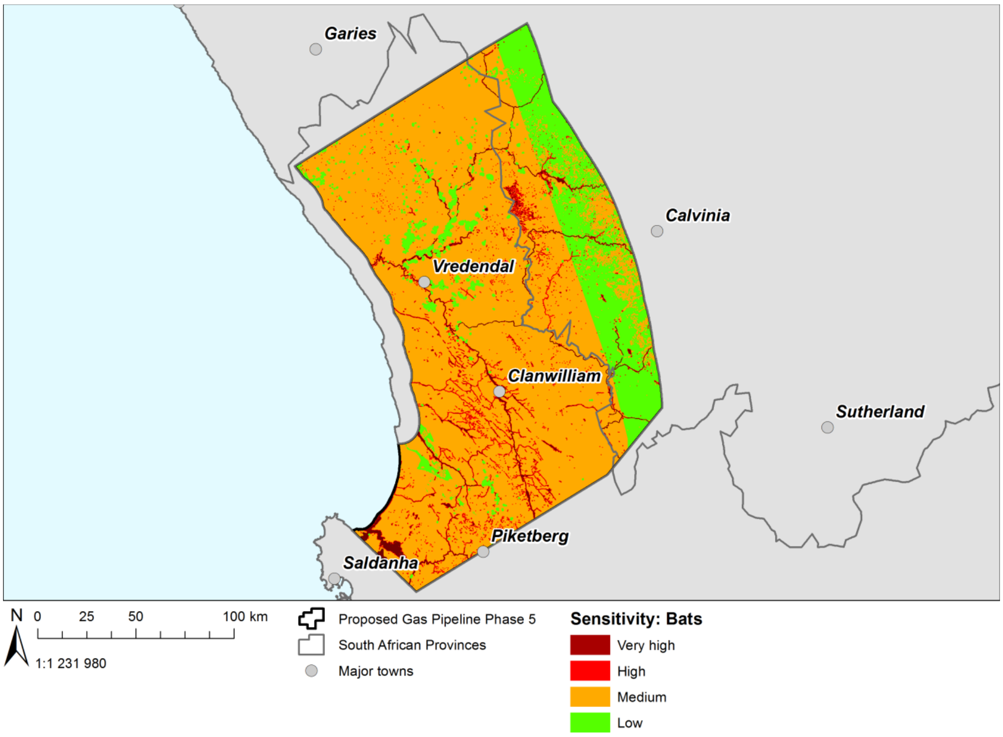

Figure 10: Bat sensitivity map for the proposed Phase 5 gas pipeline corridor.

5.6 Phase 6

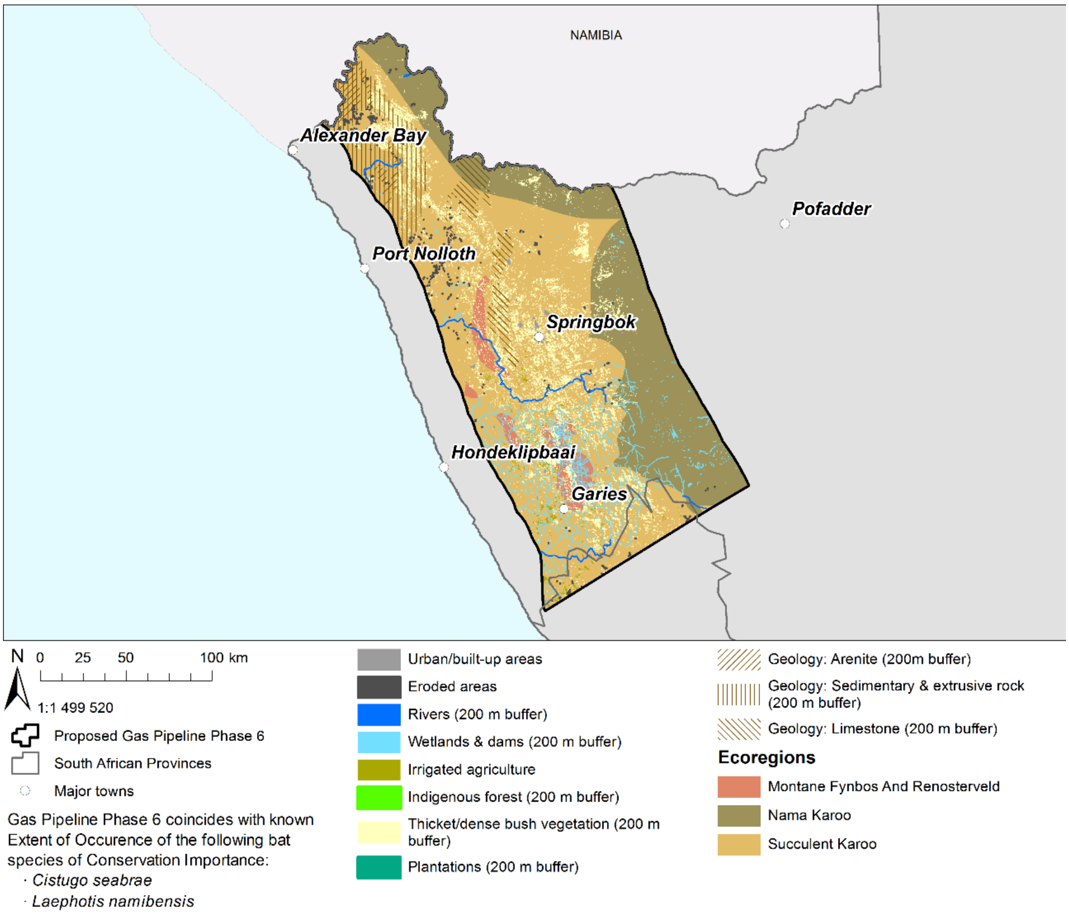

Figure 11: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 6 gas pipeline corridor.

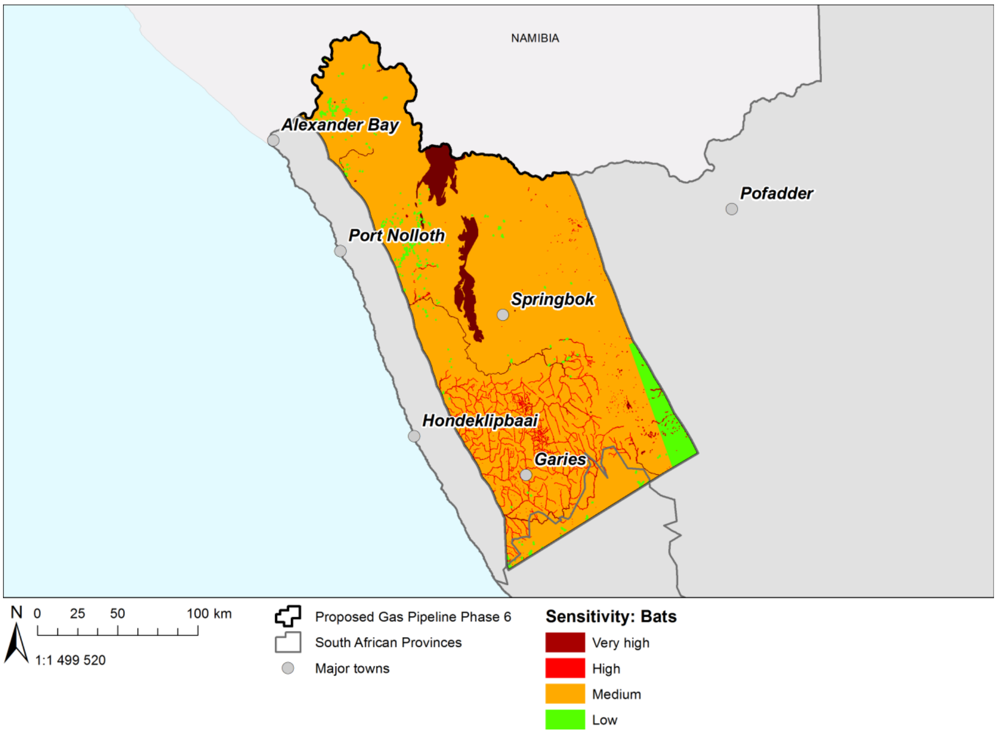

Figure 12: Bat sensitivity map for the proposed Phase 6 gas pipeline corridor.

5.7 Phase 7

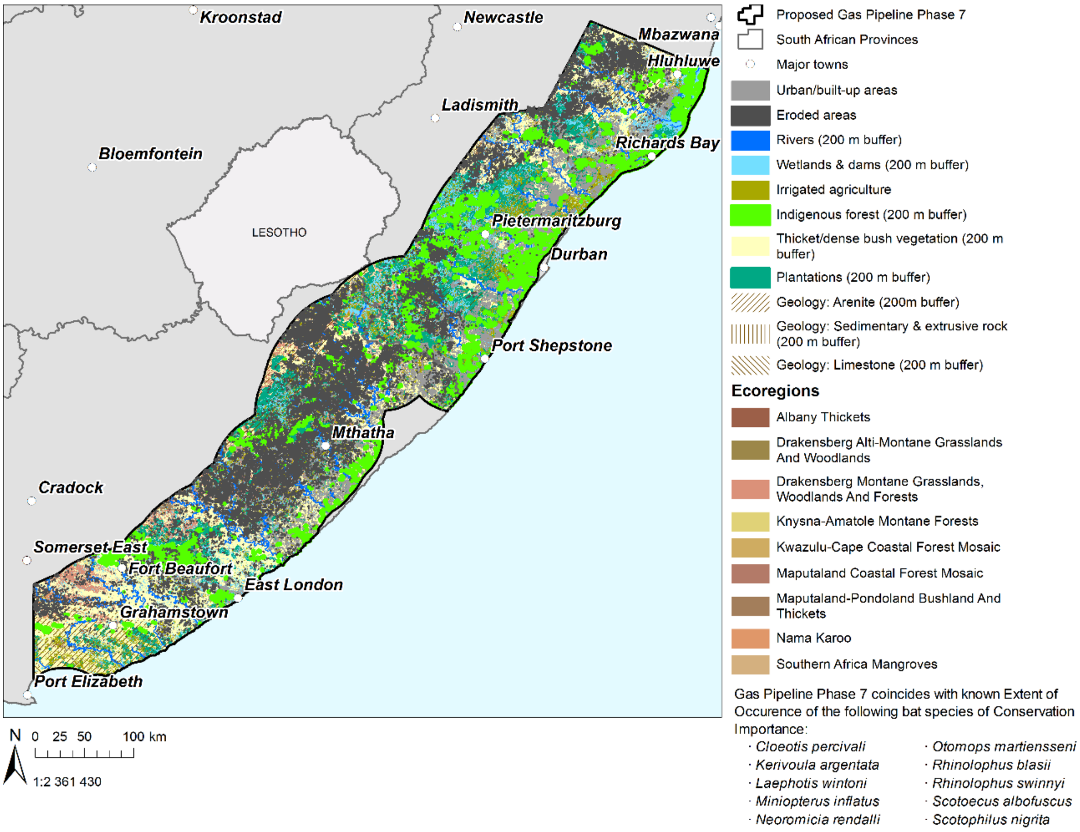

Figure 13: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 7 gas pipeline corridor.

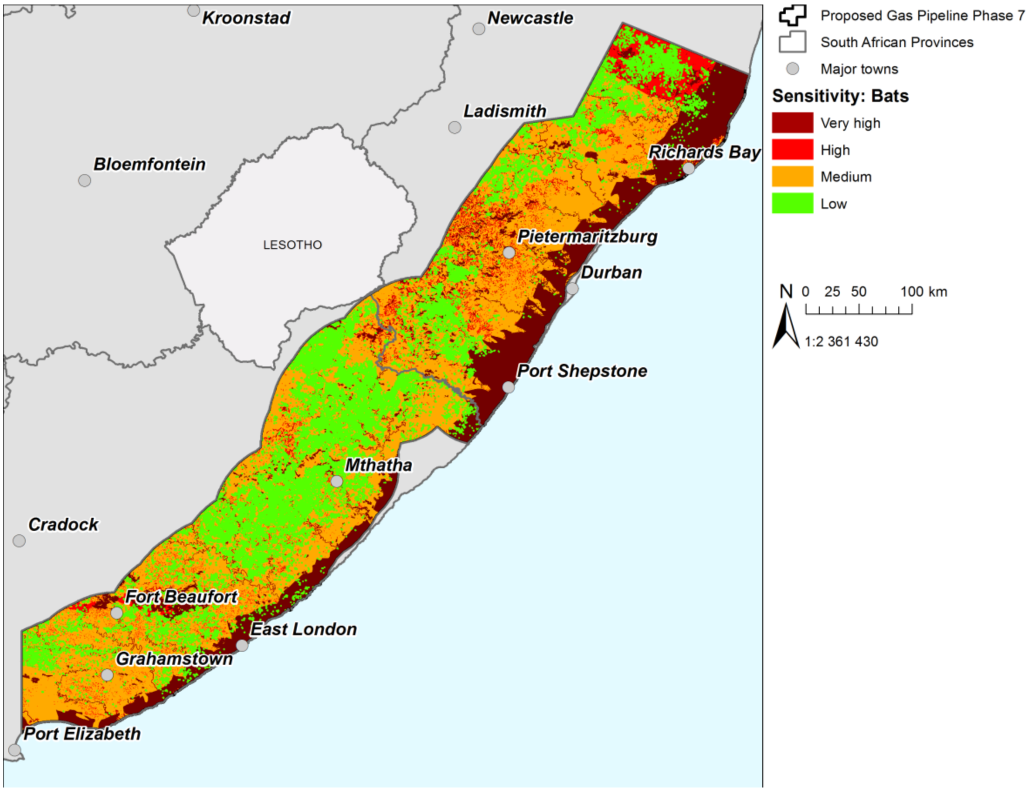

Figure 14: Bat sensitivity map for the proposed Phase 7 gas pipeline corridor.

5.8 Phase 8

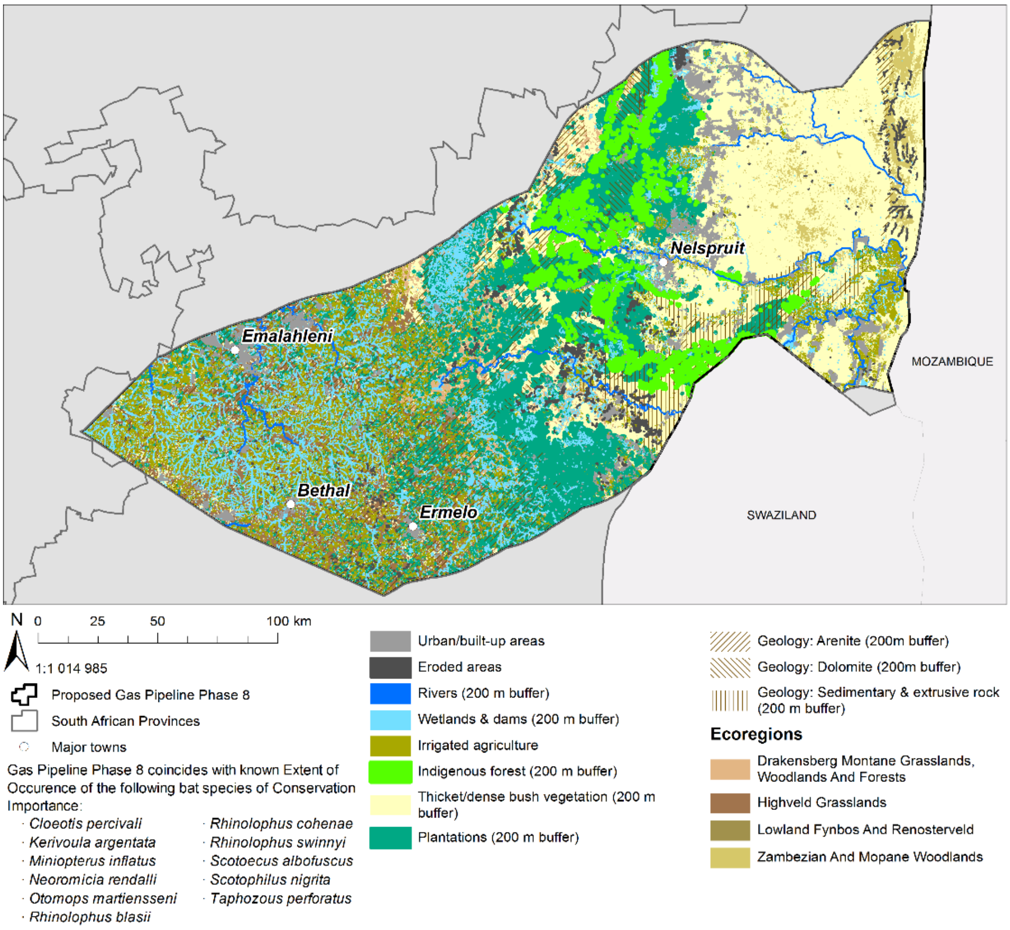

Figure 15: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Phase 8 gas pipeline corridor.

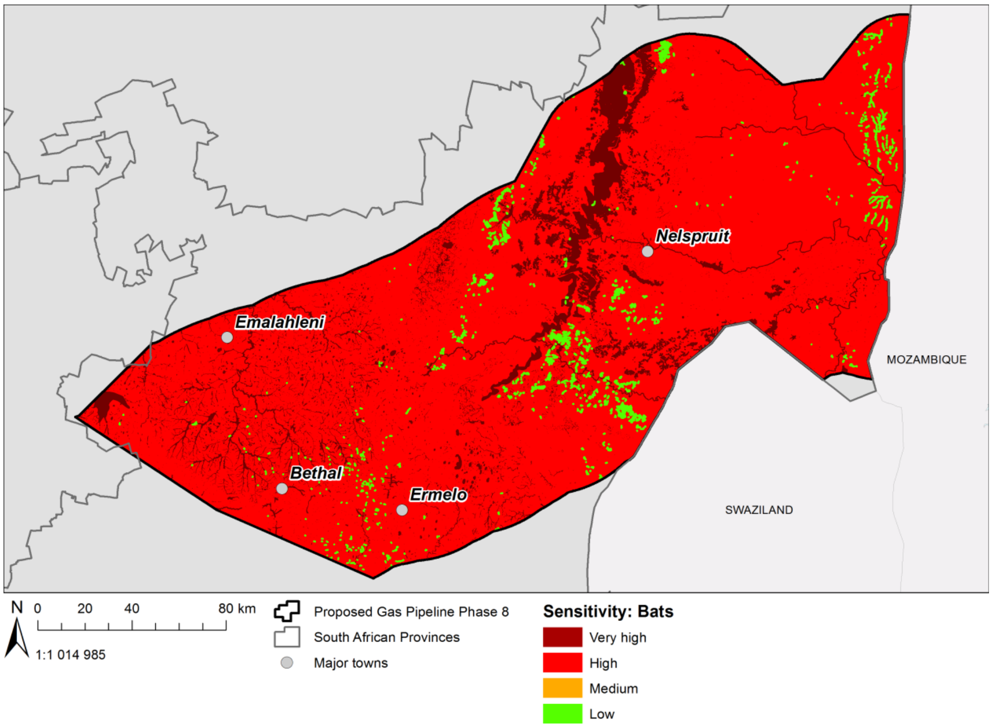

Figure 16: Bat sensitivity map for the proposed Phase 8 gas pipeline corridor.

5.9 Inland

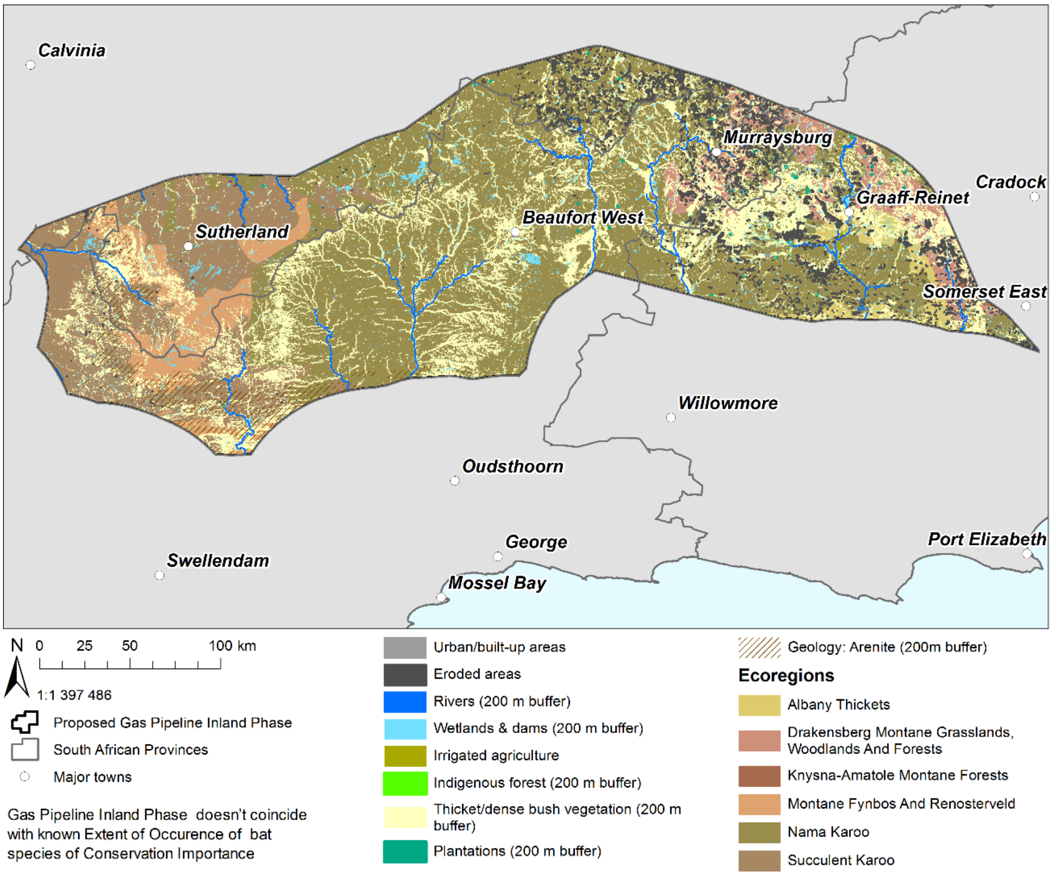

Figure 17: Key habitat features for bats, as well as an indication of the species of Conservation Importance that may be encountered in the proposed Inland Phase gas pipeline corridor.

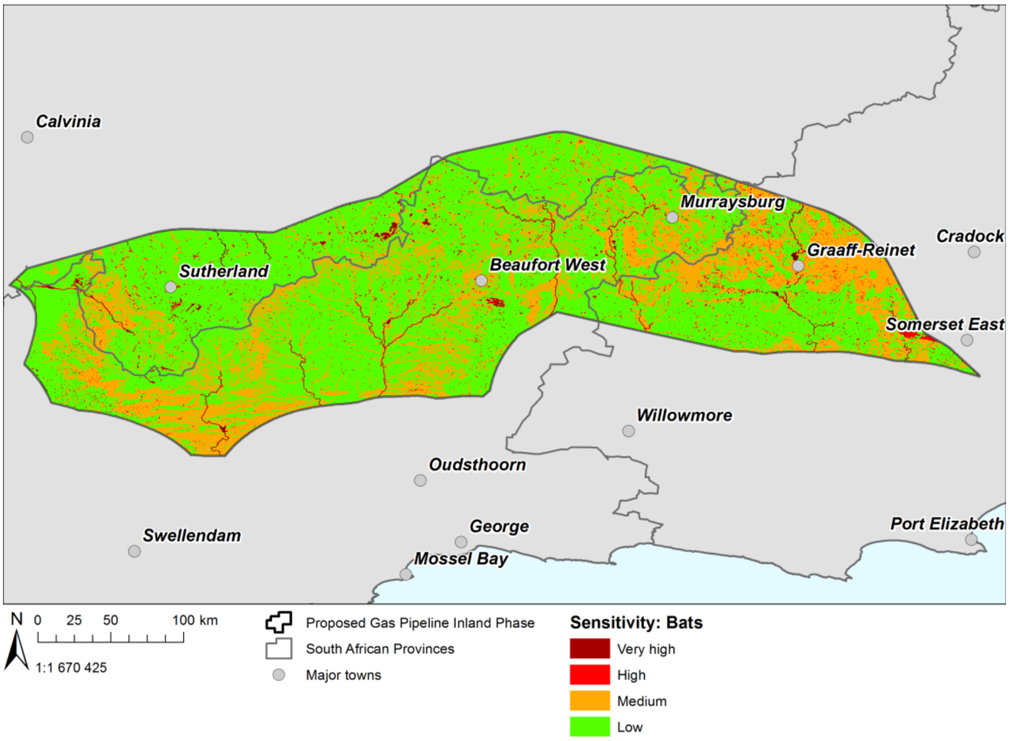

Figure 18: Bat sensitivity map for the proposed Inland Phase gas pipeline corridor.

6 KEY POTENTIAL IMPACTS AND MITIGATION

Construction activities, such as trenching, blasting and vehicle movement could cause noise, dust and vibrational disturbances to roosting colonies, especially during the breeding season from approximately October to March. The best measure to avoid potential negative consequences for bats would be to avoid placing infrastructure in the vicinity of known and potential roosts, especially known large maternity roosts and near areas utilized by bats of conservation importance. While species differ in their preferences, the following act as ideal habitats for bats to roost:

- Large trees or bush clumps;
- Caves and sinkholes;
- Rock crevices;
- Disused or old mining adits;
- Tunnels; and
- Dwellings/buildings with sufficient roosting space under roofs.

Additionally, bats require adequate surface water for feeding and drinking (Sirami et al., 2013; Lisóon and Calvo, 2014), particularly for insectivorous bats which hunt insects congregating above water bodies or wet soil. Potential impacts on bats include but are not limited to (Table 4):

Table 4: Potential impacts from gas pipeline development to bats, and recommended mitigation actions.

Key Impacts	Site Specific Descriptions	Possible Effect	Mitigations
Displacement and disturbance	During the construction phase, the clearing of vegetation, digging and laying of pipelines, and noise and vibrations from construction activities.	Loss of ecologically significant habitats and associated species.	Avoidance of verified high and very high bat sensitivity areas, and minimise the development footprint. Particular attention in the bat assessments (where required) should be given to species of conservation importance as per Section 4.2. If development does take place in areas of verified Very High or High sensitivity, where required, based on the Decision-Making Tools (e.g. based on the recommendation of the general faunal ecologist), a bat specialist must be appointed to undertake site visits to recommend micro-siting measures, and advise on the least harmful time in terms of the breeding season of the relevant bats in the area.
Dust generation	During construction, there is likely to be dust generated from the construction activities. This dust goes into the air and covers surfaces. Dust covered vegetation and fruit will reduce the foraging potential of an area.	Reduction in food availability and displacement of bats.	Avoidance of verified high and very high bat sensitivity areas, and keep working areas damp to reduce dust production. Particular attention in the bat assessments (where required) should be given to species of conservation importance as per Section 4.2.
Sedimentation of water bodies and wetlands	Soil movement during construction could result in dust, erosion and soil sedimentation of wetlands, rivers and open water bodies.	Reduction in fresh water availability and displacement of bats.	Avoidance of verified high and very high bat sensitivity areas, and keep soil workings contained. The bat assessments (where required) should conduct a desktop review on any possible new developments in this area of research.

7 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

The only guidelines available in South Africa relating to the protection of bats in the context of development are those released by the South African Bat Assessment Association Panel (SABAAP) (Sowler et al, 2017; Aronson et al, 2014) in reference to wind energy development. However, IWS will contribute to the Decision-Making Tools that will be compiled for this specific SEA, in order to inform the site specific assessment requirements that are needed prior to commencement of the development.

7.1 Planning phase

Ensure site specific Bat Assessments are conducted to inform planning and placement, where required, based on the Decision-Making Tools (e.g. in areas of verified Very High or High sensitivity based on the recommendation of the general faunal ecologist).

7.2 Construction, Operation, Rehabilitation and Post Closure phases

Site specific Bat Assessments to conduct impact assessments and provide mitigation and monitoring requirements for each phase of development, where required, based on the Decision-Making Tools (e.g. in areas of verified Very High or High sensitivity based on the recommendation of the general faunal ecologist). The principles of avoidance, minimization, mitigation and only if unavoidable offset/ compensation should apply.

7.3 Monitoring requirements

The EMPr should be audited bi-annually to ensure that any mitigation measures listed were and continue to be adhered to.

8 CONCLUSIONS AND FURTHER RECOMMENDATIONS

Bats, the second most diverse mammal group on the planet, warrant consideration and protection at the very least due to their economic value and the ecosystem services they provide, although tourism and biodiversity heritage value is also very important.

The potential impacts to bats by the gas pipeline developments during the construction phase (and possibly during the operational phase if maintenance or repair on the pipeline is required) could include roost disturbance and foraging habitat loss associated with clearing the right of way, and sensory disturbance due to increased levels of noise and dust associated with heavy vehicles and other machinery, and sedimentation of water bodies and wetlands.

Measures to avoid and minimize impacts would include, in the planning phase, staying away from Very High and High sensitivity areas. Where required, based on the Decision-Making Tools (e.g. in areas of verified Very High or High sensitivity based on the recommendation of the general faunal ecologist), In these areas, detailed Bat Impact Assessments, including field work, must be performed to inform whether the project would have adverse effects on bats and to make informed mitigation recommendations. Such recommendations could be micro-siting to avoid key roosts or foraging habitat, avoiding construction in certain seasons, keeping the development footprint to a minimum, dust prevention and prevention of sedimentation runoff into water bodies, etc.

9 GAPS IN KNOWLEDGE

Gaps in knowledge from a bat data perspective include:

- No publicly available studies investigating the impacts of gas pipeline development on bats. We can only infer potentially adverse effects based on other human-induced landscape-level changes.
- Bat roost data is limited to data voluntarily supplied by bat specialists and published literature. The co-ordinates provided by some of the published sources are old and/ or they are only provided in degrees and minutes, therefore there are potentially accuracy concerns.
- It would be more accurate to map AoO vs EoO for species of conservation importance, but this level of detail was beyond the scope of this high level SEA. Commissioning such a detailed mapping exercise of the AoO for all species of conservation importance, both plants and animals, would be a worthwhile exercise for the DEA to consider for future conservation planning.

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Strategic Environmental Assessment for the Development of a Phased Gas Pipeline Network in South Africa

Appendix C.2

Seismicity Assessment Report

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT IN SOUTH AFRICA

SEISMICITY SPECIALIST REPORT
Impacts of Earthquakes, Seismicity and Faults

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Draft V1 – March 2018
Draft V2 – October 2018
Draft V3 – April 2019
Final Report – October 2019

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ABBREVIATIONS AND ACRONYMS

CGS	Council for Geoscience
DEA	Department of Environmental Affairs
DRR	Disaster Risk Reduction
EGI	Electricity Grid Infrastructure
GMPE	Ground motion prediction equation
M	Earthquake Magnitude
M_L	Local Magnitude
M_{max}	Magnitude of the largest credible earthquake
M_w	Moment Magnitude
MMI	Modified Mercalli Intensity
MASW	Multi-channel analysis of surface waves
PGA	Peak Ground Acceleration
PGPN	Phased Gas Pipeline Network
PPV	Peak Particle Velocity
PSA	Peak Spectral Acceleration
PSHA	Probabilistic Seismic Hazard Assessment
SANSN	South African National Seismograph Network
SANS	South African National Standard
SEA	Strategic Environmental Assessment

1 INTRODUCTION

The Department of Environmental Affairs (DEA) commissioned a Strategic Environmental Assessment (SEA) for a phased gas pipeline network (PGPN) and electrical grid infrastructure (EGI) expansion in South Africa. The geographic extent of the "energy corridors" covered by the SEA is shown in Figure 1. The nine PGPN corridors shown in Figure 1 are part of this assessment.

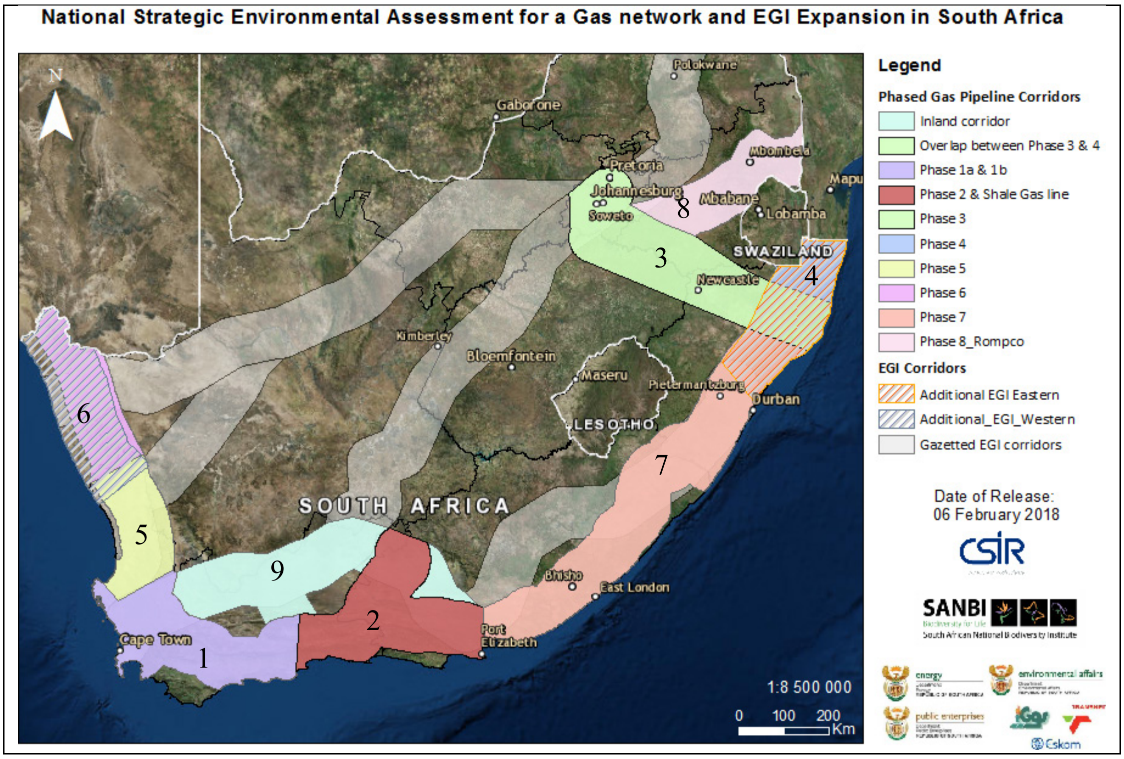

Figure 1: The PGPN and expanded EGI corridors for Specialist Assessment

PGPN corridors: 1 - Saldanha to Mossel Bay; 2 - Mossel Bay to Coega with a link to the Karoo for Shale Gas; 3 - Richards Bay to Secunda, Sasolburg and Gauteng; 4 - Mozambique (southern border) to Richards Bay; 5 - Abrahamvilliersbaai to Saldanha; 6 - Abrahamvilliersbaai to Oranjemund (Border of Namibia); 7 - Richards Bay to Coega; 8 - Mozambique border to Gauteng (Rompco Pipeline Corridor); 9 - Inland Corridor, Cape Town/Saldanha to Coega

This Specialist Assessment Report addresses the risks posed by earthquakes and associated phenomena such as landslides, liquefaction and tsunamis, on the proposed PGPN. The high level conclusions and recommendations are contained in the body of the report. The evidence on which these conclusions are based is contained in three appendices:

- Appendix A: Earthquake monitoring, hazard and risk assessment in South Africa;
- Appendix B: OpenQuake PSHA computation for South Africa and the energy corridors; and
- Appendix C: Vulnerability of Gas Pipelines.

Note that this Specialist Assessment Report was peer reviewed prior to release to stakeholders for review. The report was updated, as required, following the peer review findings. A copy of the peer review report and responses from the Specialist Team is included in Appendix D of this report.

2 SCOPE OF WORK

2.1 Terms of reference

Gas Pipeline Networks (GPN) are 'lifelines', a term used by the Disaster Risk Reduction (DRR) community to describe "man-made structures [that are] important or critical for a community to function, such as roadways, pipelines, power lines, sewers, communications, and port facilities" (Aki & Lee 2003: 1821). Lifelines are vulnerable to damage caused by the shaking of the ground during an earthquake, as well as associated phenomena such as the displacement of the ground across a fault, landslides, liquefaction of soils and tsunamis. Not only will damage to pipelines disrupt the supply of gas, but it could also trigger a cascade of other hazardous situations, such as fires, explosions or asphyxiation.

Earthquakes are driven either by geological forces (e.g. motion of tectonic plates, isostatic response to erosion, volcanism) or certain human activities (e.g. mining, impoundment of reservoirs, fluid injection or extraction). Gas Pipelines do not affect seismicity in any known way. The following issues are assessed in this study:

- What damage could earthquake-related phenomena (e.g. strong ground motion, surface displacement as the result of fault rupture, landslides triggered by strong ground motion, liquefaction of soils induced by ground shaking, tsunami) cause to GPNs?
- What impact would the damage to GPNs have on the environment and people?

This assessment focuses primarily on the interpretation of existing data and is based on defensible and standardised and recognised methodologies. It discusses direct, indirect and cumulative impacts, and identifies any gaps in information linked to earthquakes and seismicity with respect to gas pipelines.

2.2 Methodology

The following methodology was used to assess the impact of earthquakes on the PGPN, the consequent impact of any damage on the environment or people, and measures to mitigate the impact:

1. Review of available seismic and geological data, previous hazard and risk assessments and relevant research work (Appendix A).
2. Computation of the Probabilistic Seismic Hazard Assessment (PSHA) for the energy corridors considering recurrence periods, Peak Ground Acceleration (PGA) and spectral accelerations (Appendix B).
3. Assessment of the vulnerability of the proposed energy infrastructure to ground vibrations (Appendix C).
4. Assessment of the impact of earthquakes on the proposed energy infrastructure and the consequent impact of any damage on the environment or people.
5. Recommendations for site specific seismic hazard assessment studies or any supplementary monitoring that may need to be done for the actual proposed gas pipeline routes within the corridor.
6. Some of the world's most technologically-advanced countries are exposed to seismic hazard, for example, Italy, Japan and the USA. Standard methodologies have been developed to assess seismic hazard; numerous studies have been conducted to assess the risk posed by earthquakes to lifelines; and responding engineering specifications for PGN have been published. Some relevant methodologies and specifications are identified in Section 5.1.

2.3 Data sources

The primary sources of information used in this study are listed in Table 1 below.

Table 1: Primary Data Sources

Data title	Source and date of publication	Data Description
Landslide geohazard for South Africa	Singh et al. 2011	Detailed study on landslides in South Africa
CGS Geohazard Atlas	http://197.96.144.125/jsviewer/Geohazards/index.html#	Collapsing and swelling soils
Earthquake seismology	Durrheim 2015	Comprehensive review of earthquake monitoring, hazard and risk assessment in South Africa.
The history of mining seismology	Durrheim & Riemer 2015	Comprehensive review of mining-induced earthquake monitoring, hazard and risk assessment in South Africa.
Compiling a homogeneous earthquake catalogue for Southern Africa	Mulabisana 2016 (MSc dissertation)	Earthquake catalogue for South Africa
Seismic sources, seismotectonics and earthquake recurrence for the KZN coastal regions.	Singh 2016 (PhD thesis)	Active faults in the KZN coastal region
A palaeoseismic investigation of Late Quaternary reactivation of the Kango Faults and its relevance to the siting of critical structures in the southern Cape Fold Belt, South Africa	Goedhart 2017 (PhD thesis, in examination)	Active faults in the southern Cape
Seismotectonics of South Africa	Manzunzu et al. 2019	Seismotectonic model for South Africa, which includes active faults and earthquake source mechanisms.
The Probabilistic Seismic Hazard Assessment (PSHA) of South Africa.	Midzi et al. 2018 (in review)	PSHA for South Africa
Development of a South African Minimum Standard on ground vibration, noise, air-blast and flyrock near surface structures to be protected	Milev et al. 2016	Blasting-induced ground vibrations
Global catalogues of earthquakes in stable continental regions	Johnston et al. 1994	Global catalogues of earthquakes in stable continental regions

2.4 Limitations and Assumptions

The limitations and assumptions applicable in this study are listed in Table 2 below.

Table 2: Applicable Limitations and Assumptions

Limitation	Included in the scope of this study	Excluded from the scope of this study	Assumption
Completeness of the earthquake catalogue	Earthquake catalogue published by the SANSN.	Data recorded by local mine and research networks.	Catalogue sufficiently complete to provide a reasonable estimate of recurrence times and M_{max}; values from similar tectonic domains elsewhere in the world provide reasonable constraints (see Johnston et al. 1994; Vanneste et al. 2016).
Ground motion prediction equations (GMPEs)	GMPEs from similar tectonic domains elsewhere in the world.	Measurement of local GMPEs.	GMPEs from similar tectonic domains elsewhere in the world are adequate.
Site effects	Descriptions of site effects in published papers and	Measurement of site effects.	Reasonable estimates of local site amplification can be made

Limitation	Included in the scope of this study	Excluded from the scope of this study	Assumption
	reports.		from geological knowledge.
Site-specific PSHA	Review of published regional PSHA studies.	PSHA calculations that include local site effects.	PSHA for regional studies is for bedrock.
Analysis of liquefaction potential	Reports on occurrence of liquefaction in KwaZulu-Natal.	Measurement of liquefaction susceptibility.	Knowledge of liquefaction potential is poor.
Active faults	Traces of active faults described in published papers and reports.	Mapping and monitoring of active and capable faults.	Knowledge of active and capable faults is poor.
Vulnerability of GPN	Published papers and reports.	Measurement or calculation of seismic response.	The PGPN will meet international standards.

2.5 Relevant Regulatory Instruments

Table 3 below provides feedback on the relevant regulatory instruments.

Table 3: Relevant Regulatory Instruments

Instrument	Key objective
International Instruments	
Eurocode 8	In the Eurocode series of European standards (EN) related to construction, Eurocode 8: Design of structures for earthquake resistance (abbreviated EN 1998 or, informally, EC 8) describes how to design structures in a seismic zone, using the limit state design philosophy. http://eurocodes.jrc.ec.europa.eu/
ISO4866	ISO4866 provide guidelines for the measurement of vibrations and evaluation of their effects on fixed structures, not safe limits of vibration for structures. Section 12.4 of the ISO4866 guideline refers users to safe limits published by authorities in France, Germany and Norway, noting that these limit values take building category, vibration category, and frequency range into account.
National Instruments	
South African Constitution	Section 24 states: “Everyone has the right – a) To an environment that is not harmful to their health and well-being, and b) To have the environment protected, for the benefit of the present and future generations, through reasonable legislative and other measures that – i. Prevent pollution and environmental degradation; ii. Promote conservation; and iii. Secure ecologically sustainable development and use of natural resource while promoting justifiable economic and social development.”
Disaster Management Act (Act 57 of 2002; amended in Act 16 of 2015)	Each metropolitan and district municipality is required to develop such a disaster management strategy.
Geoscience Act (Act 100 of 1993; amended in Act 16 of 2010)	The Act mandates the Council for Geoscience to be the custodians of geotechnical information, to be a national advisory authority in respect of geohazards related to infrastructure and development, and to undertake reconnaissance operations, prospecting research and other related activities in the mineral sector; and to provide for matters connected therewith.
South African National Standard (SANS) SANS4866	The South African Bureau of Standards adopted standard ISO4866 of the International Organization for Standardization (ISO). The first ISO edition was published in 1990 and a second edition in 2010. SANS4866:1990 = ISO4866:1990 SANS4866:2011 = ISO4866:2010
SANS 10160-4-2017	South African National Standard (2017). Basis of Structural Design and Actions for Buildings and Industrial Structures. Part 4: Seismic Actions and General Requirements for Buildings. Pretoria: South African Bureau of Standards. ISBN 978-0-626-30384-6.

Instrument	Key objective
Provincial Instruments	
Local Government Municipal Systems Act (No. 32 of 2000)	In terms of the Local Government Municipal Systems Act (No. 32 of 2000) all municipalities are required to complete Spatial Development Frameworks (SDFs) as a core component of Integrated Development Plans (IDPs). The Department of Rural Development and Land reform has developed guidelines to assist with the process. See http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/SDF-Guidelines/A5.pdf

3 KEY SEISMIC-RELATED ATTRIBUTES AND SENSITIVITIES OF THE STUDY AREAS

3.1 Terminology

Magnitude (M) is a measure of the energy released by the earthquake and the amount of slip on the fault. Seismograms recorded by many widely-spread seismograph stations are used to assign a single magnitude to an event. The SANSN uses either the local magnitude scale (M_L) or the moment magnitude scale (M_w), which are essentially equivalent for M<6.5. The M_L scale uses the maximum amplitude of ground motion recorded at the various local stations, is quick and easy to measure, but saturates above M6.5. The M_w scale takes the entire seismogram into account and is derived from an assessment of the mass of rock moved (or work done, hence the subscript 'w') by the earthquake. M_w does not saturate and can be estimated from local, regional or global stations. It has been calibrated to match M_L for M<6.5. Earthquakes are generally divided into the following categories: micro M<3, small 3<M<5, moderate 5<M<7 and major M>7. Natural earthquakes are generally only felt when M>3 and only cause significant damage when M>6. However, people unaccustomed to earthquakes may be frightened by the shaking that is produced by a M5 event, even though the amplitude of ground motion is only 1/10 that of a M6 event. It should be noted that earthquakes induced by mining or fluid injection may cause damage if 5<M<6 because they generally occur at much shallower depths than natural events.

Intensity (I) describes the shaking experienced on the surface of the earth. Intensity generally decreases with distance from the epicentre (the point on the earth's surface above the earthquake source), but is also affected by near-surface geology. Shaking is generally amplified where there is a thick layer of alluvium. Reports by many widespread observers are collated to derive Intensity Data Points (IDPs) and compile an isoseismal map. The SANSN uses the **Modified Mercalli Intensity (MMI) scale**.

The levels of the intensity scale can be roughly related to the **Peak Ground Acceleration (PGA)**, a quantity that is used by engineers to design structures. It is expressed either in terms of gals (cm/s^2) or the acceleration of gravity (g, 9.8 m/s^2). To give some examples: an MMI of III (0.001 – 0.002 g) indicates ground motion that is perceptible to people, especially on the upper floors of buildings; VI (0.02 – 0.05 g) is felt by all, many people are frightened and run out of doors, and a few buildings may be slightly damaged; VIII (0.1 – 0.2 g) causes slight damage to earthquake-resistant structures, considerable damage to solid buildings, and great damage to poorly-built buildings; while XII (> 2 g) indicates total destruction, with objects thrown into the air. The resonant frequency of structures depends on their height and footprint. Thus engineers make use of estimates of the **Peak Spectral Acceleration (PSA)**, a measure of ground motion at particular frequencies, to determine if structures will respond to an earthquake.

3.2 Background

South Africa is, by global standards, a seismically quiet region as it is far from the boundaries of tectonic plates and active continental rifts (Johnson & Kanter 1990). Seismicity in South Africa arises from both natural sources (e.g. plate tectonic forces, buoyant uplift of the continent after erosion) and human-induced sources (e.g. rock failure caused by mining-induced stresses, slip on faults causes by changes in load and pore fluid pressure during the filling of reservoirs, and vibrations produced by blasting for open pit mining, civil excavation and the disposal of expired munitions). Most earthquakes are induced by deep-level mining for gold and platinum, and thus restricted to the mining districts (Figure 2). However, natural earthquakes do take place from time to time. They are driven by various tectonic forces, such as the spreading of the sea floor along the mid-Atlantic and mid-Indian ocean ridges, the propagation of the East African Rift System, and the response of the crust to erosion and uplift (Calais et al. 2016). Mulabisana (2016) indicates that the homogenized earthquake catalogue is complete above M2.5 since 1965, but this is thought to be somewhat optimistic as all M>3 earthquakes were only reliably recorded after the establishment of the South African National Seismograph Network in 1971. The bedrock geology has been mapped in fair detail, while geotechnical mapping is largely confined to built-up areas. Studies of earthquake hazard and risk have recently been published by Durrheim (2015), Durrheim & Riemer (2015), Singh (2016), Goedhart (2017), Midzi et al. (2018), and Manzunzu et al. (2019). An assessment of the risk posed by open pit blasting has been published by Milev et al. (2016), while ground vibrations produced by the disposal of expired munitions has been investigated by Grobbelaar (2017).

Ground vibrations may also be produced by blasting in open pit mines and for civil excavations (e.g. road cuttings), and the disposal of expired military explosives. The effect of these blasts is local. Guidelines are available to design rock blasts so that the ground vibration levels are controlled (Milev et al., 2016). Intensities strong enough to cause damage to sensitive structures are usually limited to distances of tens to hundreds of meters, or at most a kilometre or two from the source. Expired munitions are usually detonated on the surface, so relatively little energy is transmitted into the earth and little damage done. However, the shock wave travelling through the air may cause alarm, discomfort, and in some cases damage.

The Council for Geoscience has made measurements of the ground motion produced by military explosives detonated on surface and their effects on buildings (B Manzunzu, pers. Comm., 2018). The measured peak particle velocity (PPV) and dominant frequency of the ground motion was compared with the US Code of Federal Regulations (CFR) that deals with the control of adverse effects caused by explosives. Ground motions were recorded at distances ranging from 5.25 to 29.07 km in a sandy terrain. The biggest charge detonated had a mass of 25000 kg and the highest PPV recorded was 0.0095 cm/s, which is only 0.5% of the CFR limit. The highest PPV was recorded at another range where the geology is hard rock and the equipment was installed within 100 m of the explosion caused by a missile fired from an aircraft. The reading obtained was equivalent to 15% of the CFR limit.

It is important to note that a low rate of seismicity does not mean that there cannot be large earthquakes; just that earthquakes are less frequent. The history of earthquake occurrences and seismological observations and research in South Africa is reviewed in **Appendix A**. Three damaging M>6 tectonic earthquakes have occurred in the last 120 years: in the Western Cape (M6.3, 1969), northern KwaZulu-Natal (M6.3, 1932), and the southern Free State (M6.2, 1912). A moderately-sized earthquake could prove disastrous should it occur close to vulnerable buildings and lifelines, especially if the structures are not designed to be earthquake-resistant, the terrain is steep and prone to landslides, or the soil is thick and prone to local site amplification or liquefaction.

A recent example of a serious damage produced by a 'moderate' earthquake is the M6.0 event that struck Christchurch, New Zealand, on 13 June 2011, claiming nearly 200 lives and causing substantial damage due to soil liquefaction.

Manzunzu et al. (2019; see Figure 1 in Appendix B) compiled a map of faults in Southern Africa that were potentially active during the Quaternary (2.588 ± 0.005 million years ago to the present). This is an update of the seismotectonic map of Africa produced by Meghraoui et al. (2016). See Figure 1 in Appendix B. It should be noted that the 2.588 Ma time period is considerably longer than that commonly used in the definition of an "active fault". For example, the glossary in the International Handbook of Earthquake and Engineering Seismology (Aki and Lee, 2003) define an active fault as "a fault that has moved in historic (e.g., past 10,000 years) or recent geological time (e.g., past 500,000 years)". Only two of these faults (Kango and Bosbokpoort) have palaeoseismological evidence of large earthquakes of magnitude exceeding M7 that caused surface ruptures. It is not clear whether the fissure created by the 1809 Cape Town earthquake (M_L6.1) is a surface expression of the fault rupture or the result of near-surface mass movement caused by the shaking. A literature search yielded descriptions of several other faults that have been active during the Quaternary. For example, a thrust fault exposed in an open pit platinum mine near Brits that displaced strata with a maximum age of 175,000 by about 4 m; and a fault near the KwaZulu-Natal – Mozambique border that displaced the 75,000 year-old Port Durnford Formation by 30 m. For further details see the sections headed 'Neotectonics' and "Paleoseismology" in **Appendix A**.

The impact of some recent earthquakes on gas pipelines are described by Lee et al. (2009). The M_w6.9 Hyogo-Ken Nanbu earthquake of 1995 caused gas leakage from buried pipelines at 234 different places and 531 different fires were started primarily due to gas release and electricity sparks, with burnt areas over 1 km^2 in extent. The M_w7.6 Chi-Chi earthquake in Taiwan caused serious damage to natural gas supply systems, with more than 100,000 industrial and residential customers cut-off and the economic loss to supply companies estimated at US$25 million.

In summary, a great deal is known about the risk that earthquakes pose to GPN from work done both locally and internationally, although further work (e.g. sensitive seismic monitoring, detailed geological and geotechnical mapping) would be beneficial to further detail site specific hazards.

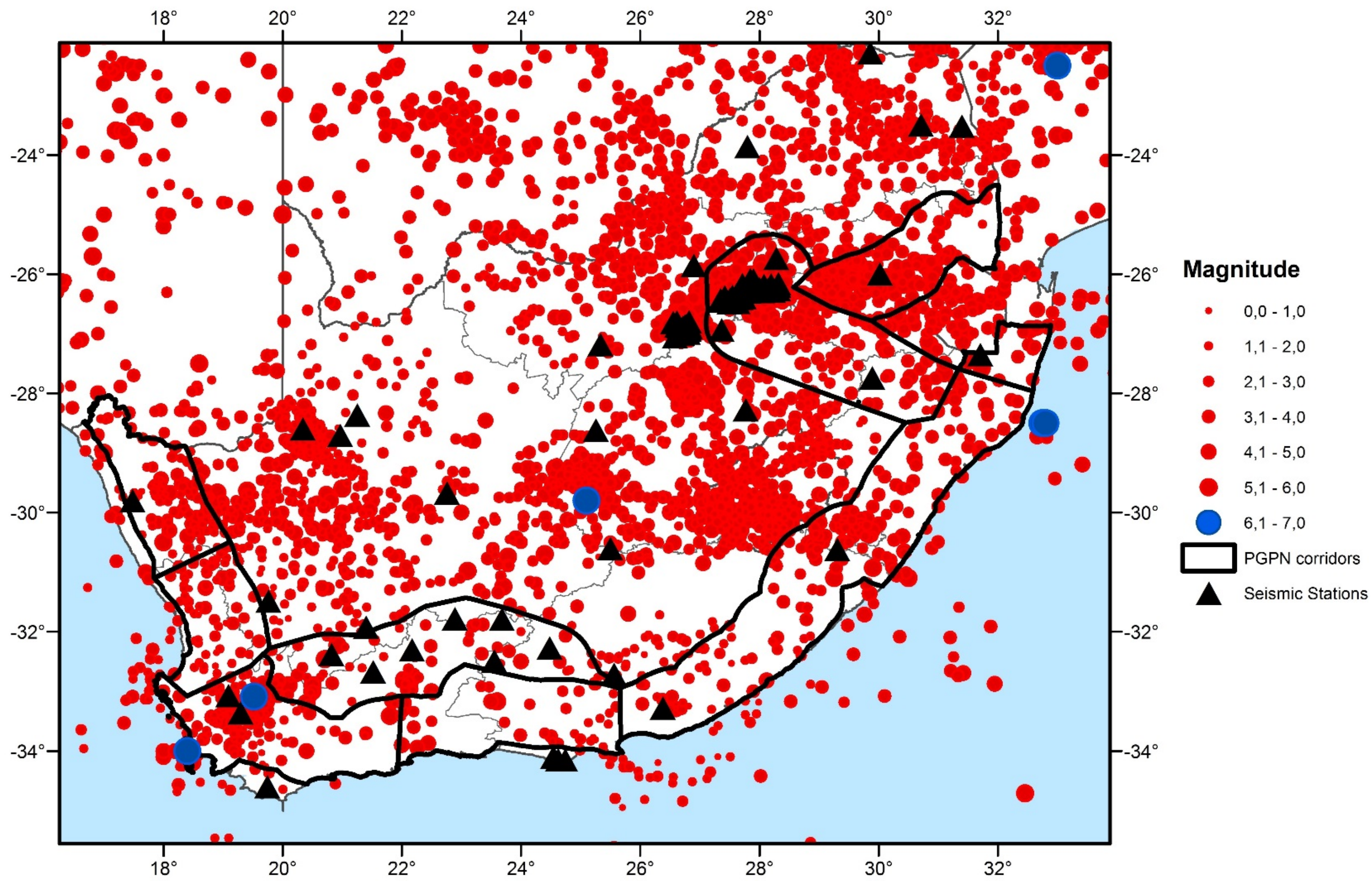

Figure 2: Location of recorded earthquakes in southern Africa from 1811-2014 in relation to the proposed PGPN corridors. Triangles mark the position of the stations that comprise the South African Standard Seismograph Network (SANSN)

3.3 Key sensitivities within the proposed corridors

Earthquake-related hazards are divided into two categories: (i) primary hazards *viz.* ground shaking and displacement; and (ii) secondary hazards *viz.* landslides, soil liquefaction. Parts of GPN corridors that are sensitive to earthquake hazards lie within the following regions.

i. Regions with **elevated seismic hazard**. An earthquake may cause the ground and GPN to shake to such an extent that damage occurs; or the earthquake rupture may cause a displacement between opposite sides of the fault that is large enough to damage structures or break pipelines that straddle it. Aftershocks may exacerbate the damage caused by the main shock. [Generally the largest aftershock is about 1.2 magnitude units smaller than the main shock (Båth, 1965).] There are numerous examples of damage to GPNs as a result of large earthquakes in tectonically-active regions. Moderate dynamic loading may occur throughout South Africa however while large dynamic loading is possible; the probability of it occurring is estimated to be very low within decadal timescales. GPNs built according to international standards should be resilient to this (see **Appendix C**).
ii. Regions **prone to landslides** and/or characterised by **problem soils** (i.e. soils that are prone to collapse, swelling or liquefaction). Earthquake shaking may trigger landslides and rockfalls and cause soils to liquefy. All these phenomena may lead to damage and loss.

These earthquake-related phenomena could cause damage to GPNs (such as leaks or rupture of the pipeline) that might disrupt the supply of gas and cause a cascade of effects, each involving large uncertainties, for example asphyxiation associated with a sudden high concentration of gas released into the atmosphere, fires or explosions in the event of an ignition source present, or the release of toxic substances.

Of course, there are many other natural and anthropogenic hazards that may also damage GPNs, such as storms, floods, wildfires, aircraft crashes and terrorist attacks, and thus the mitigation of the risk posed by earthquakes should not be considered in isolation, but as part of an integrated DRR strategy. The Disaster Management Act (Act 57 of 2002; amended in Act 16 of 2015) makes it obligatory for each metropolitan and district municipality to develop such a strategy.

3.3.1 Probabilistic Seismic Hazard Assessment

The latest and most complete assessment of seismic hazard (PSHA) in South Africa was performed by the Council of Geoscience (Midzi et al. 2018) using an up-to-date homogenised earthquake catalogue. Here we extend the CGS assessment to focus on the energy corridors (Refer to **Appendix B** for further details). The main results for the PGA calculations are shown in Figure 3.

It is important to realise that the PSHA estimates are calculated on a relatively coarse grid (0.5° x 0.5°) and at a few key localities. There is no quick and easy way to increase spatial resolution or reduce uncertainty in the PSHA calculations. This can only be done through decades or centuries of monitoring with a denser and more sensitive seismological network. Identification and mapping of palaeoseismic faults will require extensive field work.

The PGA (10% probability of exceedance in 50 years) in corridors 1, 2, 4, 5, 6, 7 and 8 do not exceed values of about 0.07 g. These values are typical of MMI VI, where the shaking is strong enough to cause alarm but only cause minor damage to buildings and well below the damage thresholds of modern GPNs (**Appendix C**). Larger events are possible, but have recurrence times of centuries.

The risk is relatively high (but still quite low) in corridor 3, which includes mining districts in the Gauteng, North West and Free State Provinces, where gold mining at depths approaching 4 km has induced three shallow earthquakes with M>5 that caused damage to surface structures (M5.2, Welkom, 1976; M5.3, Stilfontein, 2005; M5.5, Orkney, 2014). Here the PGA (10% probability of exceedance in 50 years) reaches values of about 0.2 g, which is typical of MMI values of about VIII where the shaking is strong enough to cause slight damage to earthquake-resistant structures, considerable damage to solid buildings, and great damage to poorly-built buildings.

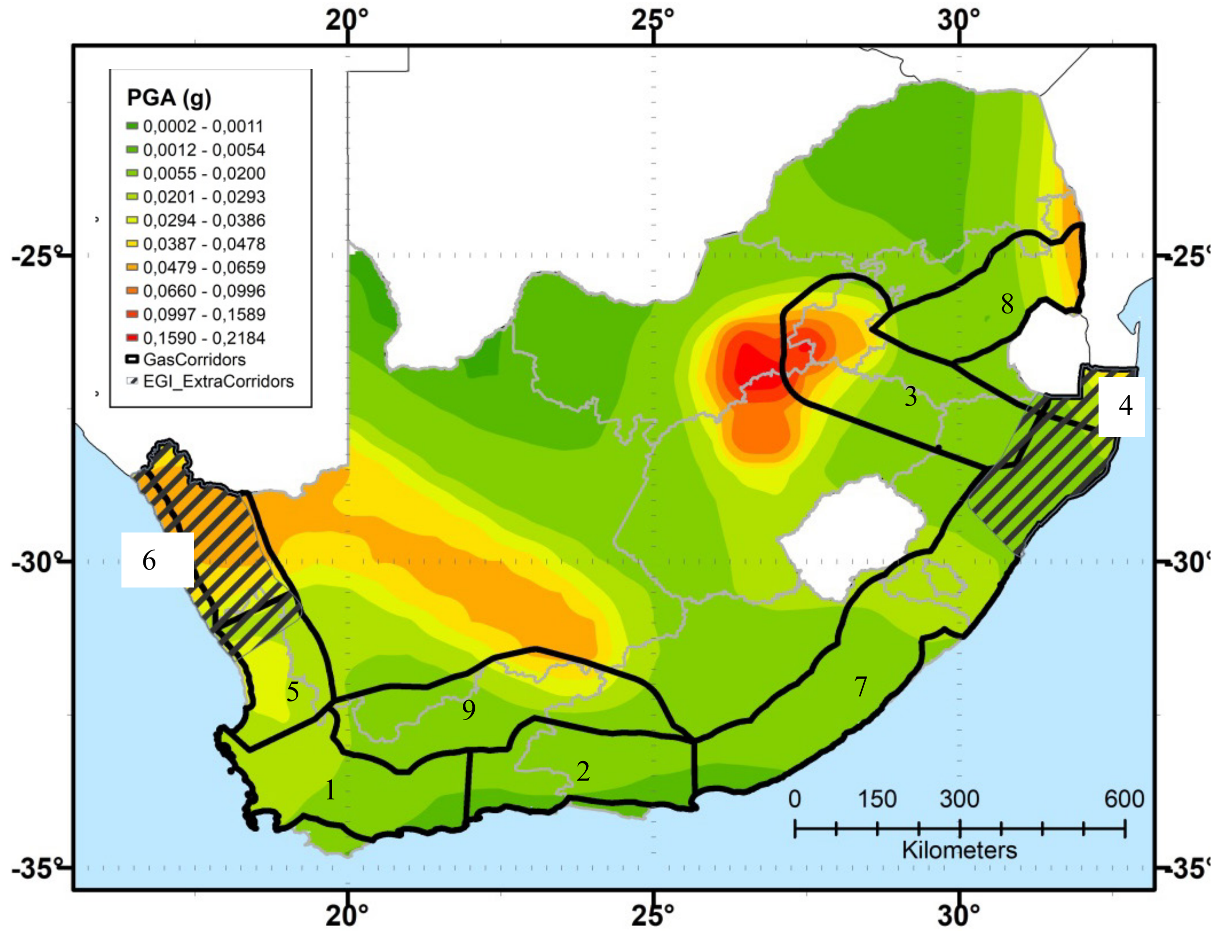

Figure 3: PGA (g) with 10% probability of exceedance in 50 years

PGPN corridors: 1 - Saldanha to Mossel Bay; 2 - Mossel Bay to Coega with a link to the Karoo for Shale Gas; 3 - Richards Bay to Secunda, Sasolburg and Gauteng; 4 - Mozambique (southern border) to Richards Bay; 5 - Abrahamvilliersbaai to Saldanha; 6 - Abrahamvilliersbaai to Oranjemund (Border of Namibia); 7 - Richards Bay to Coega; 8 - Mozambique border to Gauteng (Rompco Pipeline Corridor); 9 - Inland Corridor, Cape Town/Saldanha to Coega.

The South African National Standard seismic hazard map and hazard zones (SANS, 2017) is shown in Figure 4. The parametric-historic procedure (Kijko & Graham 1998; 1999) was used. The parametric-historic procedure was developed to combine the best features of the “deductive” and “historic” procedures. Two zones are identified, namely: Zone I Natural seismic activity only, and Zone II Regions of mining-induced and natural seismic activity. Buildings were classified into four “importance classes”: I Buildings of minor importance for public safety, e.g. agricultural buildings, etc.; II Ordinary buildings, not belonging to the other categories; III Buildings for which seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions, etc.; and IV Buildings for which integrity during earthquakes is of vital importance for protection, e.g. hospitals, fire stations, power plants, etc. Depending on the seismic zone and importance classes, buildings were required to comply with certain construction standards.

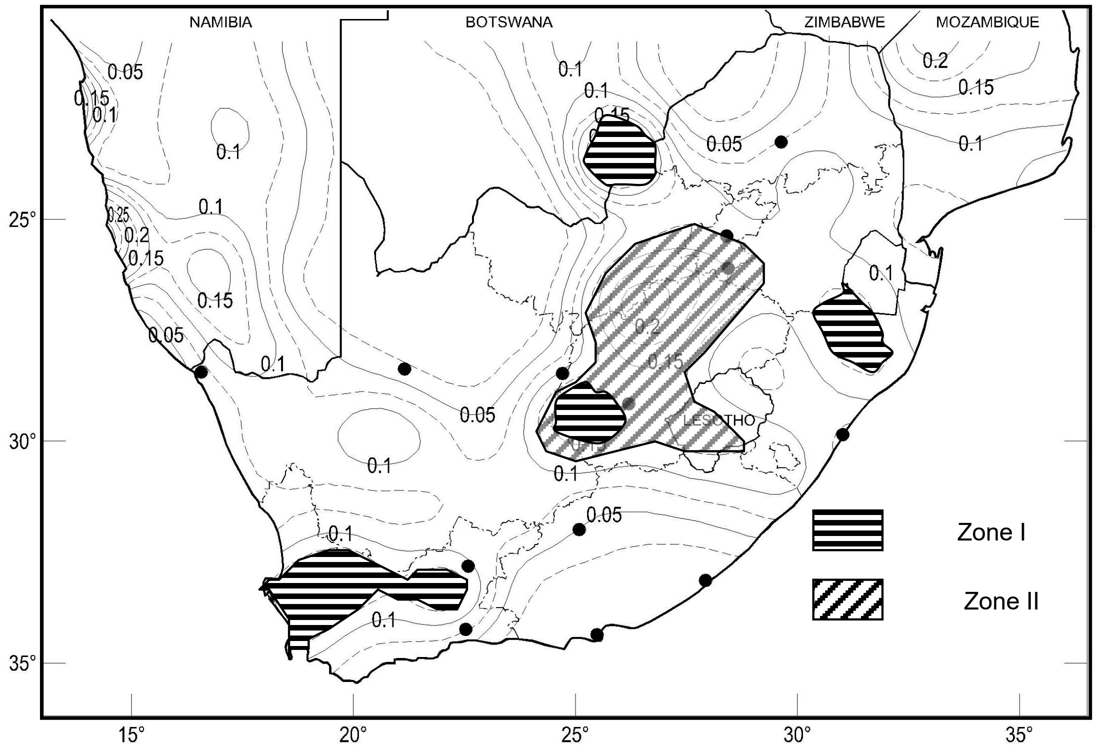

Figure 4: South African National Standard seismic hazard map and hazard zones (SANS, 2017)

Seismic hazard map of South Africa computed for 10% probability of exceedance in 50 years (return period of 475 years) with the nominal peak ground acceleration expressed in g (9,98 m/s^2); South African National Standard (2017). SANS 10160-4-2017. Basis of Structural Design and Actions for Buildings and Industrial Structures. Part 4: Seismic Actions and General Requirements for Buildings. Pretoria: South African Bureau of Standards. ISBN 978-0-626-30384-6. The procedure used to produce the seismic hazard map is described in the Council for Geoscience report, *Probabilistic Seismic-Hazard Maps for South Africa*, Version 1, 2003, Pretoria (Kijko et al. 2003).

There are significant differences between the seismic hazard maps produced using PSHA method (Figure 3) by Midzi et al (2018) and the parametric-historic method (Figure 4) by Kijko & Graham (1998, 1999), most significantly in the distribution of areas with relatively high PGAs. Both methods agree that PGAs >0.1g have a 10% or greater chance of exceedance in 50 years in the gold mining districts. However, there are large differences with regard to the assessment of the hazard posed by tectonic seismicity. The parametric-historic method gives greater weight to the regions where the large earthquakes have been recorded in the last century, (e.g. southern Free State, Western Cape, northern KwaZulu-Natal), while the PSHA method places greater weight on regions with generally elevated seismicity (e.g. Northern Cape). It is beyond the scope of this study to evaluate the methods, apart from noting that the PSHA method places great emphasis on the definition of seismic source zones using both seismic and non-seismic data, while the parametric-historic method relies on seismic data alone. Of course, the ultimate test lies in the accuracy of their predictions. Unfortunately, this will take decades or even centuries as large events are rare and the predictions are long term. They may be considered to provide an example of the challenges of earthquake hazard assessment.

3.3.2 Landslide Hazards

Comprehensive surveys of the **landslide hazards** South Africa have been conducted by Singh et al. (2008, 2011). The landslide susceptibility map is shown in Figure 5. [Note that the predominant trigger of landslides is infiltration of intense rainfall, not earthquakes.] Susceptibility is low for most of the area covered by the GPN corridors considered in this study, although significant areas with rugged terrain is found corridors 1, 2, 5, 7 and 8.

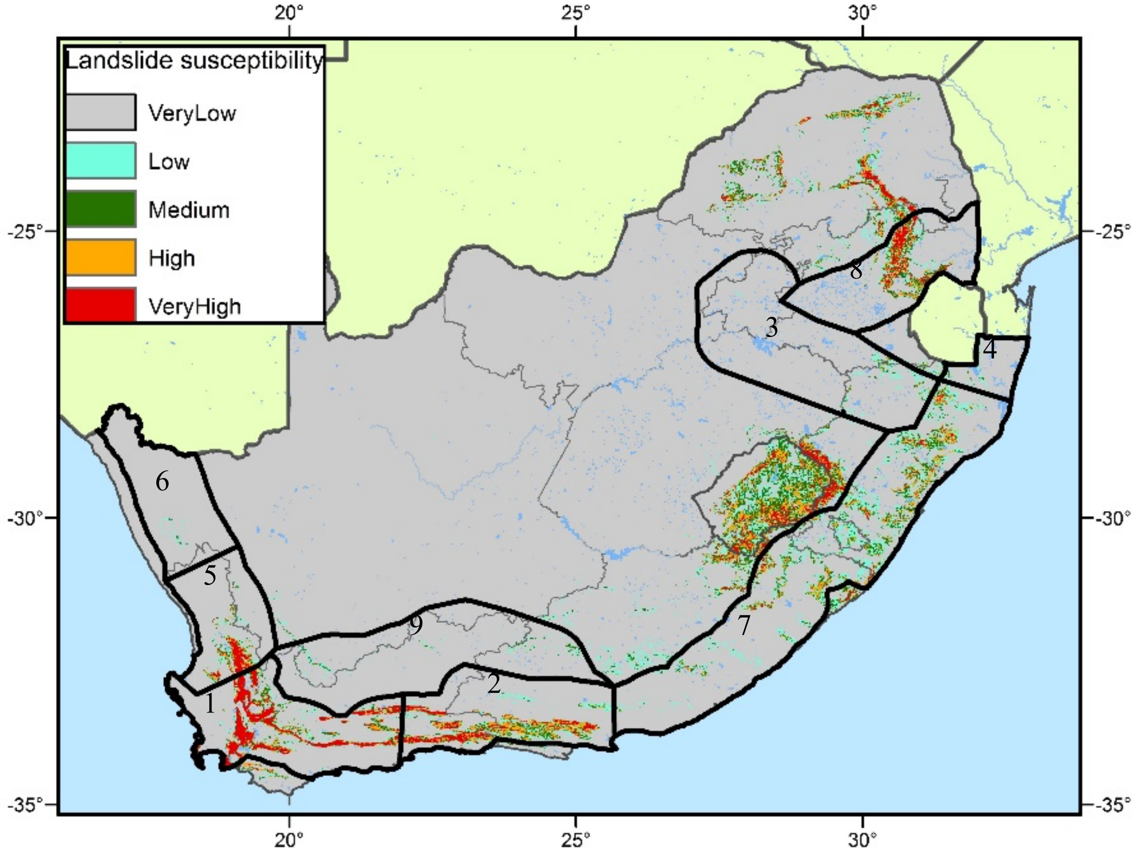

Figure 5: Landslide susceptibility map (Singh et al. 2011). This page of the CGS Geohazard Atlas can be viewed online viewed at http://197.96.144.125/jsviewer/Geohazards/index.html

3.3.3 'Problem-soil' Hazards

The gas pipelines will be buried. Thus the upper few meters of the earth should be mapped along proposed GPN routes to establish the optimum trenching method (e.g. what type of mechanical excavator is required, or if blasting is necessary). Some soils may liquefy during an earthquake. These zones should be identified so that they can be taken into account when choosing GPN routes or deciding on remedial measures. However, it is important to note that some soils can create problems even in the absence of earthquakes. The severity of the problem along proposed GPN routes should be assessed by geotechnical engineers as it is affected by a host of factors (e.g. soil properties and thickness, weight and 'footprint' of structures) that affect the cost of remedial measures (e.g. re-routing of pipelines, re-siting of infrastructure, re-design of foundations). Problem soils are divided into two main categories.

i. **Collapsible soils** (Figure 6), also known as metastable soils, are unsaturated soils that undergo a large volume change upon saturation. The sudden and usually large volume change could cause considerable structural damage. The most common types are aeolian soils, typically wind-deposited sands and or silts, such as loess, aeolic beaches, and volcanic dust deposits characterized by showing in-situ high void ratios and low unit weights; and residual soils, which are a product of the in-situ weathering of local parent rocks that leaches out soluble and colloidal materials producing soils with a large range of particle size distribution and large void ratios. Collapsible residual granite sand is found in parts of corridors 1, 7 and 8; and collapsible transported sands are found in parts of corridors 3, 7, 8 and 9.
ii. **Swelling soils** (Figure 7), also known as expansive clay soils, are prone to large volume changes (swelling and shrinking) that are directly related to changes in water content. Soils with a high content of expansive minerals can form deep cracks in drier seasons or years, e.g. the 'black turf', a product of the weathering of the mafic rocks of the Bushveld Complex, is found in corridor 3.

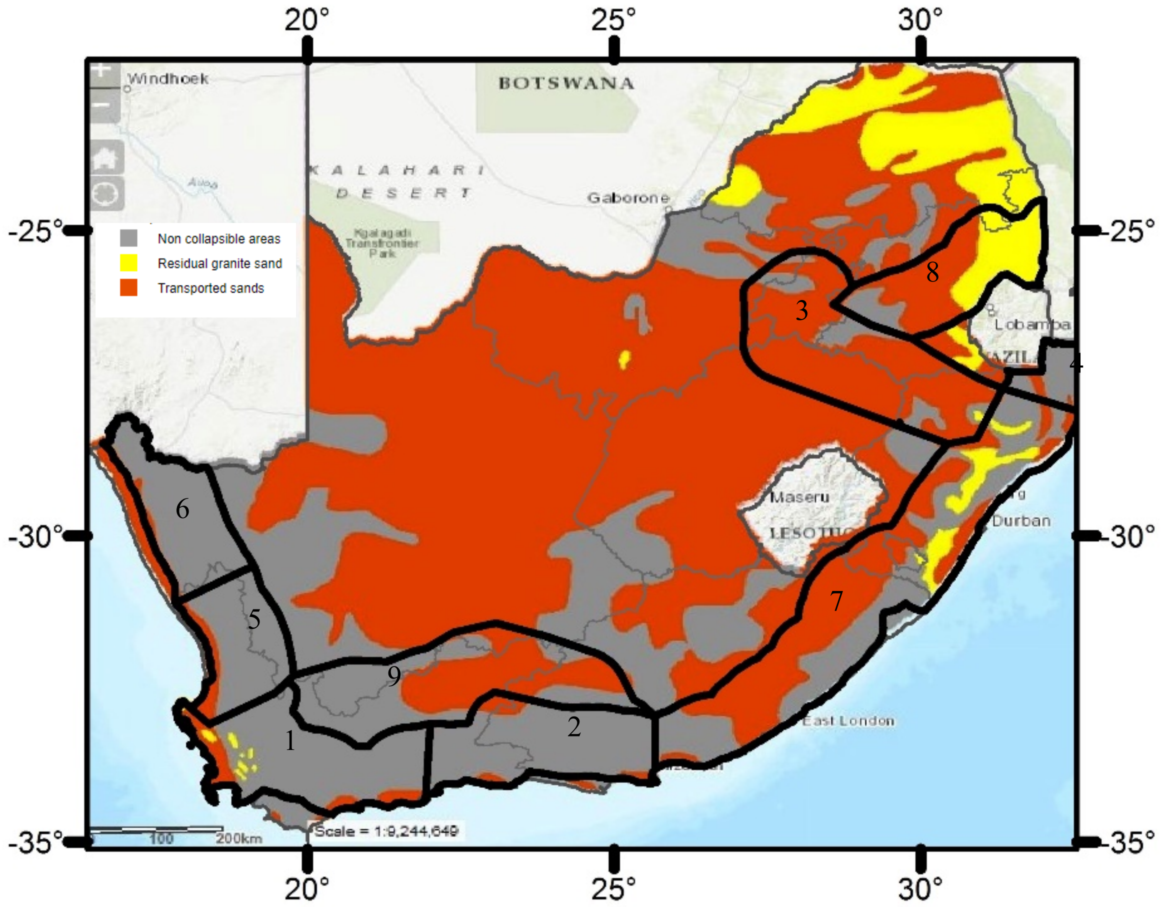

Figure 6: Collapsible soils. This page of the CGS Geohazard Atlas can be viewed online viewed at http://197.96.144.125/jsviewer/Geohazards/index.html

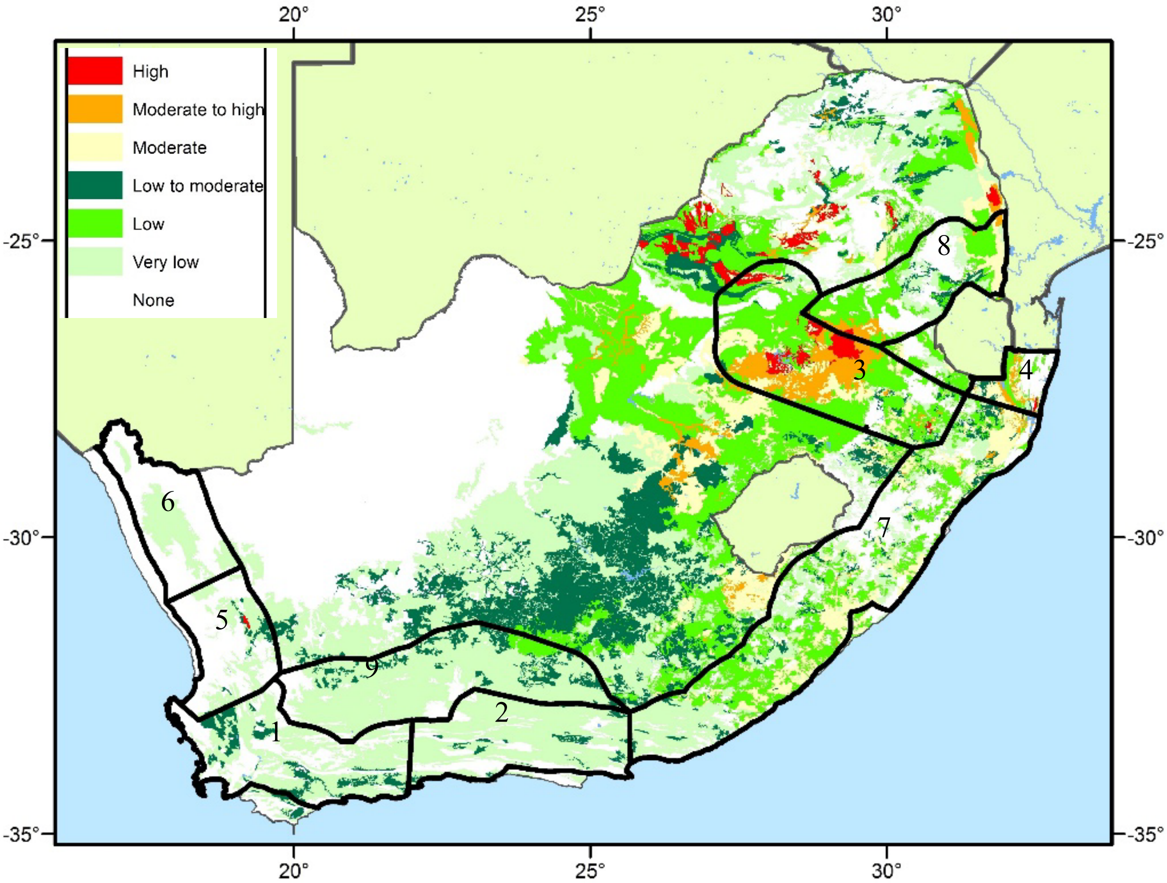

Figure 7: Swelling soils. This page of the CGS Geohazard Atlas can be viewed online viewed at http://197.96.144.125/jsviewer/Geohazards/index.html

3.4 Key sensitivities criteria

The following criteria are proposed to identify regions where GPNs may be sensitive to the effects of earthquakes:

1. Elevated seismic hazard, *viz.* regions that have:
    a. Historical or instrumental records of M>5 earthquakes,
    b. Palaeoseismic evidence of M>6 earthquakes (age <100,000 years, indicated by mapped and dated fault scarps),
    c. PGA>0.05 g (475 years recurrence, equivalent to 10% probability of exceedance in 50 years), or
    d. Active faults (indicated by present-day seismic activity).

2. Elevated vulnerability, *viz.* sub-regions that have:
    a. Steep topography prone to seismically-triggered landslides,
    b. Thick near-surface low-seismic-velocity layers prone to site amplification, or
    c. Problem soils and sands prone to collapse, swelling or liquefaction when shaken.

The pertinent results of the PSHA (Midzi et al. 2018, Appendix B), landslide susceptibility and problem soil cover for the various GPN corridors are summarised in Table 4 below. A value of 7.5 has been used for M_{max}. In their global study of M_{max} in stable continental regions, Vanneste et al. (2016) found that M_{max}7.9, and suggested that the recurrence rate for an event this size in an area of 10^6 km^2, roughly the size of South Africa, was about 70,000 years.

Table 4: Corridor Sensitivities

<table>
<tr><th>Corridor</th><th>Brief description
PGA (peak ground acceleration) and PSA (peak spectral acceleration) for a return period of 475 years (10% probability of exceedance in 50 years); $M_{max}$is the size of the largest credible earthquake.</th></tr>
<tr><td>1</td><td>Saldanha to Mossel Bay

M>6 tectonic earthquakes occurred near Cape Town (M6.1, 1809, with liquefaction) and Tulbagh (M_L6.3, 1969, with rock falls), MMI VIII
M>6 events could occur once or twice per century, M_{max}<7.5
PGA<0.03 g
Presence of active faults determined from seismicity interpretation. Date of last major earthquake to cause surface rupture is unknown.
Areas of rugged topography are prone to landslides.
Small areas with collapsing sand and swelling clay soils.

PGA and PSA on bed rock for Cape Town (CT)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>CT</td><td>3.45E-02</td><td>2.72E-02</td><td>2.19E-03</td><td>5.04E-04</td></tr>
</table></td></tr>
<tr><td>2</td><td>Mossel Bay to Coega with a link to the Karoo for Shale Gas

M>6 events could occur once or twice per century, M_{max}<7.5
PGA<0.03 g
The Kango Fault produced a M7.4 earthquake with a ca. 80-km-long and 2-m-high fault scarp in the Little Karoo ca. 10,000 years ago.
Areas of rugged topography are prone to landslides.
Small areas with collapsing sand and swelling clay soils.

PGA and PSA on bed rock for George (G), Willowmore (W) and Port Elizabeth (PE)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>G</td><td>4.29E-03</td><td>1.14E-03</td><td>9.04E-05</td><td>2.20E-05</td></tr>
<tr><td>W</td><td>1.27E-02</td><td>4.41E-03</td><td>7.42E-05</td><td>2.53E-06</td></tr>
<tr><td>PE</td><td>2.85E-03</td><td>1.12E-03</td><td>9.06E-05</td><td>2.22E-05</td></tr>
</table></td></tr>
<tr><td>3</td><td>Richards Bay to Secunda, Sasolburg and Gauteng

M>6 tectonic earthquake occurred near St Lucia (M_L6.3, 1932, with liquefaction); two M>5 earthquakes occurred in the Klerksdorp mining district (Stilfontein, M_L5.3, 2005; Orkney, M_L5.5, 2014).
M>6 tectonic events could occur once or twice per century; M_{max}<7.5
M>5 mining events could occur in mining districts every decade or two; M_{max}<6.5
PGA <0.2 g in Gauteng; elsewhere <0.07 g.
Many active faults in deep gold mines. Seismicity is induced by mining activity and the active faults are confined to mining areas.
Areas of rugged topography (e.g. escarpment) are prone to landslides.
Small areas with collapsing sand and swelling clay soils.

Estimates of PGA and PSA on bed rock for Richards Bay (RB) and Pretoria (P)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>RB</td><td>2.74E-02</td><td>6.14E-03</td><td>3.24E-04</td><td>8.46E-05</td></tr>
<tr><td>P</td><td>7.16E-02</td><td>7.65E-03</td><td>8.76E-05</td><td>1.96E-05</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Corridor</th><th>Brief description
PGA (peak ground acceleration) and PSA (peak spectral acceleration) for a return period of 475 years (10% probability of exceedance in 50 years); $M_{max}$is the size of the largest credible earthquake.</th></tr>
<tr><td>4</td><td>Mozambique (southern border) to Richards Bay

M>6 tectonic earthquake occurred near St Lucia (M_L6.3, 1932, with liquefaction)
M>6 tectonic events could occur once or twice per century; M_{max}<7.5
PGA<0.03 g except for extreme northern KZN where PGA<0.07g
A fault near the KwaZulu-Natal – Mozambique border that displaced the 75,000 year-old Port Durnford Formation by 30 m is described by Kruger and Meyer (1988).
Areas of rugged topography are prone to landslides.
Some collapsing sands. Some areas with moderate to high swelling

Estimates of PGA and PSA on bed rock for Richards Bay (RB)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>RB</td><td>2.74E-02</td><td>6.14E-03</td><td>3.24E-04</td><td>8.46E-05</td></tr>
</table></td></tr>
<tr><td>5</td><td>Abrahamvilliersbaai to Saldanha

M>6 tectonic earthquakes occurred near Tulbagh (M_L6.3, 1969, with rock falls); MMI_{max} VIII
M>6 events could occur once or twice per century, M_{max}<7.5
PGA<0.03 g
No active faults have been mapped.
Areas of rugged topography are prone to landslides.
Small areas with collapsing sand (along coast) and swelling clay soils.</td></tr>
<tr><td>6</td><td>Abrahamvilliersbaai to Oranjemund (Border of Namibia)

No recorded M>6 earthquakes
M>6 events could occur once or twice per century, M_{max}<7.5
PGA<0.07 g
Several faults have been mapped as “potentially active” by Manzunzu et al. (2019).
Areas of rugged topography are prone to landslides.
Small areas with collapsing sand (along coast) and swelling clay soils.

Estimates of PGA and PSA on bed rock for the Namaqua National Park (NNP)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>NNP</td><td>4.41E-02</td><td>2.91E-02</td><td>9.12E-04</td><td>6.90E-05</td></tr>
</table></td></tr>
<tr><td>7</td><td>Richards Bay to Coega

M>6 tectonic earthquake occurred near St Lucia (M_L6.3, 1932, with liquefaction)
M>6 tectonic events could occur once or twice per century; M_{max}<7.5
PGA< 0.03 g
The Tugela Fault has been mapped as “potentially active” by Manzunzu et al. (2019).
Areas of rugged topography which are prone to landslides.
Some areas with collapsing sands and swelling clay soils.

Estimates of PGA and PSA on bed rock for Richards Bay (RB), Newcastle (N), Durban (D), East London (EL) and Port Elizabeth (PE)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>RB</td><td>2.74E-02</td><td>6.14E-03</td><td>3.24E-04</td><td>8.46E-05</td></tr>
<tr><td>N</td><td>2.64E-02</td><td>2.27E-03</td><td>9.16E-06</td><td>2.61E-07</td></tr>
<tr><td>D</td><td>2.37E-02</td><td>1.16E-02</td><td>1.13E-03</td><td>3.33E-04</td></tr>
<tr><td>EL</td><td>8.45E-03</td><td>4.25E-03</td><td>9.06E-05</td><td>4.29E-06</td></tr>
<tr><td>PE</td><td>2.85E-03</td><td>1.12E-03</td><td>9.06E-05</td><td>2.22E-05</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Corridor</th><th>Brief description
PGA (peak ground acceleration) and PSA (peak spectral acceleration) for a return period of 475 years (10% probability of exceedance in 50 years); $M_{max}$is the size of the largest credible earthquake.</th></tr>
<tr><td>8</td><td>Mozambique border to Gauteng (Rompco Pipeline Corridor)

No recorded M>6 earthquakes
M>6 tectonic events could occur once or twice per century; $M_{max}<7.5$
PGA <0.03 g except for area near Mozambique border where PGA<0.07 g.
No active faults have been mapped.
Areas of rugged topography (e.g. escarpment) which are prone to landslides.
Large areas with collapsing sands and swelling clay soils.</td></tr>
<tr><td>Inland Corridor</td><td>Inland Corridor: Cape Town/Saldanha to Coega

M>6 tectonic earthquakes occurred near Cape Town (M6.1, 1809, with liquefaction) and Tulbagh (M_L6.3, 1969, with rock falls), MMI_{max} VIII
M>6 events could occur once or twice per century, $M_{max}<7.5$
PGA<0.03 g
No active faults have been mapped.
Areas of rugged topography which are prone to landslides.
Small areas with collapsing sand and swelling clay soils.

Estimates of PGA and PSA on bed rock for Cape Town (CT)
<table>
<tr><th></th><th>PGA</th><th>PSA= 0.1s</th><th>PSA = 0.5s</th><th>PSA = 1.0s</th></tr>
<tr><td>CT</td><td>3.45E-02</td><td>2.72E-02</td><td>2.19E-03</td><td>5.04E-04</td></tr>
</table>
</td></tr>
</table>

4 RISK ASSESSMENT

Honneger & Wijewickreme (2013) describe a four step process of conducting a risk assessment for oil and gas pipelines. This is described below:

1. Definition of the scope of the risk analysis, including performance metrics and tolerable levels of risk. They propose the following system performance metrics: number of deaths or injuries, duration of service interruption, number of customers served, amount of monetary loss, and quantity of release.
2. Definition of the potential hazards to pipelines and the likelihood of these hazards occurring. The effort put into the risk analysis should be consistent with the potential level of risk. In the case of seismic risk, hazard is linked to earthquake size, location and style of faulting, and can either be a direct hazard such as ground shaking or surface fault displacement, or an indirect hazard such as triggered slope movement, liquefaction, lateral spread displacement, and post-earthquake consolidation settlement. In this report we have summarised the state-of-knowledge in South Africa.
3. Estimation of the level of pipeline vulnerability for each hazard event. There are several sources of significant uncertainty in determining the potential for earthquake-induced pipeline damage:
    a. Estimates of ground displacement, which are related to the earthquake recurrence rate, earthquake location, and triggering of indirect earthquake hazards. Pipelines crossing fault ruptures may be subjected to displacements ranging from centimetres to metres.
    b. Subsurface soil characteristics for determining soil restraint on buried pipelines,
    c. Pipeline strains produced by ground displacements, and
    d. Pipeline strain capacity for a particular performance level, e.g. continued operation and pressure integrity.
4. Estimation of the various consequences of pipeline damage e.g. thermal radiation due to ignited gas jets from holes or tears in the pipe, blast pressure and heat from the ignition of a gas cloud, etc. Typically, an event tree is used to assess the likelihood of various consequences.

Once the hazards have been identified and the vulnerabilities of the various structures determined (e.g. pipelines, pigging stations), mitigation measures are considered. There are generally four options:

1. Avoid the hazard by relocation.
2. Isolate the pipeline from the hazard. For example, horizontal directional drilling to install the pipeline below the zone of ground displacement, or the construction of 'isolation culverts'.
3. Accommodate the hazard by strengthening the pipeline or increasing flexibility. For example, using low-friction pipeline coatings or wrapping the pipeline with two layers of geotextile fabric;
4. Mitigate the hazard by geotechnical remediation (ground improvement). For example, dynamic deep compaction, compaction piling, vibro-replacement using stone columns and compaction grouting. Detailed site-specific studies are required to quantify the potential for damage and establish the most effective measures.

4.1 Hazards identification

Two hazard scenarios are considered:

1. **Direct impact** i.e. ground displacement across the earthquake fault to cause a gas pipeline to leak or rupture. This would likely require an earthquake with M>7, producing a surface rupture with a length of 20-80 km and a displacement exceeding 0.5 m. The likelihood of such an earthquake occurring in South Africa is considered to be of the order of 1/1000 per annum. The likelihood of a randomly located rupture (length 20-80 km) straddling a gas pipeline is perhaps 1/10 and thus the combined probability of an M>7 occurring and straddling a gas pipeline is perhaps <u>1/10,000 per annum</u>. While considered very unlikely, such events are certainly possible. In the last 120 years, three M>6 earthquakes have occurred, giving an average recurrence time of, say, 40 years. However, none of these events caused a surface rupture. A M7.4 event that occurred about 10,000 years ago in the Cape Fold Belt had a rupture length of about 80 km and a throw of up to 2 m. The M7.0 earthquake that occurred in the Machaze district of Mozambique in 2006 had a rupture length of the order of 40 km and a maximum displacement 1.0-1.5 m. The Hebron fault in Namibia is another example of a southern African fault with clear surface offsets, although the number and magnitude of the events that formed this scarp remain debatable (White et al. 2009).
2. **Indirect impact** i.e. ground displacement such as landslides, liquefaction and lateral spreading triggered by the earthquake shaking causes a gas pipeline to leak or rupture. This would likely require a tectonic earthquake with M>6 (recurrence time of about 40 years as described above) or a shallow mining-related earthquake with M>5. Three M>5 mining-related earthquake have occurred in the last 50 years, and caused strong shaking due to their shallow origin. The frequency of earthquakes capable of triggering indirect impacts is therefore considered to be of the order of <u>1/20 per annum</u>. The maximum distance from the epicentre in which significant displacement could be triggered is about 50 km for 5<M<6.5 earthquakes. The three tectonic earthquakes that occurred in South Africa in the last 120 years triggered some sort of ground displacement, notably a few landslides or areas of liquefaction, while the mining-related earthquakes did not cause any landslides or liquefaction, probably because there were no susceptible conditions nearby. However, the risk of a tailings dam liquefying following an earthquake and subsequently damaging a gas pipeline cannot be overlooked. On the night of 22 February 1994 a tailings dam failed due to operational shortcomings and flooded the suburb of Merriespruit in Virginia in the Free State. Eighty houses were destroyed and 200 others were severely damaged. Seventeen people were killed.

4.2 Consequence levels

An example of a multi-hazard consequence table developed by GNS Science New Zealand was used as a guideline (Table 5[1]). Note that New Zealand's population is about 5 million, less than 10% of South Africa's.

Table 5: GNS Science New Zealand multi-hazard consequence table

Severity of Impact	Built				Economic	Health &Safety
	Social/Cultural	Buildings	Critical Buildings	Lifelines		
Catastrophic (V)	≥25% of buildings of social/cultural significance within hazard zone have functionality compromised	≥50% of affected buildings within hazard zone have functionality compromised	≥25% of critical facilities within hazard zone have functionality compromised	Out of service for > 1 month (affecting ≥20% of the town/city population) OR out of service for > 6 months (affecting < 20% of the town/city population)	> 10% of regional GDP	> 101 dead and/or > 1001 inj.
Major (IV)	11-24% of buildings of social/cultural significance within hazard zone have functionality compromised	21-49% of buildings within hazard zone have functionality compromised	11-24% of buildings within hazard zone have functionality compromised	Out of service for 1 week – 1 month (affecting ≥20% of the town/city population) OR out of service for 6 weeks to 6 months (affecting < 20% of the town/city population)	1-9.99% of regional GDP	11 – 100 dead and/or 101 – 1000 injured
Moderate (III)	6-10% of buildings of social/cultural significance within hazard zone have functionality compromised	11-20% of buildings within hazard zone have functionality compromised	6-10% of buildings within hazard zone have functionality compromised	Out of service for 1 day to 1 week (affecting ≥20% of the town/city population) OR out of service for 1 week to 6 weeks (affecting < 20% of the town/city population)	0.1-0.99% of regional GDP	2 – 10 dead and/or 11 – 100 injured
Minor (II)	1-5% of buildings of social/cultural significance within hazard zone have functionality compromised	2-10% of buildings within hazard zone have functionality compromised	1-5% of buildings within hazard zone have functionality compromised	Out of service for 2 hours to 1 day (affecting ≥20% of the town/city population) OR out of service for 1 day to 1 week (affecting < 20% of the town/city population)	0.01-0.09 % of regional GDP	<= 1 dead and/or 1 – 10 injured
Insignificant (I)	No buildings of social/cultural significance within hazard zone have functionality compromised	< 1% of affected buildings within hazard zone have functionality compromised	No damage within hazard zone, fully functional	Out of service for up to 2 hours (affecting ≥20% of the town/city population) OR out of service for up to 1 day (affecting < 20% of the town/city population)	<0.01% of regional GDP	No dead No injured

The consequence levels used in this assessment (Table 6) are based on the multi-hazard consequence table developed by GNS Science New Zealand but also take into consideration the scale of losses that could be produced by other natural and human-induced hazards such as floods, flash floods, landslides, windstorms, earthquakes, volcanoes, wildfires, chemical spills, mechanical impacts, etc. as well as annual mortality in South Africa due to road accidents (ca. 14,000 in 2016; https://www.arrivealive.co.za/stats.aspx) and murders (ca. 19,000 in 2016/17; https://en.wikipedia.org/wiki/Crime_in_South_Africa).

[1] https://www.gns.cri.nz/Home/RBP/Risk-based-planning/A-toolbox/Risk-based-planning-approach-and-steps/Step-2-Determine-severity-of-consequences/Consequence-table

Table 6: Proposed consequence table to assess risks posed by earthquakes to GPNs
South Africa's GDP in 2016 was about USD 300 billion (say R4,500 billion)

	Consequence level	Slight	Moderate	Substantial	Severe	Extreme
	Impact ↓					
Economic loss	Repairs to property, loss of production, etc.	<R1 million	<R100 million	<R1 billion	<R100 billion (<2% of GDP)	>R100 billion (>2% of GDP)
Environmental loss	Burning or pollution of grazing areas, orchards, plantations or forests	<1000 m^2	<10,000 m^2 (1 hectare)	<1 km^2 100 hectare	<100 km^2	>100 km^2
Human loss	Injury and death	<10 injuries 0 deaths	<100 injuries <10 deaths	<1000 injuries <100 deaths	<10,000 injuries <1,000 deaths	≥10,000 injuries ≥1,000 deaths

4.3 Risk assessment results

The results of the risk assessment are summarised in Table 7.

It is assumed that all transmission gas pipelines will be built with appropriate mitigation measures. For example:

- Pipelines will be built to most recent applicable international standards. Guidelines may be found in the technical literature. See for example, Yokel & Mathey 1992 and Lanzano et al. 2013a,b,c,d.
- Pipelines will be equipped with valves that will stop gas flow in a specific section if there is a significant drop in pressure.
- Sites prone to landslides, lateral spreading and liquefaction will be identified. The sites will either be avoided; or the pipeline will be strengthened or made more flexible as deemed appropriate; or the ground will be improved; or some combination of the above measures will be implemented.

Furthermore, it is proposed that the PGPN will mostly run outside of populated built-up regions; thus the exposure of people and assets to harm and loss will generally be low. Health and safety risks associated with a gas pipeline incident as well as safety distances to the proposed pipeline (and associated relocation requirements) are considered as part of the Settlement Planning, Disaster Management and related Social Impacts Report (separately attached within Appendix C.3 of the Gas Pipeline SEA Report).

Table 7: Negative Impacts applicable to the Gas Corridors

Impact	Corridor	Location	With mitigation		
			Consequence	Likelihood	Risk
Direct M>7 earthquake causes fault displacement over 20-80 km that ruptures a gas pipeline	All	M>7 earthquake could occur anywhere in SA	Substantial	Extremely unlikely	Very Low
Indirect Impact Landslides, liquefaction or lateral spreading that damages a gas pipeline triggered by a M>6 tectonic earthquake or M>5 shallow mining-related earthquake	Sections of all corridors. The Gauteng section of corridor 3 is prone to mining-related earthquakes	Flat terrain without problem soils	Slight	Extremely unlikely	Very Low
	Limited sections of all corridors, especially where they cross the escarpment and the Cape fold mountains	Steep terrain without problem soils	Moderate	Very unlikely	Low
	Sections of all corridors	Flat terrain with problem soils	Moderate	Very unlikely	Low
	Substantial section of corridor 8; limited sections of other corridors	Steep terrain with problem soils	Substantial	Very unlikely	Low

The risk posed by GPNs in the event of earthquakes in South Africa is considered to be generally low, provided local ground motion amplification, liquefaction and landslide phenomena are taken into account.

Lastly, it should be noted that there are very few 'no go' areas for earthquake engineers. They have the option of either: (i) avoiding sites that are susceptible to earthquake damage; (ii) stabilising the sites e.g. driving piles, using raft foundations, dewatering potential landslides, anchoring critically-balanced rocks; or (iii) reinforcing or protecting the GPNs. The decision is based on numerous factors, including environmental impacts, risk and cost.

Based on the above findings and providing that recommended management actions are effectively implemented when planning and constructing the pipeline, all corridors are deemed suitable for the development of a PGPN as far as the risk posed by earthquakes is concerned.

5 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

5.1 Planning phase

The following best practices are recommended in order to find the best route (from a social and economic perspective) for the proposed gas transmission pipeline.

Map the regions within the GPN corridors that have:
- (i) Historical or instrumental records of M>5 earthquakes,
- (ii) Palaeoseismic evidence of M>6 earthquakes (age<100,000 years), or
- (iii) Seismically-active faults.

Within the corridors, map sub-regions that have either:
- (i) Steep topography prone to landslides,
- (ii) Thick near-surface low-seismic-velocity layers that could cause site amplification, or
- (iii) Problem soils and sands that could collapse or liquefy when shaken.

These regions should be designated as "sensitive".

Current knowledge, as summarised in **Appendix A**, is inadequate to map these regions accurately. It must be remembered that the duration of the earthquake catalogue is short compared to the likely recurrence time of M>5 events. The current national network is simply not dense or sensitive enough in these regions to relate earthquake hypocentres to any particular fault. Geological maps frequently show numerous faults but it is important to realise that these faults are the result of tectonic forces and earthquakes that were active tens, hundreds or even thousands of millions of years ago. The mapping of currently active faults involves arduous palaeoseismic studies and detailed and sensitive seismic mapping.

Site effects are an important consideration (see e.g. Tamaro et al. 2013). The account of site effect (at least its first approximation) can be done by the account of average S velocity (Vs30) of the top 30 meters. Vs30 can be calculated from the topographic slope (Allen and Wald, 2007) and its implementation is easy (e.g. Atkinson and Boore, 2006). Geological and geophysical investigations should be conducted in "sensitive" regions to quantify the hazard of landslides, strong ground motion or liquefaction. Should these surveys indicate that there is a significant probability that GPN damage thresholds will be exceeded, the GPN should either be relocated, reinforced or protected (e.g. landslide mitigation measures).

The Vaalputs nuclear waste disposal site and the Thyspunt nuclear build site are examples of sites in South Africa where such studies have been conducted. For example, sensitive and dense local seismic networks have been deployed, historical records have been scoured for evidence of earthquakes, geotechnical surveys of the near surface have been conducted, and trenches have been dug for palaeoseismic studies. The detailed mapping of areas that may be prone to local site effects such as amplification, liquefaction and landslide requires detailed geological, geotechnical and geophysical mapping. This activity is known as 'microzonation'. Such studies have been carried out at nuclear power station sites and nuclear waste disposal sites. The Council for Geoscience recently commenced seismic microzonation studies in the Johannesburg and Cape Town areas.

Some of the world's most technologically-advanced countries are exposed to seismic hazard, for example, Italy, Japan and the USA. Standard methodologies have been developed to assess seismic hazard; numerous studies have been conducted to assess the risk posed by earthquakes to lifelines; and engineering specifications for GPNs have been published. It must be emphasised that risk posed by earthquakes is generally not viewed in isolation, but as part of a multi-hazard strategy. For example:

- *Earthquake Resistant Construction of Gas and Liquid Pipeline Systems Serving, or Regulated by the Federal Government*, published by the US Federal Emergency Management Agency (Yokel & Mathey, 1992).
- *Fire Following Earthquake*, monograph published in 2005 by the Technical Council on Lifeline Earthquake Engineering (TCLEE) of the American Society of Civil Engineers (ASCE) (edited by C. Scawthorn, JM Eidinger, AJ Schiff).
- *Seismic risk assessment for oil and gas pipelines*. In *Handbook of Seismic Risk Analysis and Management of Civil Infrastructure Systems*. Honneger & Wijewickreme (2013).
- *Seismic vulnerability of natural gas pipelines*, by Lanzano et al. (2013a).
- *Seismic vulnerability of gas and liquid buried pipelines*, by Lanzano et al. (2013b).
- *Seismic behaviour of a buried gas pipeline under earthquake excitations*, by Lee et al. (2009).
- *Seismic fragility formulations for water systems – Part 1 Guidelines and Part 2 - Appendices*, by the American Society of Civil Engineers (ASCE) and Federal Emergency Management Agency (FEMA), for the American Lifelines Alliance (2001).

5.2 Construction phase

Install seismic sensors and monitor both weak and strong ground motion in "sensitive" regions to improve hazard assessments.

5.3 Operations phase

Monitor both weak and strong ground motion in “sensitive” regions to improve hazard assessments. If necessary, increase the sensitivity and/or density of the sensors. Relocate, reinforce or protect the GPN if a significant increase in hazard or risk is indicated.

5.4 Rehabilitation and post closure

Not applicable.

5.5 Monitoring requirements

Statutory requirements for instruments to monitor ground motion are listed in **Appendix C**. In summary, the South African National Standard (SANS 4866:2011, based on ISO 4866:2010) specifies measuring ranges for various vibration sources, including earthquakes and blasts. These standards should be applied when carrying out surveys related to GPNs.

The standard prescribes that instruments used to monitor ground-borne blast vibrations must be capable of measuring ground motions over the range 0.2 mm/s to 100 mm/s in the frequency range of 1 Hz to 300 Hz; while instruments used to monitor earthquakes must be capable of measuring ground motions over the range 0.2 mm/s to 400 mm/s in the frequency range of 0.1 Hz to 30 Hz.

6 GAPS IN KNOWLEDGE

A great deal is known about the impact of earthquakes and faults on GPNs from work done in regions that are both highly-developed and tectonically-active, such as Italy, Japan and the western USA.

South Africa has a seismic monitoring network and a homogenized earthquake catalogue, although further work is required to reduce the uncertainties in hazard assessment along particular corridors and at specific sites. In particular, this would involve:

- Sensitive seismic monitoring to detect active faults. This would involve the deployment of temporary local seismograph network.
- Strong motion monitoring to determine local ground motion prediction equations (GMPEs). However, it could take decades or even centuries to produce useful results as large earthquakes are rare.
- Determination of local site effects by geological, geotechnical and geophysical surveys.
- Analysis of the local site response to shaking through amplification studies e.g. multi-channel analysis of surface waves (MASW) to determine the average shear wave velocity in the uppermost 30 metres (V_s30) and spectral ratio surveys.
- Detailed palaeoseismological and geological mapping to map the length and throw of prehistoric fault ruptures, and geochronological studies to date past events.
- Detailed site-specific PSHA and deterministic seismic hazard assessment studies.
- Liquefaction potential analysis.
- Landslide susceptibility studies.
- Detailed assessment of the vulnerability of GPNs.

In general, there is however sufficient information available to guide decisions on the PGPN development in South Africa. South Africa is regarded as a stable continental region. Earthquakes are far less frequent than in tectonically active regions such as Italy, Japan and the western USA. This does not mean that strong earthquakes cannot occur; but that the return periods are centuries or millennia. Experience in developed tectonically-active countries has shown that GPNs are generally resilient to moderate intensities of ground motion. It is recommended that focused studies of earthquakes risk be conducted at critical GPN sites situated in areas deemed to be exposed to a higher risk of damage (see Table 5).

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Appendix A: Seismic Hazard in South Africa

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Summary
Earthquakes were responsible for some of the most devastating disasters to occur in the early years of the 21st century. On 26 December 2004 an M_w9.1 earthquake occurred off the coast of Sumatra, triggering a tsunami that swept across the Indian Ocean, killing some 228 000 people (USGS 2012). The M_w9.0 Great Eastern Japanese earthquake and tsunami of 11 March 2011 was the costliest disaster of all time, with losses amounting to USD210 billion, not including the cost of the incident at Fukushima nuclear power station (New Scientist 2012). Fortunately, large earthquakes are relatively rare in South Africa, the most deadly earthquake on record being the M_L6.3 event that struck the Ceres-Tulbagh region on 29 September 1969, claiming the lives of nine people (Van Wyk & Kent 1974). Nevertheless, South Africans cannot afford to be complacent. A moderate-sized earthquake with a shallow focus occurring close to a town can be devastating, especially if the buildings are not designed to be earthquake-resistant, the terrain is steep and prone to landslides, or the soil is thick and prone to amplification and liquefaction.

EARLY SCIENTIFIC INVESTIGATIONS (circa 1600 to 1900)
Historical catalogues
In 1858 an Irish civil engineer named Robert Mallet (1810-1881), sometimes referred to as 'the father of seismology', published a global map of earthquake epicentres based entirely on reports of felt earthquakes (Agnew 2002). It was obvious that most earthquakes occurred in distinct zones, particularly around the Pacific Ocean and near high mountain ranges such as the Alps and Himalayas. The region surrounding the Cape of Good Hope was shaded orange, indicating that earthquakes had been felt and reported. The historical seismological catalogue for southern Africa (Brandt et al 2005, which superseded Fernández & Guzmán 1979a) lists forty-five earthquakes prior to the 20th century: four in the 17th century, three in the 18th century, and the balance in the 19th century. The catalogue is largely based on the work of Finsen (1950), Theron (1974) and De Klerk and Read (1988), who searched for reports of earthquakes in historical documents such as local newspapers and journals kept by explorers and travellers. The earliest event in the South African catalogue is dated at 1620. However, a recent re-examination of historical records by Master (2012) concluded that the event, recorded by the captain of a ship anchored in Table Bay, was most likely a thunderclap and not an earthquake. Consequently the oldest event is now dated at 1690. Discoveries of 'old' earthquakes continue to be made. For example, Master (2008) discovered a report in the *Cape Monthly Magazine* (Bright 1874) of an intensity III earthquake that was felt by many people in Maseru in February 1873, a recent study by Albini et al (2014) reviewed reports of seismic events that occurred in the Eastern Cape region between 1820 and 1936, while Singh et al (2015) were able to assign intensity values to reports of ground shaking produced by seven events felt in KwaZulu-Natal between 1927 and 1981 that were not listed in the historical database.

The most damaging event to occur in the pre-instrumental era struck the Cape Town district on 4 December 1809. Three strong quakes were felt, and many buildings suffered numerous cracks. Von Buchenröder (1830) provided an eyewitness account of the event: *In the evening, a little after ten o'clock, three shocks, each accompanied by a tremendous noise, were felt, within the space of a minute or two. .... While we were standing in the street, the second shock took place, which was felt much stronger; was accompanied by a louder, and very tremendous noise, that continued longer than the first ... The second shock roused all the inhabitants, who came running into the streets in great consternation, many of them undressed from having being in bed.* The next day Von Buchenröder undertook an inspection of the town and noted that chimneys, parapets and figurines on gables had been damaged. On 9 December he undertook an expedition to Blaauweberg's Valley (near present-day Milnerton), where he made quantitative observations of a scientific type: *[N]ear the Kraal I found rents and fissures in the ground, one of which I followed for about the extent of a mile.* The deduced intensity (on the Modified Mercalli scale) and magnitude were VII-VIII and M_L6.1, respectively (Brandt et al 2005).

The renowned explorer William Burchell provides an equally vivid account of an earthquake that struck Cape Town on 2 June 1811 in his *Travels in the Interior of Southern Africa* (Burchell 1822). He was staying in the Lutheran parsonage in Cape Town at the time: *I hastened out of doors to ascertain what had happened;[...] I came into the street and beheld all the inhabitants rushing out of doors in wild disorder and fright; [...] when I beheld this, I instantly guessed that an earthquake had happened.* Burchell goes on to describe the structural damage: *Walking afterwards about the town [...] I was told that many houses were exceedingly rent, and some more materially damaged; but none were actually thrown down [...] Many* *of the ornamental urns which had escaped the earthquake of 1809, were now tumbled from the parapets down into the street [...]and the wall of my bedroom was in the same instant divided by a crack which extended from the top of the house to the bottom.* The deduced intensity (on the Modified Mercalli scale) and magnitude were VII and M_L5.7, respectively (Brandt et al 2005).

INSTRUMENTAL SEISMOLOGY (circa 1900 – 1970)
The first seismometer installed in South Africa was a Milne-type horizontal pendulum instrument installed at the Royal Observatory in Cape Town in 1899 (Schweitzer & Lee 2003). It was deployed as part of a campaign to establish a worldwide seismograph network. Seismometers were installed in Johannesburg in 1910 to monitor earth tremors associated with mining, one in the Union Observatory and another near Ophirton. While most events were related to mining activity, some natural regional events were also recorded (Wood 1913). Over the next fifty years, seismometers were installed in Cape Town, Johannesburg, Grahamstown, Pietermaritzburg, Kimberley and Pretoria. Details of these early installations are provided by Wright and Fernández (2003).

A network of five seismographs was deployed on the northern rim of the Witwatersrand Basin in 1939 by researchers at the newly established Bernard Price Institute for Geophysics (BPI) at the University of the Witwatersrand. Data were transmitted by radio to a central point, where continuous 24-hour registration, coupled with an ingenious device that triggered distant seismographs, allowed all the larger mining-related events to be located accurately in space and time (Gane et al. 1949; 1946). This was the first use of a telemetered network anywhere, and is the only South African achievement included in the 'History of Seismology' chapter in the *International Handbook of Earthquake and Engineering Seismology*, published by the International Association for Seismology and the Physics of the Earth's Interior (IASPEI) (Agnew 2002).

It is important to note that instrumental recording does not guarantee correct location, especially in the early period. For example, the International Seismological Summary (ISS), the most comprehensive global earthquake catalogue for the time period between 1918 and 1963, lists a M6.5 earthquake on 31 October 1919 with its epicentre in Swaziland based on phase readings from 22 stations distributed around the globe. The absence of any local reports of shaking or damage led Manzunzu and Midzi (2015) to investigate its authenticity. They concluded that the event did not occur in Swaziland and should be removed from the local catalogue. The mis-location was either due to the wrong association of phases by ISS, or the simultaneous recording of phases from multiple events.

THE SOUTH AFRICAN NATIONAL SEISMOGRAPH NETWORK (1971 to the present)
The history of the South African National Seismograph Network (SANSN) is comprehensively reviewed by Saunders et al., (2008), so only a few highlights will be mentioned here. The first seven short-period (1 sec) vertical component seismic stations of the SANSN were deployed in 1971, shortly after the Ceres-Tulbagh event. Since then the SANSN has provided the essential infrastructure for the assessment of seismic hazard in South Africa. By 1997 the network had expanded to twenty-seven stations. In 1991 several digital seismographs were installed, first with dial-up landlines and later with dial-up GSM (Global System for Mobile Communications) modems.

The network was rejuvenated and modernized in 2003, partly motivated by a seismic hazard assessment programme in support of the South African government's plan to build nuclear power stations. Seven Geotech KS-2000 broadband seismometers (100 s) were installed across the network, and Guralp CMG-40T three-component extended short-period (30 s) seismometers at the other stations. There is also one very broadband Streckeisen STS-2 (120 s) seismometer at Silverton. Delays in transferring the waveforms of the Stilfontein event of 9 March 2005 triggered further upgrades to the SANSN to enable near-real-time data transmission. In 2006 seismic stations were installed in the Far West Rand (KLOF) and Central Rand (ERPM) gold fields. The KLOF station also recorded triggered data at 750 Hz, compared to the SANSN continuous recording standard of 100 Hz.

The velocity model is one of the most important factors affecting the accuracy of earthquake locations. Midzi et al. (2010) reviewed the model used by the SANSN and derived a new 1-D model by inverting P-wave travel times recorded by the SANSN. Moment tensors provide important information for seismotectonic and hazard studies. However, earthquakes with M_w<4.5 are too weak to be analysed using global moment tensor techniques. Prior to 2010, moment tensors had only been calculated for six South African earthquakes. Brandt & Saunders (2011) supplemented seismograms recorded by the SANSN with data recorded between 1996-1999 by the Southern African Seismic Experiment (SASE), conducted by the Wits University, MIT and the Carnegie Institute of Washington. The data were used to compute regional moment tensors (RMTs) for three near-regional M_w~4.0 earthquakes, two of which were mining-related events in the Far West Rand gold field, while the third was a tectonic event from the Koffiefontein cluster. The M_L scale for South Africa was recalibrated using 263 tectonic earthquakes recorded by the SANSN from 2006 to 2009 at epicentral distances of 10-1000 km, and station corrections determined for twenty-six stations (Saunders et al 2013). The anelastic term derived in this study indicated that the ground motion attenuation is significantly different from that of Southern California (which had been used previously), but comparable with other stable continental regions.

The Council for Geoscience (CGS) also operates seismographs stations and/or delivers data as a service to other organizations.

US Geological Survey National Earthquake Information Centre (NEIC) and the International Seismological Centre (ISC): The CGS releases digital seismological data, including phase readings and located epicentres, to the NEIC and ISC, where the phase readings are incorporated in international bulletins and released.

Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO): South Africa ratified the Comprehensive Nuclear Test Ban Treaty (CTBT) in 2003, and the CGS is responsible for the operation and maintenance of two stations of the International Monitoring System (IMS): a primary seismograph and infrasound station at Boshof (BOSA), and an auxiliary seismograph station at Sutherland (SUR). The stations are equipped with both short-period (1 s) and very broadband (120 s) sensors. The BOSA station is also part of the Global Telemetered Seismological Network (GTSN) of the US Air Force, while the SUR station is part of the Global Seismological Network (GSN) operated by the Incorporated Research Institutions for Seismology (IRIS).

Indian Ocean Tsunami Warning System (IOTWS): The devastating Indian Ocean tsunami of 26 December 2004 led to an initiative to establish the IOTWS by the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO). In June 2005, during the 23rd session of the IOC, the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) was formally established. Five SANSN stations were equipped with broadband equipment and were linked to the IOTWS. In 2018 the group had 28 member states, including South Africa. Many countries participate through national tsunami warning centres. However, three Regional Tsunami Service Providers (Australia, India and Indonesia) are the primary source of tsunami advisories for the Indian Ocean (http://iotic.ioc-unesco.org/indian-ocean-tsunami-warning-system/tsunami-early-warning-centres/57/regional-tsunami-service-providers; last access 30 April 2018).

AfricaArray (2005-present): The Council for Geoscience was a founding member of the AfricaArray programme, established in 2005 (Nyblade et al 2008; Nyblade et al 2011). CGS contributes data from eleven broadband stations to the programme. The data is archived at the IRIS facility in the US.

Water Ingress Project (2008 – present): A 12-station-strong ground motion array was deployed in the Central Rand in 2008 to monitor seismicity associated with the flooding of mines.

Mine Health and Safety Council (2010-present): A 25-station-strong ground motion array was established in the Klerksdorp region to monitor mining-related seismicity in 2010. The array proved its worth when it recorded the M_L5.5 event that occurred on 5 August 2014 and its numerous aftershocks.

Observational Study in South African Mines to Mitigate Seismic Risks (2010-present): A 10-station array was deployed in 2011/12 in the Far West Rand mining district to monitor mining-related seismicity as part of a Science and Technology Research Partnership for Sustainable Development (SATREPS) project. SATREPS is a Japanese-South African collaboration funded by the Japan Science and Technology Agency (JST), Japan International Cooperation Agency (JICA), the Department of Science and Technology (DST), the Council for Geoscience, and the CSIR (Durrheim et al 2012; Durrheim et al 2010).

MEASUREMENTS OF STRESS AND STRAIN IN THE EARTH'S CRUST

Earthquakes are driven by stresses in the Earth's crust that are indirectly quantifiable by measuring strains in the rock. Crustal deformation is often extremely difficult to measure, as rates of strain and tilt are generally extremely small, especially in 'stable' continental regions.

Stress measurements in southern Africa

In the early 1970s Nick Gay of the BPI compiled in situ stress measurements made at fifteen localities in South Africa, Rhodesia (now Zimbabwe) and Zambia (Gay 1975). At that time, the most commonly used strain cell was the CSIR doorstopper developed by Leeman (1964, 1969). Measurement depths ranged from 20-2500 m. At shallow depths the horizontal stresses are generally greater than the vertical stresses, but at greater depths the vertical stresses are about double those acting horizontally. Gay subsequently published two important global reviews (McGarr & Gay 1978; Gay 1980). Stress measurements in the mining districts were compiled by Stacey & Wesseloo (1998).

Neotectonic studies
There are several concepts related to the assessment of earthquake hazard that are often used loosely, and hence we recommend using definitions contained in the glossary in International Handbook of Earthquake & Engineering Seismology (Aki & Lee 2002).

Active fault: A fault that has moved in historic (e.g. past 10,000 years) or recent geological time (e.g. past 500,000 years). It should be noted that all faults that move in earthquakes today are active, but not all active faults generate earthquakes – some are capable of moving aseismically.
Neotectonics: The study of post-Miocene structures and structural history of the Earth's crust (the Miocene ended about 5 million years ago).
Paleoseismology: The study of ancient earthquakes decades, centuries or millennia after their occurrence, made possible by evidence of surface faulting, displacments in young sediments, or other near-surface phenomena such as liquefaction.

Meghraoui et al (2016) published the Seismotectonic Map of Africa, showing faults considered to have been active since the Quaternary (2,588 Ma to present) and during the last 150 ka. Manzunzu et al (2019) published a study of the seismotectonics of South Africa, in which they update Meghraoui et al's (2016) map, highlighting the fault segments that have strongest evidence for activity during the past 150 ka.

The assessment of seismic hazard at potential sites for the disposal of radioactive and toxic waste requires a detailed knowledge of any geological structures that may be active. Marco Andreoli of the Nuclear Energy Corporation of South Africa (Necsa) and his co-workers compiled observations of neotectonic faults, Landsat, SEASAT and GEOSAT imagery, aerial photography, hot springs, earthquake focal mechanisms, and detailed field mapping, amongst others (Andreoli et al., 1996). They deduced that neotectonic activity is taking place in the south-western Cape and Namaqualand, as well as in a broad region extending from the Free State to the Limpopo and Kwazulu-Natal, and also defined a broad region of NW-SE trending maximum horizontal compressive stress, which they named the Wegener Stress Anomaly.

There are several other faults that have been active during the last 5 million years. For example, Steenekamp et al (2018) describe a thrust fault exposed in an open pit platinum mine near Brits that displaced strata with a maximum age of 175,000 by about 4 m, and Kruger & Meyer (1988) describe a fault near the KwaZulu-Natal – Mozambique border that displaced the Port Durnford Formation by 30 m more recently than 75,000 years ago. Howver, without knowledge of the strike of the faults and the date, size and rate of individual slip events, it is impossible to estimate the magnitude and recurrence times of earthquakes along these structures. Hobday & Jackson (1979) and Jackson & Hobday (1980) attribute faults and overturned folds in coastal exposures of the Port Durnford Formation in Zululand to a combination of gravity gliding and clay diapirism, which may have been triggered by seismicity or rapid loading of lagoonal sediments by transgressive barrier sands.

Global and regional stress and strain models
Peter Bird of the University of California, Berkeley and his co-workers (including Marco Andreoli of Necsa) used a thin-shell finite element technique constrained by realistic heat flow and rheology to investigate the propagation of the East African Rift and compute the state of stress in the southern African crust (Bird et al., 2006). One objective of the study was to investigate the origins of the Wegener Stress Anomaly, first identified by Andreoli et al (1996). The boundary conditions of the Bird model are provided by the rates of spreading at the Mid-Atlantic and Indian Ocean Ridges, as well as various stress measurements compiled in the World Stress Map database (Reinecker et al 2004). It was concluded that the Wegener Stress Anomaly is caused primarily by resistance to the relative rotation between the Somalia and Africa plates. While the model of Bird et al (2006) certainly provides interesting results, the continental fracture that describes the East African Rift System is shown to continue along a line that joins the clusters of mining-related earthquakes in the Central and Far West Rand, Klerksdorp and Free State, before tracking through Lesotho and heading into the Indian Ocean. This plate boundary model is perpetuated in the series of earthquake posters published by the National Earthquake Information Centre at the US Geological Survey (see, for example, the poster for the M_w7.0 Machaze earthquake of 22 February 2006 (NEIC 2006)).

An analysis of the evolution of the regional stress field over the past 500 Ma was carried out by Viola et al (2012). Only one stress tensor was assigned to the Cenozoic tectonic evolution of the area, obtained from a "weathered" fault set and tentatively attributed to the Pliocene-Early Pleistocene NW-SE oriented extensional tectonic phase reported in the Kalahari basin, related to the propagation of the East African Rift System into southern Africa and formation of local fault-bounded depressions.

InSAR

Interferometric synthetic aperture radar (InSAR) is a satellite-based method that is used to detect ground deformations associated with geophysical phenomena such as the inflation of volcanoes and earthquakes. Its application to earthquake studies in South Africa has been limited. Doyle et al. (2001) used it to assess the surface deformation associated with a M_L4.5 tremor that occurred in the Free State Gold Fields on 23 April 1999. A 5-km-long elliptical depression centred on the Eland shaft of Matjhabeng Mine was mapped, with a maximum depth at its centre of 9 cm. InSAR has also been used to assess movement along the Kango-Baviaanskloof Fault (Engelbrecht & Goedhart 2009; Goedhart & Booth 2009).

Trignet CGPS network

Starting in 2001, the National Geo-Spatial Information (NGI) Directorate deployed a network of about sixty-five continuously observing global positioning system (CGPS) stations covering South Africa. Richard Wonnacott (NGI Directorate) was the leader of this programme. The average distance between stations is 200 km, with local densifications (70 km) around Cape Town, Durban and Johannesburg. Data are freely available from the Trignet web page (www.trignet.co.za). The first findings were published by Malservisi et al. (2013) using the stations with at least a thousand days of recording by June 2011. The results show that the South African region behaves rigidly, with deformation in the order of one nanostrain/year or less. The Trignet data were compared with data for the Nubian plate, and it was found that the South African block is rotating in a clockwise direction with respect to the African continent, which is consistent with the propagation of the East African Rift along the Okavango region.

SIGNIFICANT SOUTH AFRICAN EARTHQUAKES SINCE 1900

Earthquake size is expressed in terms of the intensity of shaking, which diminishes with distance from the epicentre; and magnitude, which is proportional to the deformation caused by the earthquake rupture or the seismic energy that is radiated by the source. In South Africa, the Modified Mercalli Intensity (MMI scale) and local magnitude scale (M_L, a local implementation of the Richter scale) are commonly used, though other scales, such as surface wave (M_s) and moment magnitude (M_w) are sometime used.

At the end of 1905 the Transvaal Meteorological Department acceded to a request from the Kaiserliche Hauptstation für Erdbebenforschung to collect information on earthquakes, and postcards with printed questions were sent to meteorological observers. Wood (1913) reported that there had not been a single earthquake of great importance during seven years of observation, and only three shocks that had been widely felt.

M_L5.0 earthquake in the Zoutpansberg, 5 August 1909

The M_L5.0 earthquake in the northern Zoutpansberg was felt as far away as Bulawayo and Johannesburg. It was the first event for which macroseismic data was systematically collected over a large area, enabling an isoseismal map to be drawn. Wood (1913) provides an account given by Mr Forbes Mackenzie, a superintendent at the Seta diamond mines, not far from the epicentre. The earthquake was assigned a peak MMI of VI (Brandt et al 2005).

Earthquakes near Philipstown (M_L5.0, 21 October 1910) and Koffiefontein (M_L6.2, 20 February 1912)

The Philipstown and Koffiefontein earthquakes near the border between the Cape and the Free State were amongst the first natural events to be recorded by the Wiechert seismometers installed in Johannesburg in 1910. Many farm buildings south of Koffiefontein were destroyed and buildings in Kimberley were cracked. Wood (1913) provides isoseismal maps for both these events. The MMI scale intensities of the Philipstown and Koffiefontein events were V-VI and VIII, respectively (Brandt et al 2005).

M_L6.3 earthquake off Cape St Lucia, 31 December 1932

The M_L6.3 Cape St Lucia event of 31 December 1932 occurred off the Zululand coast and was felt as far away as Port Shepstone and Johannesburg, some 500 km away (Krige & Venter 1933). The nearest point on land to the epicentre was Cape St Lucia, where a MMI of IX was assigned on the evidence of sand boils and cracks in the surface. In the severely shaken areas, poor-quality houses (built of unburned or half-burnt bricks, or other low-quality materials) were severely damaged, while cracks were occasionally seen in well-built houses. As this region falls within the Eastern PGPN corridor, the description of the more intense phenomena is repeated verbatim.

The shocks reached the intensity 7 in a small area in Zululand, including Palm Ridge, Matubatuba, St. Lucia, Estuary Lots, St. Lucia Lighthouse, Umfolosi, Eteza, Empangeni, Felixton and Mtunzini. At these centres the earthquake had the following effects:

Everybody was frightened and all ran outside.
Movement of ground caused persons standing to stagger.
The shocks appeared to come from the south-east at St. Lucia Lighthouse, from the east at Eteza, and Mtubatuba, from the south at Palm Ridge.
Buildings rattled as if about to collapse.
Plaster fell from ceilings.
Many chimneys and walls were cracked, also cement pavements and steps at St. Lucia Lighthouse and at St. Lucia Estuary Lots.
A few houses were so badly damaged that they were abandoned.
One house collapsed.
Crockery, bottles and glasses were smashed.
Water splashed over sides of large railway tanks and out of some smaller tanks.
Corrugated-iron tanks sprang leaks, burst or were dislodged.
Trees and shrubs moved like waves caused by a mighty hurricane, the movement lasting three minutes. One large tree was uprooted.
Water in Nyalazi River, near Palm Ridge, appeared as if boiling.

Fissures up to four inches or more wide, and often several hundred yards long, formed in the sand hills near St. Lucia Lighthouse and in the damp ground near rivers and streams. One fissure was over two miles long and affected a railway embankment, which it crossed ten miles north of Matubatuba, to such an extent that a train was derailed.

At Mr. Shire's sugar mill, near the Umfolosi River, south-east of Matubatuba, some of the fissures opened to a width of about two feet during the earthquake, and then closed up again partly, sending columns of water resembling geysers into the air for 10 feet or so. They left deposits of white sand on the black soil on both sides of the fissure. One of the fissures, which was parallel to the river, was followed for over a mile, but extended further in both directions. As Mr. Shire's house also suffered considerable damage, it seems that intensity 8 was reached at this locality.

At St. Lucia Lighthouse, which is built on the sand hills near the shore, 370 feet above sea level, the 30-foot iron lighthouse-tower was violently shaken for two minutes. The gas cylinders weighing between 300 and 400 lbs. were moved about. The lamp and lenses were thrown out of position. The lighthouse-keeper's wife was flung from a sofa on to the floor.

The shocks attained or exceeded intensity 8 on the rocky shore from Cape St. Lucia, to the mouth of the "Estuary" and perhaps also along the banks of the Umfolosi River during the last few miles of its course. Near the mouth of the Estuary "a low rumbling noise like underground thunder" accompanied the tremor, which was "quite violent for about 15 seconds". It appeared to be moving from S.W. to N.E. Close to the observer six or eight fountains were seen to gush up from the surface of the water to heights of 2½ or 3 feet. They spouted black, muddy water, containing lumps of black clay. Numerous cracks were also formed in the sand on the banks, some of them a foot wide. As this area is very sparsely inhabited, it seems probable that similar phenomena occurred, without being observed or reported, along the banks of the Umfolosi River as far up as Mr. Shire's sugar mill, mentioned above.

The effects of the earthquake were conspicuously displayed on the sea-shore below the St. Lucia Lighthouse, where numerous cracks had formed in the calcareous sandstone. These were generally a quarter to half an inch wide, but occasionally an inch or more. They ran in different directions, being for the most part approximately vertical, although some followed the bedding which is nearly horizontal. The cracks were seen over a distance of about a mile. It is possible that they extend somewhat further, as the rocks were not well exposed at the time of our visit, which coincided with neap tide and a strong sea breeze. The rock sometimes contains a few pebbles, and where these were in the way of a crack they were occasionally shot out of their sockets. Two or three large loose fragments were seen that had been broken off from the fixed rock along perfectly fresh fractures. The intensity of the shocks here must have reached the 9th degree.

The interpreted link between geology and the intensity of shaking is also repeated verbatim.

The isoseismal of the 8th degree runs close to the shore from Cape St. Lucia northwards, and then projects inland along the Umfolosi River. The reason for its nearness to the shore is the great thickness of *sand in the costal dunes, which acted as a protective cover and reduced the intensity of the shocks. In this region, near the epicentre, the severity of the earthquake effects was seen to depend to a large extent upon the nature of the surface materials. The calcareous sandstone on the beach was cracked to a considerable extent, and it seems likely that any ordinary house built upon this rock would have collapsed entirely. And yet the lighthouse-keeper's wooden-frame residence and its brick kitchen-chimney, situated less than half a mile from the shore, suffered hardly any damage. This building stands on the sand hills at an altitude of over 350 feet. The thick cover of sand acted as a buffer and protected the house from destruction. At the St. Lucia Lots the two hotels and the other houses are all built upon sand, which is about 100 feet or more thick. They did not suffer any more than the buildings at Mtubatuba, which is about 13 miles further from the epicentre, and they also were protected by the sand.*

In the moist alluvial soil along the banks of the Umfolosi River, on the other hand, the intensity of the earthquake shocks was greatly increased.

These effects are in agreement, with the common experience that a thin cover of unconsolidated material above bedrock, especially if it is wet alluvial soil, increases the destructive effects of earthquakes, while a thick cover of sand or other loose material greatly diminishes them.

M_L6.3 earthquake in the Ceres-Tulbagh region, 29 September 1969

The most destructive earthquake that has occurred in South African recorded history was a M_L6.3 event that occurred at 10:03 pm (local time) on 29 September 1969 in the Ceres-Tulbagh region of the Western Cape, killing nine people. Modern concrete-frame buildings sustained relatively minor damage, but some well-constructed brick houses were badly damaged, and many adobe-type buildings were completely destroyed. Many historical buildings, such as the Drostdy in Tulbagh, were severely damaged. Rockslides started a large number of fires on the surrounding mountains. The earthquake was felt as far as Durban, 1175 km away. No surface rupture was found. The maximum intensity was VIII on the MMI scale (Van Wyk & Kent 1974).

An array of seven continuous-recording seismographs was deployed to monitor the aftershocks (Green 1973). The first two stations (at Paarl and Tulbagh) were deployed within two days of the main shock, and the remaining five stations a week later (Green & Bloch 1971). Over 2000 events were recorded during the five weeks of operation. Aftershock activity had virtually ceased when an M_L5.7 event occurred on 14 April 1970, causing further damage in the towns of Ceres and Wolseley. A bulletin issued by the Geological Survey (Van Wyk & Kent 1974) covers many topics, including a record of disaster relief efforts; an assessment of the focal mechanisms determined by Fairhead & Girdler (1969), Green & Bloch (1971), and Green & McGarr (1972); an assessment of earthquake risk; and recommendations for the construction of earthquake-resistant buildings. A microseismic study of the area was conducted in 2012 (Smit et al 2015): 172 events with M_L<0.5 were recorded in a three month period, delineating a 5-km-wide and 15-km-deep sub-vertical zone subparallel to the 1969 aftershock zone.
The Ceres-Tulbagh earthquake had some positive results. It jolted South Africa out of complacency regarding the risks posed by earthquakes, and the National Seismograph Network was established shortly thereafter. Strong shaking was felt in Cape Town, and earthquake-resistant measures adopted in the construction of the Koeberg nuclear power plant. The buildings lining historic Church Street in Tulbagh were restored to their original splendour and a small Earthquake Museum was established.

M_L5.2 earthquake near Welkom, 8 December 1976

The M_L5.2 Welkom earthquake was the first seismic event in a mining district to cause serious damage to buildings on the surface, most dramatically the collapse of Tempest Hof, a six-storey apartment block (Fernández & Labuschagne 1979). Fortunately, it was possible to evacuate the building before it collapsed. An array of seismographs was deployed to monitor the aftershocks and investigate the origin of the event (Arnott 1981).

M_L5.3 earthquake near Stilfontein, 9 March 2005

An M_L5.3 earthquake occurred at 12:15 pm on 9 March 2005 at Durban Roodepoort Deep’s (DRD) Northwest operations (Durrheim et al 2006). The event and its aftershocks shook the nearby town of Stilfontein, causing serious damage to some buildings. Shattered glass and falling masonry caused minor injuries to fifty-eight people. The underground workings were severely damaged: two mine workers died and 3,200 were evacuated under difficult circumstances. The mine went into liquidation soon afterwards and some 6 500 mine workers lost their jobs. Some R500 million was claimed from insurers for damage to mine infrastructure and loss of production.

Shortly thereafter, the Chief Inspector of Mines initiated an 'Investigation into the risks to miners, mines and the public associated with large seismic events in gold mining districts' (Durrheim et al 2006). The terms of reference listed nine specific issues that were to be addressed, top of the list being whether the events of 9 March 2005 could be attributed to mining activity. The team considered both statistical and mechanistic evidence. Andrzej Kijko (Council for Geoscience) presented evidence that the number of events with M>3 in the Klerksdorp mining district exceeded the average for the rest of South Africa by a factor of 700. Analysis of seismic records for the main event and its aftershocks showed that the source was close to the Number 5 Shaft fault and the reef horizon. Art McGarr (United States Geological Survey) showed that the dewatering of the rock mass during mining operations will tend to stabilize natural faults that might be close to failure. The team found that: *The magnitude 5.3 event and its aftershocks can be ascribed to past mining. The event was caused by rejuvenated slippage on an existing major fault, with extensive mining activities in the region contributing most of the strain energy. The chance of the events being solely due to natural forces is considered to be extremely small.*

M_w7.0 earthquake, Machaze district, Mozambique, 23 February 2006

The M_w7.0 earthquake struck Mozambique just after midnight, local time (Saunders et al., 2010). The shaking was sufficiently strong to cause many residents of Maputo and Beira to flee into the streets, and was felt in South Africa (Durban, Johannesburg and Pretoria), Zambia and Zimbabwe. The epicentral region is sparsely populated, but four people were killed and thirty-six injured, and at least 288 houses, six schools and two small bridges were destroyed (UNOCHA 2006). Fenton & Bommer (2006) surveyed three segments of the fault rupture with a combined length of some 15 km (the total rupture length is expected to be in the order of 30-40 km). The surface rupture, although visible in the field, could not be followed along its entire length due to the danger posed by buried land mines. They observed average vertical displacements of 1.0-1.5 m, and in one segment left-lateral offsets of 0.7 m. They also observed spectacular liquefaction features, such as sand blows with diameters of 5-8 m, and a 318-m-long liquefaction fissure. Fenton & Bommer (2006) were unable to decide if the earthquake was on an 'old, slow fault', similar to those found in intraplate regions, or a new structure related to the southward propagation of the East African Rift (NEIC 2006). Satellite radar interferometry allowed both the co-seismic and post-seismic displacement along the entire surface rupture to be measured (Raucoules et al., 2010).

M_L5.5 earthquake near Orkney, 5 August 2014

The M_L5.5 earthquake, with its epicentre near Orkney in the North West Province, occurred at 12:22 local time (Midzi et al 2015b). The earthquake shaking was felt as far away as Cape Town. More than 600 houses were damaged and one person was killed. Many people completed an online questionnaire administered by the Council for Geoscience (CGS), whilst others reported the event and its effects on social networks and in newspapers (Midzi et al 2015b). The CGS also sent out a team of scientists to further assess the effects of the event by interviewing members of the public and completing additional questionnaires. A total of 866 observations were collected. Analysis of the macroseismic data produced 170 intensity data points which showed a maximum MMI of VII in the epicentral area (Midzi et al 2015b).
This earthquake, being the largest recorded to date around the mining regions of South Africa, is mysterious for several reasons (Ogasawara 2015; Moyer et al., 2017). The mechanism was a left-lateral strike-slip on a NNW-SSE striking and nearly vertically dipping plane. This differs significantly from typical mining-induced earthquakes in the region, which usually exhibit dip-slip on NE-SW striking normal faults close to the mining horizon. The geological structures mapped on the mining horizon in the Orkney district are characterized by a horst and graben structure trending NE-SW, intruded by multiple dykes trending NNW-SSE. So, the strike-slip might be on a dyke. However, the hypocenter was significantly deeper than the mining horizon (at least 1-2 km deeper), and no dyke or seismic fault rupture was reported on the mining horizon. The maximum principal stress measured in situ at 3.0 km depth and several km from the hypocenter was almost vertical, while the intermediate principal stress was horizontal, trending NNW-SSE almost parallel to the M5.5 fault plane.

In order to assess the seismic hazard posed by such earthquakes as this, it is very important to understand stress field and loading mechanism (or tectonics) to address the above mysteries, because such dykes may prevail elsewhere. A proposal was submitted to the International Continental scientific Drilling Programme (ICDP) by a South African – Japanese team to investigate the source zone directly by drilling (Ogaswara et al. 2015). The ICDP granted funds to hold a workshop to form an international consortium and prepare a full proposal. The proposal was approved, and drilling commenced in 2017.

M_w6.5 earthquake in Botswana, 3 April 2017

The M_w6.5 earthquake occurred on the evening of 3 April 2017 in Central Botswana, southern Africa (Midzi et al 2018a). Its effects were felt widely in southern Africa and were especially pronounced for residents of Gauteng and the North West Province in South Africa. In total 181 questionnaires were obtained by the

Council for Geoscience through interviews and 151 online from South Africa, Zimbabwe and Namibia in collaboration with the Meteorological Services Department, Zimbabwe and the Geological Survey of Namibia. All data were analysed to produce 79 intensity data points located all over the region, with maximum MMI values of VI observed near the epicentre. These are quite low values of intensity for such a large event, but are to be expected given that the epicentral region is in a national park which is sparsely populated. The CGS and Botswana Geoscience Institute deployed a network of aftershock recorders. More than 450 aftershock events of magnitude M_L> 0.5 were recorded and analysed for this period. All the events are located at the eastern edge of the Central Kgalagadi Park near the location of the main event in two clear clusters. The observed clusters imply that a segmented fault is the source of these earthquakes and is oriented in a NW-SE direction, similar to the direction inferred from the fault plane solution of the main event.

Reservoir-induced earthquakes

The impoundment of large reservoirs may trigger local earthquakes as a result of increases in the surface load and the pore fluid pressure, and seismic hazard should be taken into account when designing any large dam, regardless of whether the seismic loading is due to natural tectonic earthquakes or reservoir-induced seismicity (World Commission on Dams 2000).

Kariba Dam, Zimbabwe: The filling of Lake Kariba on the Zambezi River and subsequent fluctuations in water level has been accompanied by seismicity. The Kariba Dam was built from 1955 to 1959, and is one of the world's largest dams. The wall of the Kariba Dam is 128 m high, and the reservoir is 280 km long and has a storage capacity of 180 km^3. Seismic loading was not taken into account during the design of the dam, even though the reservoir is located in a tectonically active branch of the East African Rift system and an M_s6.0 earthquake had occurred in the region in 1910. (M_s denotes the surface wave magnitude, which is similar to other magnitudes.) No local measurements of seismicity were carried out prior to the impoundment, but many studies were carried out after 1959 (World Commission on Dams 2000). Geophysical work in Rhodesia (now Zimbabwe) did not begin in earnest until 1958 when seismograph stations were deployed around the Zambezi Valley to monitor seismic activity as Lake Kariba filled behind the Kariba Dam. Substantial seismic activity was recorded, increasing as the dam filled and peaking in 1963 (Gough & Gough 1970a; 1970b). The larger earthquakes (M>5) occurred in the vicinity of the dam wall. The largest event (M_L6.1, which occurred in 1963) caused damage to the dam structure and some property in nearby settlements, but no casualties were reported. Since 1963 there has been a general decline in seismic activity. It was initially thought that the loading of the water filling the dam on the crust was the cause of the seismic events. Consensus later swung towards the increase in hydrostatic pressure in faults as the likely cause of the seismicity.

Gariep Dam, South Africa: The 61-m-high and 600-m-long Gariep Dam (previously known as the HF Verwoerd Dam) on the Orange River was impounded in 1970. Seismicity was monitored by Milner (1973). A seismometer array comprising one three-component and six vertical component stations was deployed prior to impoundment. Seismicity was first recorded in February 1971, six months after impoundment, when the water level reached 40 m. During the next ten months 93 events were recorded, the largest of which being an M2.1 event. Seismicity declined after December 1971.

Katse Dam, Lesotho: Seismicity was also associated with the filling of the 185-m-high Katse Dam on the Malibamat'so River in Lesotho, which was completed in 1996 (Brandt 2000, 2001). Seismicity was monitored from 1995 to 1999. The first recorded event occurred when the water level in the reservoir had risen by 45 m. The largest event had a magnitude of M_L3.0, when fresh fissures opened along a shear zone adjacent to the dam; dwellings in the village of Mapeleng suffered minor damage. The ground motion expected by a hypothetical M5 reservoir-induced seismic event was modelled by Brandt (2004). It was concluded that such an event does not pose any risk to the dam wall. Although it may pose a risk to the villages built on the steep slopes surrounding the dam.

SEISMIC HAZARD ASSESSMENT

The African continent is largely a tectonically stable intraplate region and has been surrounded by spreading ridges since the break-up of Gondwana, about 120 million years ago. The only parts of Africa that do not display the characteristics of an intra-plate region are the Africa-Eurasia collision zone, the Cameroon Volcanic Line, and the East African Rift System and its continuations into Botswana and Mozambique. The rest of Africa and South Africa (apart from the mining regions) is characterised by a relatively low level of seismic activity, with earthquakes randomly distributed in space and time. However, it is important to note that global observations have shown that intraplate earthquakes, while rare, can occur even without significant precursory seismic activity; moreover, they may have large magnitudes and cause considerable damage.

Hazard assessment is the process of determining the likelihood that a given event will take place. Probabilistic seismic hazard assessment (PSHA) is generally expressed in terms of the ground motion (for example, peak ground acceleration (PGA)) that has a certain likelihood of exceedance (say 10%) in a given period (say fifty years). There are many PSHA schemes, but all require a catalogue of earthquakes (size, time, location); the characterisation of seismically active faults and areas (usually in terms of the maximum credible magnitude and recurrence periods); and a prediction of variation in ground motion with distance from the epicentre. The longer the duration of the catalogue, the smaller the magnitude of completeness, and the better the zonation, the more reliable is the PSHA.

Palaeoseismology

In order to assess the risk posed by earthquakes, it is important to have a record of past earthquake activity. These parameters are best known if earthquakes are recorded by seismographs. However, the global instrumental catalogue does not go back much further than a century, and, in many parts of the world, the recurrence times of the largest plausible earthquake is much longer than this. Thus historical records of earthquakes, while less accurate and complete, are a vital supplement to instrumental catalogues. However, the historical record often only covers a few centuries and is inevitably incomplete. Thus palaeoseismologists seek to extend the catalogue back in time by discovering and deciphering clues left by prehistoric earthquakes (say events occurring during the last 100 000 years). For example, geomorphological features such as fault scarps and knick points in rivers can be used to deduce the length and displacement of the rupture caused by a particular earthquake, while geochronological techniques can be used to determine the age of sediments deposited along fault scarps, and hence the minimum age of the earthquake.

Soutpansberg M8.0 event: A project was commissioned by Eskom (1998) to investigate palaeo-seismic movement of Tshipise and Bosbokpoort faults, this was then used to investigate as part of a study of the slope stability within Mutale upper dam basin. Evidence for the recent reactivation of the faults was first reported in 1977 by Tim Partridge (Eskom 1998). Different fault zones were mapped, and the length, throw and age of the palaeoseismic fault ruptures estimated. The biggest event, based on rupture length and throw, was estimated to have been an M8.0 earthquake that occurred about 100 000 years ago.

Kango fault M7.4 event: Palaeoseismic studies have been carried out as part of an investigation into the Quaternary tectonic history of the south-eastern continental margin, in support of the assessment of seismic hazard at proposed sites for nuclear power stations (Engelbrecht & Goedhart 2009; Goedhart & Booth 2009; Midzi & Goedhart 2009; Goedhart & Booth 2016a, 2016b). There is little seismic information for this region, and the record is too short to include the long recurrence intervals typical of large, surface-rupturing earthquakes in intraplate regions. Goedhart & Booth (2016a) interpreted a scarp running parallel to the Kango fault in the Cape Fold Belt to be the surface expression of an 84-km-long extensional surface rupture (Figure 1). An 80-m-long, 6-m-deep and 2.5-m-wide trench was dug across the fault, exposing twenty-one lithological units, six soil horizons, and nineteen faults strands. Vertical displacement indicated a fault throw of about 2 m. Optically stimulated luminescence dating indicated that the fault was active between 12 200 and 8 800 years ago, and most probably around 10 600 years ago. Goedhart and Booth (2016b) used published relations between surface rupture length, displacement and magnitude to estimate the magnitude of the event at M_w7.4.

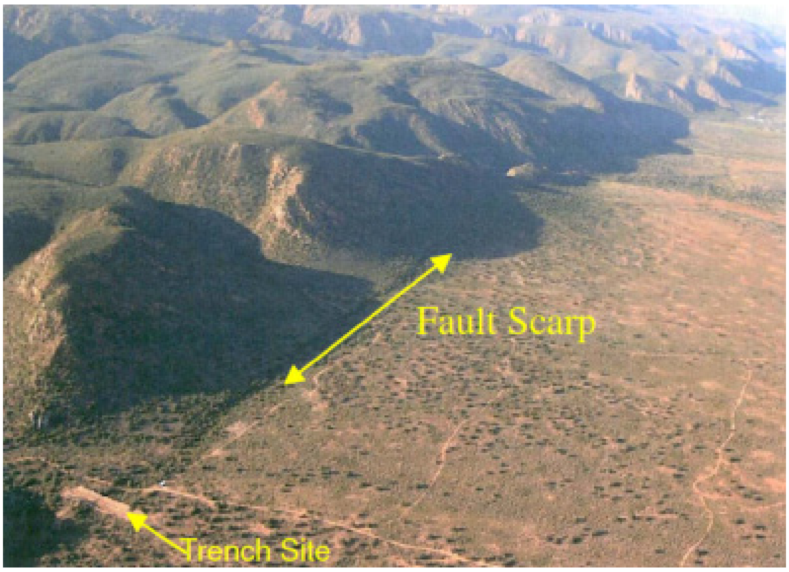

Figure 1: The Kango fault, showing part of a 84-km-long and 2-m-high fault scarp produced by an M_w7.4 event about 10 600 years ago (Source: Midzi & Goedhart 2009)

Early efforts to quantify seismic hazard

The 1969 M_L6.3 Ceres-Tulbagh earthquake gave impetus to the establishment of the Southern African Seismograph Network. The number of stations increased from five in 1969 to 11 in 1973, and in 1992 consisted of 25 stations in South Africa and five in neighbouring countries (Fernández & Du Plessis 1992). Monthly bulletins and annual catalogues were published from 1971 onwards, and in 1979 a bulletin was published containing several maps depicting earthquake hazard levels in South Africa based on the distribution of annual extreme values (Fernández & Guzmán 1979b).

The *Seismic Hazard Maps for Southern Africa* poster was published in 1992 (Fernández & Du Plessis 1992). The poster features explanatory notes and three maps: a plot of the maximum reported Modified Mercalli scale intensities from 1620-1988; a contour plot of the Modified Mercalli scale intensity with a 10% probability of being exceeded at least once in fifty years; and a contour plot of the PGA with a 10% probability of being exceeded at least once in 50 years. The areas exposed to the greatest natural hazard (where PGAs were considered to have a 10% probability of exceeding 100 cm/sec^2 (0.1 g) at least once in fifty years) are the south-western Cape, the southern Free State and Lesotho, and Swaziland. In 1990 the South African Bureau of Standards (SABS) issued the *Code of practice for the general procedures and loadings to be adopted for the design of buildings* (SABS 1990). The Code designated two zones: Zone 1, corresponding to the three areas noted above; and Zone 2, regions exposed to mining-related seismicity.

In 1996, Luiz Fernández, head of the Seismology Unit at the Geological Survey, summarized the state of the art with regard to seismic hazard evaluation in a report entitled *The seismic climate of Southern Africa: Peak ground accelerations to be expected from tectonic and mining seismicity* (Fernández 1996). Standard methods (for example, McGuire 1993; Cornell 1968; Kijko 2011) of assessing seismic hazard required a priori knowledge of the seismogenic regions, including a clear demarcation of their borders and their activity rates. In regions that have low seismic activity rates, such as the interior of the global plates, this knowledge is rudimentary, especially when the time window of data is very short. This is the case for South Africa.

One of the first attempts to estimate the maximum credible magnitudes of earthquakes in South Africa was made by Shapira et al. (1989). It was concluded that the catalogue of earthquakes was complete for $M_L \geq 4.6$ events since 1950; for $M_L \geq 4.9$ events since 1910; and for $M_L \geq 5.3$ events since 1906, and that the maximum credible magnitudes of tectonic and mining-related earthquakes were M7.5 and M5.5, respectively. Shapira and Fernández (1989) also estimated the probability that a defined horizontal PGA will be exceeded at fourteen cities in southern Africa.

Ideally, the historical and instrumental catalogue used to assess seismic hazard should be complete; that is, there should be no data gaps or changes in the threshold of completeness. However, this ideal is often not met, particularly in the developing world. A 'parametric-historic method' that compensates for these difficulties was developed by Professor Kijko, previously at the Council for Geoscience and now at the University of Pretoria (Kijko & Graham 1998; 1999; Kijko & Sellevol 1989; 1992; Kijko et al 2016) and is used in many countries. Kijko also applied his formidable statistical skills to the related important problem of estimating the maximum credible earthquake magnitude m_{max} (Kijko 2004, 2012; Kijko & Singh 2011; Kijko & Smit 2012). In 2003 the Council for Geoscience published seismic hazard maps showing the 10% probability of exceeding the calculated PGA at least once in fifty years at 1, 3, 5 and 10 Hz, frequencies that are important for the fragility of buildings (Kijko et al 2003; Kijko 2008). The parametric-historic procedure of Kijko and Graham (1998; 1999) was used.

Recent efforts to quantify seismic hazard

During the 1990s the Global Seismic Hazard Assessment Programme (GSHAP 2013) compiled and published a seismic hazard map of the world (Giardini et al 1999). The GSHAP map for Africa (Grünthal et al 1999; Midzi et al 1999) is currently being updated under the auspices of the Global Earthquake Model initiative (GEM-SSA 2013; Pagani et al 2018).

The first step in assessing the seismic hazard and risk for any site is to develop a seismotectonic model. The area under investigation is divided into smaller zones or regions that have a similar tectonic setting and similar seismic potential. These zones are then used in a seismic hazard assessment model to determine the return periods of certain levels of ground motion at a given site in the area in question. Mayshree Singh (née Bejaichund) of the Seismology Unit of the Council for Geoscience developed a first-order seismotectonic model for South Africa. The outputs of the project were first reported in an unpublished MSc dissertation (Bejaichund 2010) and published in a series of three papers (Singh et al 2009; Singh & Hattingh 2009; Singh et al 2011). The inputs to the seismotectonic model include the historical and instrumental earthquake catalogue for South Africa, maps of geological and geophysical terrains, evidence of Quaternary fault activity, thermal springs, and so forth (Singh et al 2009). Isoseismal maps are extremely useful for assessing seismic hazard, in particular for determining parameters such as crustal attenuation and identifying local site effects. If possible, surveys of macroseismic effects (damage to buildings, surface ruptures, liquefaction, and so forth) are conducted immediately after an earthquake, but historical documents can also be used. Singh and Hattingh (2009) compiled thirty-two isoseismal maps for South Africa, the earliest being for the 1932 earthquake with its epicentre offshore from St Lucia (M_L6.3, intensity VIII). Eighteen seismotectonic zones were defined. Finally, the frequency-magnitude relations were analysed using ten different procedures. Estimates of the earthquake recurrence parameters and maximum possible earthquake magnitudes m_{max} were obtained for each seismotectonic zone (Singh et al 2011). This work has been extended with a more detailed study of KwaZulu-Natal (Singh et al., 2015; Singh 2016).

As part of CGS's effort to improve hazard assessment in South Africa, a database of the intensity of earthquakes occurring between 1912 and 2011 was compiled (Midzi et al., 2013), as well as intensity surveys of two moderate-sized earthquakes that occurred in 2013 (Midzi et al 2015a). The CGS made use of GEM products and tools (notably the OpenQuake software package), coupled with a new zonation model for South Africa, to compute the seismic hazard (Midzi et al 2018b). Seismotectonic data was compiled and interpreted by Manzunzu et al (2019). The outputs of these studies are used for this assessment (see Appendix B of this report).

SEISMIC RISK ASSESSMENT

A risk assessment is an attempt to quantify the losses that could be caused by a particular hazard. It is calculated as follows:

Risk = likelihood of the hazard occurring X seriousness of consequences

The consequences of an earthquake depend on four main factors: the vulnerability of structures (e.g. EGI infrastructure or gas pipelines) to damage, the exposure of persons and other assets to harm, the cost of reconstruction, and the cost of lost economic production. Risk assessments are useful for raising awareness of possible disasters and motivating policies and actions to mitigate losses and avoid disasters. For example, vulnerable structures may be reinforced, building codes enforced and insurance taken out to cover possible losses. An important input into the assessment of consequences is the vulnerability of structures subjected to shaking. The vulnerability curves for typical South African buildings have been published by Pule et al (2015).

Insuring against earthquake risk: In 2001 a global reinsurance company, Hannover Re, published a report assessing the risk posed by seismicity to the South African insurance industry (Hannover Re 2001). The seismic research was performed by Andrzej Kijko and Paul Retief of the CGS, while the application to the insurance industry was carried out by Nicholas Davies of Hannover Re. The main findings of these studies were translated into the language of the insurance industry and published in the *South African Actuarial Journal* (Davies & Kijko 2003).

Quantifying earthquake risk in the Tulbagh region: A comprehensive study of seismic hazard and risk in the Tulbagh area was conducted by Kijko et al 2002, 2003). The worst case scenario is an event that produces shaking with a PGA of 0.3 g.

FIFA 2010 Soccer World Cup stadia: In 2010 South Africa hosted the FIFA Soccer World Cup. To coincide with this event, the global reinsurance company, Aon Benfield, issued its report *South Africa Spotlight on Earthquake* in conjunction with the Aon Benfield Natural Hazard Centre Africa (Aon Benfield 2010). According to the report, earthquake is "regarded as the natural hazard most likely to trigger the country's largest financial loss" (Aon Benfield 2010). The objective of the report was to enable insurers to obtain a more accurate estimate of their exposure and in turn purchase appropriate reinsurance cover. Earthquake risk was assessed in Cape Town and Durban, two cities where major new stadia had been built and which had experienced the largest seismic events recorded in South African history, and hence where risk would most likely be greatest. The losses associated with a scenario earthquake similar to the M_L6.1 1809 Cape Town earthquake were considered. The worst case scenario, a M6.9 earthquake on the Milnerton Fault, would produce a MMI of about IX, which would be "ruinous" (Aon Benfield 2010) to the Cape Town CBD and Cape Town Stadium, only 10 km away. Fortunately, the probability of such an event is low, in the order of one in 1000 years. While a M6.3 earthquake occurred near St Lucia, 220 km north of Durban, on New Year's Eve 1932, Durban is not regarded as being exposed to high seismic risk as no active faults are known to exist close to the city. The report concluded that M5.0 and M6.0 events would only cause structural damage if their epicentres were closer than 45 and 90 km, respectively. The return periods of such events was estimated to be 735 and 5000 years, respectively.

Risk posed by tsunamis: Numerical tsunami simulations have been conducted to investigate the realistic and worst-case scenarios that could be generated by the nearest (but distant) subduction zones, *viz.* Makran, South Sandwich Islands, Sumatra and Andaman (Okal & Hartnady, 2009; Okal et al., 2009; Kijko et al. 2018). The simulated tsunami amplitudes and run-up heights calculated for the coastal cities of Cape Town, Durban, and Port Elizabeth are relatively small and therefore pose no real risk to the South African coast.

Nuclear power stations: The damage to the Fukushima nuclear power station caused by the M_w9.0 Great Eastern Japanese earthquake and tsunami of 11 March 2011 naturally raised concerns about the safety of the Koeberg nuclear power station, situated on the Atlantic seaboard 30 km north-west of Cape Town. The managing director of Eskom's operations and planning division, Kannan Lakmeeharam, promptly assured parliament and the public that Koeberg was designed to withstand both earthquakes and tsunamis (News24, 2011). The construction of the 1800-megawatt power station began in 1976. The pressurized water reactors are housed within a containment building mounted on a base-isolated raft. It is designed to withstand an M_L7 earthquake without any risk of rupture.

In 2006 the South African government announced plans to build several more nuclear power stations, and a programme to identify suitable sites was launched. Five potential sites were identified, two on the Indian Ocean coastline (Thyspunt near Jeffrey's Bay, and Bantamsklip near Gansbaai) and three on the Atlantic coastline (Duynefontein (Koeberg), and two sites in Namaqualand). Environmental Impact Assessments (EIAs) were commissioned and published on the internet (http://www.eskom.co.za/c/article/1719/nuclear-1-eia-documentation/). The EIAs addressed a wide range of issues, including geology, seismology, hydrology and geotechnics (addressing issues such as liquefaction potential). Neotectonic and palaeoseismic investigations were undertaken and field measurements of Vs30 were made (Park 2013). The earthquake catalogue for each site was updated, the maximum ground velocity determined deterministically for each site, and the expected PGA determined probabilistically for each site. Site-specific SHAs were previously undertaken for the three sites by the Council for Geoscience (CGS), employing a methodology called the Parametric-Historic SHA. Using this methodology, median PGA values of 0.16 g, 0.23 g and 0.30 g were calculated for the Thyspunt, Bantamsklip and Duynefontein sites, respectively (CGS 2011). In order to enhance the probability that the assessment of the hazard associated with vibratory ground motion (due to natural earthquakes) will be accepted by the National Nuclear Regulator, methodologies with considerable precedence and recognition by the US Nuclear Regulatory Commission (USNRC) and regulators from other countries were used, in particular a process that was drafted by the USNRC Senior Seismic Hazard Committee (SSHAC). The SSHAC process is documented by Budnitz et al (1997) and Hanks et al (2009), and the application to Thyspunt by Strasser & Mangongolo (2012), Bommer et al (2013) and Bommer et al (2015).

Nuclear waste disposal facilities: The Namaqualand-Bushmanland region has numerous features that make it attractive for the storage of radioactive waste. In the late 1970s a programme was launched to find a suitable site for low- and intermediate-level waste. The Vaalputs facility, approximately 100 km south of Springbok, was opened in 1986. Seismicity is one of several key factors that are monitored as part of the ongoing operations. A two-station network of short-period seismometers was installed in 1989 and replaced in 2012 with a three-station network comprising one broadband and two short-period seismometers (Malephane, Durrheim & Andreoli 2013). Data from these networks, the South African National Seismological Network, and the International Seismological Centre has been used to compile a catalogue of the general seismicity of the region.

Large dams: A seismic risk classification was performed for 101 large (wall height >30 m) state-owned dams (Singh et al 2011). The risk is strongly dependent on the method used to construct the dam wall, with gravity and earth-fill dams being the most vulnerable to ground shaking.

Fracking: The risk posed by fracking-induced earthquakes in the Karoo basin was assessed as part of a Strategic Environmental Assessment commissioned by the Department of Environmental Affairs (Durrheim et al 2016).

Open-pit mine blasting: The risk posed by open pit blasting was assessed in a study commissioned by the Mine Health and Safety Council (Milev et al 2016).

CONCLUSIONS

South Africa is fortunate to be situated far from a plate boundary. Large, damaging tectonic earthquakes (6.5<M<7.5) are rare and losses due to earthquakes have been small. However, it should be noted that a damaging earthquake (5.0<M<6.5) could occur anywhere in South Africa. Mining-related earthquakes are restricted to the regions where deep and extensive gold mining has taken place, notably the Welkom and Klerksdorp districts. Earthquakes have been identified as the (natural) hazard with the potential to cause the greatest financial losses. A low rate of seismicity does not mean that the maximum size of an earthquake will be small, just that earthquakes are less frequent. A moderate-sized earthquake (such as those that occurred near Cape Town in 1809 and Ceres in 1969) can prove disastrous if it occurs beneath a town with many vulnerable buildings. .

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Appendix B: OpenQuake PSHA computation for South Africa and the energy corridors

Primary references:

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Summary:

More than 20 years has passed since previous national seismic hazard maps were prepared for South Africa. In those maps, zone-less techniques were applied. The availability of more reliable seismicity and geological data has made it possible to update those maps using state of the art probabilistic seismic hazard assessment methodologies that take into consideration all available data. The papers by Manzunzu et al (2019) and Midzi et al (in press) present a summary of the work conducted to produce the latest seismic hazard maps for South Africa. This involved the systematic compilation and homogenisation of an earthquake catalogue, which comprised both historical and instrumental events. The catalogue played a prominent role in the preparation and characterisation of the seismic source model. Two ground motion prediction equations were identified from available international models for regions that are tectonically similar to South Africa. These two models were then implemented in the hazard calculations, which were done using the OPENQUAKE software. Uncertainties associated with input parameters in both the seismic source and ground motion models were taken into account and implemented using the logic tree technique. Maps showing the distribution of acceleration at three periods (0.0s, 0.15s and 2.0s) computed for 10% probability of exceedance in 50 years were produced. These maps constitute a valuable product of this study that can be useful in updating South African building codes.

The map of 'major' and 'active faults' produced by Manzunzu et al. (2019), shown in Figure 1, is an update of the faults identified as 'active (<150 ka)' by Meghraoui et al. (2016), shown in Figure 2.

Manzunzu et al's 'major' faults are identical to Meghraoui et al's 'active faults (<150 ka)'. Manzunzu et al's 'active faults' (coloured yellow in Figure 1) are segments of faults where additional evidence of seismic activity has been found, mainly published geological information (cited in Manzunzu et al., 2019), or through association with seismicity (Manzunzu, personal communication, 15 August 2019).

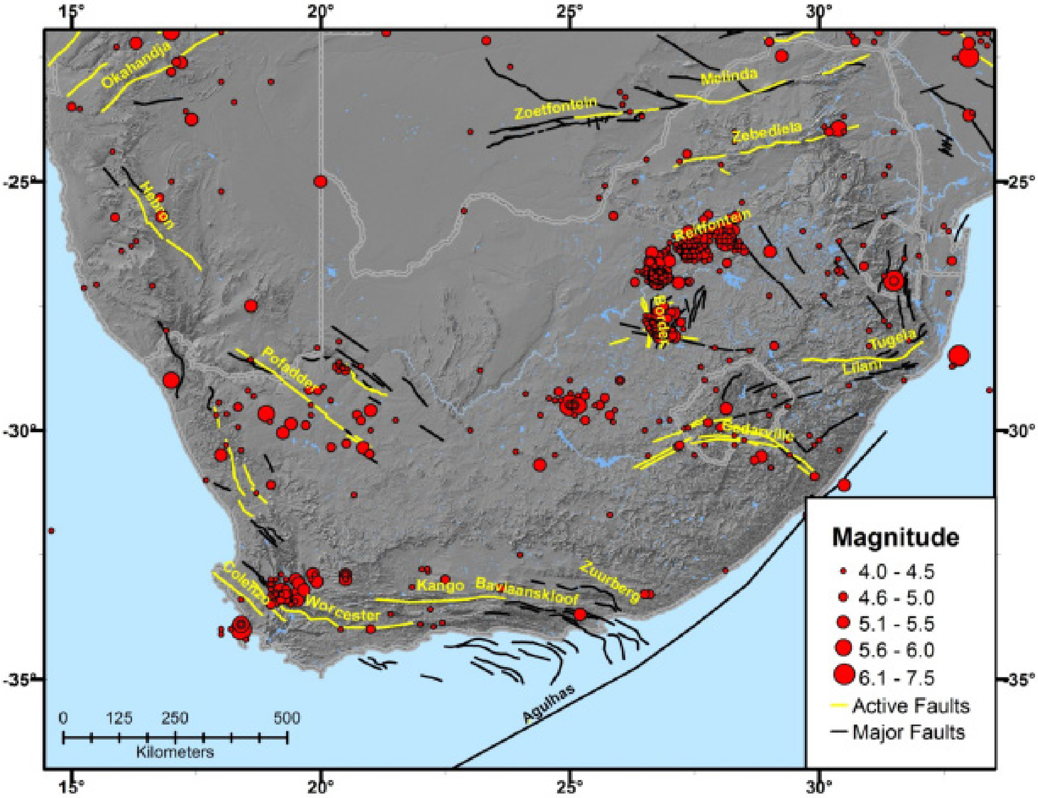

Figure 1: Neotectonic faults of southern Africa (from Manzunzu et al., 2019). Red circles are southern African earthquakes of magnitude greater than or equal to 4.0

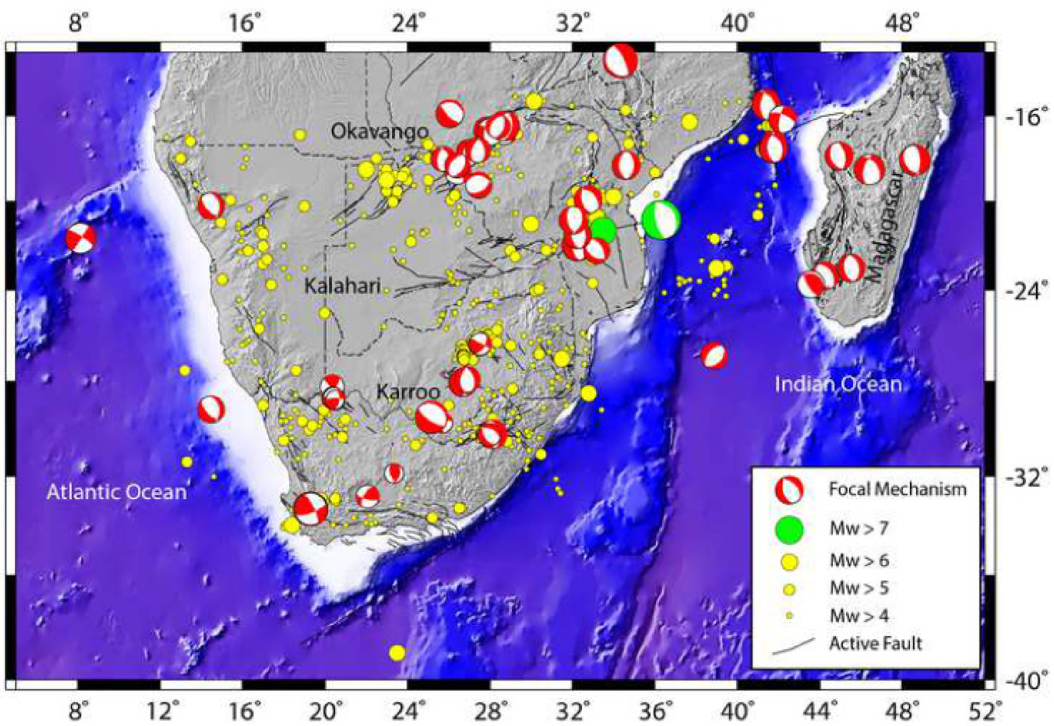

Figure 2: A seismotectonic map of southern Africa combining available information used in the identification of seismic sources (from Meghraoui et al., 2016)

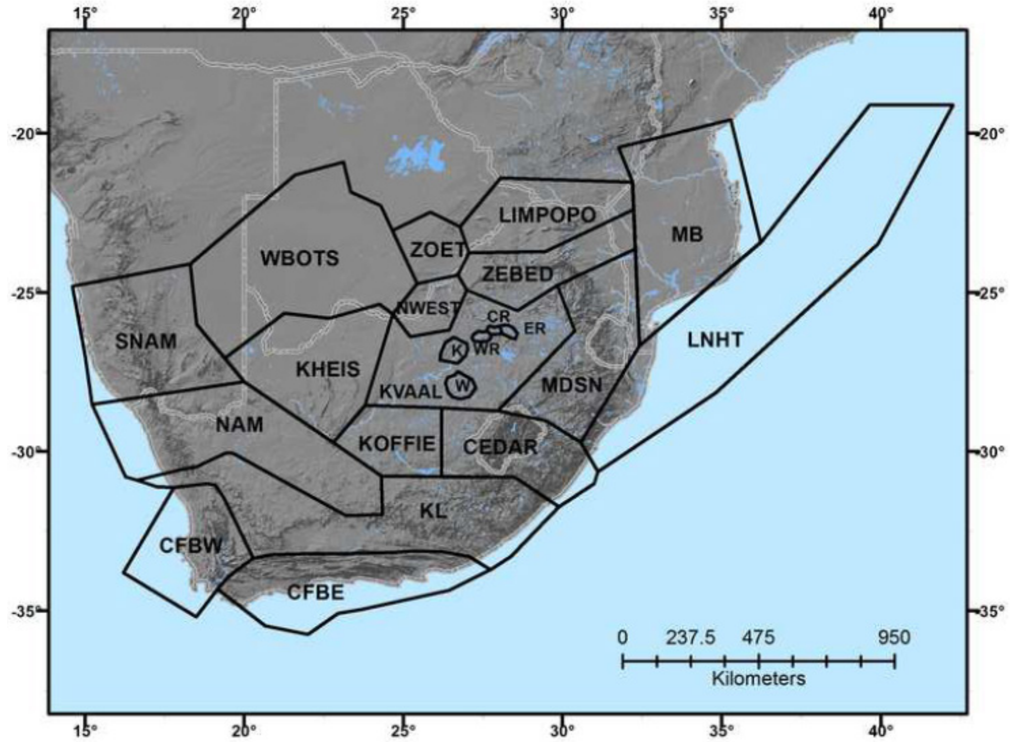

Figure 3: Illustration of the individual area source zones used in this study. ER- ERAND, WR – WRAND, CR – CRAND, K – KOSH and W – Welkom (from Midzi et al., in press)

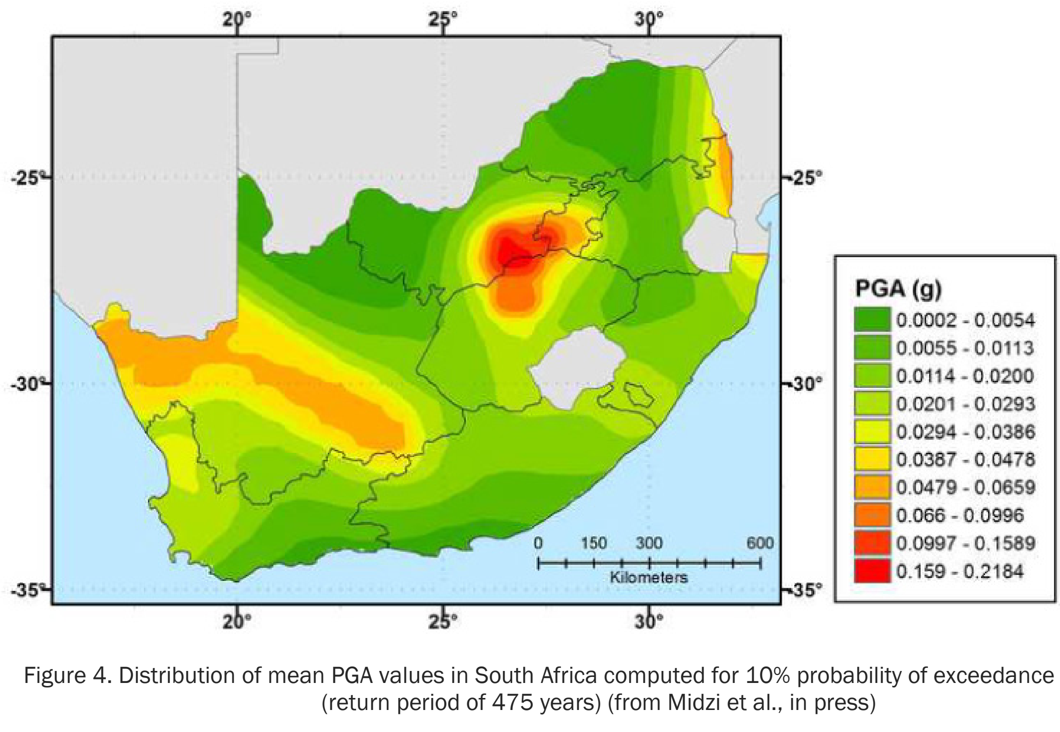

Figure 4. Distribution of mean PGA values in South Africa computed for 10% probability of exceedance in 50 years (return period of 475 years) (from Midzi et al., in press)

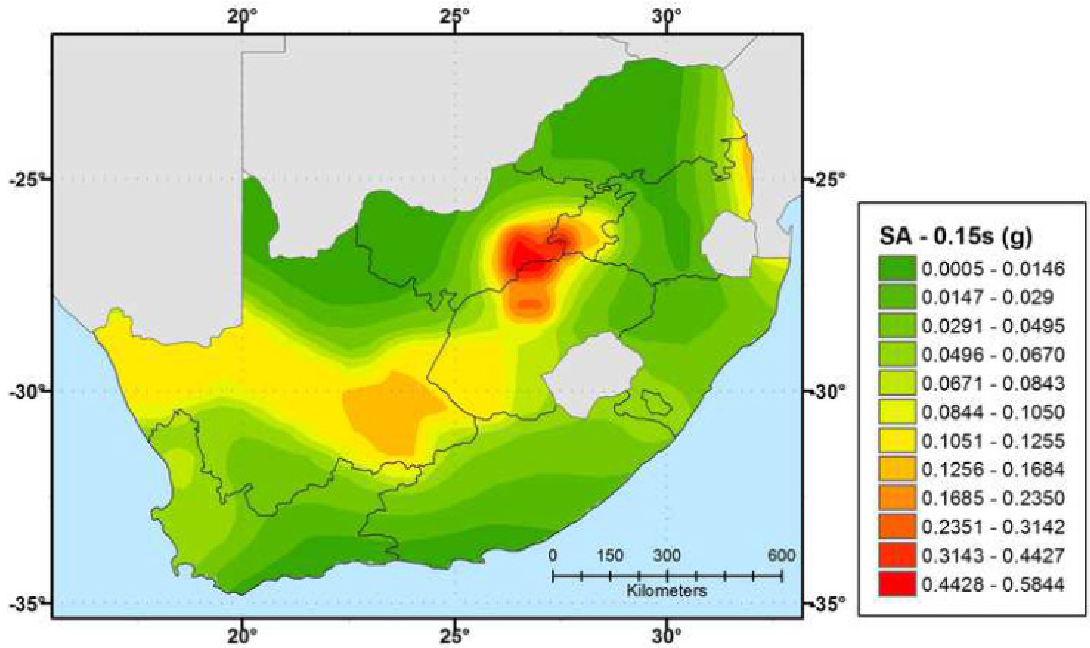

Figure 5. Distribution of spectral acceleration (period of 0.15s) values in South Africa computed for 10% probability of exceedance in 50 years (return period of 475 years) (from Midzi et al., in press)

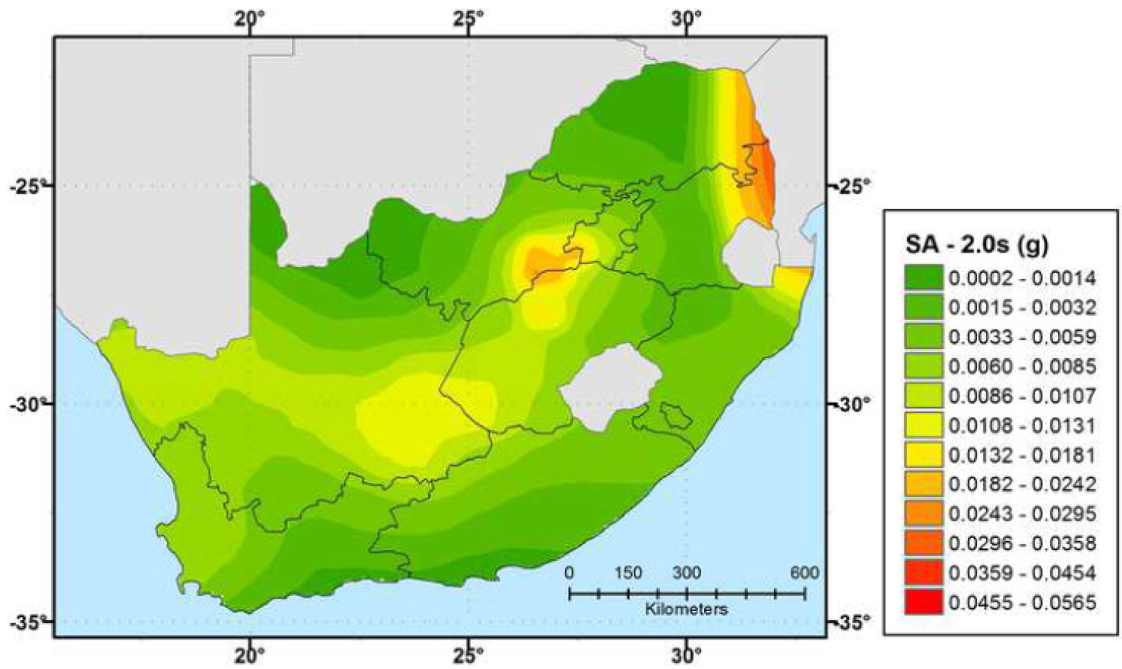

Figure 6. Distribution of spectral acceleration (period of 2.0s) values in South Africa computed for 10% probability of exceedance in 50 years (return period of 475 years) (from Midzi et al., in press)

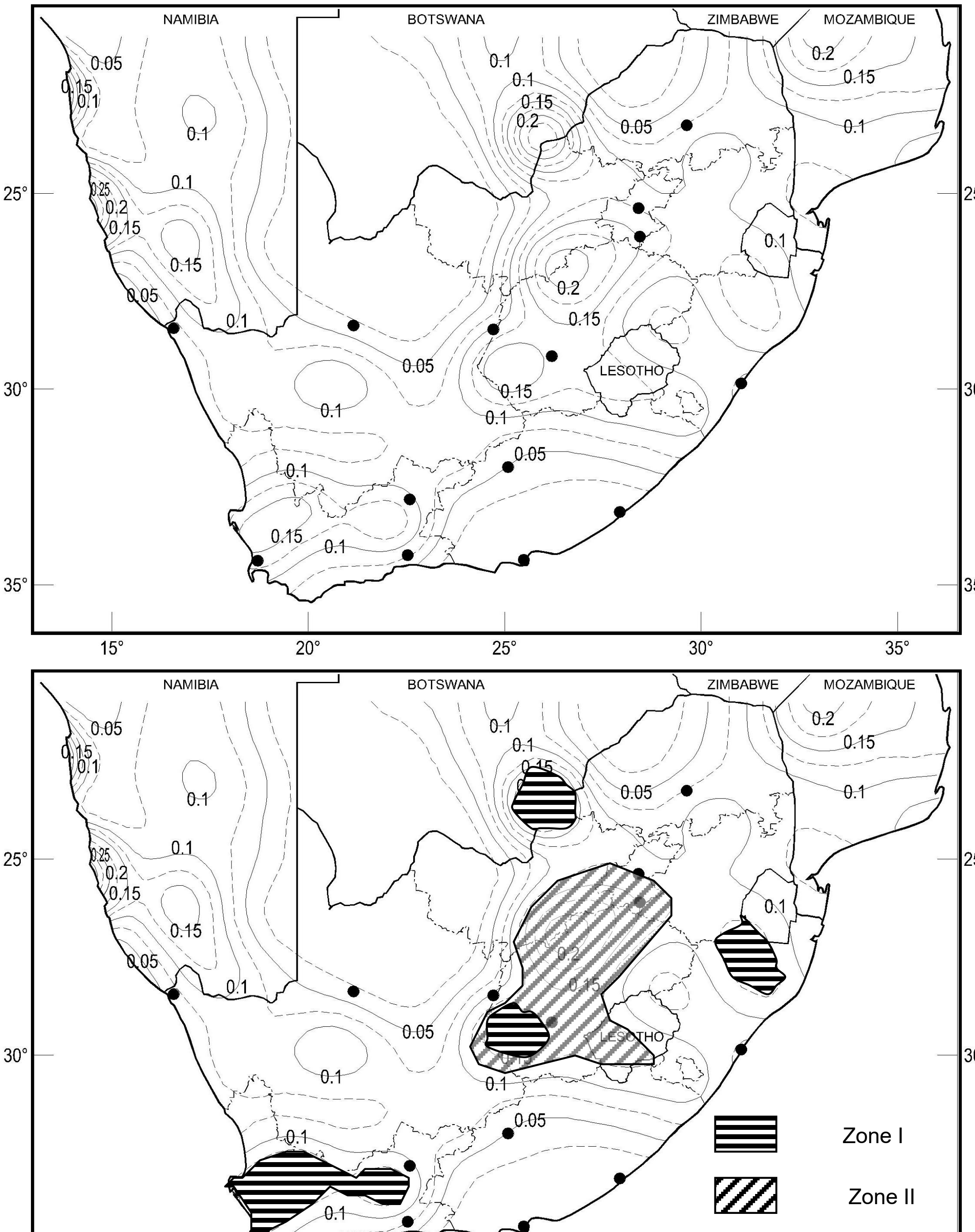

Figure 7. (above) Seismic hazard map of South Africa computed for 10% probability of exceedance in 50 years (return period of 475 years) nominal peak ground acceleration in g (9,98 m/s²); (below) Seismic hazard zones of South Africa. South African National Standard (2017). SANS 10160-4-2017. Basis of Structural Design and Actions for Buildings and Industrial Structures. Part 4: Seismic Actions and General Requirements for Buildings. Pretoria: South African Bureau of Standards. ISBN 978-0-626-30384-6.

Appendix C: Vulnerability of PGPN and Monitoring

Primary reference: Milev, A, Durrheim, R, Brovko, F, Kgarume, T, Singh, N, Lumbwe, T, Wekesa, B, Pandelany, T & Mwila, M, 2016. *Development of a South African Minimum Standard on Ground Vibration, Noise, Air-blast and Flyrock near Surface Structures to be Protected.* Final Report, Project SIM14-09-01, South African Mine Health and Safety Council Report.

GROUND SHAKING

Ground vibrations are the inevitable results of earthquakes. The rock close to the fault zone may be crushed or fractured, but a proportion of the energy is radiated as elastic energy in the form of compressional (P) and shear (S) waves. The class of seismic waves that distort the Earth's surface most severely are known as 'surface waves', and are formed by the 'trapping' of P- and S-wave energy in near-surface layers. Surface waves have both compressional (and dilatational) components and vertical and horizontal components of shear. Their effect on buildings and other structures depends on the wavelength of the waves and the footprint and height of the structures. The seismic wavelength, in turn, depends on:

i. the size of the earthquake, and
ii. the seismic velocity of the rock, weathered material, alluvium or soil that comprises the near-surface layer of the Earth (say the uppermost 10-30 m).

Surface wave velocities (c) for near surface materials typically range from 200 m/s (alluvium) to 2000 m/s (slightly weathered granite); while the frequencies (f) produced by a typical blast in an open cast mine range from 5-200 Hz. The wavelength ($\lambda = c/f$) thus ranges from 1 m to 400 m. The potential to cause damage to buildings is greatest when the wavelength is of the same order as the footprint of the building (Figure 1).

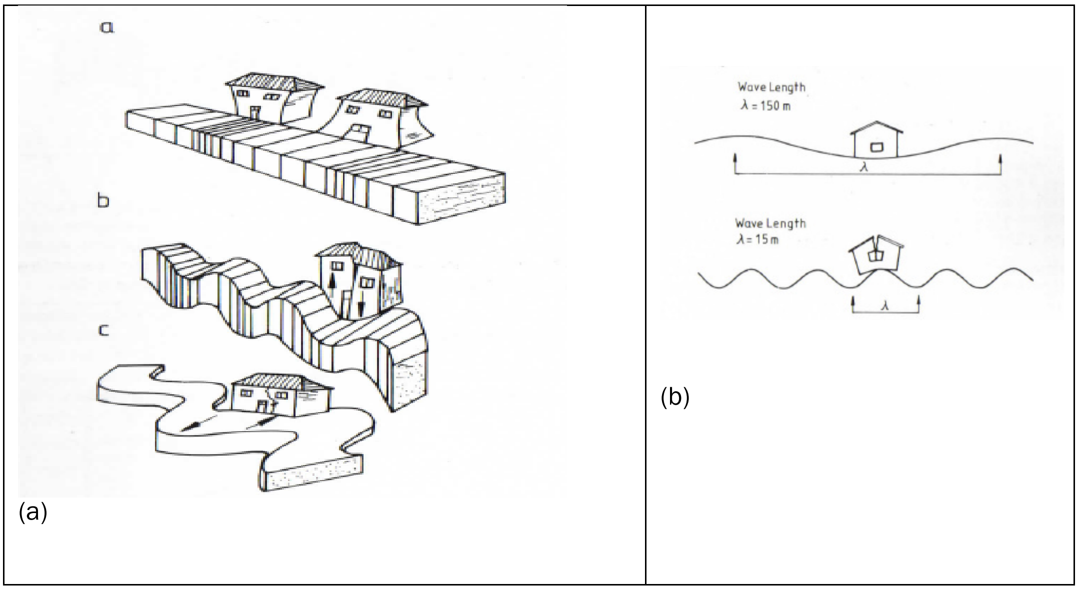

Figure 1: (a) How seismic waves distort structures; (b) The effect of wavelength
(Source: Tamrock, 1984, p. 166-167)

Earthquake-induced ground vibration can be measured using three different parameters: ground displacement (u), particle velocity (V) or acceleration (a). These parameters are related by the frequency (f) and π:

$$V = 2\pi fu$$
$$a = 2\pi fV = 4\pi^2 f^2 u$$

- **Acceleration (a)** is a measure of how quickly the point of interest changes velocity over a set period of time. This is usually expressed in millimetres per second per second (mm/s^2) or as a multiple of gravitational acceleration (9.8 m/s^2, or "g"). Acceleration on its own does not necessarily cause damage, but differential acceleration between objects or structures can create dynamic stresses and strains, causing damage.
- **Velocity (V)** is a measure of how far the point of interest moves in a set period of time. It is usually expressed in millimetres per second (mm/s). Like acceleration, velocity on its own does not cause damage. A house, car or person can sustain high speeds without damage; we see this every time we fly in a passenger jet.
- **Displacement (u)** is the distance that the point of interest moves from a certain reference point. This is usually expressed in millimetres (mm). Displacement alone does not cause damage; a house on the back of truck can be moved kilometres without being damaged. It is differential displacement (strain) that ultimately causes damage.

The potential to cause damage to buildings is most closely correlated with the Peak Particle Velocity (PPV). People can detect ground motions with PPVs as low as 0.8 mm/s; buildings may experience cosmetic damage at PPVs of 10 mm/s at frequencies of 10 Hz; while severe structural damage may occur when PPVs exceed 200 mm/s.

The methods used to record and analyse vibrations produced by earthquakes and mine blasts are similar, but there are important differences (Table 1). This means that the relationships and conclusions that are valid in earthquake engineering do not necessarily apply to mine blasting (JKMRC, 1996, p. 270).

Table 1: Comparison of blast-induced and earthquake ground vibrations

	Typical opencast blast	**Damaging Earthquake (M>6)**
Frequency (Hz)	5 – 200	0.1 – 5
Duration (sec)	0.5 – 5	10s of seconds to minutes
Displacement (mm)	0.001 – 2	100s of mm
Peak velocity (mm/s)	0.1 – 1000	Up to 1000
Peak acceleration (m/s^2)	0.01 – 100	Seldom > 10

SAFE LIMITS OF GROUND VIBRATION FOR VARIOUS ENGINEERED STRUCTURES

Vibration limits have been published in the literature for different types of equipment and structures. Although these may differ slightly from application to application, the guidelines by Bauer and Calder (1977) are based on empirical information (Table 2).

Table 2: Vibration amplitudes for structures and equipment other than buildings
(Rorke, 2011; citing Bauer and Calder, 1977)

Type of Structure	**Type of Damage**	**PPV at which Damage starts (mm/s)**
Rigidly mounted mercury switches	Trip-out	12.7
Concrete blocks (e.g. floor slabs)	Hairline cracks in concrete	203
Cased drill holes	Horizontal offset	381
Mechanical equipment (e.g. pumps and compressors)	Shaft misalignment	1016
Prefabricated metal buildings on concrete pads	Cracked floor, building twisted and distorted	1524

The Australian Coal Association Research Programme (ACARP) project C14057 investigated methodologies for the assessment of the strength of infrastructure types and established limits for installations such as conveyors, power transmission towers, wooden poser poles, electrical substations, pipelines, bridges, public access roads and underground working (Richards and Moore, 2007 and 2008). Some of the conclusions are listed below:

- **Power transmission towers:** Transgrid had commonly specified a limit of 50 mm/s. The study showed that this was conservative and a higher limit of 100 mm/s was validated, subject to effective measurement and control.
- **Wooden power poles:** Investigations showed that vibrations up to 240 mm/s did not adversely affect the poles.
- **Electrical substations:** The vibration limit is determined by the sensitivity of the trip switches in the substations, and the sensitivity of the switches varies considerably.
- **Conveyor structures:** Tests were limited to 25 mm/s. It was found that no significant additional stresses were imparted to the structure. Based on conservative assumptions, it is predicted that the conveyor will remain within serviceability limits at ground vibrations of 50 mm/s.

Vibration limits for civil and engineering structures such as power lines, roads, pipelines and conveyors are provided by Rorke (2011):

- **Eskom Power Lines:** Eskom places a limit of 75 mm/s at its pylons. This is a conservative limit as the steel structure of each pylon and the concrete foundation blocks can both withstand significantly higher vibrations.
- **Public Roads:** For public roads, such as the regional and national roads (e.g. R545, N4), the risk of desegregation of the road material will start to appear at vibration amplitudes of the vertical component above 150 mm/s. Thus vibration levels at these structures need to be kept below 150 mm/s.
- **Telkom Relay Tower:** Structurally, towers will be able to withstand relatively high vibration at frequencies above 5 Hz. However, the electronic circuitry will be more sensitive, and a ground vibration limit of 10 mm/s is applicable.
- **Pipelines (Water and Transnet):** The limit at which pipelines will start to become damaged is high. Blasting near pressurized steel pipelines has taken place safely at PPV's in excess of 50 mm/s in South Africa. Unless the pipelines are in very poor condition or made of old concrete/asbestos, a level of 50 mm/s is considered to be safe. Transnet prescribed a limit of 25 mm/s on their pipeline that runs close to blasting operations along the N12 highway. (The purpose of the pipeline is not specified).
- **Conveyors:** A steel conveyor structure will withstand very high vibrations and the concrete plinths will remain undamaged by ground vibration up to 200 mm/s.

A similar compilation of vibration limits for civil and engineering structures such as power lines, roads, pipelines and conveyors is given in Table 3.

Table 3: Vibration limits for civil infrastructure used in South Africa
(Source: Blast Management & Consulting, 2015):

Structure Description	Ground Vibration Limit (mm/s)
National Roads/Tar Roads	150
Electrical Lines (Pylons)	75
Railway	150
Transformers	25
Water Wells	50
Telecoms Tower	50
General Houses of proper construction	USBM Criteria or 25 mm/s
Houses of lesser proper construction	12.5
Rural building – Mud houses	6

MONITORING OF VIBRATIONS

The South African National Standard (SANS 4866:2011, based on ISO 4866:2010) specifies measuring ranges for various vibration sources, including earthquakes and blasts (Table 4). These standards should be applied when carrying out surveys related to PGPN.

The standard prescribes that instruments used to monitor ground-borne blast vibrations must be capable of measuring ground motions over the range 0.2 mm/s to 100 mm/s in the frequency range of 1 Hz to 300 Hz; while instruments used to monitor earthquakes must be capable of measuring ground motions over the range 0.2 mm/s to 400 mm/s in the frequency range of 0.1 Hz to 30 Hz.

Table 4: South African standards for measuring mechanical vibrations
(South African National Standard (SANS) 4866:2011)

Vibration source	Frequency range[a] Hz	Amplitude range µm	Particle velocity range mm/s	Particle acceleration range m/s^2	Time characteristic
Traffic road, rail, ground-borne	1 to 100	1 to 200	0,2 to 50	0,02 to 1	C[b]/T[c]
Blasting vibration ground-borne	1 to 300	100 to 2 500	0,2 to 100	0,02 to 50	T
Air over pressure	1 to 40	1 to 30	0,2 to 3	0,02 to 0,5	T
Pile driving ground-borne	1 to 100	10 to 50	0,2 to 100	0,02 to 2	T
Machinery outside ground-borne	1 to 100	10 to 1 000	0,2 to 100	0,02 to 1	C/T
Machinery inside	1 to 300	1 to 100	0,2 to 30	0,02 to 1	C/T
Human activities inside	0,1 to 30	5 to 500	0,2 to 20	0,02 to 0,2	T
Earthquakes	0,1 to 30	10 to 10^5	0,2 to 400	0,02 to 20	T
Wind	0,1 to 10	10 to 10^5	—	—	T
Acoustic (inside)	5 to 500	—	—	—	C/T

NOTE 1 The ranges quoted are extreme, but they still indicate the values which may be experienced and which may have to be measured (see also Note 2). Extreme ranges of displacement amplitudes and frequencies have not been used to derive particle velocities and accelerations. Values lower than 0,2 mm/s can also be considered. For building security and human annoyance, these values may be insignificant, but for sensitive equipments they are significant.

NOTE 2 Vibration values within the given ranges may cause concern. There are no standards which cover all varieties of structures, conditions and durations of exposure, but many national codes associate the threshold of visible (or otherwise noticeable) effects with peak particle velocities at the foundation of a structure of more than a few millimetres per second. A significant damage is linked to peak particle velocities of several hundred millimetres per second. Vibration levels below the threshold of human perception may be of concern in delicate and industrial processes.

[a] Ranges quoted refer to the response of structures and structural elements to a particular type of excitation and are indicative only.

[b] Continuous.

[c] Transient.

The guideline *Noise and Vibration from Blasting* issued by the Queensland Department of Environment and Heritage Protection (EM2402, version 3.00, approved 22 January 2016) differs slightly from SANS 4866:2011, recommending that ground vibration instrumentation used for compliance monitoring must be capable of measurement over the range 0.1 mm/s to 300 mm/s with an accuracy of not less than 5% and have a flat frequency response to within 5% over the frequency range of 4.5 Hz to 250 Hz.

Field Practice Guidelines for Blasting Seismographs, published by the International Society of Explosives Engineers (ISEE, 2015), is the industry standard for the correct monitoring of blast vibrations. It can be downloaded at https://www.isee.org/digital-downloads/290-isee-field-practice-guidelines-for-blasting-seismographs-2015. It notes that the following issues require special attention:

- **Coupling of vibration sensors:** If transducers are placed on the ground alongside the building being monitored, the recorded vibrations can be significantly affected by surface or near-surface features which may have a very localised affect. At high levels of vibration which occur at certain frequencies, it is also possible for transducers to leave the ground. In principle, this can be addressed by driving a stiff steel rod into the ground through the loose surface layer and attaching the transducer to it, but good coupling is often difficult to achieve. Alternatively, the transducer can be fixed to a rigid surface plate such as a well-bedded paving slab. Some equipment manufacturers suggest placing the transducer on a hard surface with a small sandbag on top of it. However, even if good coupling is achieved, the nature of the ground under the hard surface is unknown, and it might be very broken and affect the vibrations. Better coupling can be achieved if the transducers are buried in a density-matching box, but this is only practicable for permanent monitoring stations.

- **Calibration of vibration sensors:** The detectors commonly used to measure ground vibrations are either geophones (velocity transducers) or accelerometers. The vibrations produced by mining operations generally occur over the frequency range of 2-200 Hz and thus the detectors should be capable of accurately monitoring vibrations across this range. Geophones require regular re-calibration over a period of time and if shaken violently. Geophones should be calibrated annually at least.
- **Orientation of vibration sensors:**
  - Some sensors are sensitive to orientation; a vertical 2 Hz geophone cannot be used as a horizontal sensor and vice-versa.
  - In a permanent array, sensors are usually orientated with respect to geographic north; while for a temporary measurement, the radial component is pointed towards the blast.
  - The three axes (directions) of measurement, the longitudinal (or "radial", the vector connecting the seismograph transducer and source of vibration), transverse (the vector in the same plane as, but perpendicular to, the longitudinal) and vertical (up and down) vectors, are always measured and reported separately. One reason for this is that they have different degrees of importance in causing damage. Structures are built to withstand vertical forces. For that reason, vibrations along the vertical vector are usually of lesser importance in causing damage, though not always benign. Vibrations in both the longitudinal and transverse directions have the potential for causing shear in the structure, which is a major contributor to damage effects. When in shear, various parts of the house move at different speeds or even in different directions, which can cause cosmetic cracking or even structural damage.
  - Vibration standards generally do not take these differences in damage potential between vibration direction components into account, but simply specify a single limit that applies to all three axes of measurement.
- **Parameter(s) to measure**
  - PPV is a "vector" quantity (i.e. it has both a value and an associated direction).
  - The Peak Vector Sum (PVS) is usually also quoted; it is simply the square root of the sum of the squares of the PPV values in all three vector directions measured by the geophones. PVS is a "scalar" quantity, i.e. one with only a value, which is always larger than the individual PPV vector values.
  - Scientific studies have shown that the PPV, of all the tested characterizations of ground movement (e.g. acceleration, displacement, or strain), correlates best with damage potential.
  - All the standards are quoted in PPV values, not PVS or other measures of movement, although the "acceptable" values of PPV differ with the standard applied and with the frequency of the vibration components.

It is important that ground and structure vibrations should be measured properly to ensure the receipt of correct records. A contemporary transducer for velocity measurement is a tri-axial pack of geophones with the frequency response from 1-300 Hz.

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Appendix D: Peer Review and Specialist Response Sheet

Peer Reviewer: Professor Andrzej Kijko; University of Pretoria

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Prof Andrzej Kijko	General Overview			The report presents a comprehensive study of the potential effects of seismic activity on the planned phased gas pipe network (PGPN) and electricity grid infrastructure (EGI) in South Africa. The report consists from "*List of acronyms, abbreviations and units*", brief summary, six chapters and three appendices. The "*List of acronyms, abbreviations and units*" provide some basic terminology and lexicon used by seismologists, required to understand the findings of the report. The Summary is short but to the point. The report starts with a comprehensive introduction in Chapter 1, followed by the formulation of the scope of the work in Chapter 2, and some quantitative assessments of Probabilistic Seismic Hazard Analysis (PSHA) for the potential locations (corridors) of PGPN and EGI in Chapter 3. Chapter 4 deals with the assessment of associated risk to the pipelines. The Report concludes with Chapter 5 describing "*Best Practice guidelines and Monitoring Requirements*", Chapter 6 describing "*Gaps in knowledge*" and finally the "*References*". The Report also has the following three Appendices: Appendix A - "*Seismic Hazard in South Africa*", Appendix B - "*OpenQuake PSHA computation for South Africa, The Energy Corridors*", and Appendix C - "*Vulnerability of PGPN and Monitoring*". The Report is very well structured and organised, easy to read and results are presented in a consistent way. However, in my professional opinion, there are significant shortcomings in the report as discussed below.	Noted.
Prof Andrzej Kijko	Ad. Chapter 1. Introduction (Page 5)	1		This chapter serves as an introduction to the problem. It describes the methodology required to assess the impact of earthquakes on Gas Pipeline Networks (GPN) alternatively termed lifelines in the report. It also summarises what the reader can expect in the following five chapters and three appendices. Authors are aware of the limitations of their work that are listed in Table 2. However, some	Noted

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				of the limitations could be easily removed and make the report better.	
Prof Andrzej Kijko	Ad. Table 1. (Page 7)	4	Table 1	Table 1 is very useful. The Authors of the Report used the probabilistic seismic hazard map compiled by Midzi et al. (2018c) as the main source of seismic hazard for South Africa. This article and the subsequent map are, as stated in the report, still under peer review. Along with concerns raised in my comments on Section 3.3.1, I have fundamental reservations against using Midzi et al (2018c) as a source of information at this stage.	Noted. The reviewer's concerns relating to the use of the probabilistic map of Midzi et al (in press) are addressed when responding to the comments on Section 3.3.1.
Prof Andrzej Kijko	Ad. 2.4 Limitations and Assumptions Table 2. Site effect. (Page 8)	4		In studies of seismic hazard and risk for lifelines, the site effect plays a fundamental role (see e.g. Tamaro et al., 2013). The account of site effect (at least its first approximation) can be done by the account of average S velocity (Vs30) of first 30 meters. Information on Vs30 is available for South Africa (Allen and Wald, 2007) and its implementation is easy (e.g. Atkinson and Boore, 2006). Since the impact of site effect from different geological sources can be significant, its implementation would significantly improve the Report.	Noted. The importance of the site effect has been emphasised and reference made to the articles cited by the reviewer.
Prof Andrzej Kijko	Ad. 2.4 Limitations and Assumptions Table 2. Analysis of liquefaction potential. (Page 8)	4		Besides the effect of fault displacement (also known as permanent ground deformation or PGD), the effect of liquefaction is one of the major threats to any pipeline. Since its effect can be fatal to any lifeline, I would have expected that the Report provided at least some idea or even rough quantification of its effect on the pipelines. The Authors should address this aspect.	Noted. The dangers posed by liquefaction are given greater emphasis in the report.
Prof Andrzej Kijko	Ad. 2.4 Limitations and Assumptions Table 2. Active faults. (Page 8)	4		As a rule, the major threat to any lifeline is not so much peak ground acceleration (PGA) or velocity of vibration. The major threat comes from fault displacement in the vicinity of the structure. I am not familiar with details of the mandate the Authors had when they were seconded to perform the hazard and risk analysis, but any assessment of hazard and risk for lifelines is incomplete if quantification of the effect of fault displacements is not provided.	The authors agree that fault displacement is the major threat rather than ground shaking. The authors are of the opinion that the uncertainties in predicting fault displacement are large, and this is beyond the terms of reference of this study.

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Expert Reviewer Name	**Page Range**	**Line/s**	**Table Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Prof Andrzej Kijko	Ad. 2.4 Limitations and Assumptions Table 2. The vulnerability of GRN. (Page 8)	4		Again I am not familiar with the mandate the Authors of the Report had, but the title of the report make promises, that the report will provide quantification of risk and damage to the proposed pipelines. The risk quantification is not provided in the report.	The mandate evolved during the course of the study, as it became evident that the way in which the impact of seismicity on the routing of gas pipeline should be assessed differed significantly from the other factors that were included in the study e.g. biodiversity, economics. The quantification of risk required geotechnical and engineering studies well beyond the original scope and budget.
Prof Andrzej Kijko	Ad. 2.5. Relevant Regulatory Instruments. Table 3. Relevant Regulatory Instruments. (Page 9)	4		I like the list of regulations listed in Table 3. However, no mention is made to the major and official source of information for the analysis, which is the latest version of the South African Building Code (SANS 10160-4-2017). The document is missing in Table 3.	Noted. The hazard map in the South African Building Code (SANS 10160-4-2017) has been inserted as Figure 4 and is discussed in the text.
Prof Andrzej Kijko	Ad. Section 3.2. Background. (Page 10)	39		This Section provides a very good review of South African seismicity, with a warning that in low rate seismicity, intraplate regions like South Africa, the unexpected can happen. For example the 1809 and 1969 Western Cape earthquakes, the recent Botswana 6.5 earthquake. The only reservation I have is regarding the assessment of the completeness of the data for the southern African catalogue by Mulabisana (2016). The assumption that starting from 1965, the Southern African catalogue is complete starting from MW = 2.5 is not correct. In 1965, this part of the country the sparse seismic networks were not yet able to detect seismic event with magnitude 2.5.	Noted. This has been corrected.

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
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Prof Andrzej Kijko	Ad. Section 3.2 (p. 11)	21		The study by Meghraoui et al. (2016) identified only the major faults. For hazard and risk analysis as undertaken by Authors of the Report, more detail neotectonic studies are required to make sure all potential faults, including smaller ones, are taken into consideration. I am therefore not convinced Meghraoui et al. (2016) is the appropriate source of information to use in this study. Again, I am not familiar with the mandate the Authors of the Report had, but a more detailed analysis of active faults along the considered energy corridors is required. Such a study can be done in different ways. Youngs et al. (2003) developed the most advanced approach to study the effect of the earthquake that causes a ground displacement (PGD), known as probabilistic fault displacement hazard analysis (PFDHA). This method, however, requires a significant amount of information, which often, is not available. There are at least two alternative and less laborious approaches to assess the effects of ground displacement that can be applied, namely probabilistic, (e.g. ALA, 2001; Lanzano et al., 2013a, b) and deterministic (e.g. Wells et al., 1994). Study of such a nature is crucial in any assessment of seismic hazard and risk for energy and/or pipelines.	Noted. The authors agree that the study by Meghraoui et al. (2016) extremely qualitative and agree that more detailed studies must be done. The authors have cited all studies of active tectonic faulting in South Africa of which they are aware. The authors also agree that efforts should be made to model ground displacements. However, this did not fall within the scope of the present study.

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Prof Andrzej Kijko	Ad. 3.3.1 (page 12)	40		All the quantitative assessments of seismic hazard expressed in terms of probability of ground vibration in the vicinity of the considered energy corridors are based on the map provided by Midzi et al. (2018). For the purpose of a study like this reviewed Report, it is imperative to refer only to official South African documents and an official South African seismic hazard maps as provided in the most recent South African Building Code (SANS 10160-4-2017). The map by Midzi et al. (2018) it is not an official document and was not yet published in a peer-reviewed journal. Even, if in the future, it is will be published, it cannot be considered as an official document and standard to be applied unless accepted into South African building guidelines and regulations. It can be referred to as additional information but cannot serve as the main source of information until such time. In addition, the map differs SIGNIFICANTLY from the accepted seismic hazard map in the current South African Building Code (SANS 10160-4-2017). For example, the seismic hazard in Western Cape differs fundamentally with the map by Midzi et al. (2018). In exchange, it shows significant seismic hazard north (ca. 250 km) of Cape Town and Ceres which is not the case in the SANS map. These discrepancies are however not mentioned or discussed in the reviewed Report. This is an import matter. If the all the assessments of seismic hazard provided in the reviewed Report (as e.g. Table 4), are based on a map by Midzi et al. (2018), there are serious concerns that first must be addressed before being accepted.	The Council for Geoscience has been mandated (in terms of the Geoscience Amendment Act 16 of 2010) to be the the custodians of geotechnical information, to be a national advisory authority in respect of geohazards related to infrastructure and development, and to undertake reconnaissance operations, prospecting research and other related activities in the mineral sector; and to provide for matters connected therewith. For example, the Bill seeks to put mechanisms in place to address problems which are associated with infrastructure development on dolomitic land, and empowers the Council for Geoscience to be the custodian of all geotechnical data with the purpose of compiling a complete geotechnical risk profile of the country. The Act is listed in Table 3 (Relevant Regulatory Instruments) On 3 October 2018 the lead author of the paper on probabilistic seismic hazard assessment of South Africa, Dr Vunganai Midzi of the Council for Geoscience, reported that the Journal of Seismology has accepted the paper subject to the correction of minor errors and that the revised paper has been submitted and should be published shortly. Nevertheless, the points raised by the reviewer are noted and discussion of the SANS Code is now included in the report and the discrepancies between the two seismic hazard maps are discussed.

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
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Prof Andrzej Kijko	Ad 4. Risk Assessment (page 20)	1		Base on the title of the chapter, I expected the quantification of the seismic risk posed to the lifelines associated with the seismic hazard. In other words the quantification of the likelihood of a certain amount of damage to infrastructure during the specified time interval. Nothing close to that is contained in the chapter. The Authors provides some quantitative assessments, which create an impression to be the loose collection of information gathered from different sources, and it is unclear where information came from. It is however clear, that the provided information is very approximated and uncertain. In short, the promised risk assessments for future infrastructure in the considered energy corridors are not provided by the report. If I correctly understood the required scope of the report, it supposed to discuss the potential consequences of pipeline damage on the environment. This aspect is not present in the Report.	The Terms of Reference did not require a detailed assessment of pipeline performance under seismic loading or surface rupture caused by an earthquake.
Prof Andrzej Kijko	Ad. Table 6. Proposed consequence table to assess risks posed by earthquakes to GPNs (Page 23)	1	Table 6	The reference to the source of the table is missing.	A discussion of the SANS Code is now included in the report, and the discrepancies between the two seismic hazard maps are discussed.
Prof Andrzej Kijko	Ad. Table 7. Negative impacts applicable to the Gas Corridors. (Page 24)	1	Table 7	Again, I do not know the mandate and the requirements of the Authors of the Report, but the quantification of seismic risk (in my opinion) requires significantly more than just a classification of consequences in terms of "Substantial, Slight, or Moderate". The same is true for the statements: "extremely likely", "extremely unlikely", etc., (as seen in the column "Likelihood"). I expected to see the calculated percentages of expected damage to the proposed pipelines at each site, as well as calculated probabilities of such "extreme likely" or "extreme unlikely" events. At the very least, the risk quantification should have been provided as applied by Lanzano et al. (2013a, b).	The authors followed the methodology provided in their Terms of Reference. Further quantification was not required at this stage of the study. Response from the CSIR: The Risk Assessment template was designed by the CSIR and provided to the specialist for completion. The specialist has completed this accordingly. Quantification of the risks was not part of the Terms of Reference. A semi-quantitative/qualitative assessment was required and has been provided. This has been the approach for all specialist studies.

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Prof Andrzej Kijko	Ad. Appendix A. Seismic hazard in South Africa (Page 30)	1		I really enjoyed reading it. This part of the report should be obligatory literature for every student of geophysics in South Africa. The only remark I have is regarding the map of seismic hazard by Fernandez (1996). As far as I know, the map was computed through the application of the Gumbel III extreme distribution and not by Parametric - Historic procedures.	Noted. The description of the method used by Fernandez (1996) has been deleted as it is merely of historical interest.
Prof Andrzej Kijko	General Conclusion			1. All the seismic hazard assessments provided in the Report (probability of ground vibration in the vicinity of the considered energy corridors) are based on the map provided by Midzi et al. (2018). For the purpose of a study like the reviewed Report, it is imperative to refer only to official South African documents. The current officially accepted South African seismic hazard maps as provided in the most recent South African Building Code (SANS 10160-4-2017). 2. The Report does not provide an adequate assessment of seismic hazard in terms of ground displacement. 3. The Report does not provide an assessment of seismic risk as it is required for lifelines.	1. The paper by Midzi et al has been accepted for publication by the Journal of Seismology and was "in press" on 3 October 2018. A discussion of the SANS Code is now included in the report. In should be noted that the Council for Geoscience is the agency mandated to assess geohazards in South Africa, and so their latest thinking in this regard should be taken into account. 2. Very few active faults and instances of surface rupture have been documented. Consequently, the uncertainties with regard to the hazards posed by surface rupture and ground displacement (where? how often? how big?) are far larger than those associated with the hazard posed by ground shaking. Quantitative assessment of the hazard associated with ground displacement is beyond the scope of this study. 3. A key component of any risk assessment is a consideration of the vulnerability of the structures and systems. This did not fall within the scope of the present study.
Prof Andrzej Kijko	References			ALA (American Lifeline Alliance) (2001) Seismic fragility formulations for water system. American Society of Civil Engineers (ASCE) and Federal Emergency Management Agency (FEMA).	Reference added to the bulleted list in Section 5.1 that is preceded by the paragraph “Some of the world’s most technologically-advanced countries are exposed to seismic hazard, for example, Italy, Japan and the USA. Standard methodologies have been developed to assess seismic hazard; numerous studies have been conducted to assess the risk posed by earthquakes to lifelines; and engineering specifications for GPNs have been published. It must be emphasised that risk posed by earthquakes is generally not viewed in isolation, but as part of a multi-hazard strategy. ”

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Prof Andrzej Kijko				Allen, T.I. and D.J. Wald (2007). *Topographic Slope as a Proxy for Seismic Site-Conditions (V_{S30}) and Amplification Around the Globe.* Open-File Report 2007-1357. U.S. Department of the Interior, U.S. Geological Survey.	Inserted
Prof Andrzej Kijko				Atkinson, G., and D. Boore (2006). Ground motion prediction equations for earthquakes in eastern North America, *Bull. Seismol. Soc. Am*., **96**, 2181–2205.	Inserted
Prof Andrzej Kijko				Lanzano, G., E. Salzano De. Santucci, F. Magistris and G. Fabbrocino (2013a). Performance assessment of continuously buried pipelines under earthquake loadings, **31**, 631–636.	Inserted as 2013c as two papers by these authors were already cited.
Prof Andrzej Kijko				Lanzano, G., E. Salzano De. Santucci, F. Magistris and G. Fabbrocino (2013b). Vulnerability of pipelines subjected to permanent deformation due to geotechnical co-seismic effects. *Chem Eng Trans.* **32**, 415–420.	Inserted as 2013d as two papers by these authors were already cited.
Prof Andrzej Kijko				Mulabisana, T. (2016). *Compiling a homogeneous earthquake catalogue for Southern Africa.* MSc dissertation (unpublished), University of the Witwatersrand Johannesburg	The dissertation was already included in the reference list
Prof Andrzej Kijko				SANS (South African National Standard) (2017). SANS 10160-4-2017. Basis of Structural Design and Actions for Buildings and Industrial Structures. Part 4: Seismic Actions and General Requirements for Buildings. Pretoria: South African Bureau of Standards. ISBN 978-0-626-30384-6.	Inserted
Prof Andrzej Kijko				Tamaro, A., S. Grimaz, M. Santulin and D. Slejko (2013). Characterization of the expected seismic damage for a critical infrastructure: the case of the oil pipeline in Friuli Venezia Giulia (NE Italy). *Bull Earthquake Eng*., **13**, No. 4, DOI 10.1007/s10518-017-0252-1.	Inserted
Prof Andrzej Kijko				Wells, D.L. and K.J. Coppersmith (1994). New empirical relationship among magnitude, rupture length, rupture width, rupture area, and surface displacement. *Bull Seism Soc Am*. **84**, 974–1002	Inserted

Peer Reviewer: Dr Alistair Sloan; University of Cape Town

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
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Dr Alistair Sloan			Noted	General comments. Providing such a risk assessment for lifeline infrastructure in a comparatively stable region, such as South Africa, is a challenging task. This is due to the large uncertainties inherent in assessing the impact of events with repeat times which are much longer than the period for which we have detailed observations. The authors have walked the line between over-confidence and alarmism extremely well, and have communicated the uncertainties involved in a responsible and credible way. The report also highlights methods of reducing these uncertainties and in continuing with this project in a responsible manner and notes the unfortunate lack of data in some areas. Some specific comments are listed below:	Noted
Dr Alistair Sloan	1	12		Mmax appears within the body of the report before it is expanded and defined in the appendix. This explanation should occur here or when it first appears in the body of the report.	Added to the list of acronyms, abbreviations and units on the cover page and the header to Table 4.
Dr Alistair Sloan	2	12		'could take place anywhere' could be interpreted as meaning that all possible locations are associated with an equal probability. An alternative phrasing that emphasises the utility of identifying active faults might be: Larger tectonic earthquakes ($6.5<M<7.5$) are rare in stable regions, but occur both on faults with a recent (100s-10,000s years) history of earthquake activity, and in areas with no known precursory activity. Such events could therefore take place anywhere.	Valid point. The proposed sentence has been inserted.
Dr Alistair Sloan	6	8		typo: does > do	Corrected

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Dr Alistair Sloan	7	Table 1		An additional data source that could help to constrain (in particular Mmax) are global catalogues of earthquakes in stable continental regions. The rationale for this is that by considering a broader area of 'similar' continental regions we can make up for the fact that our period of observation is much shorter than the occurrence interval for large earthquakes in any one region. This methodology was followed by Johnston et al. 1994, The Earthquakes of Stable Continental Regions. Volume 1: Assessment of large earthquake potential, Electric Power Research Institute (EPRI), Palo Alto, California, a report which was also intended to constrain hazard assessments for lifeline infrastructure in a stable region. It should be noted that it is difficult to assess whether two regions are really 'similar' (in the sense of having comparable values of Mmax) and this introduces a source of subjectivity to the assessment. This methodology has been influential in hazard assessment of 'lifeline' infrastructure and so could be mentioned as an alternative (though not necessarily superior) method of Mmax estimation. The results of such an analysis would be similar to those presented here.	Valid point. The proposed data source has been added to Table 1, and a mention of this constraint added to Table 2.
Dr Alistair Sloan	8	Table 2		See comment 1. In addition, due to the short period of instrumentation compared to the repeat times of large earthquakes estimates of large earthquakes and Mmax for the instrumental record will have large uncertainties.	Valid point. This limitation is noted in the first row of Table 2.
Dr Alistair Sloan	10	14		suggested edit: **significant/extensive** damage when M>6	The word 'significant' has been inserted.
Dr Alistair Sloan	11	12 to 13		Perhaps it would be beneficial to indicate the position of these events on Figure 2?	Good suggestion. We will do so.
Dr Alistair Sloan	11	21		Meghraoui et al. (2016): Reference appears to be missing from bibliography.	The reference has been added to the reference list.
Dr Alistair Sloan	12	6		typo: economic	Corrected
Dr Alistair Sloan	12	24-25		What is meant by 'moderate' dynamic loading? Perhaps a more conservative phrasing of this would be that the probability of large dynamic loading is estimated to be extremely low.	The phrasing suggested by the reviewer has been used.

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/ Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Dr Alistair Sloan	17-19	Table 4		An explicit definition of Mmax and discussion of the methodology of Mmax estimation and Mmax uncertainty in the main report or appendix B would be beneficial. The value chosen appears to be reasonable when compared to similar regions (see comment 4). It is lower than the largest paleoseismic event interpretation in South Africa (the M8 Soutpansberg event, pg. 42) though perhaps this is because this (very high) magnitude estimate is considered by the authors to be unreliable? There appear to be discrepancies between statements regarding the absence of mapped faults in Table 4 and those depicted in App. B Fig. 1 (e.g. within Corridor 7).	Mmax has been defined in the text. In the present case, the data is too sparse to allow a good level of constraint on Mmax values; hence this parameter was assessed separately, based on the maximum observed magnitude values, as well as consideration of the values assigned for equivalent zones in past studies. The paper (in press) describes the calculation of Mmax as follows. "Techniques, as previously presented by Kijko and Sellevol (1989), were applied to estimate Mmax values. For some zones, alternative Mmax values were estimated using the Wells and Coppersmith (1994) equations that link earthquake magnitude to sub-surface rupture length (Table 1). Faults identified as active in those zones were used in this calculation with the length estimated from segments that can be associated with earthquake locations. Such alternative Mmax values obtained for each source were used in the hazard calculation in conjunction with assigned weights (WM) reflecting the level of confidence in each value. These values and weights are also summarised in Table 1." On 3 October 2018 the lead author (Midzi) reported that the Journal of Seismology has accepted the paper subject to the correction of minor errors and that the revised paper has been submitted and should be published shortly, thus making it unnecessary to go into technical details in this report.
Dr Alistair Sloan	21	14		The Hebron fault in Namibia is another example of a southern African fault with clear surface offsets, although the number and magnitude of the events that formed this scarp remain debatable. (e.g. White et al. 2009, Pleistocene to Recent rejuvenation of the Hebron Fault SW Namibia. Geological Society of London, Spec. Pub. 316, 293-317).	We did not refer to the Hebron Fault because of the large uncertainties. However, we agree that it is an important feature, and the sentence proposed by the reviewer has been inserted in the report.

EXPERT REVIEW AND SPECIALIST RESPONSES: Seismicity – Gas Pipeline Development					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/ Figure**	**Expert Reviewer Comments**	**Responses from Specialists**
Dr Alistair Sloan	23	2		The dollar-rand conversion seems somewhat low in both 2016 and 2018 exchange rates.	The reviewer is right. In 2016 the R/$ fluctuated between 14 and 16. We have now used a value of 15, retained the Rand values describing the boundary between 'severe' and 'extreme' consequence levels at R100 billion, but changed the % value from 3% to 2%.
Dr Alistair Sloan	24	Table 7		I initially misinterpreted the second row of this table with reference to the hazard and risk associated with moderate, shallow mining related earthquakes by reading it as implying that there was a very low likelihood of a Mw>5 shallow mining-related earthquake occurring in the vicinity of the pipeline in corridor 3. On rereading it became clear that the likelihood of occurrence of such an event in the vicinity of the pipeline in corridor 3 is moderate, however in regions with flat terrain, no problem soils and appropriate mitigation the likelihood that such an event would actually damage the pipeline is extremely low. It may be worth considering if this distinction could be made clearer.	We have tried to improve Table 7 to avoid misunderstanding
Dr Alistair Sloan	27	1		Expand MASW.	MASW and Vs30 has been expanded.
Dr Alistair Sloan	41	7 to 8		Is there a reference for this statement?	See, for example, https://www.internationalrivers.org/earthquakes-triggered-by-dams, where it is stated "In a paper prepared for the World Commission on Dams, Dr. V. P Jauhari wrote the following about this phenomenon, known as Reservoir-Induced Seismicity (RIS): 'The most widely accepted explanation of how dams cause earthquakes is related to the extra water pressure created in the micro-cracks and fissures in the ground under and near a reservoir. When the pressure of the water in the rocks increases, it acts to lubricate faults which are already under tectonic strain, but are prevented from slipping by the friction of the rock surfaces.'" This conclusion is based on various technical studies.

Strategic Environmental Assessment for the Development of a Phased Gas Pipeline Network in South Africa

Appendix C.3

Settlement Planning, Disaster Management and related Social Impacts Report

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT IN SOUTH AFRICA

Settlement Planning, Disaster Management and related Social Impacts

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Draft V1 – March 2018
Draft V2 – August 2018
Draft V3 – April 2019
Final Report – October 2019

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ABBREVIATIONS AND ACRONYMS

COGTA	Department of Co-operative Governance and Traditional Affairs
DAFF	Department of Agriculture, Forestry and Fisheries
DisM	Disaster Management
DM	District Municipality
EA	Enumerator Area
EIA	Environment Impact Assessment
FBB	Fire Brigade Board
FBSA	Fire Brigade Services Act (1987)
FPA	Fire Protection Association
ICDM	Inter-ministerial Committee on Disaster Management
IDP	Integrated Development Plan
IFRC	International Federation of Red Cross and Red Crescent Societies
LM	Local Municipality
MHI	Major Hazardous Installation
MSA	Municipal Systems Act
NAFSAC	National Fire Services Advisory Committee
NDMC	National Disaster Management Council
NGO	Non-Governmental Organisation
NSDF	National Spatial Development Framework
PGDS	Provincial Growth and Development Strategy
PIPA	Pipelines and Informed Planning Alliance
PSDF	Provincial Spatial Development Framework
RSDF	Regional Spatial Development Framework
SALGA	South African Local Government Association
SAPS	South African Police Service
SDF	Spatial Development Framework
SEA	Strategic Environmental Assessment
SOE	State Owned Enterprises
SPLUMA	Spatial Planning and Land Use Management Act
StatsSA	Statistics South Africa
TRB	Transportation Research Board
UNDP	United Nations Development Programme
USAR	Urban Search and Rescue

1 SCOPE OF WORK

With over 53% of the population living in Metros, Cities and Large regional centres, 18% in small and medium service centres and a further 5-6% living in small towns and villages in rural areas, settlements and larger urban conurbations are the key drivers of economic growth and are expanding rapidly to accommodate growth in urban populations in South Africa (van Huyssteen et al, 2018). The proposed large scale gas transmission pipeline corridor intervention is of strategic nature, with an extensive national footprint traversing almost all provinces (as illustrated in the Project Description Chapter (Part 2 of the Gas Pipeline SEA Report)). If correctly implemented, economically feasible and well located, the proposed gas pipeline network can contribute positively to the energy mix of the country and have a positive economic impact in the longer term.

Ongoing urbanisation and growth in service and enterprise related investment and needs in fast growing cities and large towns will not only result in an increased energy demand, but most likely be accompanied by an increased demand for natural gas as part of a more sustainable energy mix. To support government's directive (NDP, 2011) to improve the energy mix and provide more sustainable and financially viable options to support national and local development objectives (including the growth of the green economy, curbing emissions and stimulating innovation and enterprise development), timeous planning, design and possible construction of an enabling natural gas transmission pipeline in support of a network of cities and towns will be required.

The proposed gas transmission pipeline design needs to consider ways to maximise regional and local development impact of potential gas resources, as well as minimise and mitigate any potential risks and unintended consequences on the well-being of people and places – including risks to health (e.g. pipeline incidents), social cohesion in communities, socio-economic development within often already vulnerable local economies and markets, as well as enterprise viability, livelihoods, and increased costs to vulnerable households and enterprises.

While the proposed gas transmission pipeline corridor is intended to be kept outside cities and towns, these areas, due to population and economic agglomeration, also form the anchor points for future gas demand. The subsequent expansion of the gas network to urban areas (via distribution networks) may stimulate the growth of associated industry and business which may increase the demand for industrial land and servitudes associated with local gas reticulation networks. Spatial and economic planning must provide a balanced approach to support growth in the economy, planned settlement growth, and the provision and maintenance of strategic infrastructure, whilst at the same time protecting ecologically sensitive areas and critical ecological infrastructure.

If avoidance of highly populated areas is not feasible, negative impacts of a gas transmission pipeline may manifest in land-use management implications (e.g. alienation of existing land uses making these uses untenable), tenure management considerations, the potential need for resettlement, restriction in future development potential of a parcel of land and negative impacts on service delivery and local economies.

At a national and regional scale, it is pertinent that the proposed gas transmission pipeline corridors are designed in such a way that the investment in large scale infrastructure is done in support of current and planned future economic nodes and corridors for South Africa in the most effective and sustainable way. To achieve this, national and regional design considerations would need to include:

- The location of existing and future national and regional nodes and corridors (considering growth areas, as well as government, private sector and people-centred built-environment investment focus areas that will most likely require such energy resources over the long term), as well as strategic economic investment areas with relatively long term spatial footprint. The proposed gas transmission pipeline corridor traverses much of South Africa, enabling connection between and within significant economic and development nodes and development corridors of the country. It covers almost the entire coastal belt with links to Gauteng from Richard's Bay and onward to Maputo via Mpumalanga.

- The location of potential gas resource access (sources, as well as e.g. existing connections to significant gas resources) and inter-modal transfer points (from land to sea based), thus considering port connections per se;

At regional and local scale, it is pertinent that the proposed gas transmission pipelines are designed to ensure the most viable, cost effective and impact limiting construction and operation. The proposed national pipeline corridor will traverse a quite diverse regional and local settlement and socio-economic development context, often concentrated within the range of cities, towns and settlements. The proposed transmission pipeline will traverse diverse settlement and socio-economic contexts, often within the vicinity of cities, towns and settlements. The proposed corridors includes the sparsely populated and arid western areas of the country, through the developed, heavily populated Southern Corridor, and the densely populated rural traditional authority areas of the country which are also the country's most critical water resource areas.

At national, provincial and sub-regional scale consideration of the different contexts of which the corridors consist will be critical to ensure the greatest development return, for the most sustainable long term infrastructure investment. It is imperative that, irrespective of whether the pipeline is developed or not, careful, coordinated and integrated planning must take place.

1.1 Integrated spatial and development planning

1.1.1 International Gas Pipeline Development: why is spatial and development planning important?

On an international scale, the United States (US) depends heavily on the transportation of fuels and gas via underground pipelines. As in many other countries, land use planning in the US is driven by development and population growth. Accordingly, land use planning is more detailed and structured in urban areas compared to rural areas. Rural areas therefore normally lack detailed zoning requirements in terms of allowable land-uses around pipelines. The problem with this is that even where areas were historically rural, due to urbanisation; these areas may now become developed and populated (Transportation Research Board (TRB), 2004). This is clearly shown in Figure 1 below, where a pipeline was developed in a rural area in 1990, with no development around it, and in 2002 the same piece of land is surrounded by a dense urban complex. With urbanisation, the likelihood of land development encroaching on transmission pipelines is increasing and with this, the risk of pipeline incidents causing causalities and/or extensive damage to properties also increases (TRB, 2004).

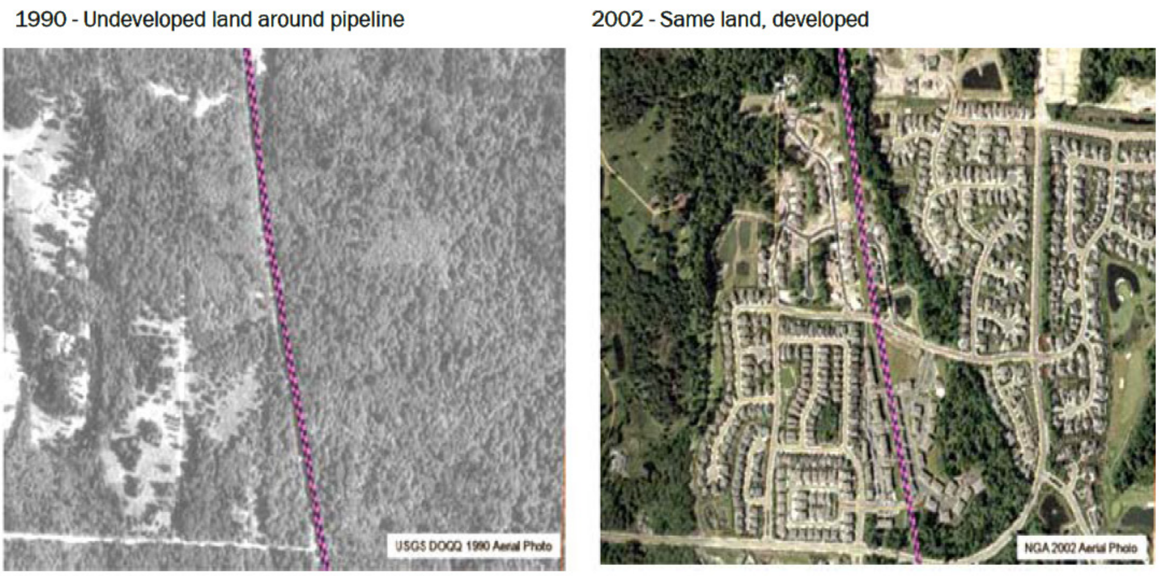

Figure 1: Development near a Transmission Pipeline in Washington State, US 1990-2002 (PIPA, 2015)

The TRB published a Special Report in 2004 with the primary objective to develop a risk-informed guidance document that could be used in land-use decisions (TRB, 2004). The report noted that pipeline safety and the regulation thereof are normally on a national level, while land-use regulations specifically relating to pipeline related matters occur on a local level, which vary considerably in how it is managed. As per the report, a key intervention noted in the report is:

"Local and state governments have little or no technical guidance available to assist them in managing the risk of the increasing number of people in proximity to pipelines through regulations and other tools governing land use, planning, zoning, and subdivision. Some local governments are proposing and developing new approaches to managing risk. However, state governments could take more of a leadership role, both in providing technical assistance and in requiring local governments to develop plans and regulations to prevent and mitigate damage from pipeline spills and explosions" (TRB, 2004).

Within Canada, guidelines have been developed to address the land-use issue around pipelines (MIACC, 1999). The MIACC noted that local governments were not aware of the location of pipelines and these were therefore not included in land-use planning and regulations. This meant that there was an increased cost to pipeline developers to maintain a pipeline that was not historically located in an urban area but due to urban sprawl, now occurs adjacent to, for instance, a hospital or school. In addition, human activity such as excavation with machinery around pipelines increased risk of incidents occurring (MIACC, 1999).

From a developing country perspective, the Bolivia-Brazil Pipeline Project (referred to as GASBOL) was established to primarily supply the Brazilian market with Bolivian gas, via a 3150 km long pipeline that traverses two countries (i.e. Bolivia and Brazil) and various states. Because of the length of the pipeline, GASBOL faced various significant environmental, institutional and social issues. The final routing of the pipeline was informed by environmental sensitive and densely populated areas that should be avoided (Quintero, 2006). Several lessons learned where highlighted, following the development of the pipeline, and include:

- Tools such as regional Environmental Assessments, SEAs and Analysis of Cumulative Effects can ensure that wider ranging project impacts are considered and addressed early in the project planning phase;
- Greater coordination between project engineering and environmental planning activities should have taken place; and
- Mapping of sensitive areas should be prepared before construction begins (Quintero, 2006).
- Environmental concerns should not overshadow social health and safety issues

As noted in Giovanni Ramírez-Camacho et al (2017), land-use regulations are essential to ensure a safe distance between the pipeline and inhabited zones. This is especially important for new pipelines but also in areas where urbanisation is occurring around existing pipelines.

1.1.2 Relevant South African Planning Related Policy

Given the international experience and applying it to South Africa, the alignment of long term infrastructure investment with current and future growth nodes on a national, regional and local scale will be critical. Within this regard, the following planning instruments provide direction and would need to be considered in future design and development phases:

- National Spatial Development Framework (NSDF) – The first Draft of the NSDF is being prepared by the Department of Rural Development and Land Reform (DRDLR) in Collaboration with the Department of Planning Monitoring and Evaluation (DPME). The current draft version of the Draft NSDF, 2018 clearly highlights (1) the importance of cities, regional towns and service nodes in gearing up for increased urbanisation, population growth and associated people centred economic activities, to support the current transitions in the national economy, and (2) the importance of cities, towns and service nodes as anchors in regional development and spatial transformation for South Africa. The growth of settlements within the coastal corridors and in existing in-land nodes up to 2050 is also clearly highlighted. At a national level various industrial and economic development interventions are also aimed at supporting employment and inclusive growth for the rising population in these spaces, including opportunities for enterprise development, a wide range of green and blue economic and industrial activities and the importance of recognising the limitations and potential associated with natural resources, recognising interrelationships in the energy, water and food nexus.

- Within the various provinces, the regional development priorities are typically captured within the provincial growth and development strategies (PGDSs) and provincial spatial development frameworks (PSDFs), under review every 5 years, and of value in considering socio-economic impact of the proposed gas transmission pipeline. The current frameworks highlight the importance and growth potential of significant cities and towns, and also place significant emphasis on context specific regional economic drivers and alignment of infrastructure investment in support thereof.
- Within a local context, investment planning and implementation of various agencies need to be incorporated into, and influenced by, municipal integrated development planning processes and subsequently reflected in municipal Integrated Development Plans (IDPs) and municipal Spatial Development Frameworks (SDFs). Large scale infrastructure investment design and implementation at municipal level will need to consider planned sector investment focus within Integrated Infrastructure Investment Frameworks (provincial and municipal), Capital Investment Frameworks (municipal) and spatially targeted budgeting instruments introduced and under development by National Treasury (i.e. within cities and intermediary cities), as well as sector specific integrated housing plans, integrated transportation plans and integrated disaster management plans;
- With regards to land development, the relevant land-use management schemes must be used to guide spatial development and change of land-uses. Land-use-management schemes are largely in place for towns, however in many cases not yet completed or managed with the necessary capacity in many local municipalities. In the Western Cape, local municipalities have all complied to the requirements of the Western Cape Land Use Planning Act (LUPA) (introduced in accordance with the national Spatial Planning and Land Use Act (SPLUMA)).

Integrated spatial and development planning and intergovernmental alignment with regards to infrastructure investment and management is therefore critical in enabling sustainable and coordinated development within the respective regional contexts. Coordinated inter-governmental planning with regards to national and regional infrastructure investment, to enhance developmental impact and efficiency, and diminish any negative impacts at local level is also quite a challenge in the context of a plethora of spatial and integrated development planning and governance instruments (see Figure 2), all requiring annual review, adaptation and alignment.

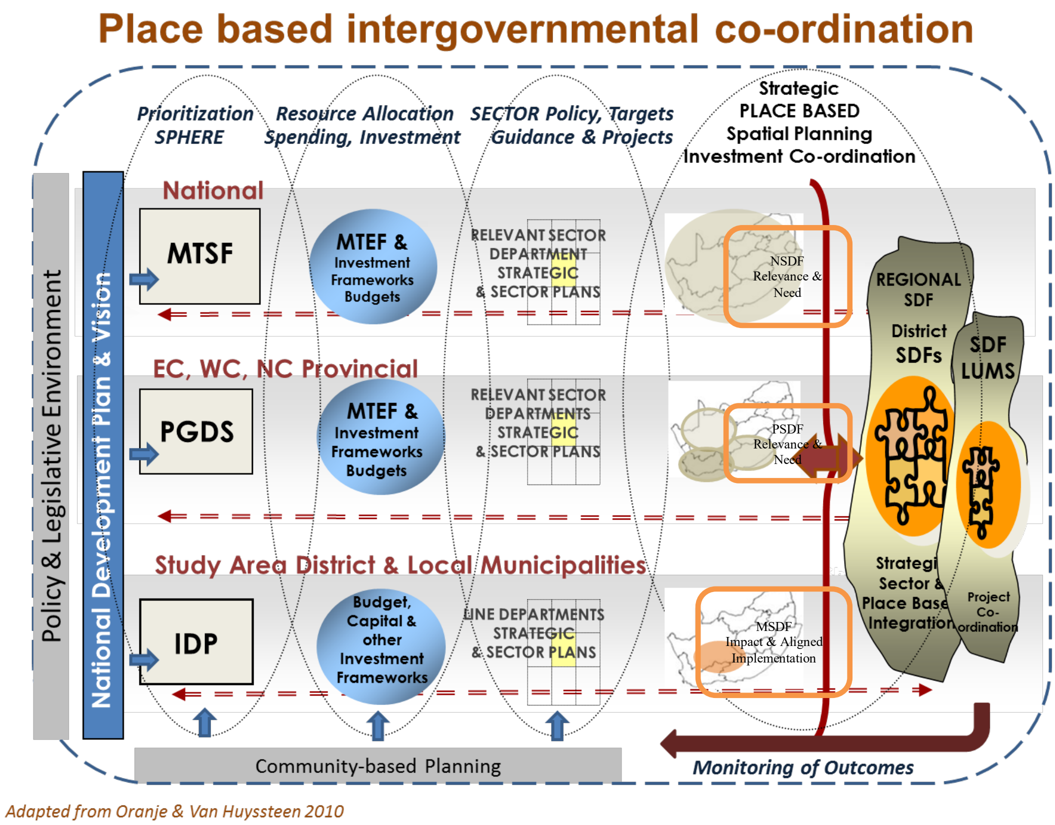

Figure 2: Overview of Relevant Integrated Spatial and Development Planning Instruments
(Adapted from Oranje and van Huyssteen 2010)

It is both (1) legally mandated and (2) evident that government needs to create an enabling and guiding context for development and investment in the country through effective pro-active and coordinated planning, budgeting and targeted investment and governance, the risks and mitigations associated with the possible impact of the gas pipeline extension on land, infrastructure and settlements could, in many respects also be addressed through such pro-active planning.

The servitude planning and proclamation will need to comply with local land use planning regulation and be included in negotiations as part of Local SDF and Land Use Management Schemes all of which need to comply with the SPLUMA regulations or provincial regulations, where provincial planning legislation is in place (such as for parts of the corridor that fall within the Western Cape Province).

There is a wide range of development activities directly and indirectly related to pipeline development. However the key focus of this chapter is specifically in highlighting implications related to urban development and spatial planning. Consideration with regards to land development in the chapter is more focussed on the impact for the developer, within the area related to the number of stakeholder that the developer will have to engage with in obtaining the required rights for servitudes and pipeline construction than land use change applications per se. No consideration was given to differential land value, neither the different use value or intensity of use or attachment of individuals to any land parcel given that this data is not readily available. Should this be considered relevant, such studies will have to be undertaken and the data purchased or surveys undertaken. This can more realistically be done closer to development once all other factors environmental and geo-technical factors have been considered. Nonetheless considerable support will be required by municipalities with regards to capacity and resources to effectuate the institutional arrangements and processes to support municipal orientated land use decision-making required within SPLUMA as related to planning permission and servitude declaration.

The challenges related to ensure high quality wall-to-wall land use management schemes, to enhance collaboration between tribal authorities and municipalities with regards to management of land development rights in many areas, to streamline possible procedural uncertainties and to increase capacity within the complex regulatory system, are well recognised.

The process associated with prioritisation of certain phases and time lines of the gas transmission pipeline will need to consider the need and relevance for national and regional development objectives and will require identified need, priorities for phasing and prioritisation for implementation.

The process associated with acquiring the required rights, with detailed planning and implementation of gas transmission pipeline development will need to be designed to contribute to integrated and coordinated planning and governance between different authorities and especially local role players in the region to ensure that development is done considering the public good and impact on local economies and the vulnerable.

1.2 Disaster Management

1.2.1 What is a disaster?

The International Federation of Red Cross and Red Crescent Societies (IFRC) defines a Disaster as a "serious disruption, occurring over a relatively short time, of the functioning of a community or a society involving widespread human, material, economic or environmental loss and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (IFRC, 2018). This is further supported by the definition outlined in the Disaster Management Act (Act 57 of 2002) that defines disaster as a progressive or sudden, widespread or localised natural or human-caused occurrence which:

1. Causes or threatens to cause (i) death, injury or disease; (ii) damage to property, infrastructure or the environment; or (iii) disruption of the life of a community; and
2. Is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using only their own resources.

Factors that influence the magnitude of a disaster are vulnerability (this can be people or the environment), the hazard (fire, leak, or explosion) and the capability to respond to it (access to resources) (IFRC, 2018). A pipeline incident can result from the operation of the gas pipeline system itself (aging, corrosion etc.), or from a human error, or they may be an indirect result of another emergency such as a structure fire or motor vehicle crash (Parsley and Schwab, 2000). Incidents may also be caused, directly or indirectly, by natural events such as storms and flooding. An incident that cannot be managed by local resources would be considered a disaster.

Compared with other methods for transporting hazardous chemicals, such as rail or road, transmission pipelines are relatively safe and transmission pipeline accidents have caused few fatalities. However, a single incident can have devastating environmental, health, and economic consequences (Osland, 2015). In addition to acute accidents, chronic spills from transmission pipelines can have negative repercussions on human health and the environment through contamination of drinking water, reduction in air quality, or other long-term environmental damage. Gas pipeline accidents would therefore qualify as disasters.

1.2.2 The responsibility to Disaster Management in South Africa

South Africans have relatively little experience of gas pipelines and Disaster Management (DisM). DisM in the South African context, and the capability of public institutions to anticipate, prevent, manage, and mitigate potential gas-related disasters must therefore be adequately considered to ensure that risks are appropriately identified and managed. DisM as a function typically has to be shared between government (representing the public good and public resources) as well as key organisations (such as Pipeline Developer). Each party needs to play a critical role in managing DisM. Governments are best able to cope with large, uncertain risks and key organisations (such as the Pipeline Developer), in turn, have the technical expertise required to deal with complex high-tech incidents. Disasters are much better prevented than managed, and this requires pre-emptive capacity-building. When disasters happen, they are best managed in collaborative ways, bringing together political, fiscal and technical resources. For this to happen, institutional capacity must be systematically developed. Furthermore, community empowerment is critical – in terms of understanding risks, appropriate responses, and community-level forms of assistance during actual disasters. Every single dimension of resilience which is built before a disaster pays handsome dividends if and when a disaster were to occur.

This raises the question of the capacity of the state, within its various agencies, to undertake the DisM function. The financial issue is a critical one: the issue for some governments is not only the absolute size of the risk; it is also the relative ability of a municipality or a country to dedicate resources to dealing with the risk (Freeman 2003:38). If Government is generally under financial pressure, then it is difficult to move resources from other sectors to the DisM function. This trade-off is faced almost anywhere in the world, where limited budgets have to be allocated to competing priorities and functions. Funding Disaster Management is always a challenge, because this has to be done before disasters happen; many stakeholders prefer to spend scarce funds on immediate and pressing functions. In South Africa, this phenomenon has been exacerbated because there is almost no specific funding allocated for disaster risk reduction efforts across the spheres of government (PMG, 2015).

In fact, the degree and types of disaster planning in place in developing countries vary considerably. The existence of government agencies says nothing about the quality of their operations in either planning or managing disasters (Quarantelli 2003:218). There may well be DisM policy papers and legislation in place, without it being translated into practice, either because of a lack of political will, or inadequate planning, or financial constraints. South African municipalities' lack of planning and management capacity have been extensively highlighted (e.g. Atkinson 2009; Koma 2010). In March 2018, the Minister of Co-operative Governance and Traditional Affairs (COGTA), Mr Zweli Mkhize, found that 31% of municipalities are almost dysfunctional, and a further 31% are fully dysfunctional. He announced a rapid programme of support for "municipalities in distress" (http://www.cogta.gov.za/?p=3447).

Another challenge is that disasters may need to be managed in cross-jurisdictional ways. Pipeline hazards, in particular, may be a regional issue. Pipeline ruptures could affect several communities or jurisdictions. Pragmatic forms of intergovernmental collaboration may well be required for hazard mitigation (Osland 2015).

Interestingly, pipeline-related hazards have often been accorded low priority, with a lack of stakeholder interest in pipelines, inconsistent regional policies for pipelines, and insufficient knowledge about pipelines (Osland 2015, writing about the United States). People are less likely to prepare for low-probability high-impact events (such as pipeline accidents) than for high-probability low-impact events (such as winter weather). The underground location of transmission pipelines may create a perception that they are less risk-prone.

A central theme in contemporary approaches to DisM is to promote risk mitigation, and to build resilience. Disasters are much better prevented than managed, and this requires pre-emptive capacity-building. When disasters happen, they are best managed in collaborative ways, bringing together political, fiscal and technical resources. For this to happen, institutional capacity must be systematically developed – and this may take years. Furthermore, community empowerment is critical – in terms of understanding risks, appropriate responses, and community-level forms of assistance during actual disasters. Every single dimension of resilience which is built before a disaster pays handsome dividends if and when a disaster were to occur.

2 SCOPE OF WORK

This chapter provides guidance on the alignment of the proposed gas corridors and assesses potential impacts that the construction of a gas transmission pipeline within the proposed corridors may have on communities' livelihoods, including well-being in local communities and safety hazards, temporary construction related job creation, disruption of population and service delivery. For the operational phase, the assessment considered the preparedness of public institutions to effectively respond to a disaster.

This chapter does not consider the economic opportunities, location of key industries and developments or key bulk users that may benefit from having access to the gas pipeline network. A separate high level economic opportunities assessment was undertaken to inform this SEA (included in Appendix 1 of Part 1 of the Gas Pipeline SEA Report).

2.1.1 Construction phase considerations

The alignment planning, servitude demarcation and construction of the pipeline will have wide-ranging impacts on settlement and development fabric in all parts of the identified final corridor and can potentially impact land development, town growth and sustainable regional and settlement development. This study therefore also examines implications related to urban development and spatial planning, effects of the construction of a gas transmission pipeline on land use management (land use application, servitude proclamation and the required changes to land use schemes, if and where applicable, risks of resettlement, development pressure) and anticipated complexities where the gas transmission pipeline would cross land on communal tenure (tribal authority areas).

The implications of gas transmission pipeline construction on agricultural land use are briefly addressed within a separate chapter (Part 4.2.4 of the Gas Pipeline SEA Report).

Once the construction is complete and affected land restored to the same or better level of development, the impact on the built environment will be negligible with the exception of any severance impact of servitudes. Land access for maintenance and/or accidents is considered to be low / unlikely. Thus a sensitivity assessment of this phase is not considered separately as it is encompassed in the planning stages with respect to servitudes.

Given the closed linear nature of pipelines, any post construction benefits (if any) to the community, can only be considered at specific identified interface / distribution nodes once specific interface points are identified. The identification of the locations of any interface point is unlikely until such time as a final alignment is selected. Thus any impact of specific distribution / interface locations cannot be considered at this time. Suffice to say, if gas becomes available, any town which has significant industry activity would have an alternative energy supply option available, but the likely derived benefit will be subject to costs of gas versus other energy forms available as well as technological and manufacturing feasibility. Another key question is the funding and construction of the local gas reticulation network to transport the gas transmission pipeline to the end users. There is insufficient information available to asses any benefit to a community at this stage.

2.1.2 Operational phase considerations

Although ruptures of gas transmission pipelines are relatively rare, impacts on surrounding communities in such an unlikely event may be catastrophic. Safety and disaster management are therefore key aspects of gas transmission pipeline planning and operations. The question of DisM, in the South African context, and the capability of public institutions to anticipate, prevent, manage, and mitigate potential gas-related disasters are therefore also considered in this Chapter. Several key factors need to be noted:

- The South African governmental “architecture” is very complex, due to the significant degree of decentralization which is built into the Constitution. National, provincial and municipal governments have complex allocations of powers and functions.
- The fire-fighting task is fundamentally bifurcated – between urban-focused legislation on Fire Brigades, and rural-oriented legislation on veld and forest fires. Each of these approaches involves a different institutional sector – respectively, the Department of Co-operative Governance and Traditional Affairs (COGTA), and the Department of Agriculture, respectively.
- In practice, intergovernmental relations are as much determined by organisational capacity as it is by Constitutional or legislative procedures. Such institutional capacity includes factors such as the tax or resource base, the number and type of staff, the level of skills, and political coherence.

- Various pieces of legislation, passed at different times in history, may still be relevant, and interact with one another in complex ways. In particular, the fire-fighting function is still largely "governed" by an Act passed in 1987, with several subsequent adjustments.

3 APPROACH AND METHODOLOGY

This assessment includes basic socio-economic conditions, land uses and key towns within the proposed gas corridors. The following socio-economic indicators have been used:

- Population numbers;
- Population growth (1996 to 2016);
- Population density;
- Economic sector and economy size; and
- Unemployment levels;
- Settlement footprints.

Note that this Specialist Assessment Report was peer reviewed prior to release to stakeholders for review. The report was updated, as required, following the peer review findings. A copy of the peer review report and responses from the Specialist Team is included in Appendix G of this report.

3.1 Sensitivity analysis in support of key social, settlement planning and development considerations

The sensitivity of the study area towards to the construction and operation of a gas transmission pipeline network will be assessed with respect to three key components of the built environment (refer to Appendix A.1 and A.2 for a description of data processing used to define the sensitivity criteria):

- Sensitivity in terms of population density: the number of people, households and dwellings affected. Due to the potential impact of construction and/or potential safety hazards related to the gas transmission pipeline construction and operation on lives and livelihoods of people within the proposed identified corridors, the areas of high population density are foreseen as highly sensitive in relation to the planned gas transmission pipeline. These specifically include cities, large coastal and inland towns and other densely settled areas.

- Sensitivity in terms of development intensity and extent: settlement development and economy extent, size and complexity. Settlement and development nodes play critical roles as:
    - Dense clusters of complex socio-economic and ecological systems providing access to housing, services and livelihood opportunities;
    - As anchors in local and regional economies through agglomeration benefits for social and economic functions;
    - Provision of centralised social services within the broader areas;
    - As infrastructure nodes within transport, trade, service delivery and engineering service networks.

- Sensitivity in terms of land-use management and tenure: the complexity of the land ownership issues in different parts of the proposed gas corridors. The key characteristic of this component is the number of impacted land holders and municipal authorities.

  Consideration with regards to land-use management and tenure in the chapter is more focussed on the impact for the developer, within the area related to the number of stakeholders that the developer will have to engage with in obtaining the required rights for servitudes and pipeline construction than land use change applications per se. No consideration was given to differential land value, neither the different use value or intensity of use or attachment of individuals to any land parcel given that this data is not readily available. It must be noted that agricultural value has been included as part of the agriculture sensitivity analysis and impact assessment. Should this be considered relevant, such studies will have to be undertaken and the data purchased or surveys undertaken. This can more realistically be done closer to development once all other environmental and geo-technical factors have been considered and once a final route has been identified.

In terms of assessment of land ownership and the likely complexity of negotiations, the assessment considered the likelihood of the pipeline passing though Tribal Authority land that is communally owned and managed versus land that likely to have freehold title. It should be duly noted that in addition to Tribal Authority Land (Former Bantustans and TBVC states) other forms of communal tenure exist elsewhere in the country. Most of this communal land is held (owned) by the State and registered under the Department of Rural Development and Land Affairs. Examples include parts of the Northern Cape Richterveld region as well as parts of the Eastern and Western Cape claimed by KhoiSan indigenous people. Land tenure, usufruct and land use rights (especially of communal land) are highly complex and subject to several recent legal processes and findings in South Africa. It is thus proposed that once the pipeline alignment is closer to finalisation that this issue is considered in local context and considering the current status quo.

Further due to the sensitivity with regard to the extent and ownership of the land, unresolved land claims and any potential “expropriation” and the use of State land for land restitution purposes; this data is not readily available, and GIS layers cannot be made publicly available in GIS format.

3.2 Status of municipalities preparedness

The following procedure was used to get a basic profile of strengths and weaknesses of the various municipalities (a total of 163 municipalities were surveyed) in terms of Disaster management preparedness:

1. Using the website www.municipalities.co.za (hosted by National Treasury) as the key source of information.
2. Selecting municipalities’ annual reports required to be submitted to National Treasury. This is a very useful repository, as information is provided according to specific formats. The latest report available (usually 2015/2016 or earlier version) was consulted. Difficulties arose when municipalities either did not supply such annual reports, or they were only partially filled in, or they used other formats which failed to provide comparable data.
3. Where annual reports were unavailable or incomplete, municipal Integrated Development Plans (IDPs) were consulted. However, IDPs generally focus on future goals and targets and do not often provide *actual* status quo information, in addition, in some cases IDPs were also not available.

Where comparable information was available, the following data was extracted, as indicators of municipal preparedness which was ranked from “marginal” to “good”:

1. Their status as **“main” or “satellite”** fire-fighting offices.
2. Number of fires and incident call-outs.
3. Number of fire fighters, disaster management volunteers and volunteers.
4. Number of vacancies (unfilled posts).
5. Number of “appliances” (vehicles and specialised equipment).
6. The repairs expenditure, to show municipal commitment to Operations and Maintenance.

Results of this assessment are shown in Figures 7 and 8.

3.3 Data Sources

Table 1: Data Sources

Data title	Source and date of publication	Data Description
CSIR Functional Town Areas, 2018	CSIR, 2018	Set of settlements or settlement areas classified largely on the basis of economic and demographic information. Drawn on the base of the CSIR mesozones from 2017. *(See Appendix E for description of CSIR Functional Town Typology, 2018)*
Settlement footprint layer, 2017	CSIR, 2017	This item aims to provide a more accurate extent of the built up footprints of South Africans settlements. It uses the Enumerator Area (EA) layer as the base, but manual adjustments were made where an EA extends beyond the built up areas.
Demographic nformation, disaggregated	Base Sources: StatsSA, 2011, Quantec, 2016 Spatial specific indicator: CSIR, Meso-frame Socio-Economic Indicators, 2017	This consists of a series of datasets from various sources as indicated. The CSIR Built Environment department has developed an algorithm, based on a hybrid method between dasymetric mapping and areal interpolation, to re-assign the socio-economic data from these different sources to the relevant analysis units, e.g. mesozones or settlement footprints.
Economic information disaggregated	Base source: Quantec, 2016 Spatial indicator: CSIR, Meso-frame Socio-Economic Indicators, 2017	Information drawn from Statistics SA but processed by Quantec to provide a year to year data series. Similar to the demographic information, the information is then processed/assigned to the relevant analysis units.
Major initiatives with potential impact on growth	Plans and development frameworks.	Range of official sector and/or provincial and/or State Owned Enterprise SOE plans and development frameworks.
Various municipalities' annual reports submitted to National Treasury	www.municipalities.co.za	Hosts annual reports submitted by local municipalities to the National Treasury.

3.4 Assumptions and Limitations

This assessment is based on high level information available based on census data and desktop literature available.

No information on the potential employment opportunities during the construction phase, the exact transhipment/distribution points or employment likely at these points and relative quantity and cost of gas or the use were available or explicitly used for this assessment, as such information would be available on a project-by-project basis. Therefore, the following assumptions were made in this regard:

- Limited short term local employment opportunities will be created, mainly during construction;
- Limited long term maintenance employment will be created, mainly with a level of skill required; and
- Some long term employment at main distribution points will be created. Note that the scope of this SEA is limited to the development of high pressure transmission lines, i.e. distribution lines are not included.

Detailed interviews with residents, site visits to the key towns within the corridors, finer scale assessments based on the receiving socio-economic environment of a specific area, direct and indirect employment opportunities and associated benefits would be considered on a project level and have therefore not been considered as part of this assessment.

It is also assumed that industry can make the technology switch to gas if cost effective and that there will be some benefits relating to wider range of energy generation and use options. It is anticipated that there will be no wide scale switch to gas for household use.

In addition, this study focuses on the DisM preparedness (including institutional capacity and resilience) of South African government agencies and not on the capacity of Pipeline Developer since it is assumed that the latter will have adequate technical skills to anticipate and manage possible accidents.

The fire-fighting data used within this analysis is highly specific for the fire-fighting function and must be regarded as, at best, a very limited proxy for actual disaster management capability. Furthermore, comparing DisM preparedness is not a straightforward matter, for at least four main reasons:

1. The sheer number of District and Local Municipalities potentially affected by a gas corridor.
2. The incompleteness of comparable data, in terms of municipal reporting.
3. The difficulties in comparing the balance between District and Local Municipalities, as regards the Disaster Management function (due to the existence of a vast array of possible kinds of relationships).
4. Choosing useful indicators, and appropriate definitions of such indicators, to capture the issue of municipal preparedness appropriately.

The ratings provided to municipalities DisM preparedness (i.e. no available information to good) are not reflective of the municipalities' general ability to effectively govern and/or supply services but is merely used to visually represent a municipality's current preparedness to respond to a disaster. However, given the extent of the corridors and the data available, the information is deemed sufficient in highlighting potential areas of concern.

4 RELEVANT REGULATIONS AND LEGISLATION

Regulations and legislation applicable from an economic, settlement planning and disaster management perspective is outlined in Table 2 Further details on legislation and regulations related to disaster management can be found in Appendix F.

Table 2: Relevant regulations and legislation relevant to gas pipeline development

Instrument	Key objective
International Instrument	
World Bank Operational Policy (4.12) on Involuntary Resettlement (Revised in 2011)	Involuntary resettlement may cause severe long-term hardship, impoverishment, and environmental damage unless appropriate measures are carefully planned and carried out. For these reasons, the overall objectives of the Bank's policy on involuntary resettlement are the following: (a) Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs. (b) Where it is not feasible to avoid resettlement, resettlement activities should be conceived and executed as sustainable development programs, providing sufficient investment resources to enable the persons displaced by the project to share in project benefits. Displaced persons should be meaningfully consulted and should have opportunities to participate in planning and implementing resettlement programs. (c) Displaced persons should be assisted in their efforts to improve their livelihoods and standards of living or at least to restore them, in real terms, to pre-displacement levels or to levels prevailing prior to the beginning of project implementation, whichever is higher.
International Finance Corporation (IFC) Performance Standards (PS) on Labour and Working Conditions (2012)	For any business, its workforce is its most valuable asset. A sound worker-management relationship is key to the success of any enterprise. PS2 asks that companies treat their workers fairly, provide safe and healthy working conditions, avoid the use of child or forced labour, and identify risks in their primary supply chain. The key objectives are: • To promote the fair treatment, non-discrimination, and equal opportunity of workers. • To establish, maintain, and improve the worker-management relationship. • To promote compliance with national employment and labour laws.

Instrument	Key objective
	• To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and workers in the client's supply chain. • To promote safe and healthy working conditions, and the health of workers. • To avoid the use of forced labour. Performance Standard 2 apply to both direct workers on the Project and also to indirect workers, including requirements in relation to primary supply chain employees and contracted workers and fair treatment of migrant workers. Employers are required to make "commercially reasonable efforts" to ascertain that the third parties who engage such workers are reputable and legitimate enterprises and have an appropriate Environmental and Social Management System (ESMS) that will allow them to meet the requirements of Performance Standard 2. Requirements are also set out for fostering workers organizations in jurisdictions where there is substantial interference in workers' freedom of association. Where these types of restrictions manifest, Performance Standard 2 requires employers to take steps to engage with workers to address issues relating to their working conditions and terms of employment, to the extent permissible by law. Employers must not impede workers from developing "alternative mechanisms" to express their grievances and protect their rights regarding working conditions and terms of employment. Alternative mechanisms include recognizing worker committees and allowing workers to choose their own representatives for dialogue and negotiation over terms and conditions of employment in a manner that does not contravene national law. Such mechanisms must be free from interference, influence or control by employers.
IFC PS on Environmental and Social Sustainability (Revised in 2012), specifically PS 5: Land Acquisition and Involuntary Resettlement, specifically PS 5: Land Acquisition and Involuntary Resettlement	PS 5 recognizes that project-related land acquisition and restrictions on land use can have adverse impacts on communities and persons that use this land. The key objectives are: • To avoid, and when avoidance is not possible, minimize displacement by exploring alternative project designs. • To avoid forced eviction. • To anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation, and the informed participation of those affected. • To improve, or restore, the livelihoods and standards of living of displaced persons. • To improve living conditions among physically displaced persons through the provision of adequate housing with security of tenure at resettlement sites.
IFC PS 7: Indigenous People (2012)	PS7 seeks to ensure that business activities minimize negative impacts, foster respect for human rights, dignity and culture of indigenous populations, and promote development benefits in culturally appropriate ways. Informed consultation and participation with Indigenous People throughout the project process is a core requirement and may include Free, Prior and Informed Consent under certain circumstances. The key objectives are: • To ensure that the development process fosters full respect for the human rights, dignity, aspirations, culture, and natural resource-based livelihoods of Indigenous Peoples. • To anticipate and avoid adverse impacts of projects on communities of Indigenous Peoples, or when avoidance is not possible, to minimize and/or compensate for such impacts. • To promote sustainable development benefits and opportunities for Indigenous Peoples in a culturally appropriate manner. • To establish and maintain an ongoing relationship based on Informed

Instrument	Key objective
	Consultation and Participation with the Indigenous Peoples affected by a project throughout the project's life-cycle. • To ensure the Free, Prior, and Informed Consent of the Affected Communities of Indigenous Peoples when the circumstances described in this Performance Standard are present. • To respect and preserve the culture, knowledge, and practices of Indigenous Peoples.
IFC's Handbook for Preparing a Resettlement Action Plan (2002)	The purpose of this handbook is to provide guidance in the planning and execution of involuntary resettlement associated with IFC investment projects. IFC's policy on involuntary resettlement applies to any project that may result in the loss of assets, the impairment of livelihood, or the physical relocation of an individual, household, or community. The audience for this handbook includes: IFC clients; host government agencies that support private investment in development projects; nongovernmental organizations; and the people whose lives and livelihoods will be affected by projects financed by IFC.
African Development Bank's (AfDB) Policy on Involuntary Resettlement (2003)	The policy has the following key objectives: • To avoid involuntary resettlement where feasible, or minimize resettlement impacts where population displacement is unavoidable, exploring all viable project designs. Particular attention must be given to socio-cultural considerations, such as cultural or religious significance of land, the vulnerability of the affected population, or the availability of in-kind replacement for assets, especially when they have important intangible implications. When a large number of people or a significant portion of the affected population would be subject to relocation or would suffer from impacts that are difficult to quantify and to compensate, the alternative of not going ahead with the project should be given a serious consideration; • To ensure that displaced people receive resettlement assistance, preferably under the project, so that their standards of living, income earning capacity, and production levels are improved; • To provide explicit guidance to Bank staff and to the borrowers on the conditions that need to be met regarding involuntary resettlement issues in Bank operations in order to mitigate the negative impacts of displacement and resettlement and establish sustainable economy and society; and • To set up a mechanism for monitoring the performance of involuntary resettlement programs in Bank operations and remedying problems as they arise so as to safeguard against ill-prepared and poorly implemented resettlement plans.
National Instrument	
The Constitution of the Republic of South Africa (Act 108 of 1996)	Places a legal obligation on the government of South Africa to ensure the health (Personal and Environmental) and safety of its citizens. In terms of section 41 (1) (b) of the Constitution, all spheres of government are required to "*secure the wellbeing of the people of the Republic*". Section 152 (1) (d) also requires local government *"to promote a safe and healthy environment"*. In light of the above, and the established understanding of disaster management, a primary responsibility for disaster management in South Africa rests with government. According to Part A, Schedule 4 of the Constitution, disaster management is a functional area of *concurrent national and provincial legislative competence*. This means that national and provincial governments have a legal imperative to ensure that disaster management is implemented according to legislative requirements (i.e. the *Constitution of the Republic of South Africa, 1996* (Act No. 108 of 1996) and *Disaster Management Act, 2002* (Act No. 57 of 2002).
Prevention of Illegal Eviction from and Unlawful Occupation of Land Act	This Act came into effect in 1998 and set out to prevent the arbitrary eviction of occupiers of a site. The Act supports the Constitution which states that "No one may be evicted from their home, or have their home demolished, without an order of court made after considering all the relevant circumstances. No legislation may permit arbitrary evictions. This Act sets out the procedure to be followed in the case of such evictions.

Instrument	Key objective
Spatial Planning and Land Use Management Act (Act 16 of 2013): National Spatial Development Framework.	Guiding large scale development priorities and national sector investment. The current draft version of the Draft NSDF, 2018 clearly highlights (1) the importance of cities, regional towns and service nodes in gearing up for increased urbanisation, population growth and associated people centred economic activities, to support the current transitions in the national economy, and (2) the importance of cities, towns and service nodes as anchors in regional development and spatial transformation for South Africa. The growth of settlements within the coastal corridors and in existing in-land nodes up to 2050 is also clearly highlighted. The importance of alignment of large scale infrastructure planning in terms of relevance, need, prioritisation at national and regional scale identified. Section 19-20 of the SPLUMA makes provision for a Regional Spatial Development Framework (RSDF). The drafting of a RSDF may be the correct spatial planning vehicle to use in relation to the proposed bulk gas pipeline where 1) there is uncertainty as to the phasing and the timing of the project which may be implemented over decades 2) there is the need for provinces and municipalities to apply consistent criteria for the assessment of development applications to assist in a situation where most municipalities would not have had to deal with bulk gas transmission pipeline applications before 3) there is a need to bridge the planning gap between an environmental assessment that focuses on the *status quo* and an Environmental Impact Assessment (EIA) that is reactive to a particular development application 4) the geographical area under consideration includes a number of provinces and municipalities 5) the nature of servitudes, development criteria for bulk, distribution, point gas facilities and gas reticulation consideration for related facilities (e.g. industrial, residential retail uses) can be included in the framework (Note that this SEA only focuses on Transmission gas pipelines) 6) bulk gas servitudes need to be preserved for an extended period of time from urbanisation 7) there are differing capacities within municipalities to undertake SDFs. This would be a means of ensuring that the correct safety measures are included in developments from the planning phase.
Fire Brigade Services Act (Act 99 of 1987)	The Act established a Fire Brigade Board, which would consist of a chairperson appointed by the national Minister responsible for provincial and local government. Other members would be appointed by the four provincial Administrators, two persons designated by the South African Local Government Association, one person designated by the Minister of Finance, one person designated by the SA Emergency Services Institute, and three other persons designated by the Minister (one has to represent organised business, and one to represent organised labour). (Note that several of these government agencies, active in 1987, have subsequently changed their names and functions). Significantly, this Board has virtually never functioned effectively since 1994, and Government has recently made fresh attempts to promote its effectiveness. In terms of the *Fire Brigade Act*, Local Authorities[1] were allowed to ("may") establish and maintain a service in accordance with the prescribed requirements. It appears that this was not a definite requirement for all local authorities. Municipalities could make relevant by-laws or regulations for their areas of jurisdiction. This apartheid-era legislation has been adapted, in 1994, by the democratic Government. *Government Gazette* No. R 153, 1994 assigned the administration of the whole *Fire Brigade Services Act*, 1987 to the Provinces – with the exception of Section 2 (Fire Brigade Board) and Section 15 (Regulations), which remained with the national government. The key role of the municipalities remained intact. In terms of the new Constitution, adopted in 1996, fire-fighting is a "Schedule 4 Part B" function. This means that it involves concurrent national and provincial legislative competences, as well as being a municipal function.

[1] Note that these were still racially-defined local authorities (in 1987). The terminology has also changed since 1987: "Local authorities" are now referred to as "Local Municipalities" or "Metropolitan municipalities".

Instrument	Key objective
Major Hazard Installation (MHI) Regulations issued under Section 43 of the Occupational Health and Safety Act (Act 85 of 1993)	The MHI Regulations apply to employers and self-employed persons, who have on their premises, either permanently or temporarily, a MHI or a quantity of a substance which may pose a risk that could affect the health and safety of employees and the public. It also deals with on-site emergency planning, and requires that such planning must be discussed with the relevant local government and fire-fighting department. No local government shall permit the erection of a new MHI at a separation distance less than that which poses a risk to airports, neighbouring MHI, housing and other centres of population. The municipality is responsible for all off-site emergency plans.
National Environmental Management Act (Act 107 of 1998)	Section 30 of the Act, deals with the control of emergency incidents – defined as an unexpected sudden occurrence including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution. After such an incident, a responsible person must report it to the SAPS and relevant fire prevention service.
National Veld and Forest Fire Act (Act 101 of 1998)	The primary focus of this Act was to create Fire Protection Associations in rural areas, to predict, prevent, manage and extinguish veld fires. These Associations would be established and managed by local land owners. The Associations' rules have to include controlled burning to conserve ecosystems and reduce the fire danger. (Significantly, these Associations would cover regions which have regular veldfires, or relatively uniform climatic conditions and vegetation. It therefore created the possibility of associations which crossed municipal boundaries). A 2007 study found that Fire Protection Associations (FPAs) were generally well established & functional in most areas. In 2013, there were an estimated 219 Fire Protection Associations in South Africa, covering about 49% of South Africa's land surface (COGTA n.d.). The main implication, for the gas pipeline project, is that the more rural parts of the pipeline may be located in areas where there are Fire Protection Associations, with their own rules in force. They would function within the jurisdictions of municipalities, but they may also straddle municipal boundaries. The pipeline developer must therefore include municipalities and Fire Protection Associations in their disaster management planning procedures.
Disaster Management Act (Act 57 of 2002)	This Act requires the local government to also deal with disaster management responsibilities. It was an attempt to address the litany of problems faced by the fire-fighting sector. It provides for: • an integrated and co-ordinated disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post-disaster recovery; and • the establishment of national, provincial and municipal disaster management centres. For the purpose of the gas transmission pipeline SEA project, two requirements are significant: (a) The integration of prevention and mitigation methodologies with municipal IDPs; and (b) promote formal and informal initiatives to encourage risk-avoidance behaviour by private and public sector organisations.[2] This suggests that, as the planning process continues for the gas transmission pipeline SEA project, COGTA and the Disaster Management Centre must take *proactive* steps to plan for possible pipeline-related disasters.
Draft White Paper on Fire Services (2016)	This White Paper seeks to reposition the country's municipal fire services from a response-oriented approach towards a greater emphasis on fire prevention and risk reduction.
National Housing Code (2009) Policy developed in terms of the Housing Act (1997)	Chapter 4 of the Housing Code (2009) includes the provision of the National Housing Programme for Housing Assistance in Emergency Housing Circumstances. The programme's objective is to provide for temporary relief to people in urban and rural areas who find themselves in emergencies.

[2] Section 22 of the Disaster Management Act, No. 57 of 2002.

Instrument	Key objective
	National Housing Programme: Upgrading of Informal Settlements deals with the process and procedure for the in situ upgrading of informal settlements as it relates to the provision of grants to a municipality to carry out the upgrading of informal settlements within its jurisdiction in a structured manner. The grant funding provided will assist the municipality in fast tracking the provision of security of tenure, basic municipal services, social and economic amenities and the empowerment of residents in informal settlements to take control of housing development directly applicable to them. The Programme includes, as a last resort, in exceptional circumstances, the possible relocation and resettlement of people on a voluntary and co-operative basis as a result of the implementation of upgrading projects.
Provincial Instrument	
Spatial Planning and Land Use Management Act (Act 16 of 2013): Provincial SDFs	SDFs guide regional and spatial development and long term implications.
Integrated Infrastructure Development Frameworks	Integrated Infrastructure Development Frameworks guide and prioritise implementation for large scale infrastructure development. There are 16 key policy proposals set out in the 2016 White Paper on Fire Services.
Municipal Instrument	
Municipal Structures Act (Act 117 of 1998)	According to Section 84, fire-fighting functions are divided between district and local municipalities. A District Municipality (DM) has the following functions: • Planning, co-ordination and regulation of fire services; • Specialised fire-fighting services such as mountain, veld and chemical fire services; • Co-ordination of the standardisation of infrastructure, vehicles, equipment and procedures; and • Training of fire officers.
Disaster Management Plan of 2002	Each Metropolitan and District Municipality must establish and implement a framework for DisM in the municipality, which must include the local municipalities within the area. It should also be integrated with non-state actors. Such a framework must be consistent with the National and Provincial frameworks. Each Metro and District Municipality must establish a Disaster Management Centre. A District municipality must establish it after consultation with the local municipalities in its area; and it may operate such a Centre in partnership with local municipalities. The Amendment Act (2015) created an important role for Local Municipalities: "(3) A local municipality must establish capacity for the development and co-ordination of a disaster management plan and the implementation of a disaster management function for the municipality … 4) A local municipality may establish a disaster management centre in consultation with the relevant district municipality in accordance with the terms set out in a service level agreement between the two parties, in alignment with national norms and standards." A Municipal DisM Centre must advise other agencies on levels of risk, assessing the vulnerability of communities, increasing the capacity of communities to minimise risks and disaster impacts, and monitor the likelihood of disasters. It should promote risk-avoidance behaviour by state and non-state actors. This would presumably be an important point of contact for a pipeline operating organisation.
Spatial Planning and Land Use Management Act (Act 16 of 2013): Spatial Development Framework and Land Use Management Scheme	Municipal SDFs: SDFs guide municipal spatial development and investment, and coordinate intergovernmental investment in municipal areas. The importance of alignment of detailed planning and implementation at municipal scale required by SPLUMA, 2013 and Municipal Systems Act (MSA), 2000. Land Use Management Systems and Schemes provide for the development and land-use rights to guide development, ensure safety, sustainability and effective urban form.
Municipal Systems Act, (2000): Integrated Development Plan	IDPs guide investment and governance priorities within municipalities and their areas of jurisdiction. The importance of alignment of detailed planning and implementation in reflection of such implementation alignment within municipal

Instrument	Key objective
	IDPs and SDFs at municipal scale required by SPLUMA, 2013 and MSA, 2000.
Communal Property Associations Act (1996), Extension of Security of Tenure Act (1997) Ingonyama Trust Act (1994)	The issue of land rights in Traditional Authorities is a contentious issue where adopted legislation has not been implemented as intended, with different pieces of legislation applicable in different provinces.

5 DESCRIPTION OF FEATURES IN CORRIDORS

Figure 3 outlines the various corridor phases and the grouping of these corridors used within this assessment.

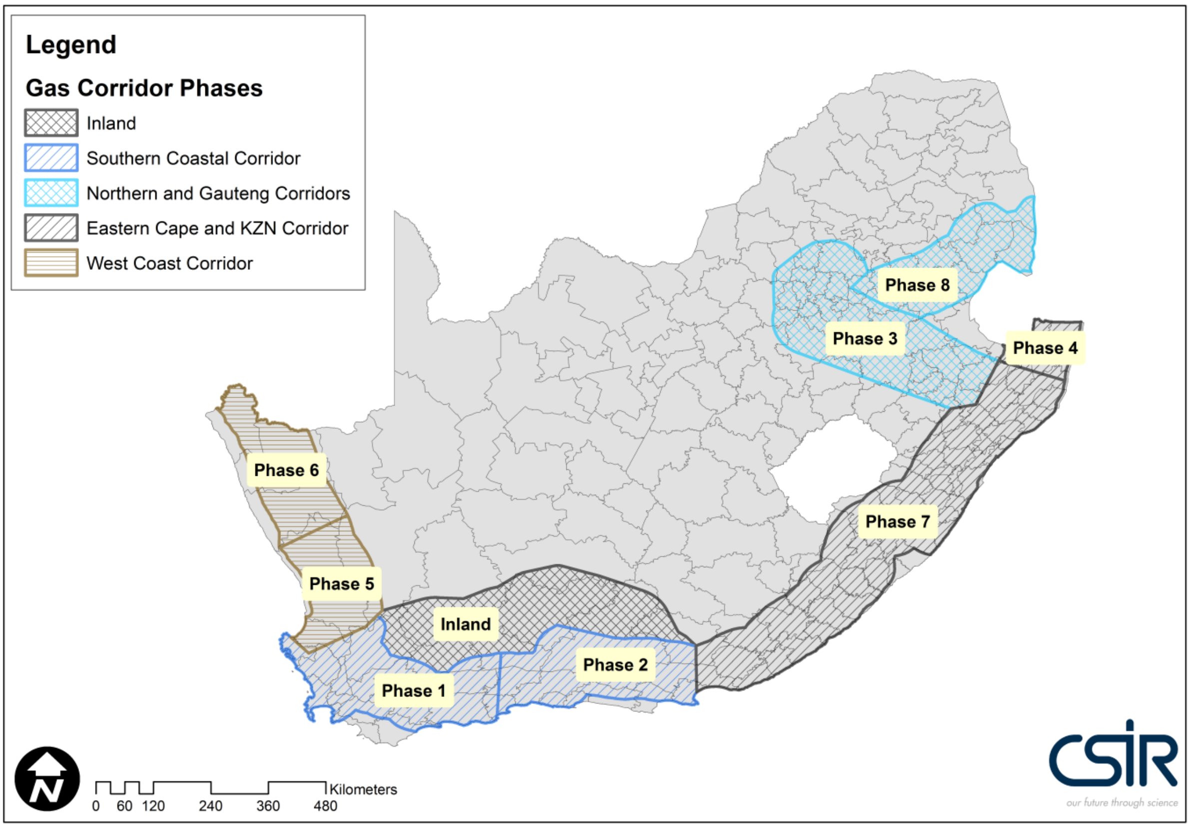

Figure 3: Corridor phases and associated grouping used in this assessment

Although it is highly unlikely that everyone will be affected by the gas transmission pipeline, it is estimated that the proposed total corridor area is home to about 35.7 million people, largely concentrated in dense rural settlements and a network of cities and towns. The most populous areas (shown in the figure below as population size) are within the main metropolitan areas of Cape Town (Phase 1), eThekwini (Phase 7), Gauteng (Phase 3) and Nelson Mandela Bay (Phase 2) (Figure 4). These are also the areas that show the most significant population growth between 1996 and 2016 (shown in the figure below as population growth) (Figure 4).

Of the 35.7 million, about 23.62 million live in large metropolitan areas, cities and large regional service centres (big towns), about 4.5 mill people in medium and large towns and about 1.45 mill people in small towns. Whilst these mostly constitute high density formal and informal settlement areas, the bigger city and town areas also constitute a significant number of traditional settlement areas which have the additional complexity of traditional or communal land tenure issues that need to be considered (StepSA Town Area Typology, 2018) (Figure 4). Within the major metropolitan areas and cities and large regional towns, more than 1 million people are actually living on traditional settlement land areas. More than 6 million people live in dense rural settlements in the study area, of which the majority (an estimated 5.9 million of this group) are settlements under traditional authority jurisdiction, largely in the east coast corridor area (shown in green in Figure 5), and only 31 000 in the sparsely populated areas (CSIR Settlement Footprint, 2017) (Figure 5). Refer to Appendix E of this report for further details on the description of the settlement typology and population numbers of all settlements impacted arranged by corridor groupings.

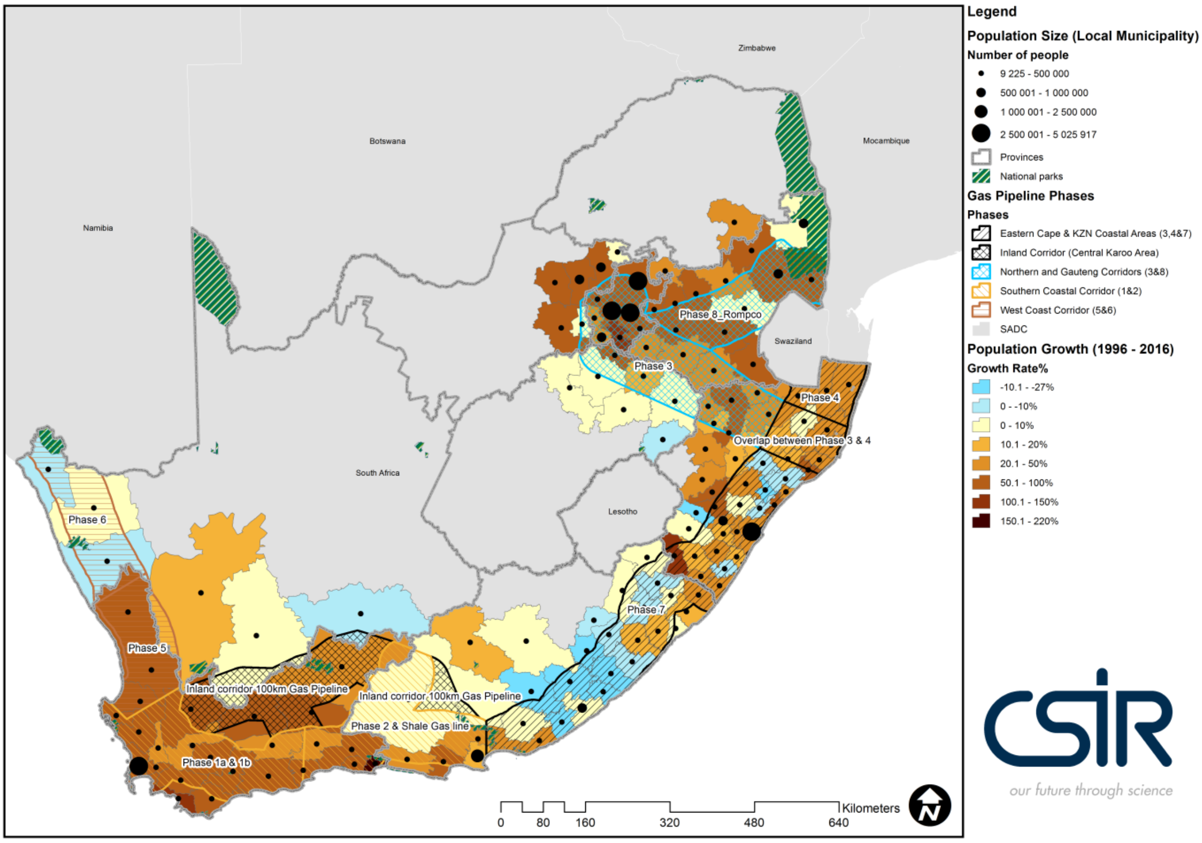

Figure 4: Population number and growth characteristics of local municipalities within the gas corridor *(Source: StepSA Town Area Typology, 2018)*

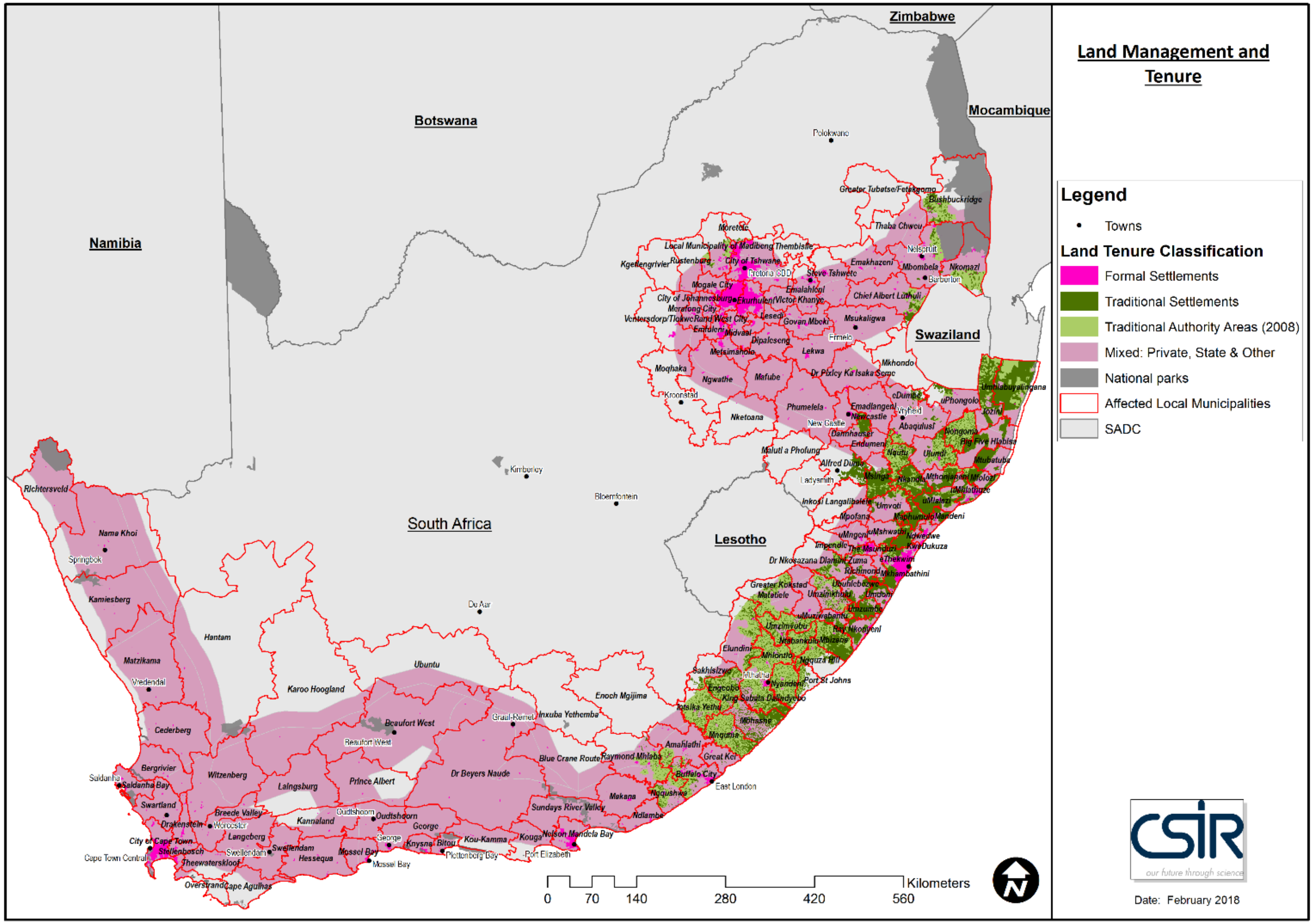

Figure 5: Land management and tenure in gas transmission pipeline corridor
(Source: StepSA Town Area Typology, 2018)

Unemployment levels (Figure 6) indicate the dire need for local employment opportunities, should this be provided during the construction phase. It also points to the vulnerability of the economic environment and that any interruption or disruption on the economy should be avoided.

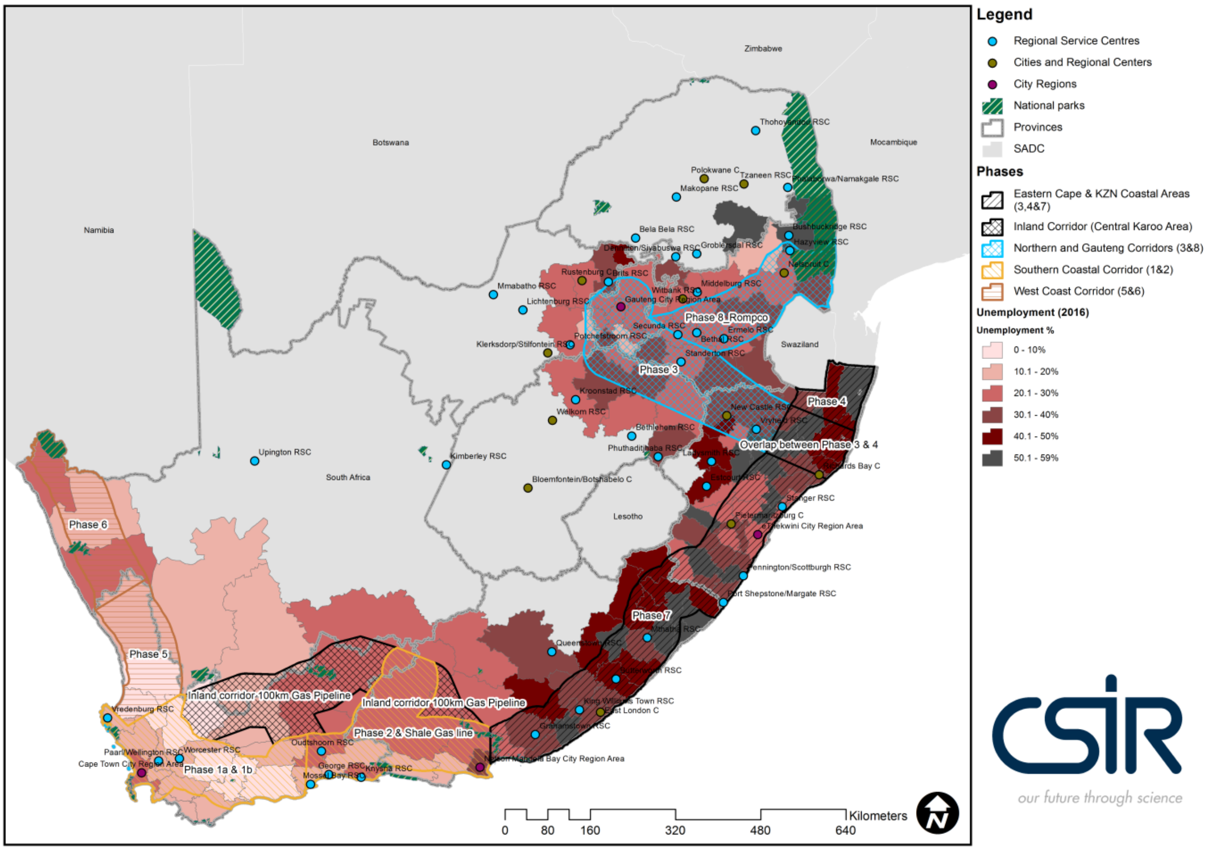

Figure 6: Unemployment percentages within municipalities
(Source: Van Huyssteen et al., 2018)

Figure 7 provides an overview of key new infrastructure (rail and road) in the affected areas. A review of development projects contained in available PGDSs (January 2018) in the corridor area can be found in Appendix E of this report. Given that time lines, phasing, scale, funding and spatial specific implications are not clearly evident from these studies and is subject to change, relevant local and provincial plans will have to be reviewed for each sector closer to the time of final construction. Available planning for the N2 road corridor and possible rail linkages in the same corridor in future is illustrated in Figure 7 to inform future alignment of the gas corridor servitude. Any other new servitudes of a linear nature for road and rail will need to be considered at the time of more detailed planning and implementation. At this stage no detailed alignment of new road or rail projects is available for public use and as such is not considered in detail. Final gas pipeline alignment must consider alternative projects in the area when the time comes.

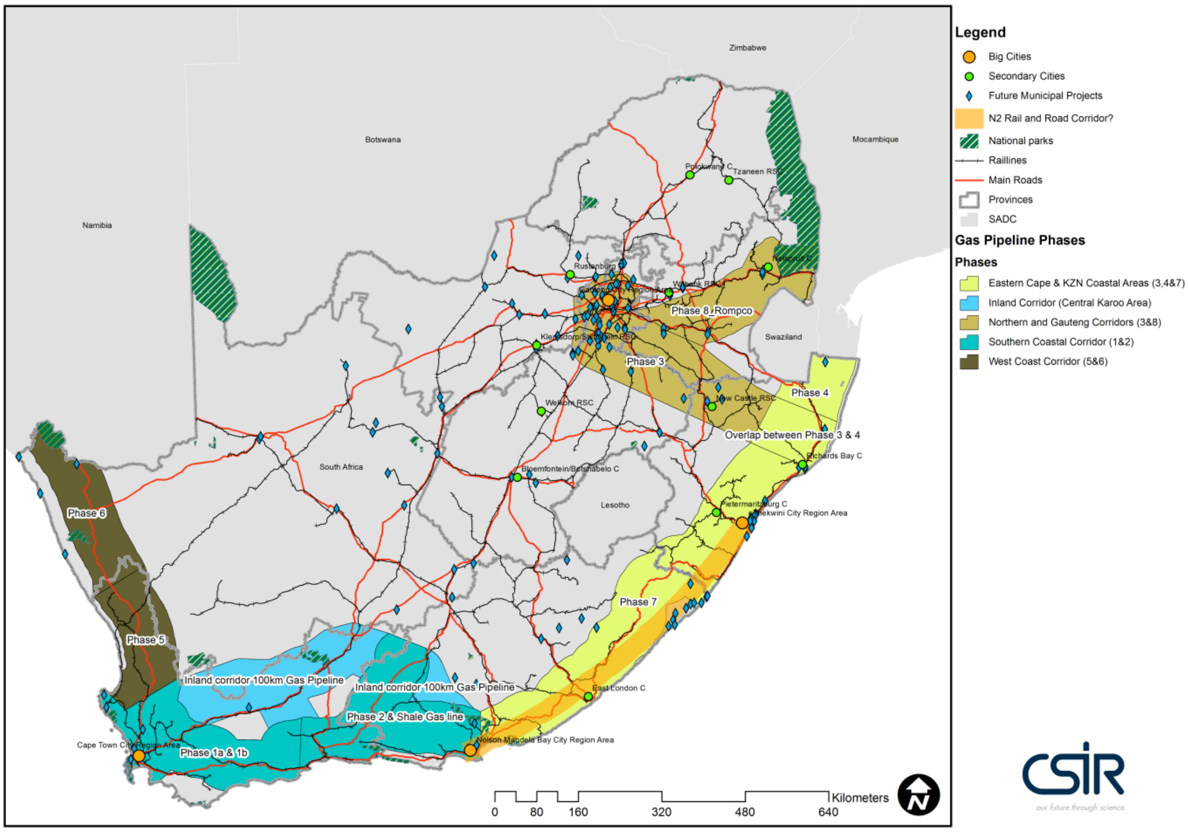

Figure 7: Road and rail infrastructure and planned municipal projects

Figures 8 and 9 show the DisM preparedness of the district (including metropolitan municipalities) and local municipalities that fall within the assessed corridors, in the unlikely event of a disaster. Details on the assessment results for the various municipalities assessed can be found in Appendix F.9. On a district level, the majority of the municipalities have a good to fair DisM preparedness currently in place. In terms of the local municipalities, the majority of the municipalities have a “marginal” rating or no information was readily available at the time of this assessment. The DisM preparedness are an important component of disaster management and would require upfront consultation and plans to ensure that the DisM functions are properly determined and the municipalities adequately capacitated to manage potential disasters.

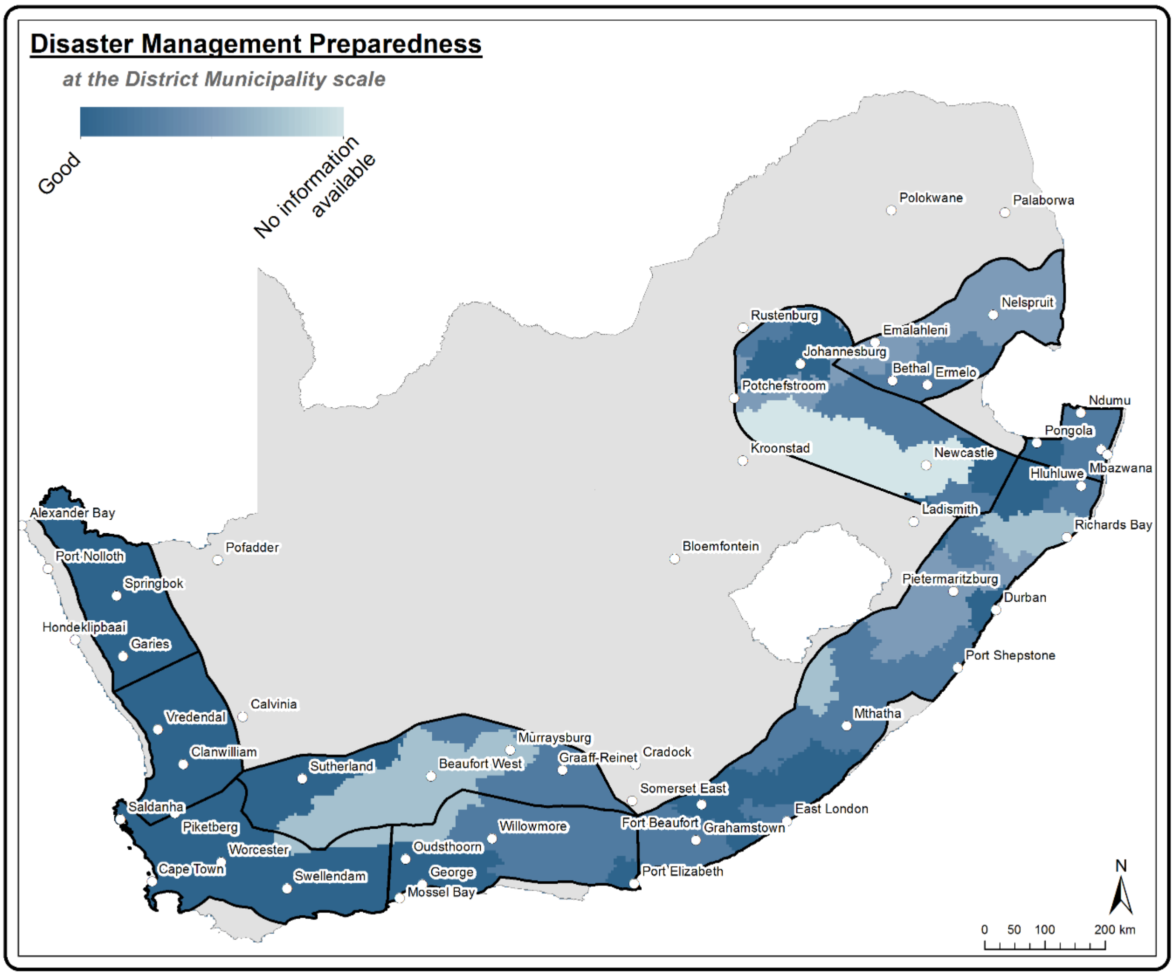

Figure 8: DisM preparedness of district municipalities that fall within the proposed corridors

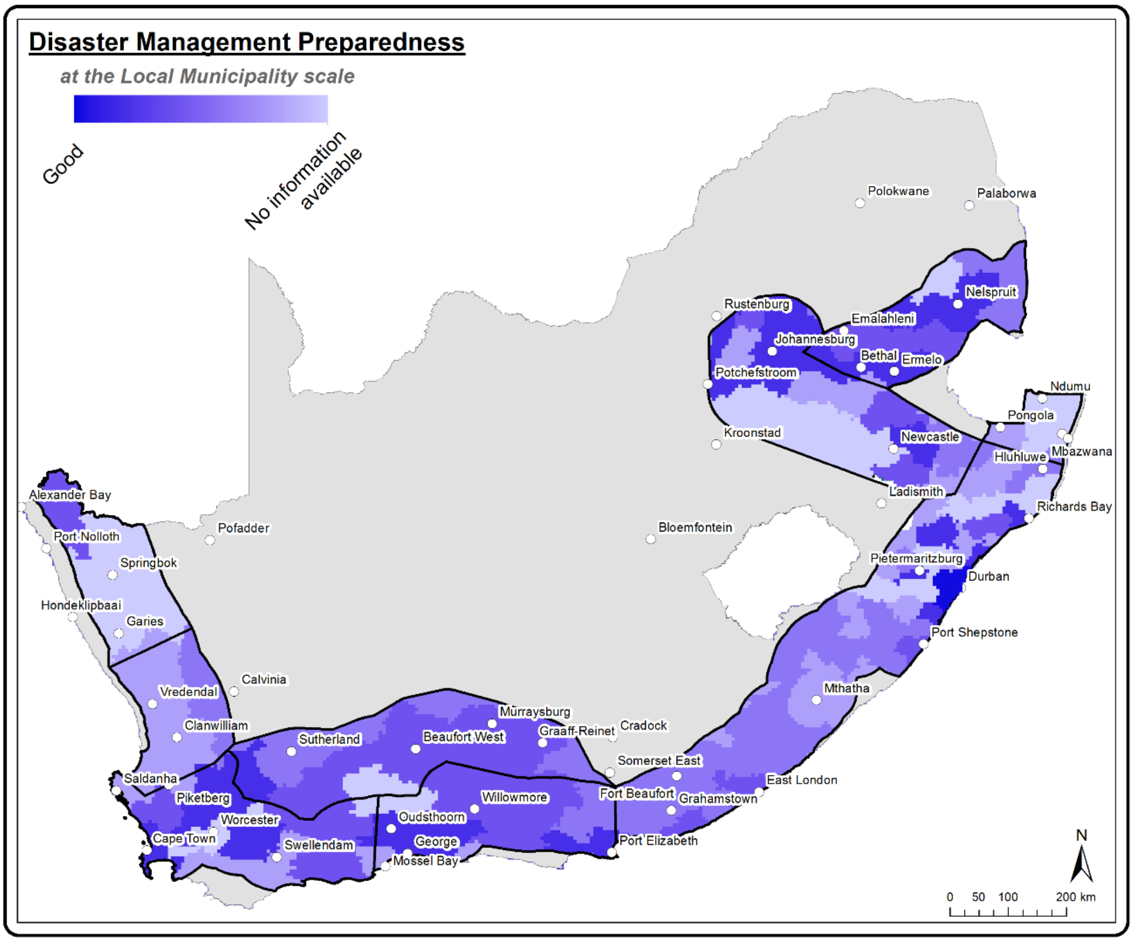

Figure 9: DisM preparedness of local municipalities that fall within the proposed corridors

5.1 Sensitivity mapping

As described in Section 3, the sensitivity of the study area with respect to the construction and operation of a gas transmission pipeline network was assessed with respect to three key components of the built environment, i.e. population density, development intensity and, tenure and land management (i.e. complexity of number of stakeholders involved in land negotiation) (individual maps are included in *Appendix C)*. Appendices A.1 and A.2 include a description of data processing used to define the sensitivity criteria. An overall sensitivity map for spatial and development planning, taking into consideration the three above criteria, is shown in Figure 10 below (refer to *Appendix D* for the individual overall sensitivity maps per corridor).

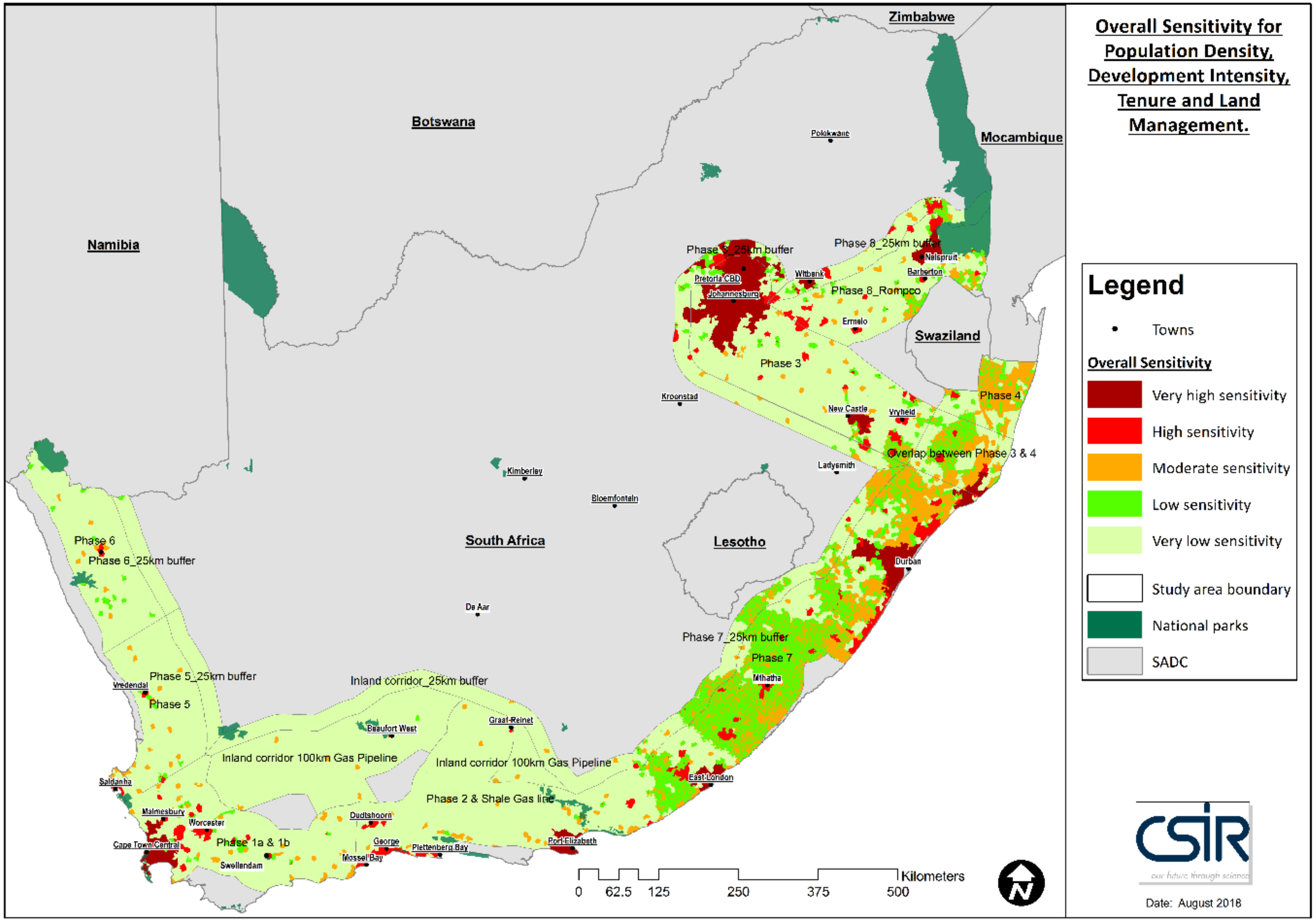

Figure 10: Overall sensitivity map for spatial and development planning

6 DESCRIPTION OF FEATURES IN EACH CORRIDOR

Table 3 below gives a brief description of the various corridors in terms of population, development intensity, land tenure and management, disaster management preparedness and overall sensitivity towards the development of a gas transmission pipeline

Table 3: Description of the Gas transmission Pipeline Proposed Corridors

Site	Brief description
West Coast Corridor Phase 5 and 6 Refer to Figures 7, 8 & 9, Appendix B (Figures B.1 to B.3), Appendix C (Figures C.10 to C.12) and Appendix D	These two phases cover the western coastal part of the country. These areas are characterised by small towns surrounded by arid and semi-arid areas and are the most sparsely populated and also declining in population. Areas within Phase 5 are mostly mixed economy while Phase 6 is mostly dependent on Government sector and services. The majority of the district and local municipalities that fall within this corridor have good to fair fire-fighting capabilities currently in place. ***The majority of this corridor has a low overall sensitivity as there are no areas of communal tenure and no large urban areas or areas of extensive economic activity. Commercial farmland covers the largest extent of the low sensitive areas. The corridor also contains some National Parks. There are a few areas of medium level sensitivity in a small number of towns with medium or dense population. These towns cover less than 5% of the area.***
Southern Coastal Corridor Phase 1 & 2 Refer to Figures 7, 8 and 9, Appendix B (Figures B.4 to B.6), Appendix C (Figures C.13 to C.15) and Appendix D	Includes large parts of the Western Cape Province extending along the coast as far as the Eastern Cape boundary. It includes the major metropolitan areas of Cape Town, the Winelands district and the southern coastal towns and Garden Route tourism corridor featuring a large number of towns and major economic infrastructure. Includes the large parts of the Eastern Cape Province Coastal areas including Nelson Mandela Bay Metropolitan. Areas within Phases 1 and 2 are mostly mixed economy. The area is also a very productive farming area, along the coastal plain between CPT and PE, also important tourist areas, plus national parks etc. See Table B.1 (Appendix A) for detail of towns and settlements affected. Various fire-fighting capabilities exists within this corridor depending on the district and local municipality being considered. Most of the district municipalities within the southern coastal corridors have good fire-fighting capabilities currently in place. Thirteen of the affected local municipalities (approximately 50%) have a 'fair to good' rating. The remainder of the local municipalities either do not have suitable fire-fighting capabilities currently in place or no information in terms of fire-fighting was readily available during this assessment. ***In this corridor the highest levels of sensitivity are within the greater Cape Town City Region area and around the coastal cities and medium sized service towns which have high populations and intensive development and economic activity. The low sensitivity areas in the corridor are dominated by sparsely populated commercial farmland.***
Inland Corridor (Central Karoo) Refer to Figures 7, 8 & 9, Appendix B (Figures B.7 to B.9), Appendix C (Figures C.4 to C.6) and Appendix D	This area is characterised by low density semi- arid farmland interspersed with small towns and rural villages. The area is the subject of Shale Gas exploration which may have a major impact on settlement growth and development in future. The northern section of the inland corridor is sparsely populated and also declining in population. Economy is highly dependent on Government sector and services. Within the Inland corridor various levels of fire-fighting capabilities exist, depending on whether district or local municipalities are being considered.

Site	Brief description
	In this corridor the highest sensitive areas are dominated by the medium sized service towns which include Beaufort West, Laingsburg and Prince Albert as well as smaller settlements like Nelspoort. These towns cover less than 1% of the area. The remainder of the area is of low sensitivity. Commercial farmland covers the largest extent of the low sensitive areas.
Eastern Cape & KZN Coastal areas (Phase 7, Phase 3 and 4 overlap, Phase 4, and part of Phase 3 Refer to Figures 7, 8 & 9, Appendix B (Figures B.10 to B.12), Appendix C (Figures C.1 to C.3) and Appendix D	This corridor extends from the Eastern Cape along the N2 highway through the former homeland areas of Ciskei and Transkei which are areas of tribal land authority and communal ownership into KwaZulu-Natal. Phase 4 extends from the St Lucia all the way up to the South Africa – Mozambique border. This area includes the eThekwini Metro, East London, Richards Bay and Mthatha as well as extensive areas of dense rural settlement. The traditional areas are home to some of the most disadvantaged people in the country. Parts of the eastern section (Phase 7) are however sparsely populated (declining in population). The economy is highly dependent on Government sector and services. The majority of the local municipalities within these corridors have a ''marginal" rating in terms of fire-fighting capabilities currently in place. In terms of district municipal capabilities, 50% of the affected municipalities within these corridors have a good or fair fire-fighting capability currently in place. ***These corridor sections have concentrations of very high sensitivity due to the large cities with high population and intensive economic development which include the greater eThekwini - Pietermaritzburg City Region area, Richards Bay urban complex, large, densely populated service towns and the coastal settlement corridors. It also has extensive areas of moderate sensitivity due to the extent of the densely settled rural areas which are mainly within traditional authority areas. The low sensitivity areas are a mixture of sparsely populated state and privately owned land and commercial farmland.***
Northern and Gauteng Corridor Phase 3 and 8 Refer to Figures 7, 8 & 9, Appendix B (Figures B.13 to B.15), Appendix C (Figures C.7 to C.9) and Appendix D	This phase includes the Gauteng City region and extends southward to eThekwini and west from the border of Gauteng, across Mpumalanga and ends at the Mozambique border. The area is densely developed with respect to both population, economy and infrastructure and land management issues are likely to be highly complex. The corridors also include areas under tribal authority jurisdiction. Areas within Phases 3 and 8 are mostly mixed economy. Approximately 50% of district municipalities potentially affected within these corridors have a good to fair rating in terms of fire-fighting capabilities. The fire-fighting capability currently in place in the local municipalities varies largely across the corridors and do not correlate with the capability of the district municipality which contains them. ***In this corridor the very high sensitive areas are dominated by densely populated and intensively developed economic zone comprising the Gauteng City Region and larger cities. There are also areas of moderate sensitivity characterised by dense population settlements in areas under tribal authority jurisdiction. In all these areas, land rights and land management issues are likely to be highly complex. The low sensitivity areas are a mixture of sparsely populated state and privately owned land and commercial farmland.***

7 KEY POTENTIAL IMPACTS

The detail planning of the pipeline alignment and the demarcation and associated proclamation of development servitude will need to be undertaken with strict diligence and consider minimum land disruption given the number of people that may potentially be impacted along the proposed gas transmission pipeline route.

The alignment should where possible minimise impact and disruption on settlements, economy, population and land use given the spatial extent and the number of towns, villages and people likely to be impacted. In addition, the safe operation of the pipeline will be critical, in particular if the gas transmission pipeline is located in areas of high population density (i.e. an unlikely situation).

7.1 Spatial and development planning, land use management

7.1.1 Land-use management and tenure implications

The extent of land parcels and stakeholders potentially affected by the proposed construction of a gas transmission pipeline as well as land ownership issues are expected to be highly complex. The complexity of land-use management and tenure implications are summarised in the table (Table 4) and expanded on below.

Table 4: Land-use management and tenure implications

Type of settlement	Implication
Large formal towns (Cities, Towns, Regional Service Centres	*Many people & land parcels are likely to be impacted by land use or servitude proclamation if the pipeline goes though Cities and Large Regional Service Centres.*
Land in traditional authority areas	*Due to the complexity of land ownership and use rights and limited legal and economic capability the residents in this area will be sensitive to changes in land use application or over servitudes being created and special measures will be required to ensure fair and ethical negotiations where these are required.*
Small Towns and Small Service Centres	*Mainly formal land tenure & freehold property rights. Thus negotiations regarding land use & servitudes will be less complex with less people impacted than in larger towns.*
Sparsely populated non-traditional authority areas	*Fewer people impacted on a fewer large tracts of land which is in private or other means of formal ownership*

The larger the settlement and the higher the number of stakeholders, the greater the sensitivity with respect to impacts for the developers and the community due to lengthy negotiations, alternative approaches to land access, road diversions and closures, and disruption of urban services. It is therefore anticipated that land-use applications and required stakeholder interaction (significant input from citizens with respect to negotiations regarding loss of usage rights, compensation and hardship suffered) associated with the development of a gas transmission pipeline network may put additional pressure on relevant authorities, in particular in large cities/towns, that may be beyond their capability. This would also lead to delays in development implementation and increase the duration of the associated impacts.

In small towns and sparsely populated non- traditional authority areas, the planning processes are likely to be less complex (no additional pressure on land-use applications), and fewer people are likely to be impacted in a negative manner. There are also likely to be major land use management implications especially for small towns and municipalities with limited capacity to address changes in land use application, servitude proclamation and the required changes to land use schemes.

The planning processes are also likely to be complex where the land is in on communal tenure (tribal authority areas). It is critical to note that much of the land within the eastern pipeline corridor phase falls with areas identified as being within traditional authority jurisdiction were communal property rights with all the associated complexities is the dominant tenure form with the exception of areas within formal settlements in the area. Planning and land use negotiation issues are likely to require a great deal of negotiation and community participation with respect to the current legal use or usufruct of land in traditional authority areas. Collaboration with regards to land use management decisions and practices between municipalities and traditional authorities might remain a challenge and will need to be considered.

Access to the land for maintenance purposed during the operational phase is also anticipated to be highly sensitive where land is under tribal authority.

Management actions

- Major sensitivity in dense rural settlements and communally owned land should be avoided.
- Timeous negotiations and detailed studies must be undertaken to minimise negative impact in vulnerable communities especially in traditional authority areas.
- The servitude planning and proclamation will need to comply with local land use planning regulation and be included in negotiations as part of Local SDFs and Land Use Management Schemes all of which need to comply with the SPLUMA regulations.

7.1.2 Resettlement and relocation/displacement impacts

The establishment of gas transmission pipelines has the potential to result in involuntary resettlement or relocation. In addition, during operation a pipeline disaster may necessitate relocation/resettlement. If the resettlement is not properly planned or managed it can have an impact on the livelihoods of the said community (DEA, 2016). Resettlement in rural areas and small villages has an impact on livelihoods in the form of the loss of houses and farmland and the loss of access to farmland and other resources. One of the key challenges therefore facing resettlement in rural areas is linked to the restoration or maintenance of livelihoods based on land and access to resources (DEA, 2016).

Resettlement issues are normally associated with large infrastructure projects such as mines or large industrial areas. Although a gas transmission pipeline network would qualify as a large infrastructure project, the physical footprint of the gas pipeline network is usually much smaller compared to these other types of large developments. In addition, due to it being a linear activity, this would further limit the impact on the loss of land or access to resources. The need to therefore relocate entire communities would be unlikely.

Should involuntary resettlement occur, two types of displacement would need to be considered; i.e. 1) physical displacement, where people have to move to a new area as a result of the direct impact of the project and thus would need to be compensated for their loss of assets; and 2) economic displacement, where access to productive assets are interrupted or cut off. The type of displacement will inform the type of Resettlement Action Plan (RAP) that would need to be developed to manage the impact of resettlement. The type of RAP will depend on the location, scale and type of project (DEA, 2016).

In addition to the above, in certain emergencies, the support provided by NGOs, communities and disaster management centres will not be sufficient to aid the affected community and additional housing support and interventions are necessary. Should a pipeline disaster require relocation or resettlement of communities, the Department of Human Settlements at the affected local and provincial municipal level should provide emergency housing response. A summary of when relocation/resettlement would be the suitable option is detailed in the figure below (Figure 11) (HDA, 2012).

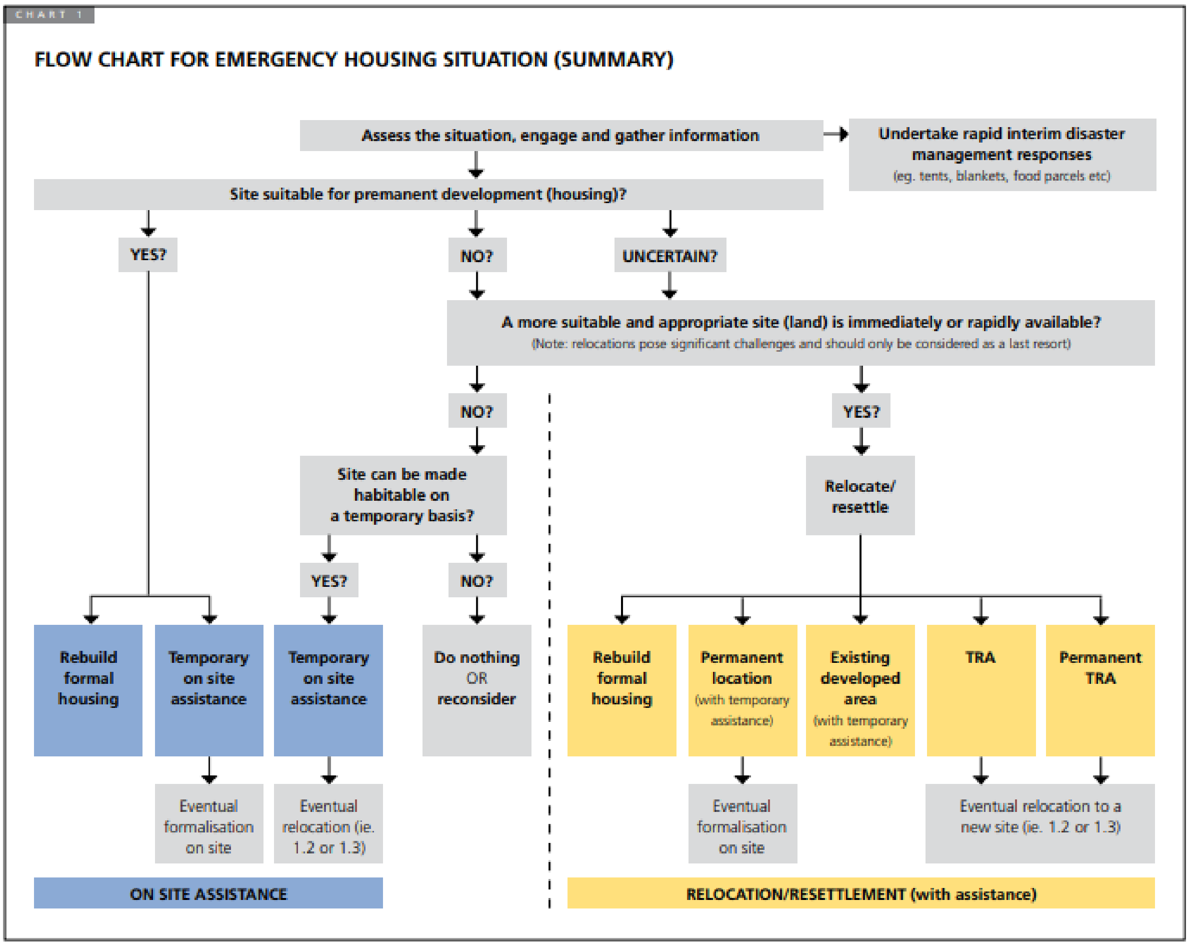

Figure 11: Flow chart for emergency housing situation (HDA, 2012)

In terms of the Prevention of Illegal Eviction from and Unlawful Occupation of Land Act, certain procedures must be followed to evict occupiers of land. Different procedures are set out within the Act, depending on whether the occupier is a private owner, is an urgent applicant or an organ of state.

Management actions

Accepted international best practice requires that involuntary resettlement be avoided where possible. If this is not possible the number of people affected should be minimised. The key mitigation measure therefore involves siting of transmission pipelines so as avoid the need for resettlement.

Where involuntary resettlement cannot be avoided, the relocation of affected households and or compensation for economic displacement should be guided by international best practice and a RAP should be developed to manage the impact of resettlement.

Key best practice documents to guide the involuntary resettlement include:

- World Bank Operational Policy (4.12) on Involuntary Resettlement (Revised in 2011);
- IFC PS on Environmental and Social Sustainability (Revised in 2012), specifically PS 5: Land Acquisition and Involuntary Resettlement;
- IFC's Handbook for Preparing a RAP (2002);
- AfDB Policy on Involuntary Resettlement (2003).

If a disaster occurs during the operation of the pipeline that require resettlement/relocation, the the Department of Human Settlements at the affected local and provincial municipal level should be consulted to ensure that any relocation/resettlement is appropriately managed.

Any eviction process must be considered under the Prevention of Illegal Eviction from Unlawful Occupation of Land Act.

7.1.3 Impact on the location options of new developments

The placement of a servitude may impact the location options of new developments (extent and direction) in towns / economic nodes and limit potential economic growth. Highly sensitive areas (such as surrounding areas of Cape Town, eThekwini and Gauteng city region areas and coastal settlement corridors) are under continuous development pressure due to continued growth and will be unable to respond to increased development pressures whereby economic nodes are constrained in terms of future development initiative. In rural settlements and sparse populated areas, restriction on new developments is not anticipated and economy can grow without being impeded by potential development constraints due to the presence of a gas pipeline and or any declared servitude.

Management actions

- At time of planning a section of the proposed gas transmission pipeline, the developer must check growth direction of nearby settlements as well as existing and approved township development applications and land use rights. New development areas indicated in SDFs and applicable municipal infrastructure masterplans must also be taken into consideration.
- The pipeline design would need to be carefully considered together with relevant design and building standards should it be constructed in the vicinity of higher density population areas and economic nodes such as eThekwini, Cape Town, Nelson Mandela Bay and Gauteng. The current development contexts, industrial and port activities within other smaller nodes might also warrant access to gas as alternative energy resources and thus also need to be considered i.e.: Witbank/Middelburg, Richards Bay, Mossel Bay, Saldanha and Buffalo City/East London. Whilst a link to supply gas to industry for power generation in these cities and towns may be beneficial this will be dependent on cost and detailed route design.
- The same requirements as above will need to be considered in future when increased or specific needs might be identified for increased access to or demand for gas as an energy resource in fast growing and high density cities. These cities include Mbombela/Nelspruit, Newcastle, Vryheid, Mthatha, the South Coast Corridor (east of Durban) and the North Coast corridor (north of Durban), the Durban-Pietermaritzburg corridor area and nodes, the coastal corridors of Plettenberg Bay and George, and smaller development concentrations and footprints in the various inland service towns.

7.1.4 Impacts on property values

The presence of a gas transmission pipeline servitude on a property may negatively influence the value of the property. The presence of a high pressure pipeline can influence property values due to health concerns, disturbance of the current land-use of the property and reduction in the amenity of use within the servitude and it creates usage uncertainty. The servitude negotiation process and, in particular, the amount paid to property owners plays a key role in mitigation. If these are fair and truly reflective of all value losses and risks associated with accommodating a gas transmission pipeline, then one would expect less opposition from land owners (DEA, 2016)

Furthermore, the impact on property values is highly case specific and depends on factors such as the use of the land, the size of the property and the uniqueness of the property (DEA, 2016). It may also be dependent on the current development pressure in the surrounding of the targeted land. Therefore, the impact of the proposed gas transmission pipeline on property values requires further investigation.

Currently, compensation is not offered as a remedy for those owning land adjacent to or nearby a site earmarked for linear infrastructure development. Under South African law, those acquiring servitudes such as Eskom, Transnet and others are not required to compensate neighbouring property owners for potential values losses. This essentially places a limit on achieving full compensation for property value decreases for a number of different infrastructure project types including EGI, roads, railways, wind farms, etc. (DEA, 2016).

Management actions

- Ensure a fair compensation process is implemented by the developer.
- Avoid high value land uses (luxury estates, high end game farms etc.) where possible.
- Use existing infrastructure servitudes where viable and agreed to.
- Refer to Section 7.4 (Disaster management) for additional management actions.

7.2 Disruption of population livelihoods due to construction activities as well as impacts on service delivery and local economies during construction

Settlements and development nodes and specifically industrial and manufacturing clusters within them, may potentially benefit from energy supply through the extension of the gas transmission pipeline or temporary construction related job creation. However, within large towns, cities and metropolitan areas, the high density of activities and livelihoods might be at risk or disrupted through construction. This is considered to be the main impact associated with the construction phase and would need to be evaluated in terms of how it impacts the built environment. The latter includes all human settlements (cities, towns and villages), the population in the area and the economic function.

The construction phase of any segment of the pipeline is indicated as 6 months. Impacts associated with construction activities that may affect livelihoods include construction noise, traffic, dust, waste management, current land use etc. Planned disruption may occur for an extended period of time and may be accompanied by uncertainty about when land use activities can revert to current/future use. During this phase any unexpected delays in either the start or completion time will increase the disruption and, in the case of agricultural land, would mean that the land in question would most likely be left unproductive or at best disrupted. Productive use of land is restricted when certainty of use period cannot be provided. This is due to lead times with respect to changing production use, acquiring alternative property or due to uncertainty with regard to completion of a production cycle before the land will become unusable. Also refer to Part 4.2.4 for further details regarding agricultural impacts.

Compensation for loss of land use amenity value will also need to be considered. This is a major issue and the associated risks will need to be limited and considered in detail during the project specific Environmental Authorisation phase. This cannot be considered now due to lack of detail. Due to the impact of uncertainty on the likely usage of land and property with respect to any production cycle, it will be critical at the planning stage to clearly outline the time period of construction and provide certainty with respect to start and end dates.

Infrastructure too may be impacted while construction over or under the infrastructure occurs. This may consequently impact on the delivery of any services in the area that may be disrupted though the construction, including engineering services that provide services to large numbers of people as well as the local economies in the city regions such as Cape Town Nelson Mandela Bay, Gauteng and of eThekwini, large cities such as Richard Bay and dense coastal settlement corridors along the garden route and the KZN north and South coast. Large cities such as Mbombela and dense boarder settlement corridors and tribal authority areas will also be impacted. The number and density of people, businesses, livelihoods and current quality of life experienced will thus increase sensitivity levels.

This may also by implication impact the local economies in the area that may be disrupted through the construction. Within medium and smaller towns, local economies are more likely to be vulnerable and thus also highly sensitive.

<u>Mitigation measures</u>

- Avoidance of sensitive areas:
  - o Avoidance of built-up areas in identified cities and functional city region areas. To limit the impact of the gas corridor it is best to avoid built-up areas in towns where large numbers of people and / or business are located in order to limit the disruption to the least number of people and the least number of economic entities. Where connections (i.e. through the development of distribution lines) need to be provided to support industrial and other future service and development needs, detailed route design will be required within the identified functional town areas.
  - o Avoidance of functional areas around identified service towns and rural service settlements recommended. For the same reason as provided above services towns should be avoided. In addition to the normal towns functions service towns provide services to large numbers of people living in the hinterland of the town. If a specific service is not provided or is cut-off through a construction process, the towns' people as well as all people in the surrounding service region will be impacted.
  - o Avoidance of high density population and economic nodes within the bigger Cape Town city region area for bulk pipeline. Avoidance of the area will limit impact and level of land use management planning required.
- Where avoidance of a populated area is not possible, the following management measures need to be put in place:
  - o Detailed route design considering existing and planned land use and developments to minimise impact on people and livelihoods as far as possible.
  - o Consult and inform the stakeholders.
  - o Ensure agreed time frames are respected.
  - o Ensure alternative access to properties is identified.
  - o At the time of construction, ensure that clear access to public facilities and public transport is maintained (e.g. detour less than 500 m (walking distance)), as well as clear 24 hour access to emergency services.).
- Timeous negotiations and compensation measures with land owners to minimise impacts on current land-use (e.g. crops harvest etc.);
- Timeous construction to avoid extended disruptions, ensure access to local businesses is not disrupted;
- Where local businesses are anticipated to be highly impacted during the construction phase, consider compensation for lost businesses, in particular for location dependent businesses;
- The EMPr should outline procedures for managing construction in an environmentally friendly manner (waste management, good housekeeping, erosion management etc.)
- Location of servitudes should not exclude existing or potential businesses or industries that use or would benefit from access to a high volume, regular source of natural gas.

7.3 Impacts associated with project workers/workforce

The potential impacts associated with the presence of project workers mainly apply to the construction phase of the gas transmission lines. Although, given that gas transmission pipelines are planned to be constructed outside towns, cities and other areas of high population densities and given the linear nature of the proposed development, the anticipated social impact associated with the development of gas transmission lines within the Gas corridors are considered to be low.

While some temporary local employment of unskilled labour is likely to be provided during the construction phase, long term employment opportunities are limited and will be considered at a project specific level.

Construction workers

The *presence of workers* during the construction phase may lead to the disruption of existing family structures and social networks, specifically in rural areas (Ruddell et al., 2014, Negi, 2014). The key risks that could lead to a social impact due to the influx of job seekers and presence of workers include:

- Increased alcohol and drug use;
- Increased crime levels,
- Increased teenage and unwanted pregnancies;
- Increased prostitution; and
- Increased prevalence of sexually transmitted diseases (STDs), including HIV.

The *movement of construction workers* on and off site in rural areas may also lead to anti-social activities within local communities and amongst farmers and farm workers in the vicinity of the construction site. Farm infrastructure such as gates and fences may also be damaged which can lead to financial losses. In addition, stock losses may occur due to the damage to the farm infrastructure or stock theft. The activities associated with the construction workers may also lead to an increase in veld fires which pose a risk to the livelihoods of the farmers (ESMAP, 2006 and DEA, 2016).

The potential risk posed by the presence of construction workers will be linked to the location of the construction activities, size of the work force, duration that they are on site and where they are accommodated. Given nature of the work associated with the establishment of linear infrastructure projects, such as pipelines, the construction activities will not be confined to a single area, as would be the case with the establishment of a say a new mine. In addition, the size of the work force is likely to be relatively small compared to large civil construction projects. The potential social impacts associated with the presence of construction workers is therefore likely to be limited and can be managed through the implementation of effective management and mitigation measures as listed below (DEA, 2016).

During the operational phase, the potential impacts associated with the presence and movement of maintenance workers is anticipated to be very limited.

Influx of job seekers

Construction projects also have the potential to attract people to the area in the hope that they will secure a job, even if it is a temporary job. These issues are similar to the concerns associated with the presence of construction workers as listed above. The impact of the influx of job seekers may pose a higher risk to the local community, compared to the presence of construction workers, since unlike the employed construction workers; job seekers may not have accommodation in the area nor a stable source of income, and may decide to stay on in the area. Linked to this, the risk of crime is therefore higher. Based on experiences of other large projects, job seekers that are unsuccessful become economically stranded and sometimes, the families of the job seekers can also follow the job seeker to the new area. This places additional pressure on existing municipal services.

Given the linear nature of pipelines, the construction activities will not be confined to a single area and unlike other major development projects, such as a mine, the employment opportunities associated with the operational phase of a gas transmission pipeline are limited to repairs and maintenance. The attraction potential for job seekers during both the construction and operational phase is therefore low. The potential social impacts associated with the influx of job seekers are therefore not regarded as a key social issue (DEA, 2016).

<u>Management actions</u>

The mitigation measures apply to construction and maintenance related activities.

- Ensure all engagement, management and communication with workers are in line with the requirements stipulated by the Department of Labour. Labour management measures that fall within the ambit of the Department of Labour include employment contracts, working hours, minimum wage, working clothing and compensation for occupational injuries and diseases.

- Ensure contractors implement a 'locals first' policy for construction jobs, specifically for semi and low-skilled job categories;
- Develop a recruitment process and/or use a recruitment agency to advertise job and secure positions beforehand, thereby minimising the amount of job opportunities offered on-site during the construction phase;
- Ensure that the number and availability of jobs is clearly mentioned and discussed during the awareness sessions that would be undertaken when the final alignment of a proposed section of the pipeline has been confirmed;
- Develop a Code of Conduct for the construction/maintenance phase. The code should identify which types of behaviour and activities are not acceptable, such as trespassing, hunting, stock theft etc. Construction/maintenance workers in breach of the code should be dismissed. All dismissals must comply with the South African labour legislation;
- The developer should be liable for compensating farmers and/or communities in full for any stock losses and/or damage to farm infrastructure that can be linked to construction/maintenance workers. This should be contained in the Code of Conduct to be signed between the Developer and the affected landowners. The agreement should also cover loses and costs associated with veld fires caused by construction/maintenance or construction/maintenance related activities;
- The EMPr should outline procedures for managing and storing waste on site, specifically plastic waste as it poses a threat to livestock if ingested, and to the general environment;
- The EMPr should also address risks posed by veld fires. In this regard no open fires for cooking or heating should be permitted, except in designated areas, the contractor(s) should ensure that construction/maintenance related activities that pose a potential fire risk, such as welding, are properly managed and are confined to areas where the risk of fires has been reduced. Measures to reduce the risk of fires include avoiding working in high wind conditions when the risk of fires is greater. In this regard special care should be taken during the high risk periods, such as dry, windy months, the contractor(s) must provide adequate fire-fighting equipment on-site and fire-fighting training to selected construction/maintenance staff;
- The Developer and the appointed contractor(s) should implement an HIV/AIDS awareness programme for all construction/maintenance workers at the outset of the construction/maintenance phase. Reference should be made to the requirements contained in Guidelines for Integrating HIV and Gender-related Issues into Environmental Assessment in Eastern and Southern Africa. Prepared for United Nations Development Programme (UNDP) Regional Centre for Eastern and Southern Africa by the Southern African Institute for Environmental Assessment (UNDP, 2012);
- The Developer and/or the appointed contractor should provide transport to and from the site on a daily basis for construction/maintenance workers. This will enable the contactor to effectively manage and monitor the movement of construction/maintenance workers on and off the site;
- Depending on the duration of the contract, the project developer and or the contractor(s) should make the necessary arrangements for construction/maintenance workers from outside the area to return home over weekends and/ or on a regular basis. This would reduce the risk posed to local family structures and social networks;
- Where feasible, no construction/maintenance workers, with the exception of security personnel, should be permitted to stay over-night on the site. This would reduce the risk to local farmers;
- Accommodation must be found in existing settlement or the construction camp must be located in or adjacent to an existing settlements;
- Ensure that construction camps do not remain permanent and should not be permanently occupied more than 3 months.

7.4 Disaster management

7.4.1 Health Risks associated with a gas transmission pipeline leak, rupture or fire

Compared with other methods for transporting hazardous chemicals, such as rail or road, transmission pipelines can be very safe, and transmission pipeline accidents are relatively rare and have caused few fatalities. Pipelines are primarily underground, which keeps them away from public contact and accidental damage. However, a single major incident can have devastating environmental, health, and economic consequences (Osland, 2015:1064) because of the high operating pressures and large volumes of escaping gas. The damage to the immediate area, including structures, can be severe even when no ignition of escaping gas occurs. Failures on transmission pipelines will almost always cause escaping gas to excavate a large crater at the point of damage. If the escaping gas ignites during the resulting pressure-release explosion, the heat release will be tremendous, creating life-safety and fire-exposure problems extending to hundreds of metres or more from the pipeline (Parsley and Schwab, 2000).

In addition to acute accidents, chronic spills from gas transmission pipelines can have negative repercussions on human health and the environment through contamination of drinking water, reduction in air quality, or other long-term environmental damage. The presence of a gas transmission pipeline in crowded urban and suburban areas would therefore lead to increased health and safety risks.

Due to the intensity of underground infrastructure lines, including water, sewerage, electricity, telecommunications and gas pipes, in urban areas unintended pipeline strikes may happen. Workers focusing on other kinds of infrastructure may well damage gas pipelines. On the other hand, gas pipeline planning processes also need to be sufficiently careful not to compromise existing infrastructure, particularly if it is located underground (refer to Section 7.2). It is therefore important for regulatory frameworks to regulate and restrict land uses near gas transmission pipelines. This would help to reduce risk, but there must be political support for the design and implementation of such measures.

Another complication lies in the inaccessibility of municipality plans indicating the location of the various underground infrastructure. In South Africa, many municipalities have lost their original “as-built” plans, increasing the risk of incidents. Given that much of the pipeline would be underground, locating and assessing the condition of components is difficult. An additional factor increasing risks is the encroachment of suburban growth upon pipelines designed for rural areas. As such, these pipelines expose large numbers of the community to risks that they are blithely ignorant of, and have no say or choice over. Land use change due to residential and other development around pipelines that were built to a rural specification.

Parsley and Schwab (2000) give valuable advice in the case of a pipeline fire: do not expect to extinguish fires on gas pipelines. The only safe way of extinguishing such a fire is to remotely eliminate the fuel source by isolating the damaged section of the pipeline - a task that only the Pipeline Developer can perform. However, it remains important to secure a water supply and stretch hand-lines where appropriate to effect viable rescues and protect properties. Do not enter the immediate fire area until the pipeline operator has indicated that it is safe to do so. Most pipelines today operate with automatic valves that open when timers and pressure sensors on the line indicate the need. The large loss in pressure that results from a pipeline failure may be read by automatic systems as an increased demand, causing valves to operate, sending a rush of gas toward the breach in the line, resulting in a violent increase in the size of the fire (Parsley and Schwab, 2000).

Management actions

- Undertake a metre by metre risk assessment over the entire length, ensuring that all threats are eliminated or at least minimised such that risk of leak/rupture of the pipeline is avoided or at least reduced to *As Low as Reasonably Practicable (*ALARP);
- Ensure that pipelines located in high population density areas or areas requiring high levels of protection for the public, are designed to leak rather than break (full bore rupture) in the event of an incident, e.g. if impacted, for example, by an excavator, or if some material failure occurs;
- Ensure that pipelines are designed and built according to international standards and based on the surrounding land-use;
- Ensure maintenance is undertaken as per required schedule and appropriate corrective actions implemented timeously. Normally, leaks are detected by abnormal pressure drops and a loss of transported volumes. Risk Based Inspection via scheduled intelligent pigging of the pipeline sets an initial baseline and thereafter monitors the condition of the pipeline. This methodology has been successfully employed on the Rompco Pipeline, detecting corrosion and signalling maintenance and repair long before failure actually occurs.

- Ensure that the latest technology is used during integrity testing (in particular to detect general corrosion, pitting corrosion, stress corrosion cracking, etc.) – for example automated ultrasonics, electromagnetic acoustic transducer (EMAT);
- Ensure that risks to the pipeline due to any changes in the environmental conditions surrounding the pipeline (e.g. increase in moisture in the drainage line where the pipe is laid down) are considered;
- Ensure that the location class of a section of existing pipeline is changed in the event of land use change. Where there are changes in land use planning (or existing land use) along the alignment of an existing pipeline, a safety assessment must be carried out and additional control measures determined to ensure that the risk associated with a rupture or leak is ALARP;
- Ensure the use of competent people for welding;
- Pigging stations must be located in an area accessible to 24 hour emergency services.

7.4.2 Preparedness in responding to a disaster

Without adequate disaster management planning, a pipeline incident can escalate into a disaster. Therefore, irrespective of what disaster occurs or whether there is loss to property or lives, the consequence would be considered to be extreme if authorities are not able to effectively respond to it.

Another concern is that most civil emergency planning looks at critical infrastructures only from the perspective of dealing with the *primary* emergency. Hardly any planning for pro-active and incident response activities is made to protect the *secondary impacts* on critical infrastructure[3] in, and directly around, the emergency area. This concerns the most obvious visible infrastructures: road, rail, hospitals. (Luiijf and Kluver 2005:3). Other secondary problems could include impacts on sewerage, electricity lines, water reticulation, burial capacity, rapid access to city planning information, food and medicine distribution, and the functioning of schools (Luiijf and Kluver 2005:6).

A *disaster response* can be defined as a wide array of reactions, measures, and policies that mitigate, counteract, and prevent disaster impacts and effects. Once a disaster has occurred, the impacts stimulate the unfolding of systemic response mechanisms and the creation of specially designed response measures. These responses provide emergency relief and rehabilitation activities and can compensate stock losses and promote reconstruction. This also stimulates an anticipatory response aimed at the prevention and mitigation of future potential disasters. There are therefore three types of responses: (a) immediate response, (b) compensatory response; and (c) anticipatory response. After the immediate disaster response, compensatory and anticipatory responses usually follow. Reversing the negative impacts is possible once the emergency response has contained the spread and worsening of indirect effects. These responses normally require a significant amount of public involvement, and puts pressure on public resources (Albala-Bertrand, 2003).

An assessment of fire and rescue services was done by the SA Insurance Association (SAIA) in **1999**. The study was precipitated by growing statistics in the preceding eight years which indicated a dramatic increase in value of fire claims. The claims of R400 m in 1990 increased to R1.4 billion during these eight years. Most insurers suffered significant losses on fire accounts. In its analysis, SAIA noted that a major contributory factor for this increase in value per loss was a *decline in ability of fire services to fight fires and contain losses* (COGTA, 2013).

The Inter-Ministerial Committee on Disaster Management conducted its own research in **1999**. It highlighted several reasons for the decline in municipal capacity:

- Lack of compulsory national standards hinders objective evaluation.
- Employment practices often overlook objective criteria due to political expediency and trade union action.
- A lack of municipal Council responsibility and accountability, so that vast areas throughout the country still have no fire service at all.
- Lack of maintenance plans result in critical shortages of equipment.
- Widespread employment of fire safety personnel as consultants in building design compromise their objectivity.

[3] Gas pipelines are now regarded as a key component of critical infrastructure (CI); this is defined as those physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, have a serious impact on the health, safety, security or economic well-being of citizens or the effective functioning of governments (Luiijf and Kluver 2005:1)

- Basic Conditions of Employment Act (BCEA): The imposition of new labour legislation has impacted negatively on shift-based fire services. Changes to accommodate the BCEA meant doubling up on manpower and a concomitant huge increase in costs.
- Municipal funding is mostly diverted to create infrastructure rather than for essential services.
- The Fire Brigade Board has been virtually dormant, to the detriment of the function (COGTA, n.d.)

The Disaster Management Act (Act 52 of 2002) was an attempt to address the litany of problems faced by the fire-fighting sector and provides for:

- an integrated and co-ordinated *disaster management policy* that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post-disaster recovery; and
- the establishment of national, provincial and municipal disaster management centres.

This Act is much more holistic than either the Fire Brigades Act or the National Veld and Forest Fire Management Act. “Disaster Management” is defined as “a *continuous* and *integrated multi-sectoral, multi-disciplinary process* of planning and implementation of measures, aimed at:

- Preventing or reducing the risk of disasters;
- Mitigating the severity or consequences of disasters;
- Emergency preparedness;
- A rapid and effective response to disasters;
- Post-disaster recovery and rehabilitation.

The Disaster Management Act is far-reaching in several ways. It has a strong focus on disaster prevention, preparedness[4], and post-disaster recovery. It includes several functional sectors; and it goes beyond the state.

In **2007**, as part of the preparations for the 2010 FIFA World Cup, the former Department of Provincial and Local Government commissioned a group of experts to determine the state of fire services in the country. The team identified two key issues affecting fire services: the first relates to the different interpretations of Section 84(1)(j) of the *Municipal Structures Act,* which has resulted in a complex and dissimilar division of fire functions between district and local municipalities. These developments have in some areas led to a two-tiered fire service in the same jurisdiction, resulting in costly and wasteful duplication of efforts and resources. The second issue relates to the relationship and jurisdictional contests between municipal fire services and other emerging government-funded initiatives aimed at addressing fire challenges such as veld fire management. In some instances, these programmes are presented as an alternative model for the provision of fire services which raises fundamental questions, as fire-fighting services are a municipal function as outlined in the Constitution. This places the Chief Fire Officer at the heart of sustainable delivery of fire services. The proposed fire service legislation should provide clarity on the jurisdiction of chief fire officers in relation to role-players (government-funded or private) who are involved in fire-fighting across the country (COGTA, 2013).

The **2007** study (i.e. 8 years after the original SAIA assessment) found additional problems (COGTA 2013)[1]:

- None of the services evaluated complies fully with SANS 10090 - Community protection against fire.
- Almost all services are under-staffed, some by over 50% resulting in some officials having to be permanently available on a 24 hour basis.
- The extension of municipal jurisdictional areas as a result of boundary re-alignment increased workloads.
- The audit suggested that a one-size-fits-all approach was not suitable, as smaller municipalities have unique needs and operating conditions.
- There were inconsistent standards for service delivery.
- There was an unclear division of functions and financial responsibilities between District and Local municipalities, and this results in duplication and inefficiency.
- There is a lack of a national three-digit emergency service telephone number outside existing cellular telephone networks.
- Most emergency communication and control centres do not have back-up facilities to ensure continuity of service during disasters.
- Most services (with a few exceptions) lack formal capital replacement policies which results in excessive downtime

[4] “Emergency preparedness” is defined as “a state of readiness which enables organs of state and other institutions involved in disaster management, the private sector, communities and individuals to mobilise, organise and provide relief measures to deal with an impending or current disaster, or the effects of a disaster. This goes far beyond urban fire-fighting and rural fire associations.

and consequent unavailability of vehicles.
- Lack of Incident Command Systems to assist in inter-agency cooperation.
- A shortage of technical training such as Urban Search & Rescue, Advanced level Hazmat response capabilities, and Incident Management.
- Some services appoint personnel without due regard to technical and physical competencies.
- Poorly coordinated workplace skills programs, no comprehensive safety policies and procedures.
- Some municipal water departments not complying with codes for fire-fighting water supply.
- General poor maintenance of fire hydrants.
- Divergent fire safety by-laws. Inadequate focus on Major Hazard Installation Regulations
- Insufficient emphasis on community fire safety education.
- The Municipal Infrastructure Grant is utilized by most municipalities to fund the updating of infrastructure, including fire stations. But some municipalities are then unable to budget for operational costs (vehicles and fire houses) to run a functional service.

Although these challenges were identified many years ago, they have not been resolved, and "require urgent and concerted efforts by all stakeholders led by government to address them effectively" (COGTA 2013:27).

This Act created a new institutional architecture and outlines the requirements of the creation of a National Disaster Management Centre (NDMC). The Centre is tasked with promoting an integrating and co-ordinated system of Disaster Management, emphasising prevention and mitigation, across all spheres of government, and with non-state actors, including communities. It is staffed by a Head, as well as staff drawn from COGTA.

For the purpose of the pipeline project, two requirements are significant: (a) The integration of prevention and mitigation methodologies with municipal IDPs; and (b) promote formal and informal initiatives to encourage risk-avoidance behaviour by private and public sector organisations.[5]

7.4.2.1 Status of DisM preparedness

As part of its functions, the NDMC must guide the drafting and updating of Disaster Management plans by organs of state; provide technical assistance in the drafting of these plans; assist in aligning these plans and co-ordinating strategies, and develop strategies for prevention and mitigation. It must promote disaster management capacity building, training and education throughout South Africa. The National Centre is also responsible for the administration of the Fire Brigade Services Act, 1987.

The effectiveness of the NDMC has been questioned. In 2012, the head of the Centre reported to Parliament about the functioning of the Centre. The Parliamentary report found that "The National Disaster Management Centre was currently hugely understaffed, and it was not possible to deal with all the issues that the Centre was confronted with" (PMG 2012). By 2015, the NDMC was still a programme within the Department. The *Disaster Management Amendment Act* (Act 16 of 2015), which made the Centre a government component only came into operation on the 1st of May 2016. After that, some progress was made. A Parliamentary report listed factors such as the creation of an integrated urban development framework, and facilitating a coordinated response to disasters such as the drought and other smaller incidents. The NDMC undertook monitoring of various prevention and mitigation initiatives during the period, including the introduction of the International Day for Disaster Reduction (IDDR) commemoration in 2015, where they visited disaster management stakeholders across the country (PMG 2016).

On a provincial level, DisM Centres in most provinces have not been implemented effectively. A Parliamentary Committee discussion heard about the National DisM Centre's challenges in implementing disaster management include the poor functionality of Disaster Management Advisory forums, the failure of government stakeholders to report on and implement disaster risk reduction measures, the non-responsiveness of the state to prescripts to respond to disaster occurrences, and the lack of funding for awareness programmes. In response, the Presidency approved the Inter-ministerial Committee on Disaster Management (ICDM) in 2016, making provincial disaster reporting a statutory requirement and creating a

[5] Section 22 of the Disaster Management Act, No. 57 of 2002.

legislative platform for effective and responsive policy creation in coordination with the NDMC (PMG 2016). However, building provincial DisM capacity will still require a great deal of attention.

When considering municipal DisM capacity, the NDMC indicated that, especially in sector departments and local municipalities, little or no organisational capacity for disaster management existed (PMG 2015). The NDMC Annual Report (2014) noted the following problems related to municipal DisM capacity:

- Lack of disaster management units or focal points for sectors lead to lack of clarification of some of the policies developed by the sectors, for example: when do sectors contribute and for what type of infrastructure before funding applications are submitted to the Treasury Committee?;
- Lack of equipment by some centres in dealing with disasters as quickly as possible to minimise the effects of the disasters, for example fire engines, appropriate vehicles;
- Lack of trained and skilled personnel, resulting in delays in submitting the required documentation to the NDMC. In most cases, the NDMC has to physically go and assist with the compilation of the report. This also relates to availability of the provincial engineers to assist with the cost estimates so as to reduce the time it takes for the application to be submitted for national contribution;
- Lack of political will in some municipalities where decisions on either declaration or reprioritisation are delayed, thus delaying the whole process of responding to the affected communities;
- Lack of involvement of government departments, for example the provincial departments of Human Settlements to provide guidance on emergency housing;
- Lack of sector participation in the municipal advisory forums and other technical task teams impact negatively on disaster planning and resource mobilisation;
- Incorrect interpretation of the Disaster Management Act, particularly with regard to the perception that a declaration means that the NDMC and national government will provide funding for the disasters; and
- Placement of the function within the organisational structure of a municipality. If the placement is not within the decision-making structures of the municipality, challenges are often experienced in implementing the legislation effectively (NDMC 2014:60).

The NDMC also noted there were common challenges raised by some Disaster Management Centres that

- Disaster management is not prioritised by many municipalities. As a result, they lack funding and the human and material capacity to do the job. It is often a consequence of the inappropriate placement of the function within the organisational structure of the municipality;
- Sector departments do not participate in local disaster management forums, but parachute projects from the province or national government without involving the Disaster Management Centres or municipalities concerned;
- Where there is political instability or frequent political changes, disaster management is often affected by those changes, as in some cases benefit from disaster relief support is said to be politicised (NDMC 2014:61).

Three years later, the NDMC recorded some issues raised during Fire Safety and Prevention Capacity Assessments: The lack of implementation of bylaws, or no relevant bylaws at all; the lack of fire services in certain municipalities; inadequately staffed fire safety units, lack of standard operating procedures; weak community-based fire education and awareness; inadequate systems for hydrant maintenance; as well as weak cooperation with the town planning division and law enforcement agencies (NDMC 2017:97).

This suggests that, as the planning process continues for the pipeline project, COGTA and the Disaster Management Centre must take *proactive* steps to plan for <u>possible</u> pipeline-related disasters.

<u>Management actions</u>

Pipeline-related disaster management

During a pipeline-related disaster, the key strategies that apply to all natural gas emergencies are to establish command and a safe staging area, secure the scene, evacuate at-risk occupants and bystanders, effect viable rescues, eliminate ignition sources, and co-operate with the local utility company. The key overall strategy involves developing a **<u>working partnership between Government (at various levels) and the</u>**

Developer. This would include conducting pre-incident planning sessions at large gas customers in the response area (Parsley and Schwab, 2000).

All of this requires ongoing public awareness and involvement. In Canada, the Onshore Pipeline Regulations require that a Pipeline Developer develops a continuing-education program for all first responders and the public residing adjacent to the pipeline. Providing continuing education ensures that these parties remain informed about the products being transported through the pipeline, the location of the pipeline, and the safety procedures to follow during emergencies (Wong, 2014). There have been many cases where the lack of technical knowledge of first responders and community members has worsened gas-related crises. For example, there have been instances of fire departments provoking explosions and fires by spraying water on otherwise inert chemicals (Qurantelli 2003).

Responders and military operations should develop awareness of and plan for safeguarding critical infrastructures. Furthermore, training exercises of first responders and military need to take critical infrastructure services into account. Preferably, joint exercises with providers of critical infrastructure services should be regularly scheduled (Luiijf and Kluver, 2005).

The Disaster Management Act requires the National Centre to create a **National Disaster Management Framework,** to guide the promotion of Disaster Management within all spheres of government, and include non-state actors. The Framework should promote disaster management capacity building, training and education, including in schools. It should also provide a funding framework, including grants to contribute to post-disaster recovery and rehabilitation, and payment to victims of disasters.

Each national organ of state indicated in the Framework must prepare **a disaster management plan**, describing its role and responsibilities, capacity, strategies, and emergency procedures. It must co-ordinate and align the implementation of its plan with those of other organs of state and institutional role-players. It must also regularly review and update its plan. The Disaster Management Amendment Act (2015) specified that each national organ of state must *(a)* conduct a disaster risk assessment for its functional area; *(b)* and identify and map risks, areas, ecosystems, and communities that are exposed or vulnerable to threats.
This elaborate institutional architecture is then replicated at **provincial level:** each province must design a Provincial Framework, to ensure an integrated approach to Disaster Management by all provincial organs of state and non-state actors. Each province must establish a disaster management centre. The Premier must designate a department responsible for DisM co-ordination. In practice, this is within provincial COGTA. The Province must create a Provincial DisM Centre, with several key functions:

- Collecting and distributing information concerning actual or potential disasters in the province;
- Advising organs of state and non-state actors;
- Recommending funding principles for DisM in the province;
- Making recommendations on draft DisM legislation;
- Making recommendations on the declaration of provincial disasters;
- Promoting the recruitment and training of DisM volunteers in the province;
- Promoting DisM training in schools;
- Promoting research on DisM in the province; and
- Giving advice to vulnerable communities.

The Provincial DisM Centres must appoint their own Head. The Amendment Act (2015) added that the staff must also consist of suitably qualified persons, designated by the Head of the department within which the provincial disaster management centre is established.

The Disaster Management Act (2002: section 33) provides a useful list of *types of guidance* which a provincial DisM Centre must provide. **These are particularly useful in the case of an important infrastructure project, such as a gas transmission pipeline**. This guidance could include:

1. Determining *levels* of risk
2. Assessing the *vulnerability of communities*
3. Increasing the *capacity of communities* to reduce the risk and potential impacts of disasters
4. Monitoring the *likelihood*, and state of *alertness to* disasters

5. Develop and implement appropriate *prevention and mitigation methodologies*
6. Integrating such methodologies with *development plans and initiatives*
7. The management of *high-risk developments* (a pipeline might be considered to fall in this category).

The Amendment Act (2015) added that (1) Each provincial organ of state must —
1. conduct a disaster risk assessment for its functional area;
2. identify and map risks, areas, ecosystems, communities and households that are exposed or vulnerable to physical and human-induced threats;
3. draft a Disaster Management plan, and align it with those of other organs of state.

Such plans must:
- Be specific to gas pipeline incidents and disasters;
- Anticipate likely types of disaster in the province, and their possible effects;
- Develop measures that reduce the vulnerability of specific areas and communities;
- Develop a system of incentives to promote DisM in the province;
- Take into account indigenous knowledge related to DisM;
- Promote DisM research;
- Identify and address weaknesses in capacity to deal with possible disasters;
- Provide for appropriate prevention and mitigation strategies;
- Facilitate maximum emergency preparedness; and
- Contain contingency plans and emergency procedures, including the allocation of responsibilities to different actors, prompt response, the procurement of essential goods and services, the establishment of strategic communication links, and the dissemination of information.

Managing medical dimensions of disasters

A pipeline disaster may bring many victims to the emergency department of a hospital, as a mass casualty incident (Kirk *et al.,* 1994). Emergency doctors must be aware of the nature of the chemical composition of the gas.

Hospitals will need a Mass Casualty Incident Plan, which should establish a hospital command centre, and define who is in charge of communication with the public. The command centre would collect information from the scene, patient care areas, local hospitals, inter-hospital transfers, and medical supplies.

Furthermore, a Haz-Mat disaster may continue after the event, due to contamination of air, soil, food, animals, and drinking water (Kirk *et al.,* 1994).

Recovery management after a pipeline disaster

Recovery deals with activities undertaken after a crisis response period is over in an attempt to return an area to normal. In the short term, the focus is on restoring infrastructure and service delivery. In the long term, the attempt is to restore community life. Specific measures can include providing financial and technical assistance to farmers in cleaning up contaminated farmland, setting up of counselling services for victims, restoring urban services, and rebuilding damaged and destroyed facilities (Quarantelli, 2003).

There may also be political consequences, due to public anger. The discovery of building codes unenforced, warning messages not passed along, and delays in disaster response can provoke the wrath of disaster victims. Once politicized, citizens may insist upon the passage of laws and regulations to prevent similar disasters in the future. Activist groups may also try to prepare the local population for future threats. Taking advantage of public interest and partnership opportunities, governments can channel resources of these groups to be better prepared in the event of other emergencies (Quarantelli, 2003).

Regular consultations and training with municipalities need to be conducted, about changing systems, operations and risks.

8 RISK ASSESSMENT

8.1 Consequence levels

Table 5 below provides a description of the consequence levels used in the rating process.

Table 5: Consequence levels determination

Impact	Consequence level	Reason
Impact to lives and livelihoods; Settlement Planning and Development	Slight	• Little or no additional disruptive impact on local economies and/or service delivery. • Little or no land-use management implications whereby there is no additional pressure on land-use applications. • Little or no impact with respect to disruption on human activity and livelihood activities through construction activities or reduction in land use amenity. • No restriction on new development in towns / economic nodes; economy can grow without being impeded by potential development constraints due to the presence of a gas pipeline and or any declared servitude.
	Moderate	• Limited and short-term (less than 12 months) disruptive impact on local economies and/or service delivery. • Limited land-use management implications whereby the additional pressure on land-use applications and stakeholder interaction required is within the capability of the local authority and does not place additional burden on the citizens with respect to negotiations on loss of usage rights, compensation and hardship suffered. • Limited impact with respect to disruption on human activity and livelihood activities through construction activities or reduction in land use amenity. Planned disruption on fixed schedule of 6 months and small areas impacted. • Little or no additional restriction on development and economic growth due to the construction or the presence of a gas pipeline.
	Substantial	• The construction has a disruptive impact on local economies and/or service delivery with respect to large areas and construction related activities and preparation phases extend between 12 to 24 months or more. • Numerous land management implications whereby the additional pressure on land-use applications and stakeholder interaction requirement is beyond the capacity of the local authority requiring significant input from citizens with respect to negotiations regarding loss of usage rights, compensation and hardship suffered. This leads to delays in development implementation and occurs for 2-3 years and affecting more than 20 % of the community members. • Disruption on human activity and livelihoods activities through construction activities or reduction in land use amenity. Planned disruption extends into 12-24 months and accompanied by uncertainty about when land use activities can revert to future use. • Development of towns and economic growth is impacted due to the construction or the placement of the servitude in areas that limit other economic potential for the future.
	Severe	• The local economies and/or social service delivery is interrupted for 2-3 years. • Numerous land management implications whereby the additional pressure on land-use applications and stakeholder interaction requirement is beyond the capacity of the local authority requiring significant input from citizens with respect to negotiations regarding loss of usage rights, compensation and hardship suffered. This leads to delays in development implementation and occurs for 4 or more years. • Disruption on human activity and livelihood activities through construction activities or reduction in land use amenity. Planned disruption extends between 2-3 years and accompanied by uncertainty about when land use activities can revert to future use and

Impact	Consequence level	Reason
		impacting more than 30% of the community. • Development of towns and economic growth is impacted due to the construction or the placement of the servitude in areas that limit other economic potential for the future.
	Extreme	• Exponential disruptive impact on local economies and service delivery from which it is unlikely to recover. • Disruption on human activity and livelihood activities through construction activities or reduction in land use amenity. Planned disruption extends more than 3 years and accompanied by uncertainty about when land use activities can revert to future use. • Affect dense rural settlements and communally owned land whereby land negotiations would be required that would increase complexity of planning and land use applications extending for 6 and more years and impacting more than 50 % of current users. • Unable to respond to increased development pressures whereby economic nodes are constrained in terms of future development initiatives.
DisM preparedness	Slight	• Minor leak. Small fire • Localised • Developer should be able to contain this disaster, with municipality providing support (e.g. water access, traffic control, evacuation of people)
	Severe	• Large leak / fire requiring specialist fire-fighting; • May threaten properties and livestock • May threaten human health and safety • May require some time (several days) to return the area to normal • Will require considerable local and district municipal support to ensure leak or fire is adequately contained
	Extreme	• Major leak/large fire/impact on other critical infrastructure • May create extensive damage to properties • May result in loss of life • May have impacts on other critical infrastructure (e.g. telecoms) • May have a significant interruption to gas supply (e.g. up to a month), with consequences for “downstream” users of gas products. • Will require local and district municipal and provincial support to ensure that leak or fire is adequately contained.

8.2 Risk Assessment results

Tables 6 and 7 provide the results of the Risk Assessment.

Table 6: Risk assessment of the gas transmission pipeline construction and operation on settlements planning and development and on lives and livelihood

Criteria	Impact	Study area	Location (sensitivity)	Without mitigation			With mitigation		
				Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Land-use management and tenure	Land-use management implications (land negotiations, servitude proclamation)	All phases (Construction)	High	Severe	Very Likely	High	Substantial	Likely	Moderate
			Medium	Moderate	Very Likely	Low	Slight	Likely	Very Low
			Low	Slight	Likely	Very Low	Slight	Likely	Very Low
Development intensity and extent (Settlement and economic nodes)	Risks to the local population due to the influx of job seekers	All phases (Construction)	Very high	Slight	Very Likely	Very Low	Slight	Very Likely	Very Low
			High	Slight	Very Likely	Very Low	Slight	Very Likely	Very Low
			Medium	Severe	Likely	High	Severe	Unlikely	Moderate
			Low	Severe	Very Unlikely	Low	Severe	Very Unlikely	Low
			Very low	Severe	Very Unlikely	Low	Severe	Very Unlikely	Low
	Impact on the location options of new developments (extent and direction) due to the presence of the gas transmission pipeline	All phases (Operation)	Very high	Extreme	Very Likely	Very High	Moderate	Likely	Low
			High	Severe	Very Likely	High	Moderate	Likely	Low
			Medium	Moderate	Very Likely	Low	Slight	Likely	Very Low
			Low	Slight	Very Likely	Very Low	Slight	Unlikely	Very Low
			Very low	Slight	Very Likely	Very Low	Slight	Unlikely	Very Low
	Disruptive impact on businesses contributing to the local economy during construction	All phases (Construction)	Very high	Extreme	Very Likely	Very High	Severe	Likely	High
			High	Severe	Likely	High	Moderate	Likely	Low
			Medium	Moderate	Likely	Low	Moderate	Likely	Low
			Low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
			Very low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
Population density	Disruptive impact on population and service delivery during construction	All phases (Construction)	Very high	Extreme	Very Likely	Very High	Moderate	Likely	Low
			High	Severe	Likely	High	Moderate	Likely	Low
			Medium	Moderate	Likely	Low	Slight	Likely	Very Low
			Low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
			Very low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
	Impacts on local population due to the	All phases (Construction)	Very high	Slight	Likely	Very Low	Slight	Unlikely	Very Low
			High	Slight	Likely	Very Low	Slight	Unlikely	Very Low

Criteria	Impact	Study area	Location (sensitivity)	Without mitigation			With mitigation		
				Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
	Presence of project workers/workforce		Medium	Severe	Likely	High	Severe	Unlikely	Moderate
			Low	Extreme	Likely	High	Extreme	Unlikely	Moderate
			Very low	Extreme	Likely	High	Extreme	Unlikely	Moderate
	Resettlement and relocation/ displacement impacts	All phases (Construction)	Very high	Extreme	Very Likely	Very High	Extreme	Very Likely	Very High
			High	Severe	Likely	High	Severe	Likely	High
			Medium	Moderate	Likely	Low	Moderate	Likely	Low
			Low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
			Very low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
	Health Risks associated with a gas transmission pipeline leak or fire	All phases (Operation)	Very high	Extreme	Very Likely	Very High	Moderate	Likely	Low
			High	Severe	Likely	High	Moderate	Likely	Low
			Medium	Moderate	Likely	Low	Slight	Likely	Very Low
			Low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low
			Very low	Slight	Very Unlikely	Very Low	Slight	Very Unlikely	Very Low

Table 7: Assessment of Health and Safety impacts associated with the operation of a gas transmission pipeline

Impact	Study area	Location	Without mitigation: Inadequate level of preparedness in the event of a disaster			With mitigation: Adequate level of preparedness in the event of a disaster		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Health and safety risks associated with a Minor leak/small fire	Rural	Extensive farms	Slight	Likely	Very low	Slight	Not likely	Very low
		Small-holding farms	Slight	Likely	Very low	Slight	Not likely	Very low
		Rural villages	Moderate	Likely	Low	Slight	Not likely	Very low
	Urban	Small towns	Moderate	Likely	Low	Slight	Not likely	Very low
		Medium towns	Moderate	Likely	Low	Slight	Not likely	Very low
		Large towns	Moderate	Likely	Low	Slight	Not likely	Very low
	Metro	Residential	Moderate	Likely	Low	Slight	Not likely	Very low
		industrial	Moderate	Likely	Low	Slight	Not likely	Very low
		CBD	Moderate	Likely	Low	Slight	Not likely	Very low
Health and safety risks associated with a Large leak / fire requiring specialist fire-fighting	Rural	Extensive farms	Moderate	Likely	Low	Moderate	Not likely	Low
		Small-holding farms	Moderate	Likely	Low	Moderate	Not likely	Low
		Rural villages	Moderate	Likely	Low	Moderate	Not likely	Low
	Urban	Small towns	Severe	Likely	High	Moderate	Not likely	Low
		Medium towns	Severe	Likely	High	Moderate	Not likely	Low
		Large towns	Severe	Likely	High	Moderate	Not likely	Low
	Metro	Residential	Extreme	Likely	High	Severe	Not likely	Moderate
		industrial	Extreme	Likely	High	Severe	Not likely	Moderate
		CBD	Extreme	Likely	High	Severe	Not likely	Moderate
Health and safety risks associated with a Major leak / large fire / impact on other critical infrastructure	Rural	Extensive farms	Severe	Likely	High	Moderate	Not likely	Low
		Small-holding farms	Severe	Likely	High	Moderate	Not likely	Low
		Rural villages	Severe	Likely	High	Moderate	Not likely	Low
	Urban	Small towns	Severe	Likely	High	Moderate	Not likely	Low
		Medium towns	Extreme	Likely	High	Severe	Not likely	Moderate
		Large towns	Extreme	Likely	High	Severe	Not likely	Moderate
	Metro	Residential	Extreme	Likely	High	Severe	Not likely	Moderate
		industrial	Extreme	Likely	High	Severe	Not likely	Moderate
		CBD	Extreme	Likely	High	Severe	Not likely	Moderate

9 GAPS IN KNOWLEDGE

Settlement Planning and Development

Regarding potential negative impacts of future gas transmission pipeline within approved corridors, the potential impact on existing mining rights (especially in Gauteng) has been identified as a potential issue to be mitigated through the routing of any future gas pipelines.

In order to make a better assessment of the impact on settlement development the following information would have been required:

- Location points of gas pipeline break bulk distribution points;
- Narrower extent of corridor with clearer idea of likely preferred alignment;
- More detail on time lines;
- Likely employment potential and or labour requirements; and
- Clarity on the process to be followed and use status of the servitude for the gas transmission pipeline.

No town growth that may occur as a result of the realisation of the gas pipeline and distribution was analysed. Thus the impact of the gas having any impact on population and or economic growth was not considered. If any growth above already anticipated growth should happen as a result of the development, additional planning to accommodate the growth will be required with respect to additional service delivery for social services, housing, facilities and bulk infrastructure.

When considering project level impacts at a later stage, there would be a need for a baseline study or studies with regard to current land use, population numbers, land ownerships and economic use of land. Baseline data on these aspects will be essential if negotiation with regards to use limitations, servitude proclamation and impact of construction and evaluation of any economic impact of the disruption or loss of earning is to be fair and transparent. Such studies are essential to attribute specific costs and negative impacts of the construction process.

There are substantial information gaps as to the state of land use management instruments, such as land use management schemes, in the country. The quality of many municipal SDFs is very weak, especially in the smaller municipalities. There is thus in general (1) a shortage of information on which decision-makers can rely when making land use and spatial planning decisions, and (2) a lack of clarity regarding the regulatory implications of the location, timing and use right of future gas transmission pipeline servitude.

Disaster Management

The DisM information presented within this assessment provided a high level indication of the disaster preparedness of the potentially affected municipalities but a much more detailed survey of municipal firefighting and DisM capacity should be undertaken, once the final routing of the gas transmission pipeline is determined.

10 BEST PRACTICE GUIDELINES AND MONITORING

In addition to the above recommended management actions (Section 7), the following best practice guidelines are also recommended.

10.1 Planning phase

Capacity building and municipal support

When a proposed bulk pipeline goes through a municipal jurisdiction, it will trigger various municipal activities, including spatial planning requirements and disaster management. Such negotiations will inevitably drag on for months, as it will involve two major aspects, namely, spatial co-ordination according to municipal SDFs, which may well have to be adjusted to cater for the pipeline (e.g. urban residential expansion) and administrative capacity, particularly regarding disaster management capacity-building, i.e. assessing current capacity, determining what additional capacity (staff, finances, skills) will be required to deal with potential pipeline problems, and determining the source of such financial support. One of the major mitigation factors critical to planning, implementation, monitoring and adaptation will therefore be the capacity, especially in smaller rural municipalities, of the relevant settlement planning, service delivery, integrated planning and other authorities in the area. Private-sector planners would also need to receive rapid technical orientation and guidance. Building capacity and expanding numbers of planners in municipalities could address this, but this requires resources. In order to deliver on this mandate, local planning officials will have to be capacitated and informed to provide the necessary enabling and regulatory services. The role and support of the South African Local Government Association (SALGA), COGTA, research councils, academia and local civil society led initiatives can be solicited in support of the respective Provincial Governments. The following mechanisms support the above requirement:

- Municipalities which may be affected by the final routing of the gas transmission pipelines must be identified. The Developer must consult with these municipalities on the roll-out of the gas transmission pipeline and what support would be required, should a disaster occur.
- The Developer must have top-level discussions with the national COGTA, as well as affected provinces, about municipal DisM capacity-building measures.
- Affected municipalities' DisM capacity needs to be investigated in detail, and a comparative matrix established as a baseline ("status quo") situation[6].
- In partnership with the provincial governments, the Developer must draft a set of interventions to build municipal DisM capacity.
- The challenges and potential opportunities posed by pipeline construction and downstream development associated with it, clearly illustrate the need for a sound IDP and SDF at municipal level and requirement of the Developer to participate in the process. All spheres of government and the Developer should participate in municipal IDP processes with SDFs providing guidance.
- For SDFs to play this role, it is critical that municipal SDFs be updated to cater for large scale infrastructure development (such as pipeline development and other major road and rail projects which may occur within the same area or any expanded renewable electricity developments) and to inform the reprioritisation of budget allocations where and if required. The process associated with acquiring the required rights, with detailed planning and implementation of gas transmission pipeline development will need to be designed to contribute to integrated and coordinated planning and governance between different authorities and especially local role players in the region to ensure that development is done considering the public good and impact on local economies and the vulnerable. The servitude planning and proclamation will need to comply with local land use planning regulation and be included in negotiations as part of Local SDF and Land Use Management Schemes all of which need to comply with the SPLUMA regulations or provincial regulations where provincial planning legislation is in place (such as for parts of the corridor that fall within the Western Cape Province).
- For coordinated spatial and delivery planning all projects have to be planned in the context of national, regional and local SDFs and IDPs, as well as relevant sector plans. Given the extent of the

[6] See Van Riet (2009) for a useful description of a Participatory Disaster Risk Assessment process in the Fezile Dabi District Municipality, Free State Province

gas transmission pipeline and construction and operational timeframes, the adaptation of sector plans is a crucial mitigation factor required for the planning, environmental clearance, servitude proclamation, land negotiation, compensation for loss of use where necessary, before construction starts. Effective and efficient land-use management and regulatory environment is critical. The process associated with prioritisation of certain phases and time lines of the gas transmission pipeline will need to consider the need and relevance for national and regional development objectives and will require identified need, priorities for phasing and prioritisation for implementation within the NSDF and associated national infrastructure alignment processes.
- The development of a RSDF (provision for this framework is included in Section 19-20 of SPLUMA) should be investigated as a suitable spatial planning tool for the gas pipeline. If determined to be the appropriate tool, a RSDF should be developed for the gas pipeline. The development of a RSDF would mean that municipalities do not need to alter their SDFs and IDPs specifically to accommodate the gas pipeline and the outcomes of the SEA will support the content of the RSDF.
- The cost of improving the state of readiness of all spheres of government, especially municipalities, to deal with the implementation of the gas transmission pipeline servitude planning must be considered when the planning and implementation of the corridor is undertaken. It is anticipated that all spheres of government (especially municipalities) will struggle to handle the increased strategic planning and regulatory challenges without creating additional capacity. When referring to regulatory capacity, special mention should be made to the need for compliance monitoring and enforcement for successful implementation of the gas transmission pipeline project.

Avoidance of key areas

- Transmission pipelines should avoid crossing through town areas, service towns, dense rural settlements and high density population areas…
- Major sensitivity in communally owned land should be avoided.
- Timeous negotiations and detailed studies must be undertaken to minimise negative impact in vulnerable communities especially in traditional authority areas.

Planning interventions and decision-making support

- Develop and implement an emergency plan – which has to be compiled beforehand, based on widespread consultation and awareness-raising.
- The main implication, for the gas transmission pipeline project, is that the more rural parts of the pipeline may be located in areas where there are Fire Protection Associations, with their own rules in force. They would function within the jurisdictions of municipalities, but they may also straddle municipal boundaries. The Pipeline Developer must therefore include municipalities and Fire Protection Associations in their disaster management planning procedures.
- All planning will have to take the current and future growth potential of towns into consideration in selecting the final gas transmission pipeline alignment.
- Ensure transparency in decision-making to provide clarity and ensure clean processes.
- All negotiations and planning process should ensure that the phasing is clear, that schedules for the construction is limited and clearly communicated to limit the impacts on the population and their livelihoods.
- The Developer should consider the need to establishing a Monitoring Forum (MF) in order to monitor the implementation of the recommended mitigation measures. The MF should be established before the construction/maintenance phase commences, and should include key stakeholders, including representatives from the relevant local municipalities, farmers, local farming unions, local community representatives etc. The MF should also be briefed on the potential risks to the local community and farm workers associated with construction/maintenance workers.

10.2 Construction phase

Disaster management

Effective DisM training/capacity-building/awareness processes must be established for municipalities. This may be part-funded by the Pipeline Developer.

10.3 Operations phase

Disaster management

- During a pipeline-related disaster, the key strategies that apply to all natural gas emergencies are to establish a command and safe staging area, secure the scene, evacuate at-risk occupants and bystanders, effect viable rescues, eliminate ignition sources, and co-operate with the local utility company.
- Government officials need to be aware of the activities of the operators of the gas infrastructure. These include:
    - Process hazard analysis, i.e. regular checking of the integrity of the infrastructure (e.g. pipes);
    - Infrastructural maps and diagrams;
    - Operating procedures;
    - Emergency training of pipeline staff; and
    - Accurate emergency planning and response procedures.
- The preparedness of local emergency responders is critical to protecting those who live and work near pipelines. They need to be aware of warning signs of a possible gas leak, such as:
    - Dirt being blown or appearing to be thrown into the air;
    - A white vapour stream or mist-like cloud over the pipeline;
    - Dead or dying vegetation in an otherwise green area;
    - A dry area in a wet field;
    - Flames coming from the ground or appearing to burn above the ground;
    - Continuous bubbling in wet or flooded areas;
    - Unexpected frost or ice on the ground;
    - A roaring, blowing or hissing sound;
    - An unusual “rotten egg” odour (Natural gas actually has no smell, but gas producers add chemicals to create a smell, and this helps with identification of leaks).
- There are some important steps emergency responders can take during the initial stages of an incident:
    - If it is safe to do so, turn off any mechanized equipment and ignition sources in the vicinity of the suspected leak
    - Secure the site and determine a plan to evacuate or sheltering place
    - Monitor for hazardous atmospheres
    - Control and redirect traffic
    - Provide immediate access to representatives from the pipeline company
- The role of the local responders would include:
    - Handling traffic control and evacuation
    - Securing the site
    - Firefighting
    - Making appropriate contacts if it appears other agencies, facilities or local authorities are impacted by the pipeline incident
    - Handling search and rescue
    - Providing medical assistance
    - Coordinating a community emergency response plan.
- Develop a continuing-education program for all first responders and the public residing adjacent to the pipeline. Providing continuing education ensures that these parties remain informed about the

products being transported through the pipeline, the location of the pipeline, and the safety procedures to follow during emergencies.

- Plans should be developed for safeguarding critical infrastructure.
- Training exercises of first responders must take into account critical infrastructure. Preferably, joint exercises with providers of critical infrastructure services should be regularly scheduled.

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APPENDIX A.1: SETTLEMENT AND DEVELOPMENT PLANNING

The following table provides a brief overview of the settlements affected in the corridors classified by settlement type and grouped by spatial regions for the corridor phases. Details per settlement are provided with respect to population numbers and growth characteristics of all land within the affected corridors. (Source: South African Functional Town Typology (Maritz *et al*, 2018) and Settlement Footprint Layer (Mans *et al*, 2017))

Table A.1: Summary statistics for affected towns

PHASE	Overview settlement feature	Functional city region areas (not metro boundaries)	Cities Large Regional Centres	Regional Service Centres	Service Towns	Small Service Towns & Service Settlements	Small Towns	Rural Settlement Areas	Sparsely Populated Area
West Coast Corridor Phases 5 and 6	# of towns	Cape Town is in the Southern Section of the Corridor			3	3	20	24	5
	Pop 2011				48 654	22 371	62 212	15 377	1 932
	% growth/decline (2001-2011)				19.36	8.52	26.41	7.87	53.50
Southern Coastal Corridor (Phases 1 and 2)	# of towns	Cape Town city region		7	11	16	38	7	15
	Pop 2011	4 940 057		752 342	288 523	126 838	142 493	15 634	6 088
	% growth/decline (2001-2011)	24.87		27.02	30.69	20.83	17.06	37.15	65.85
Inland Corridor (Central Karoo area)	# of towns	No city regions in Karoo			1	2	7	1	1
	Pop 2011				34 013	12 433	23 360	1 531	417
	% growth/decline (2001-2011)				10.16	16.55	18.79	105.53	10.44
Eastern Cape & KZN Coastal areas (Phase 7, Phase 3 and 4 overlap and Phase 4)	# of towns	eThekwini and Nelson Mandela Bay city regions	4	7	22	39	47	2 648	44
	Pop 2011	3 479 924	1 549 101	905 940	600 687	223 385	268 144	5 146 187	14 855
	% growth/decline (2001-2011)	11.47	13.27	17.44	21.86	14.25	17.81	(3.53)	(2.93)
Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)	# of towns	Gauteng city region	4	14	23	20	36	207	20
	Pop 2011	12 400 572	1 252 390	1 280 061	632 730	268 746	302 397	864 793	7 992
	% growth/decline (2001-2011)	30.97	24.01	26.55	26.92	20.86	20.27	6.07	9.95

Table A.2: Description of data processing used to define the sensitivity criteria

Sensitivity Criteria	*Data Source + Date of Publications*	*Data Description, Preparation and Processing*	*Feature Class*	Feature Class Sensitivity[7]	Buffer Distance Sensitivity[8]
Population density Due to the potential impact of construction and/or potential safety hazards related to the gas transmission pipeline operation on lives and livelihoods of people within the proposed Gas Pipeline Corridor, areas of high population density are foreseen as highly sensitive in relation to the planned gas transmission pipeline. These specifically include cities, large coastal and inland towns and other densely settled areas.	• *Census 2011 StatsSA* • CSIR Settlement Footprint Layer, 2017.	• Mapping of all formal and traditional settlements within the gas pipeline study area. The primary data source used was the CSIR Settlement Footprint Layer, 2017. This settlement footprint was recently developed for South Africa. It is based on a spatial footprint created by using a combination of StatsSA small areas and main places, the ESKOM spot building count (adapted and corrected) and land cover related information. Demographic information for the respective settlements has been compiled using the outlined data through a spatial disaggregation process. The population baseline data made use of StatsSA, 2011 demographic data. For more information see (Maritz et al, 2018 – Under process) • Population density has been determined for the corridor area both within the settlement footprint areas, as well as within the sparsely populated regions. Density categories and indicators to determine different scales of settlement density and likely sensitivity were calculated, using density categories relevant within urban service delivery and spatial planning contexts (see Green et al https://www.socialfacilityprovisiontoolkit.co.za/attachments/Social_Facility_Provision_Toolkit_Manual.pdf?etag=true & StepSA http://stepsa.org/SocialFacilityToolkit.).	More than 5000 people/km²	Very High	*500m*
			Between 1000-5000 people/km²	High	*500m*
			Between 600-1000 people/km²	Moderate	*400m*
			Between 200-600 people/km²	Low	*300m*
			Less than 200 people /km²	Very Low	*200m*

[7] Refer to Appendix A for an explanation on the various sensitivity classes

[8] The buffer area takes into account the current population and extent of the urban area, as well as a reasonable expectation of likely future population growth. Based on this, a pragmatic approach was taken to calculate an area large enough to accommodate the growth expected in 10-15 years and to distribute this as a buffer around settlements. Where specific growth was indicated on development plans, this was noted. Given that the direction of growth of each individual settlement is mostly unknown or unpredictable at this early stage, the buffer was calculated to conservatively enable most growth.

Sensitivity Criteria	*Data Source + Date of Publications*	*Data Description, Preparation and Processing*	*Feature Class*	Feature Class Sensitivity[7]	Buffer Distance Sensitivity[8]
Development intensity and extent Settlement and economic development nodes are regarded as highly sensitive for future construction of the proposed Gas transmission Pipeline. Within large towns, cities and metropolitan areas the number of people, businesses, livelihoods and quality of life increase sensitivity levels. Within medium and smaller towns local economies are more vulnerable and thus also highly sensitive.	• *CSIR Town Area Typology, 2018*	Settlement and economic development nodes, as clusters of (1) physical dense built-environment structures and infrastructure networks, as well as (2) high levels of complex socio-economic and institutional and ecological activities and systems within settlement footprint areas and surrounding hinterlands that have high levels of interaction have been identified as significant and spatially distinct areas that are considered within the sensitivity analyses. Given that the benefit to the nodes from the gas transmission pipeline will depend on the final alignment of the pipeline, the sensitivity of construction related activities will be the main focus of the assessment and thus the high density of activities and livelihoods in larger settlements might be at risk or disrupted through construction. Nodes of development intensity have been identified throughout the gas pipeline study area. The following methodology was used: • The official socio-economic information is only currently available at administrative reporting or information gathering units such as Local and District municipal levels. Data could not be analysed for population or economy for separate settlements or demarcated urban areas. The development of the StepSA Town Area Typology (2018) has changed this through the effective functional demarcation of settlements, towns and cities that can now be used for assessments such as these. The Town Areas Typology 2018 that was developed and is used here, is an adapted and updated version of the former SACN/CSIR Functional Settlement Typology, 2015 which until now has been used widely for the purpose of town growth analysis (inter alia within the National Development Plan 2011 and the Integrated Urban Development Framework, 2015). This data layer is based on the spatially disaggregated settlement footprint data sets and has attribute data for verified spatial indicators (based on population as well as disaggregated economic output data that can be used as spatial indicators for socio-economic development. The CSIR Geospatial Analyses Platform, 2017 (Maritz et al, 2018) as well as a range of additional spatial indicators and accessibility analyses (http://stepsa.org/) were used to develop this data set. • A typology of different classes of cities, towns and settlement areas was used as integrative proxy for the extent of population, economic activity, infrastructure, engineering services and related complex set of systems and functions within each of the settlement and economic development nodes within the study area.	Metro's (more than 1 million people), cities & large regional towns (typically larger than 300 000 people) with larger economies.	Very High	*500m*
			Big regional towns (about 100 000 people) & service towns (more than 20 000 people but significant (even if small) economic functions)	High	*500m*
			Smaller highly sensitive towns with less intense economies are regarded as settlements	Moderate	*200m*
			Dense rural settlements have lower sensitivities in terms of economic and	Low	*150m*

Sensitivity Criteria	*Data Source + Date of Publications*	*Data Description, Preparation and Processing*	*Feature Class*	Feature Class Sensitivity[7]	Buffer Distance Sensitivity[8]
			development extent.		
			Sparse rural areas – few people and limited economic activity	Very Low	-
Land-use management and tenure High levels of sensitivity related to institutional and land-use management and development regulatory systems are foreseen in cities, large towns and dense rural settlements in areas under traditional authority jurisdiction.	• *StepSA Town Area Typology, 2018* • *Traditional Authority layer(Demarcation Board, 2011)*	The sensitivity of institutional, land-use management and land development regulatory systems are foreseen to impact planning, land servitude proclamation, any land expropriation and construction for the gas transmission pipeline. The prevailing dominant land use management system and land tenure system may potentially point to capacity challenges for the local authority and the occupiers of the land. This will require different approaches to land access for construction and operations for the pipeline development for different land tenure or use regimes. The ideal would be to use information on land ownership and size from a national land audit register. Unfortunately this register is not complete for every land parcel in the country.	*Large formal towns (Cities, Towns, Regional Service Centres)*	High	-
			Dense Rural Settlements in traditional authority areas	Moderate	-
			Small Towns and Small Service Centres	Moderate	-
			Sparsely populated areas	Low	-

APPENDIX A.2: DETAILS ON FEATURE RATINGS

Corridor	Feature Class	Feature Class Sensitivity	Reason for rating
Population density	More than 5000 people/km²	Very high sensitivity	*The less people whose homes, roads or livelihoods are impacted the better. The rating takes into consideration the likely number of people impacted per unit area. The more densely populated an area, the more people are likely to be impacted.*
	Between 1000-5000 people/km²	High sensitivity	
	Between 600-1000 people/km²	Moderate sensitivity	
	Between 200-600 people/km²	Low sensitivity	
	Less than 200 people /km²	Very low sensitivity	
Development intensity and extent *(See Appendix E for description of CSIR Functional Town Typology, 2018)*	Metro's (more than 1 million people), cities and large regional towns (typically larger than 300 000 people) with larger economies.	Very high sensitivity	*The larger extent of the urban/ settlement development and the larger the economic activity the greater the likely impact of construction will be. In addition, any delay or uncertainty that arises before or during the construction period will increase the disruption.* *The lower the economic activity or development extent, the lower the sensitivity overall, although in limited cases the impact on a few individuals may be high.*
	Big regional towns (about 100 000 people) & service towns (more than 20 000 people but significant (even if small) economic functions	High sensitivity	
	Smaller highly sensitive towns with less intense economies	Moderate sensitivity	
	Dense and sparse rural settlements with limited economic and development or extent	Low sensitivity	
	Sparse rural areas – few people and limited economic activity	Very low sensitivity	
Land-use management and tenure	*Large formal towns (Cities, Towns, Regional Service Centres*	*High sensitivity*	*Many people & land parcels are likely to be impacted by land use or servitude proclamation if the pipeline goes though Cities and Large Regional Service Centres.*
	Dense Rural Settlements in traditional authority areas	Moderate sensitivity	*Due to the complexity of land ownership and use rights and limited legal and economic capability the residents in this area will be sensitive to changes in land use application or over servitudes being created and special measures will be required to ensure fair and ethical negotiations where these are required.*
	Small Towns and Small Service Centres	Moderate sensitivity	*Mainly formal land tenure & freehold property rights. Thus negotiations regarding land use & servitudes will be less complex with less people impacted than in larger towns. Planning Capacity may be lacking, and may negatively impact on timeframes in finalising servitudes.*
	Sparsely populated	*Low sensitivity*	*Fewer people impacted on a fewer large tracts of land which is in private or other means of formal ownership*

APPENDIX B – FEATURE MAPS

B.1 West Coast Corridor (Phases 5 and 6)

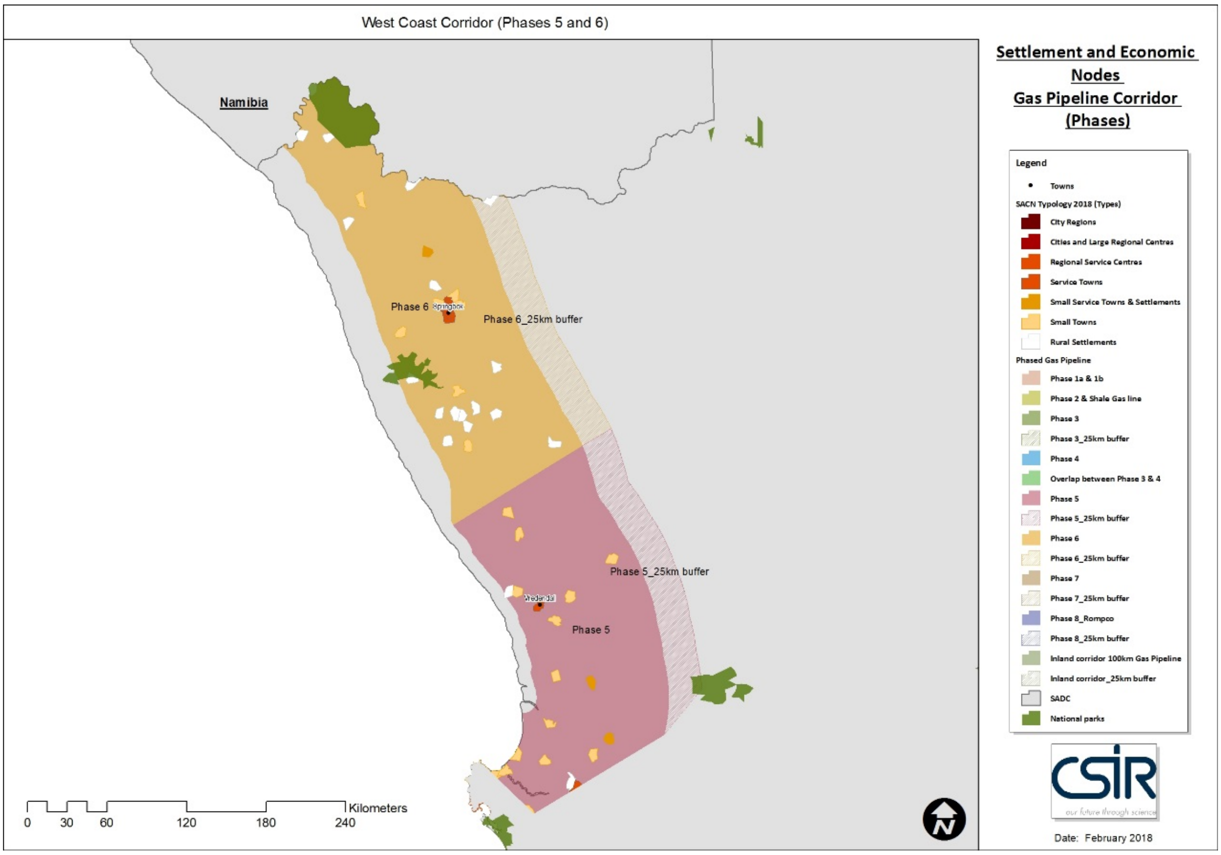


Figure B.1: Settlement and Economic Nodes Gas Pipeline Corridor (West Coast Corridor (Phases 5 and 6))

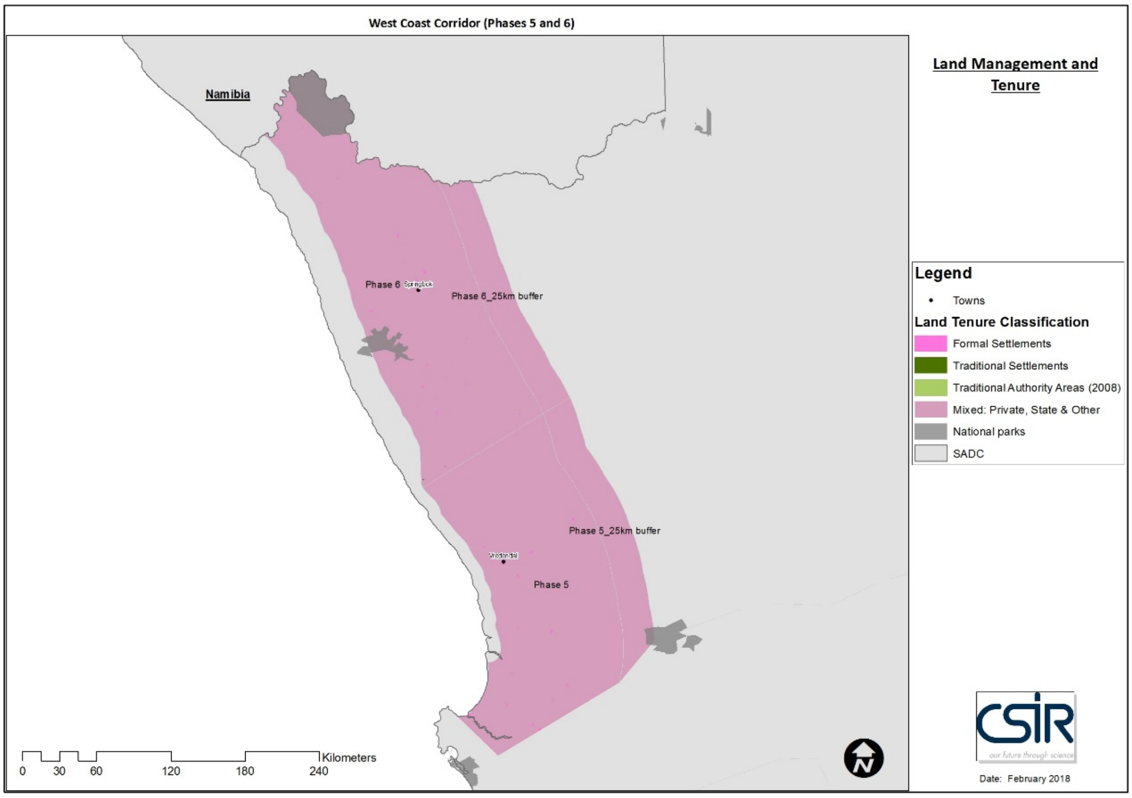


Figure B.2: Land Management and tenure in Gas Pipeline Corridor (West Coast Corridor (Phases 5 and 6))

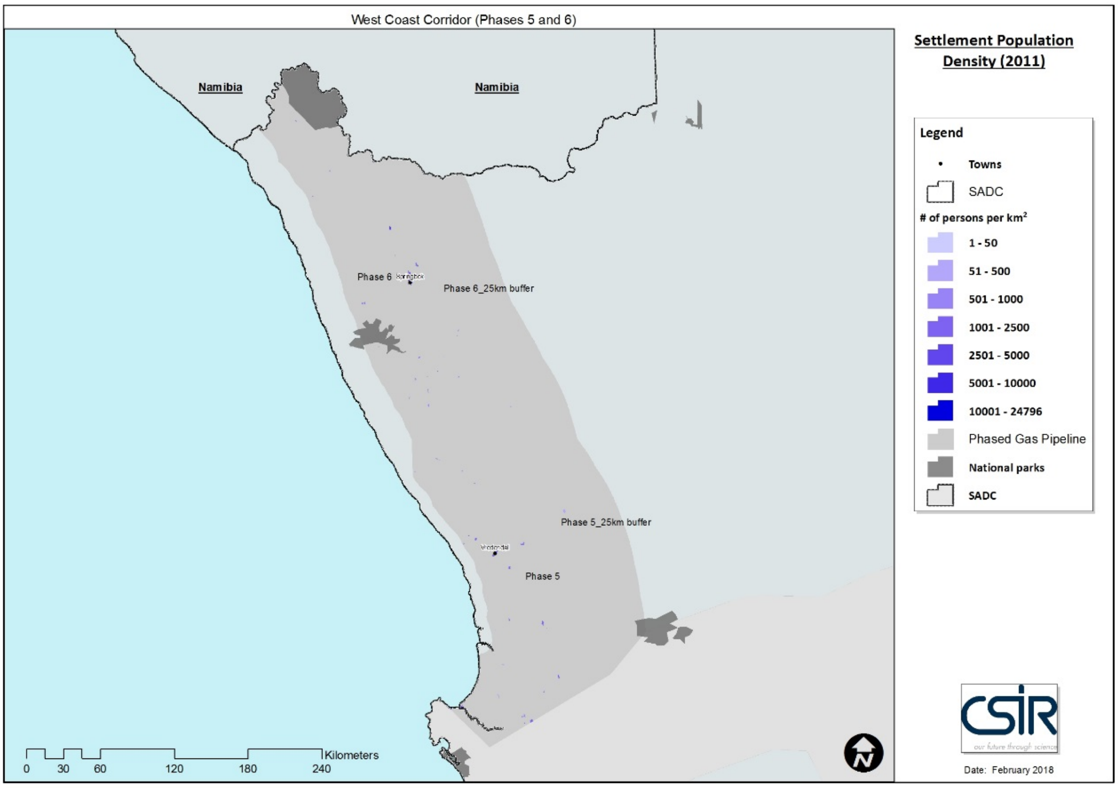


Figure B.3: Population density of Settlements in Gas Pipeline Corridor (West Coast Corridor (Phases 5 and 6))

B.2 Southern Coastal Corridor (Phases 1 and 2)

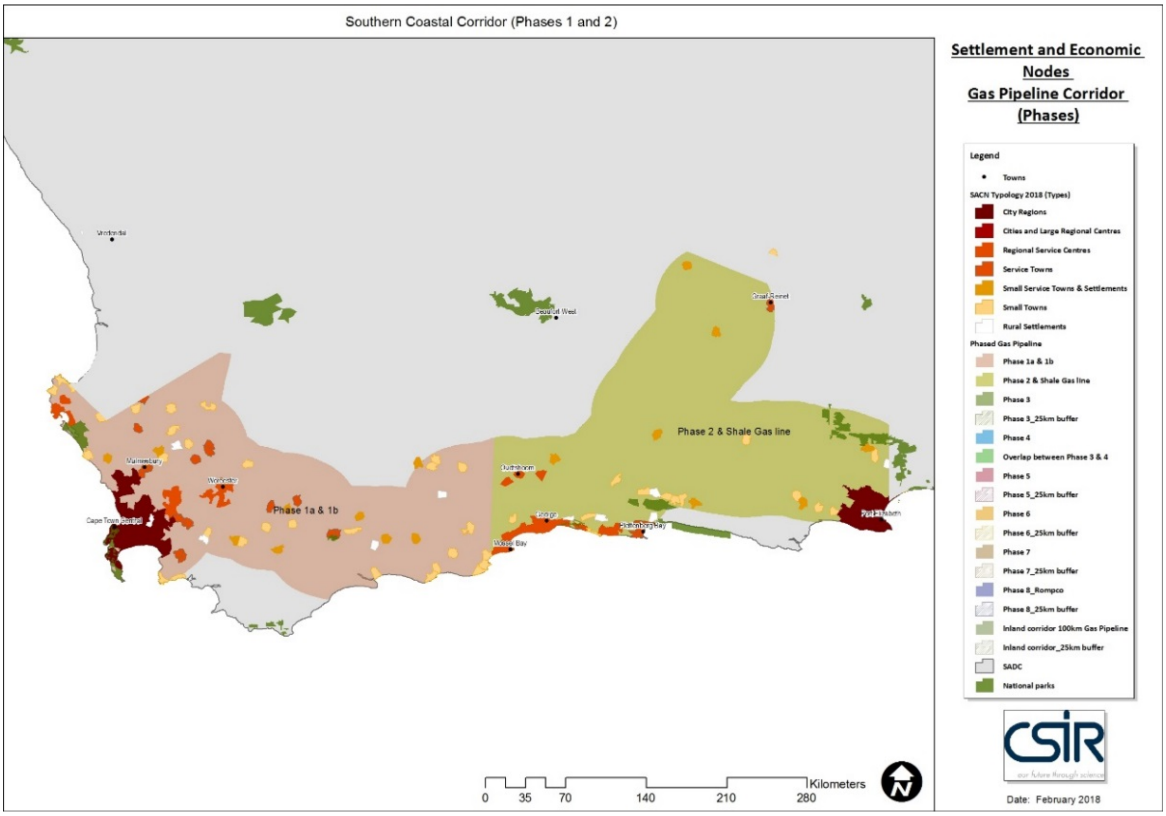


Figure B.4: Settlement and Economic Nodes Gas Pipeline Corridor (Southern Coastal Corridor (Phases 1 and 2))

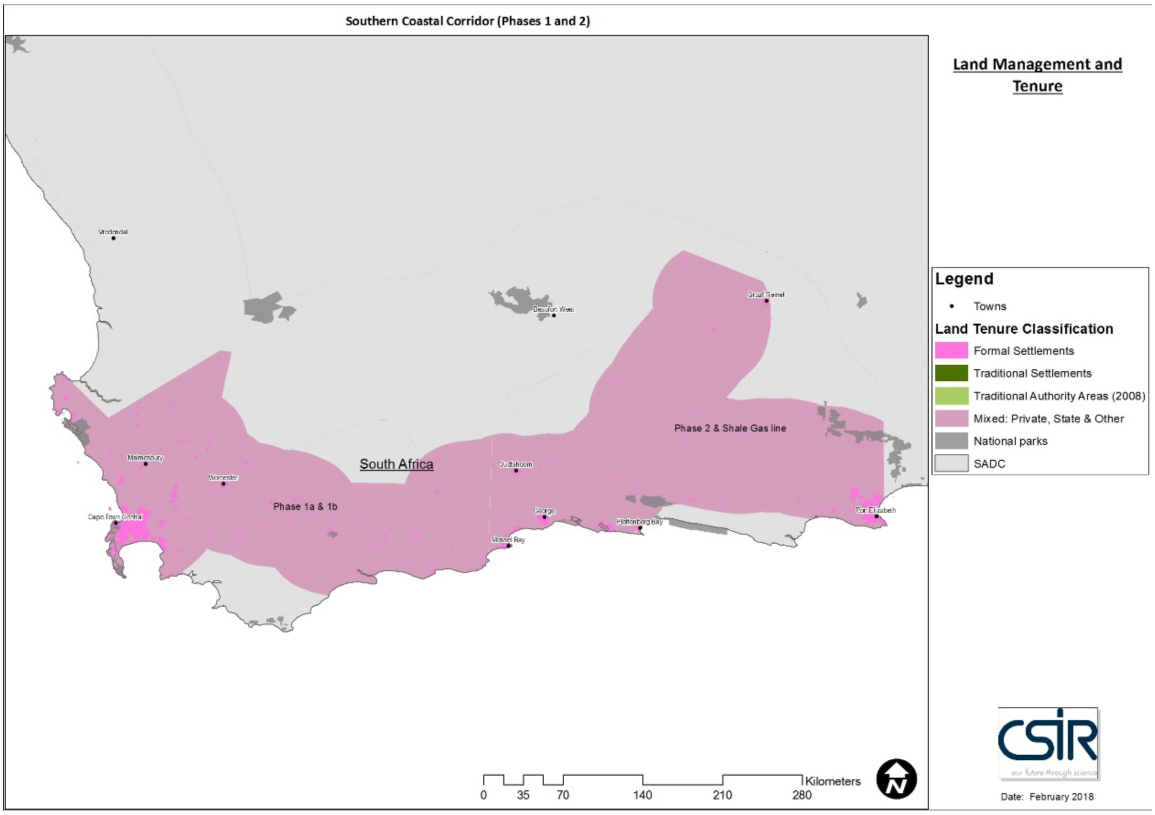


Figure B.5: Land Management and tenure in Gas Pipeline Corridor (Southern Coastal Corridor (Phases 1 and 2))

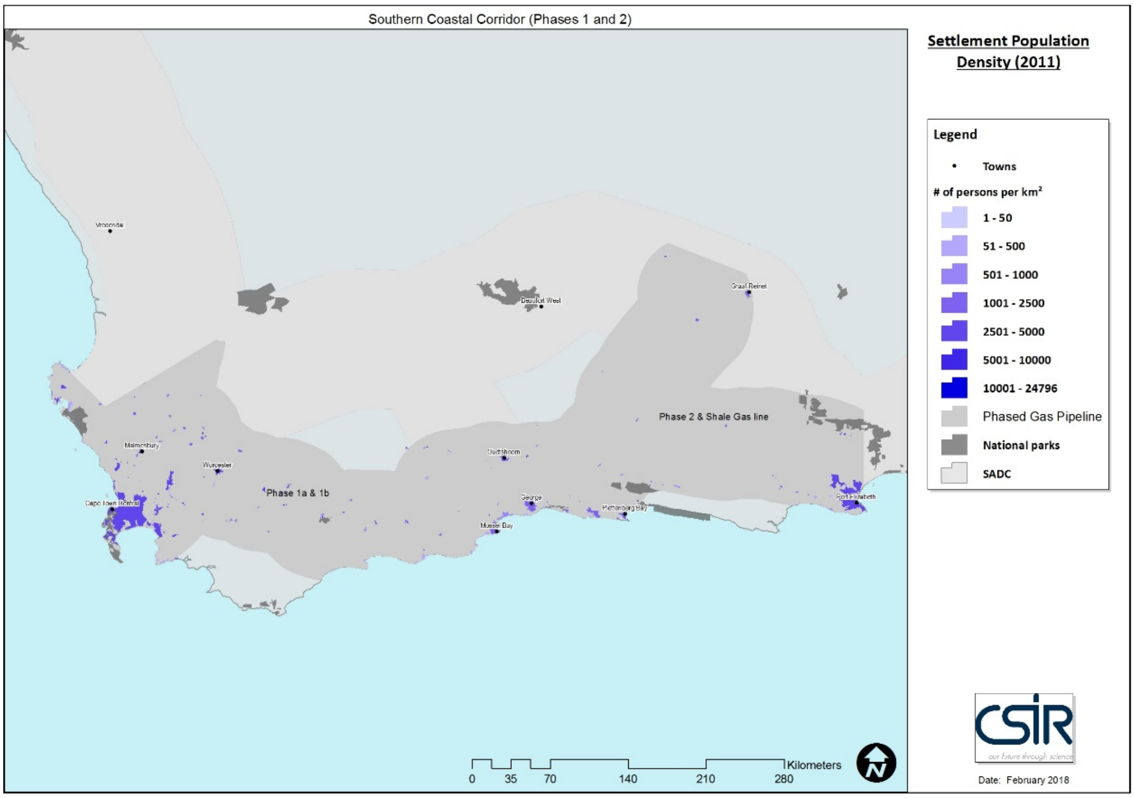


Figure B.6: Population density of Settlements in Gas Pipeline Corridor (Southern Coastal Corridor (Phases 1 and 2))

B.3 Inland Corridor (Central Karoo area)

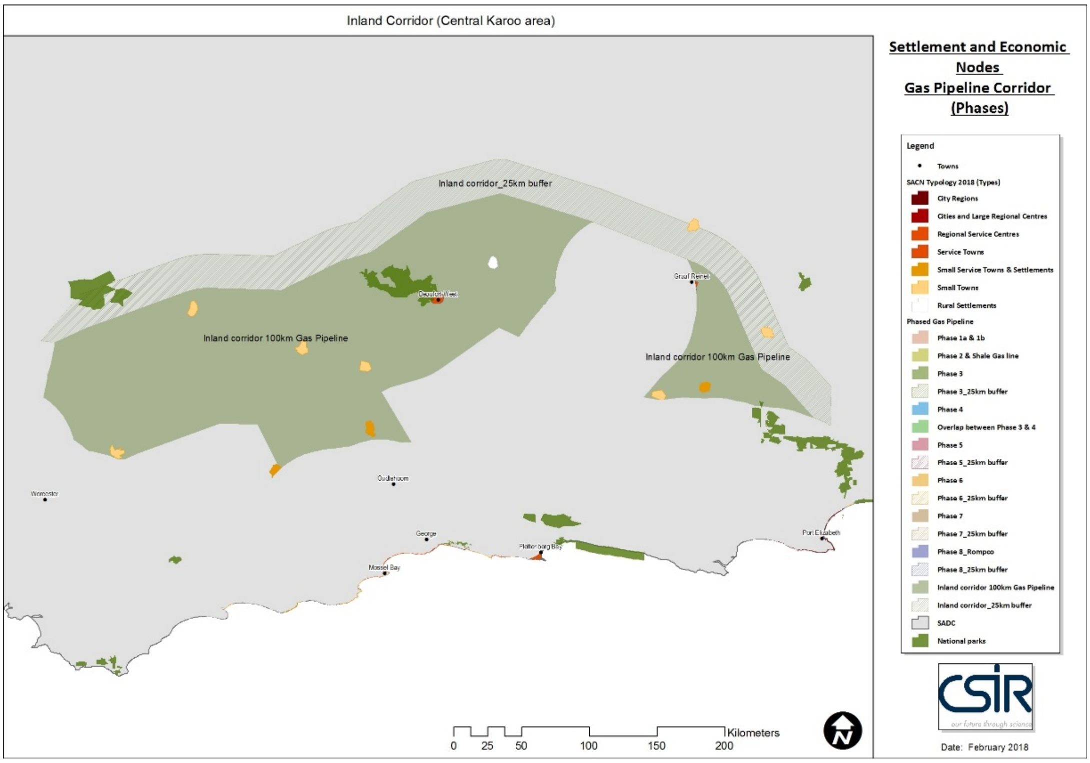


Figure B.7: Settlement and Economic Nodes Gas Pipeline Corridor (Inland Corridor (Central Karoo area))

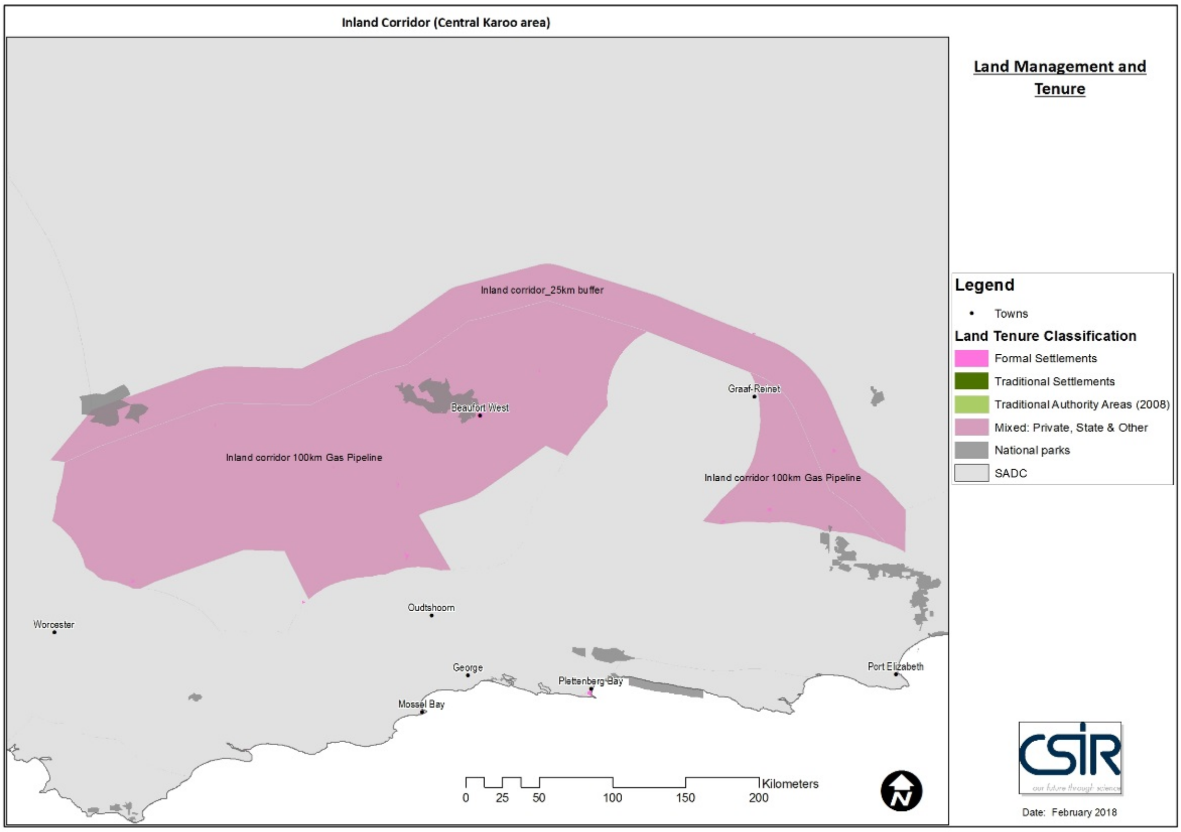


Figure B.8: Land Management and tenure in Gas Pipeline Corridor (Inland Corridor (Central Karoo area))

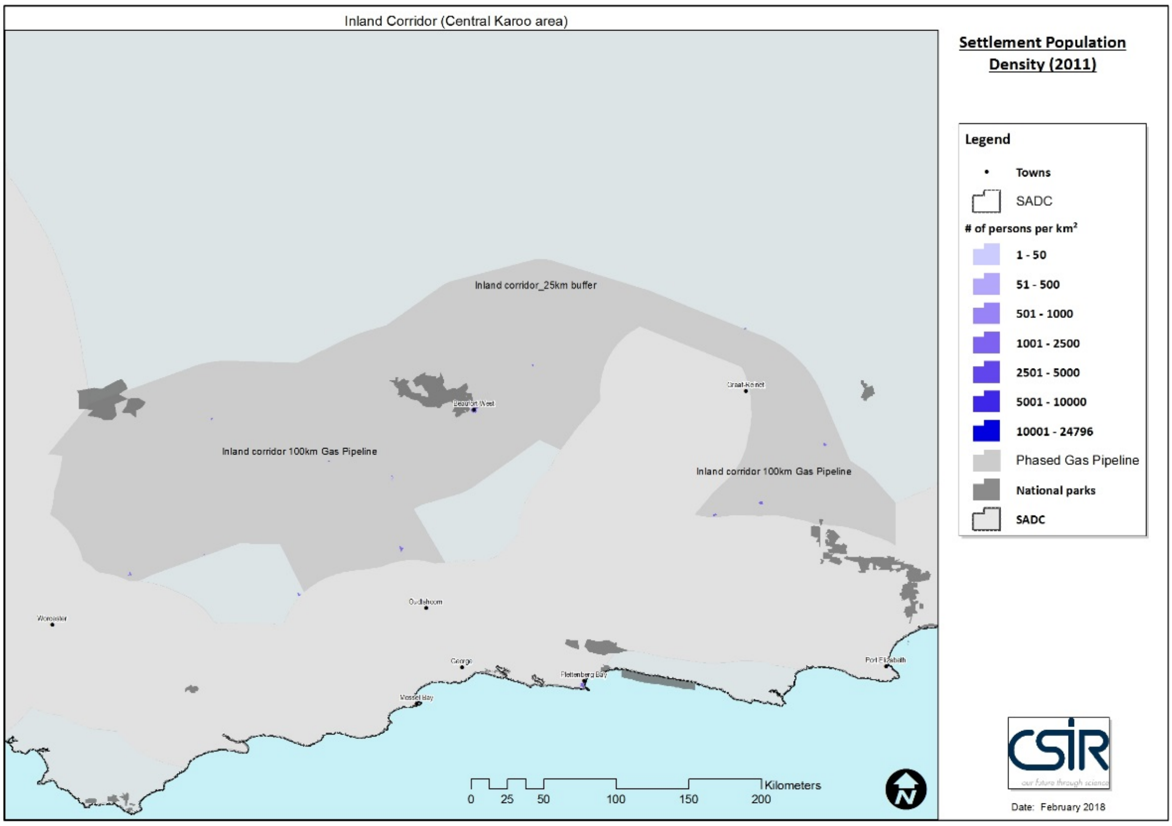


Figure B.9: Population density of Settlements in Gas Pipeline Corridor (Inland Corridor (Central Karoo area))

B.4 Eastern Cape & KZN Coastal areas (Phase 7, Portion of Phase 3 and Phase 4)

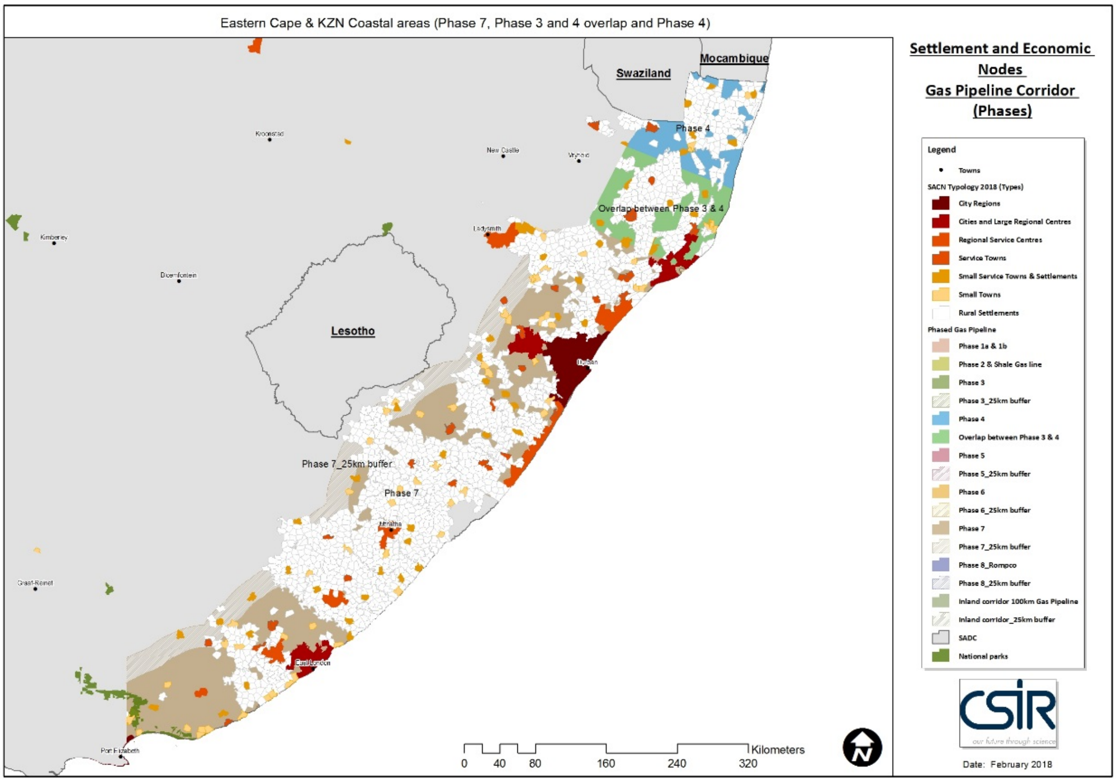


Figure B.10: Settlement and Economic Nodes Gas Pipeline Corridor (Eastern Cape & KZN Coastal areas (Phase 7, Portion of Phase 3 and Phase 4))

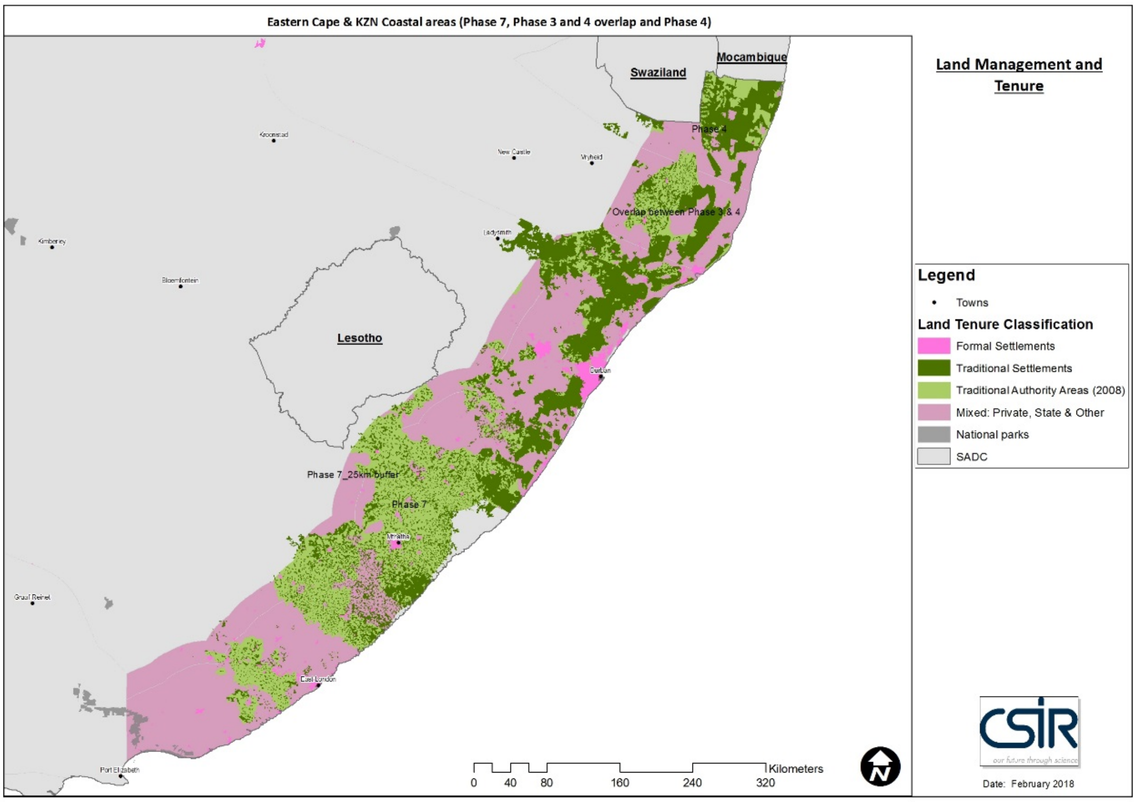


Figure B.11: Land Management and tenure in Gas Pipeline Corridor (Eastern Cape & KZN Coastal areas (Phase 7, Portion of Phase 3 and Phase 4))

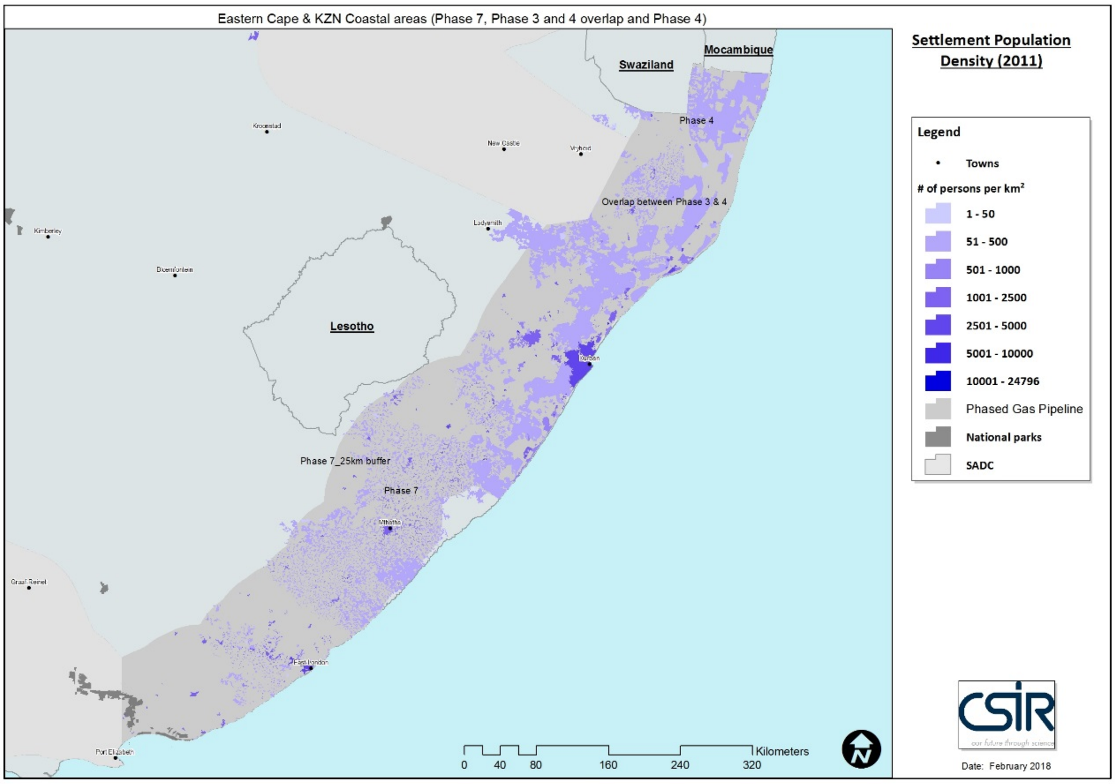


Figure B.12: Population density of Settlements in Gas Pipeline Corridor (Eastern Cape & KZN Coastal areas (Phase 7, Portion of Phase 3 and Phase 4))

B.5 Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)

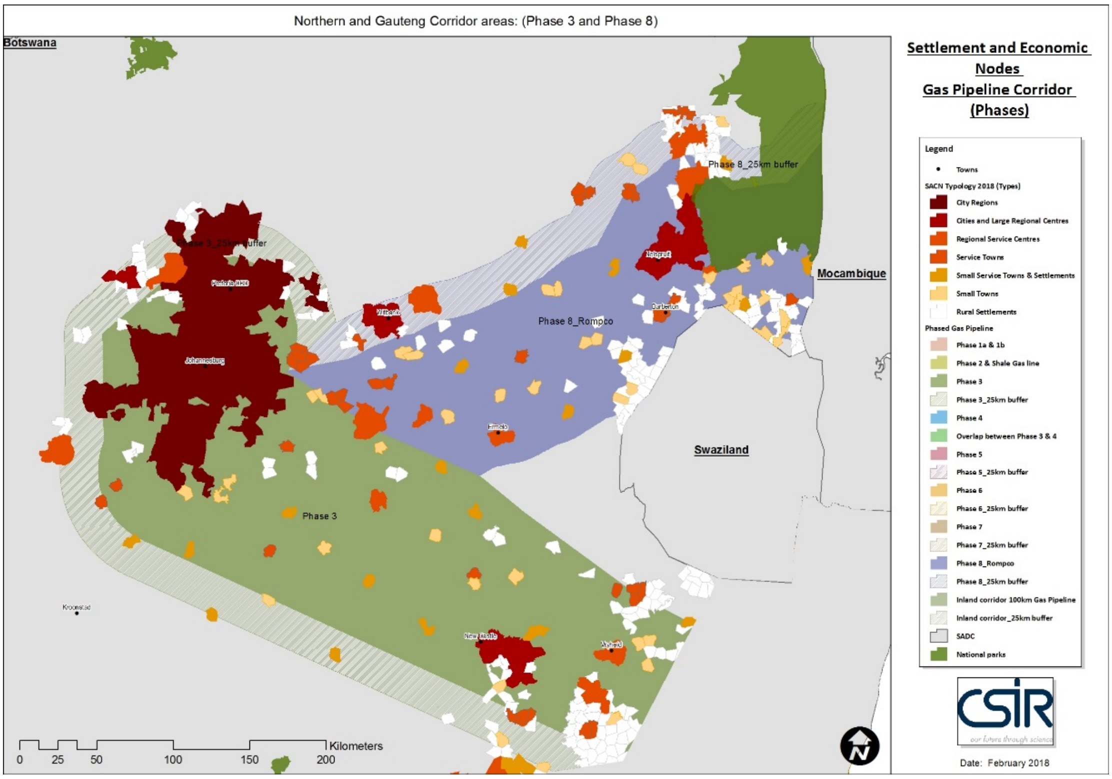


Figure B.13: Settlement and Economic Nodes Gas Pipeline Corridor (Northern and Gauteng Corridor areas: (Phase 3 and Phase 8))

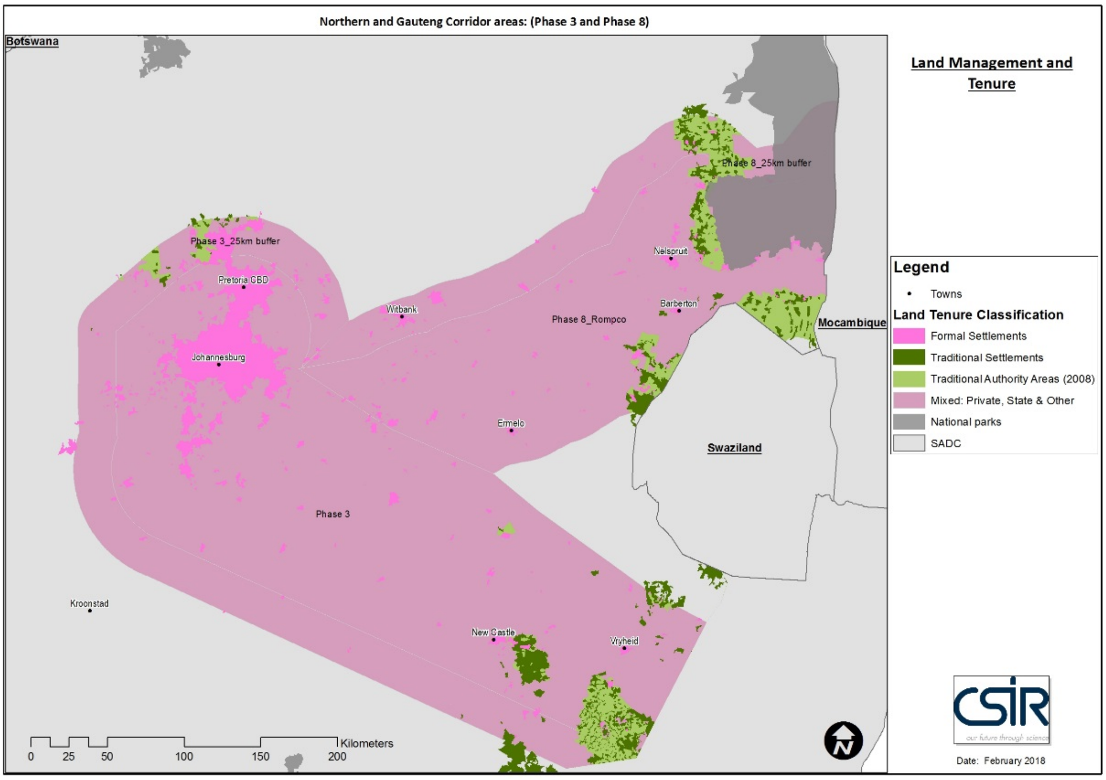


Figure B.14: Land Management and tenure in Gas Pipeline Corridor (Northern and Gauteng Corridor areas: (Phase 3 and Phase 8))

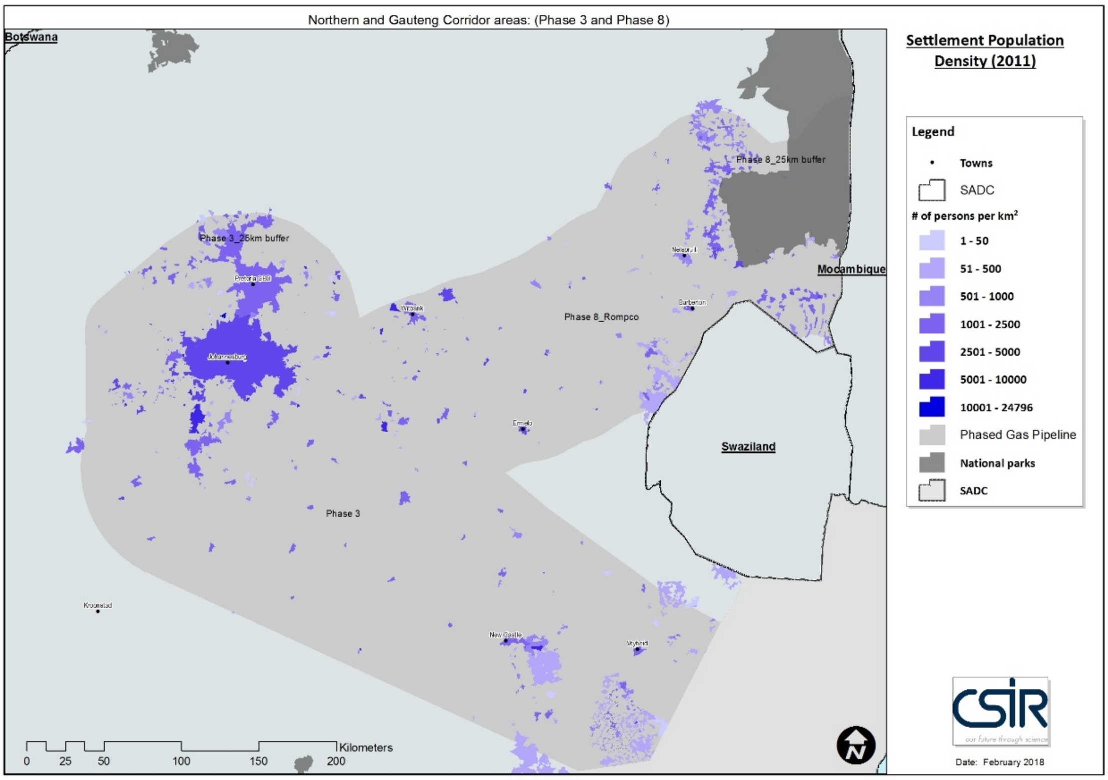


Figure B.15: Population density of Settlements in Gas Pipeline Corridor (Northern and Gauteng Corridor areas: (Phase 3 and Phase 8))

APPENDIX C – FOUR-TIER SENSITIVITY MAPPING

C.1 Eastern Cape and KZN coastal areas (Phases 7, 4 & overlap between Phases 3 and 4)

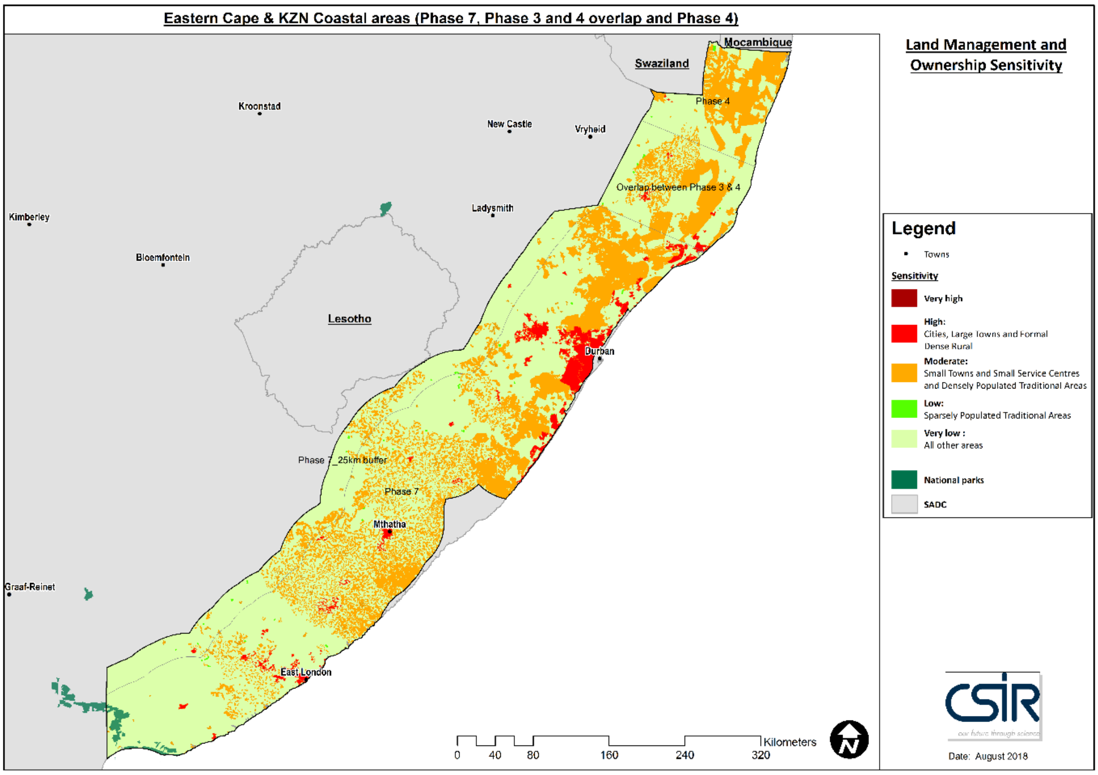


Figure C.1: Land-use Management and Ownership Sensitivity - Eastern Cape and KwaZulu-Natal Coastal Areas

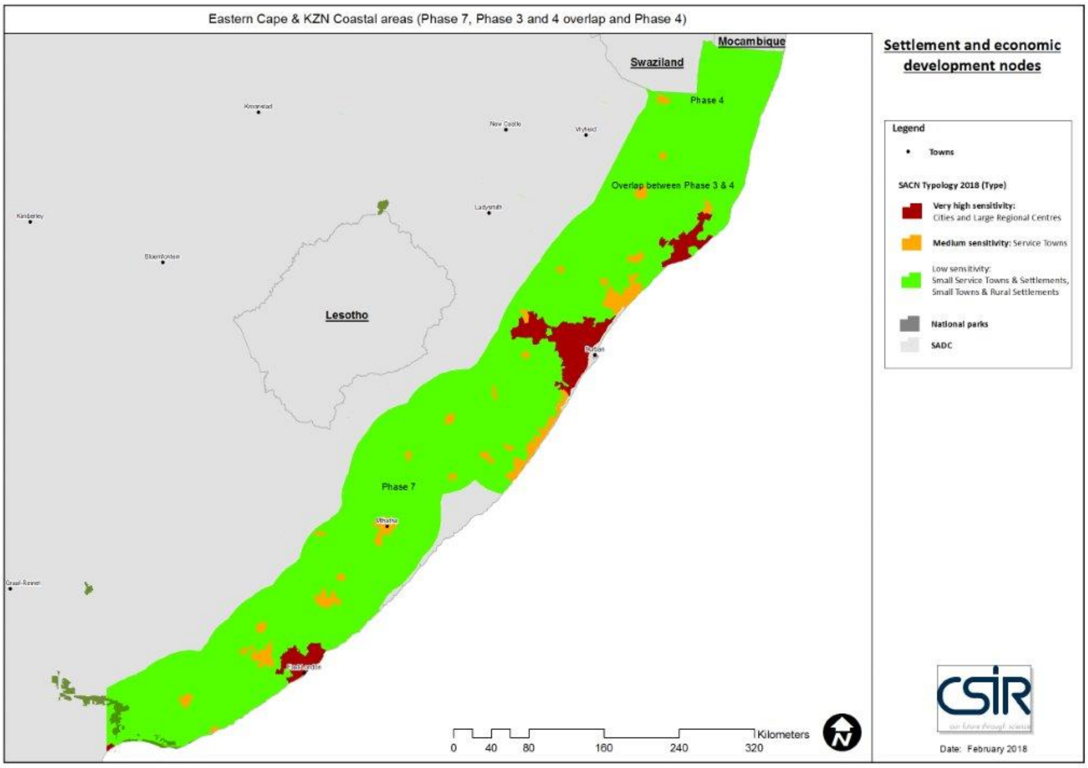


Figure C.2: Settlement and Economic Nodes Sensitivity - Eastern Cape and KwaZulu-Natal Coastal Areas

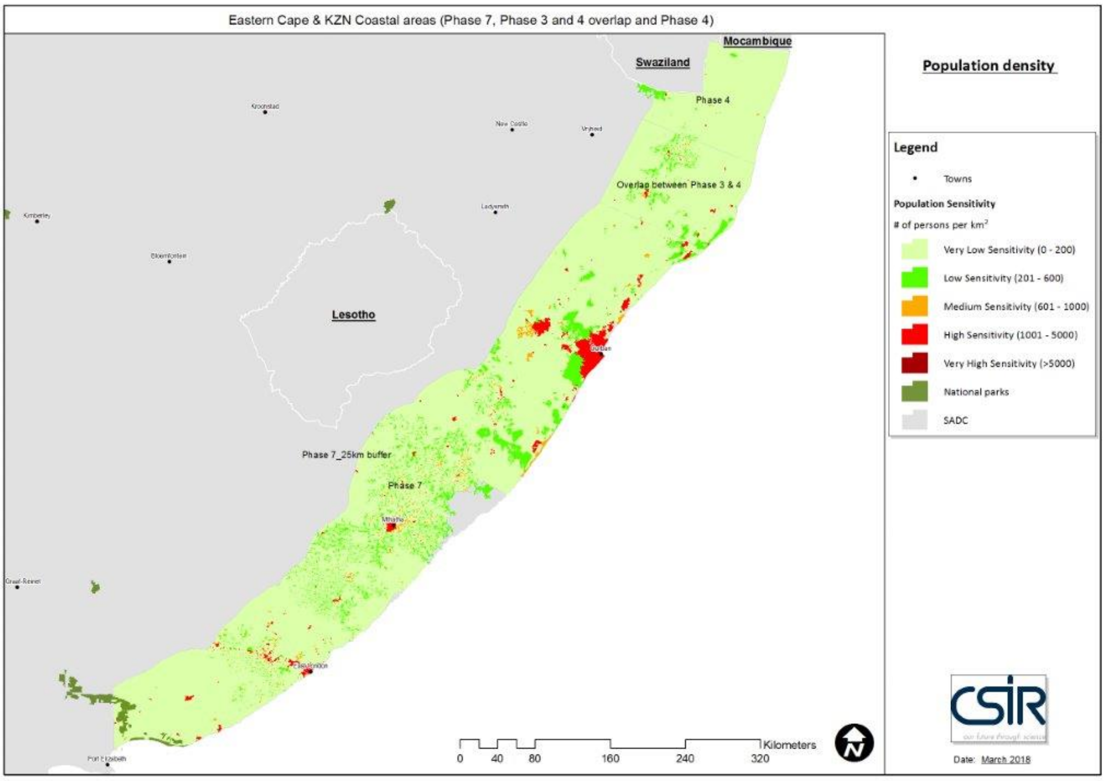


Figure C.3: Settlement population density Sensitivity - Eastern Cape and KwaZulu-Natal Coastal Areas

C.2 Inland corridor

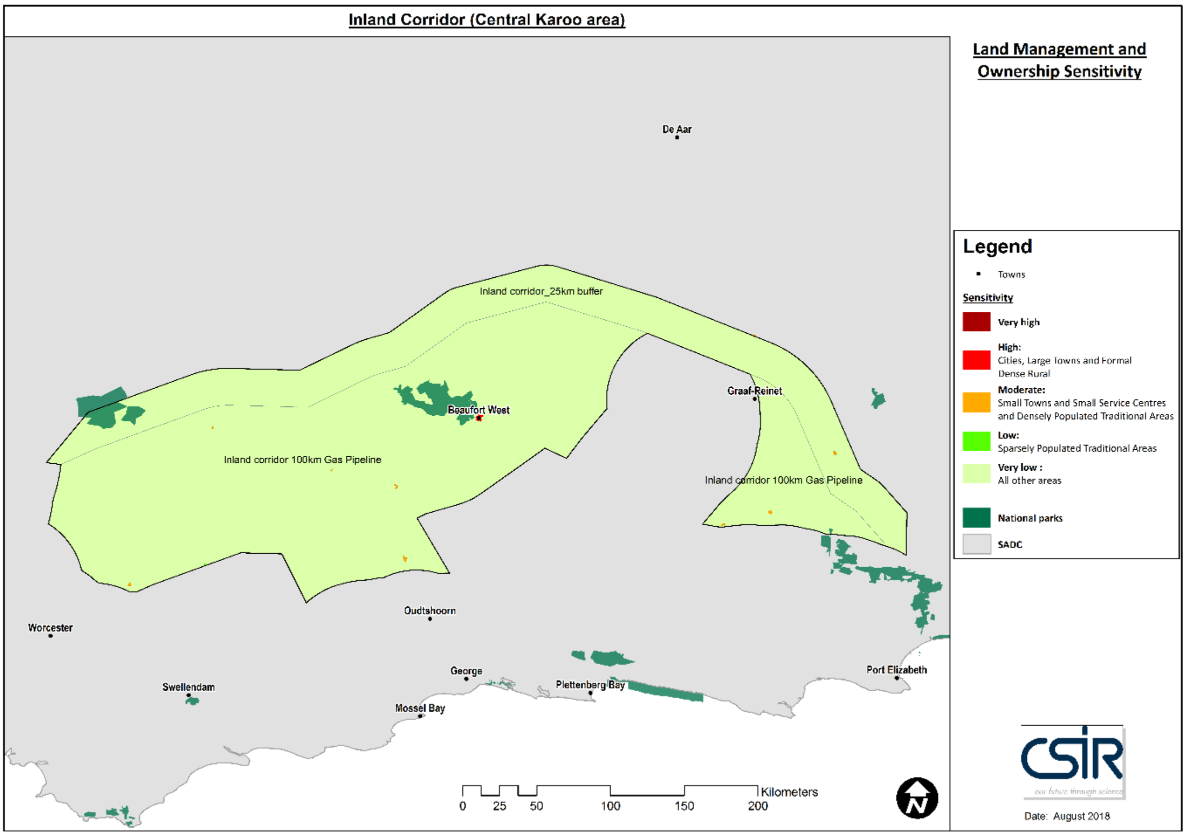


Figure C.4: Land Management and Ownership Sensitivity- Inland Corridor

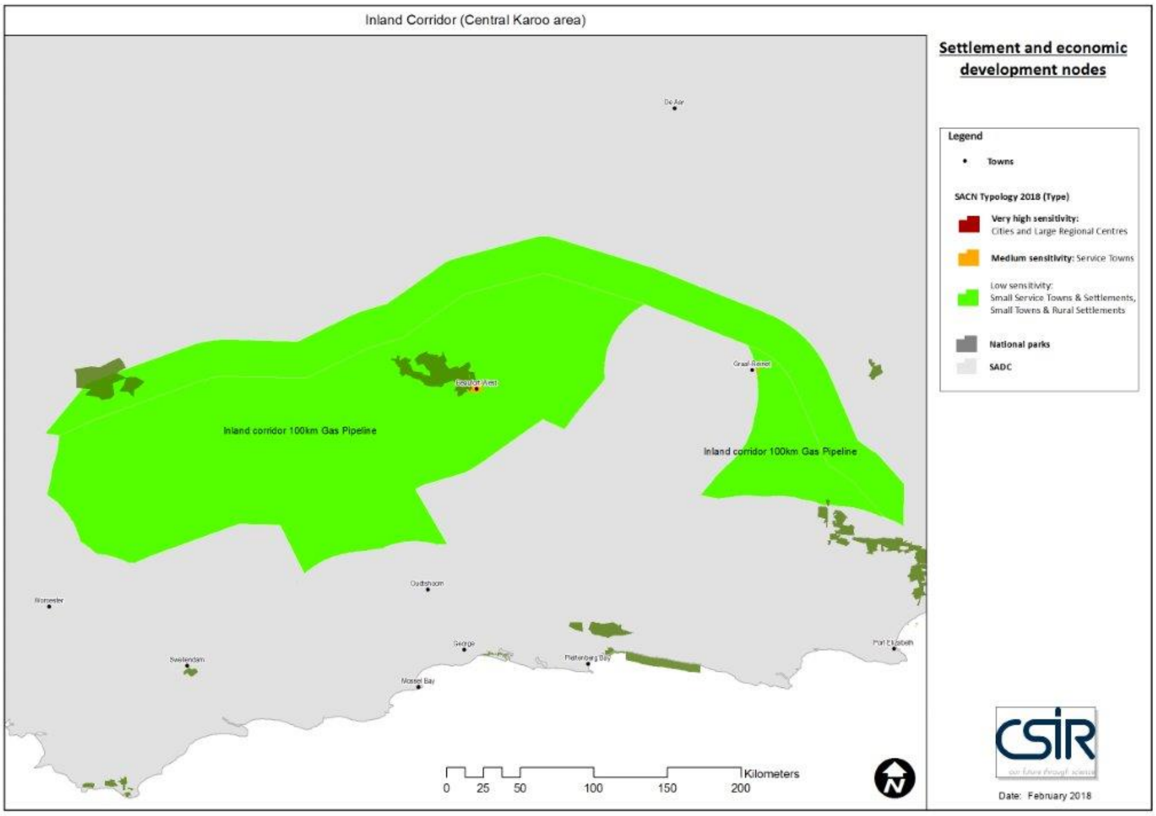


Figure C.5: Settlement and Economic Nodes Sensitivity - Inland Corridor

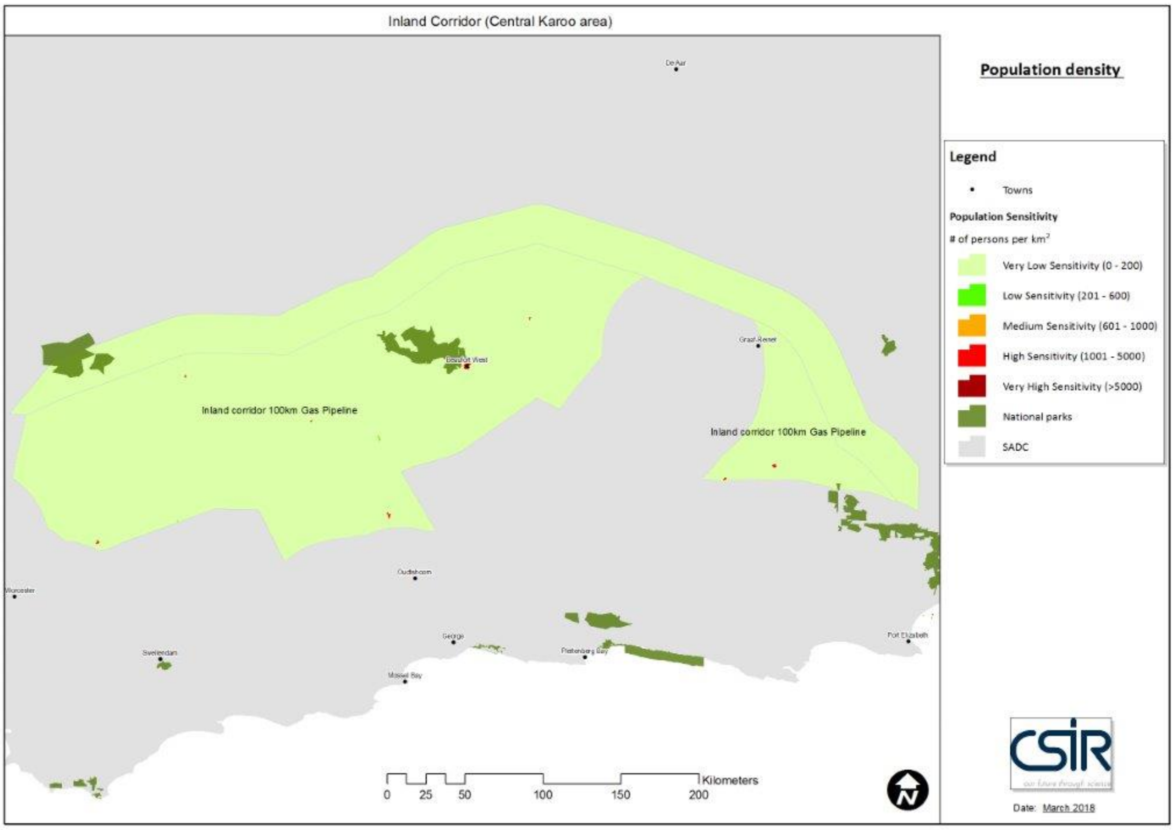


Figure C.6: Settlement population density Sensitivity - Inland Corridor

C.3 Northern and Gauteng Corridor (Phases 3 and 8)

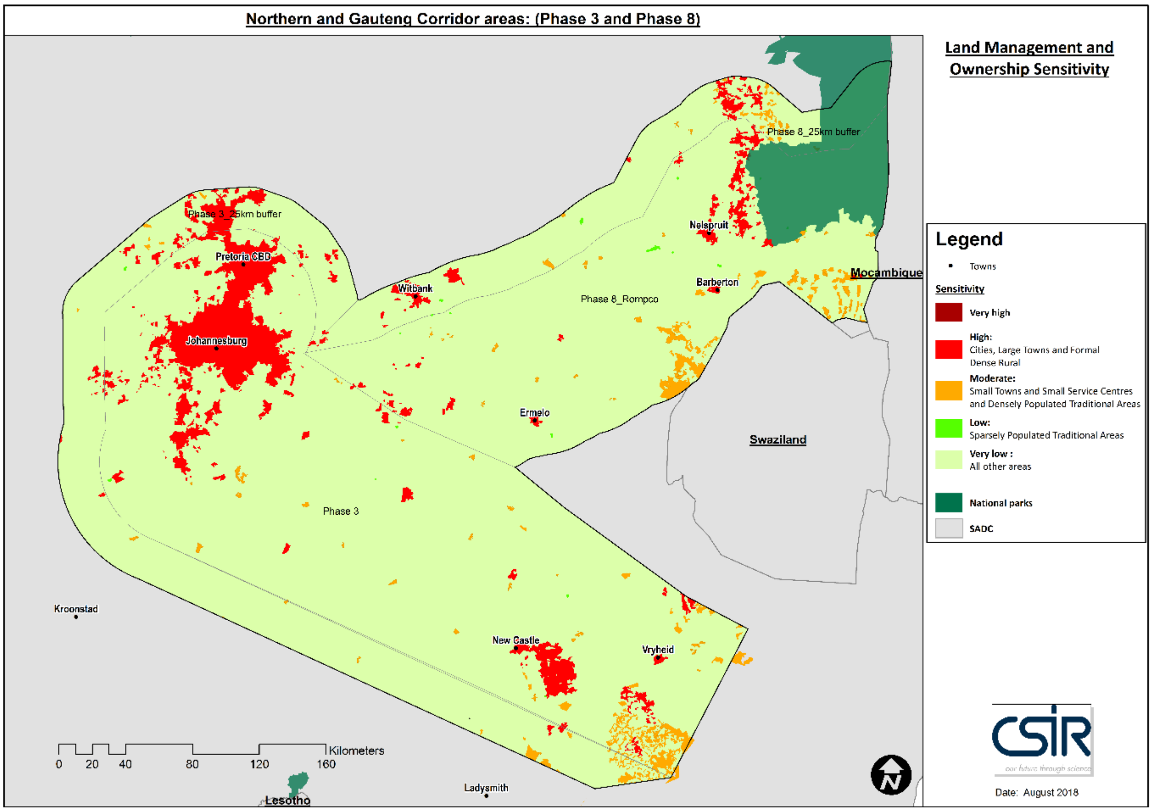


Figure C.7: Land Management and Ownership Sensitivity - Northern and Gauteng Corridor

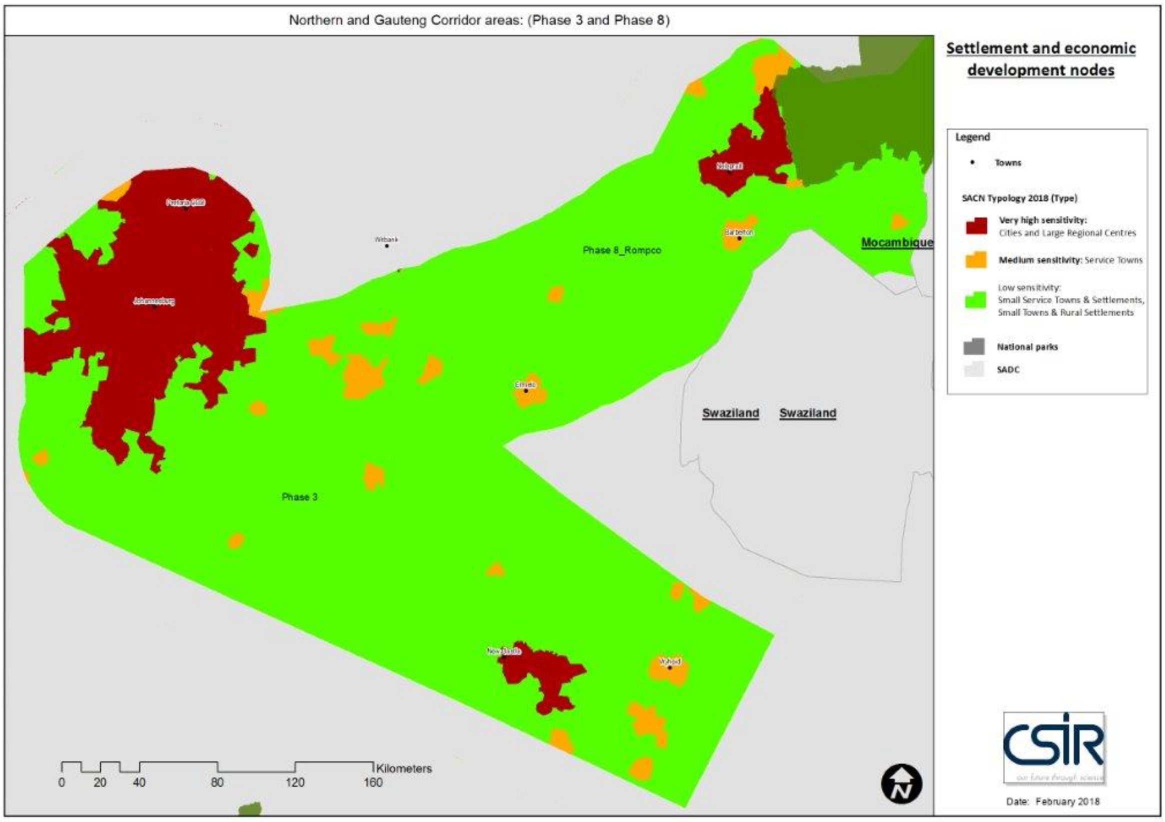


Figure C.8: Settlement and Economic Nodes Sensitivity - Northern and Gauteng Corridor

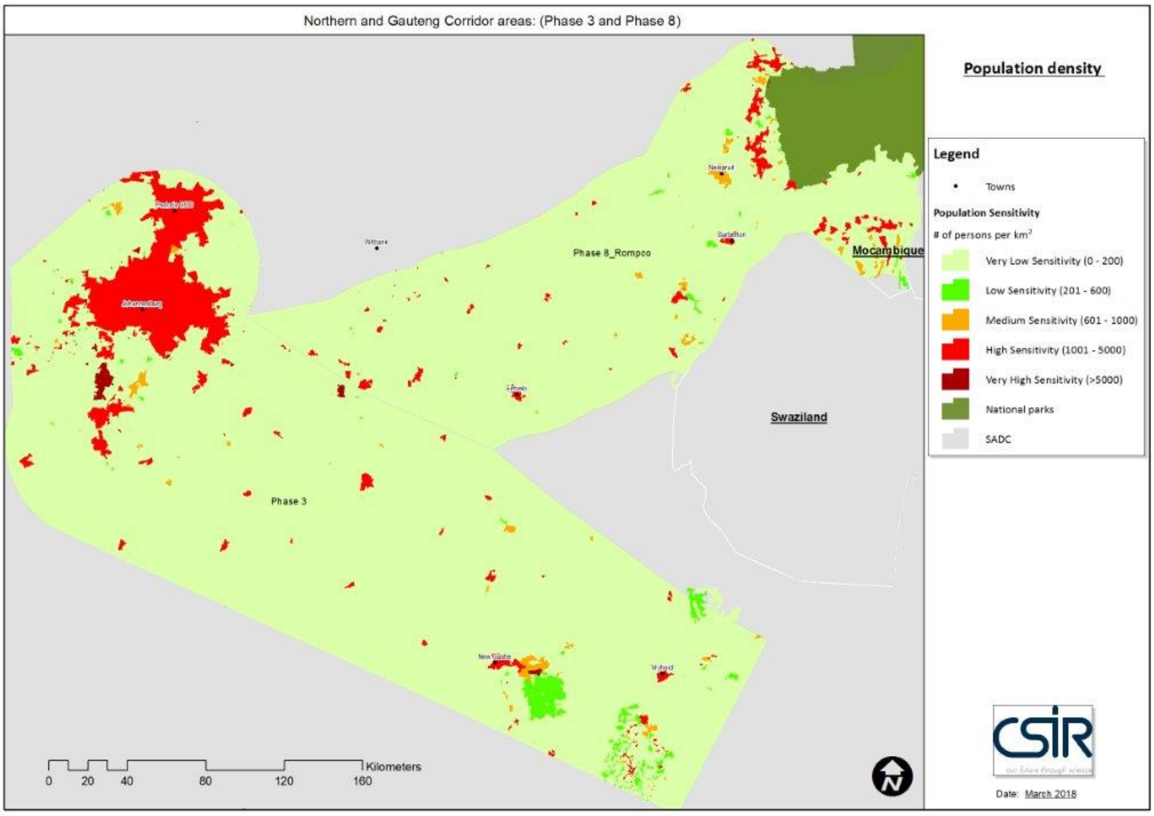


Figure C.9: Settlement population density Sensitivity - Northern and Gauteng Corridor

C.4 West Coast Corridor (Phases 5 and 6)

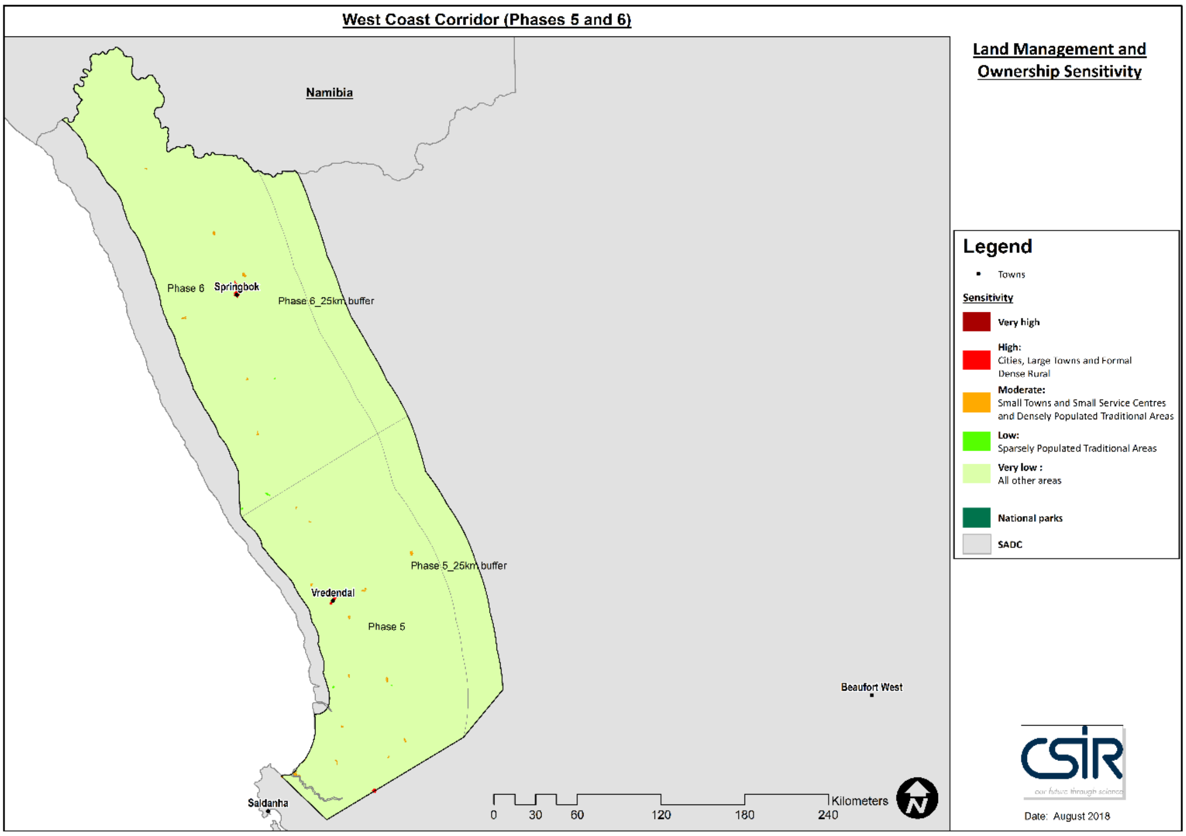


Figure C.10: Land Management and Ownership Sensitivity - West Coast Corridor

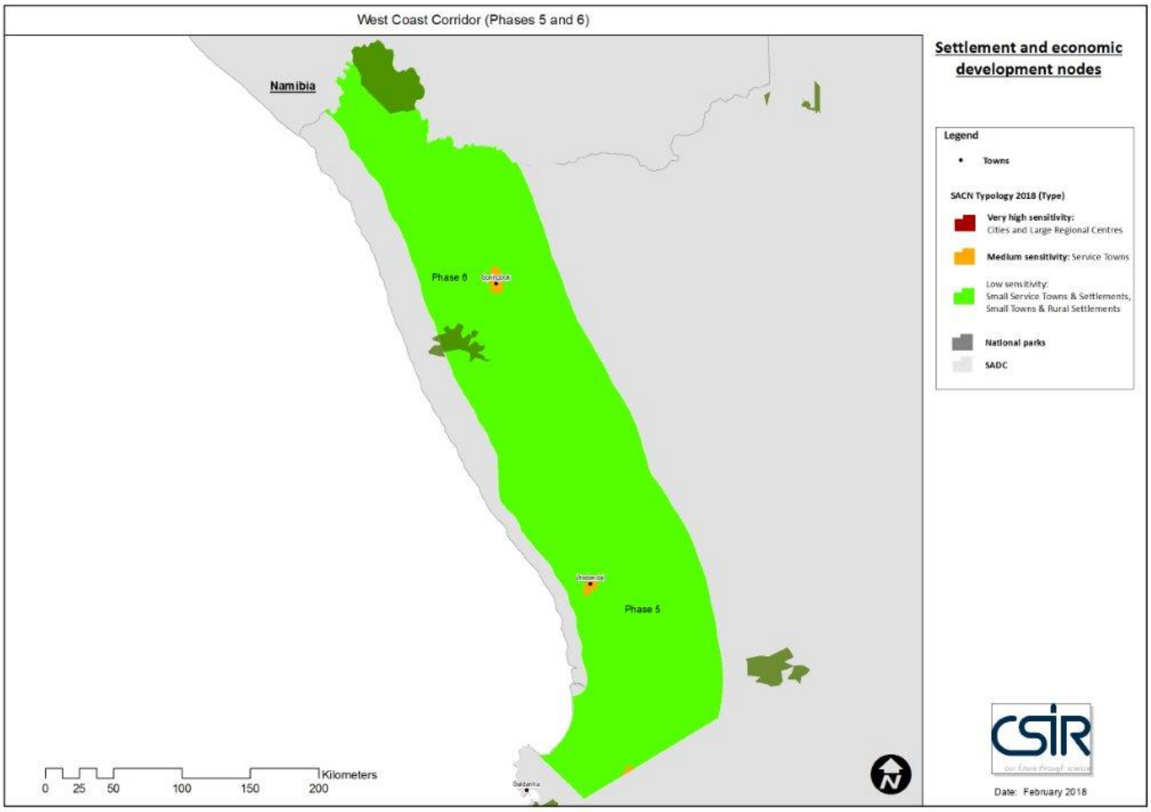


Figure C.11: Settlement and Economic Nodes Sensitivity - West Coast Corridor

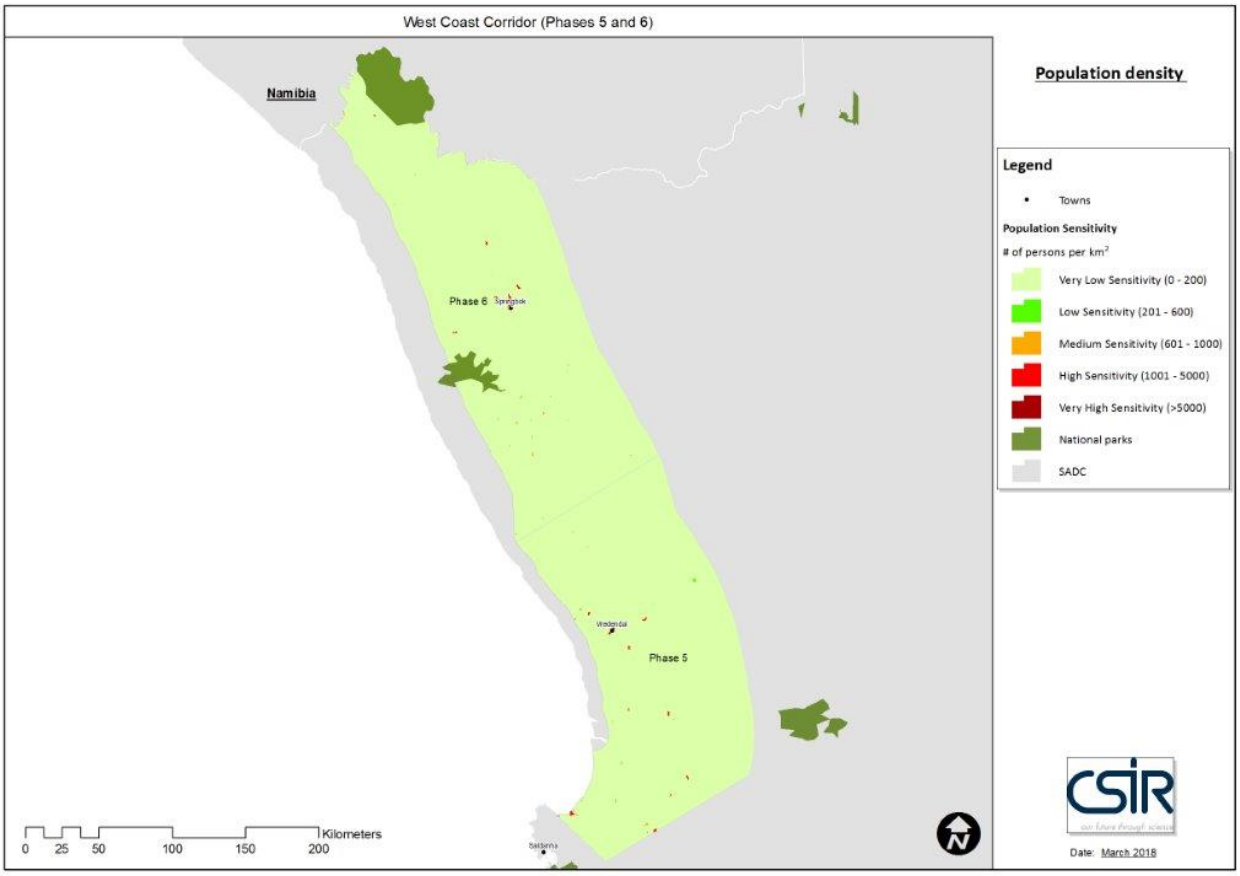


Figure C.12: Settlement population density Sensitivity - West Coast Corridor

C.6 Southern Coastal Corridor (Phases 1 and 2)

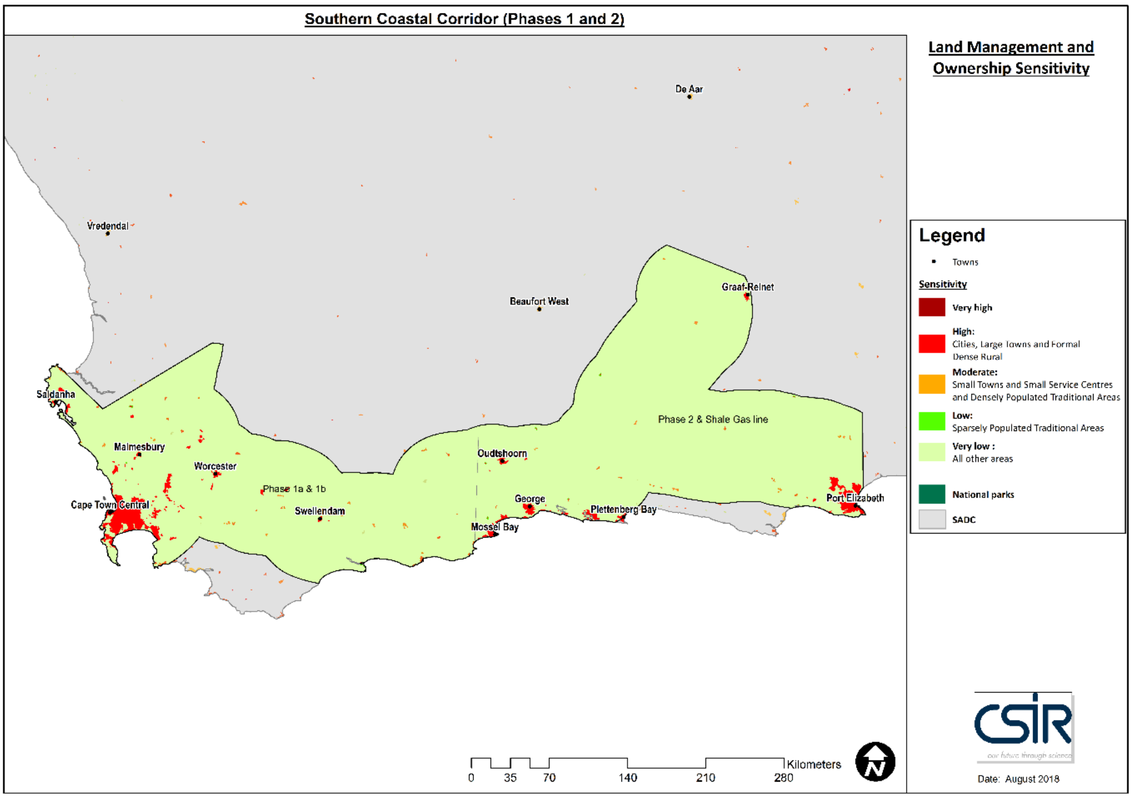


Figure C.13: Land Management and Ownership Sensitivity - Southern Coastal Corridor

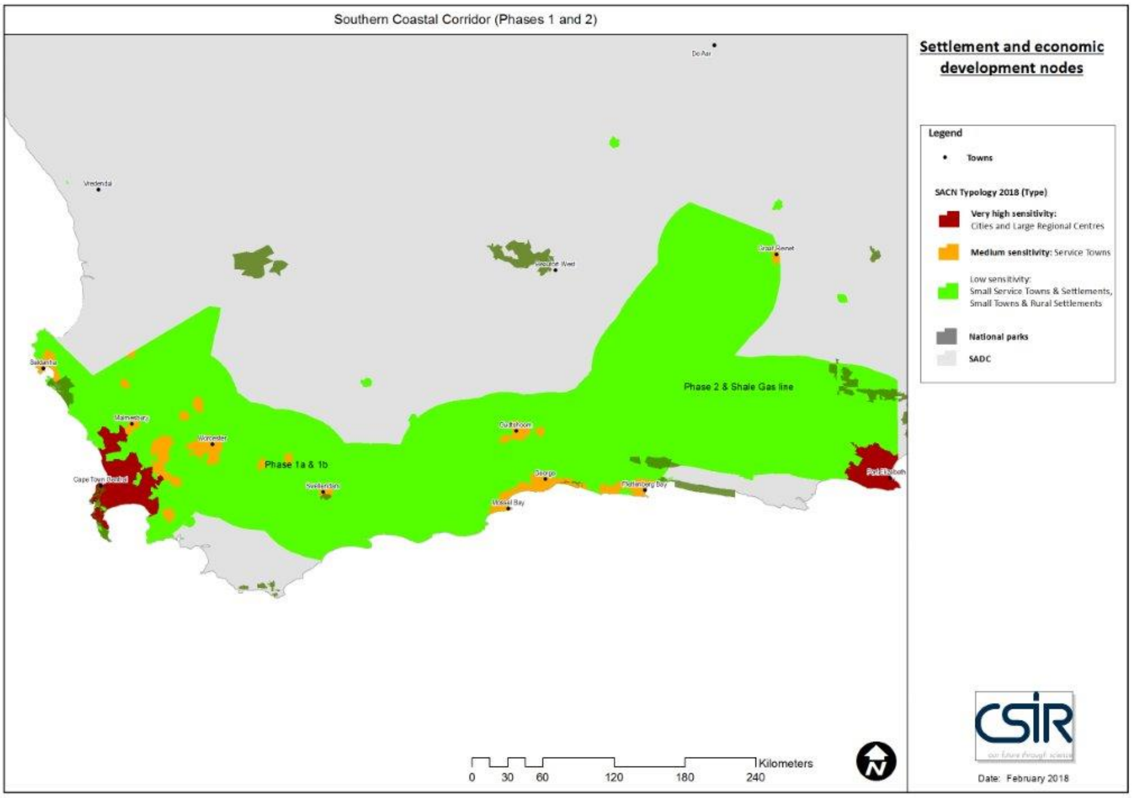


Figure C.14: Settlement and Economic Nodes Sensitivity - Southern Coastal Corridor

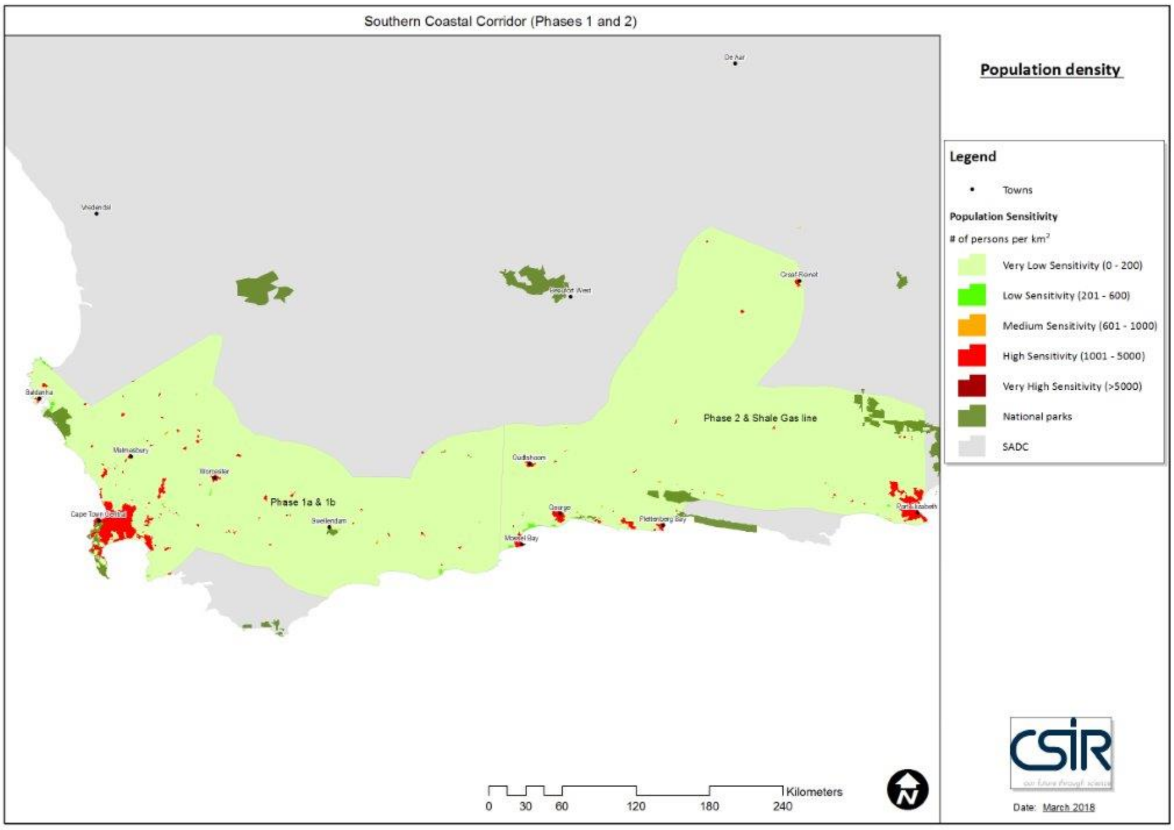


Figure C.15: Settlement population density Sensitivity - Southern Coastal Corridor

APPENDIX D – OVERALL SENSITIVITY MAPS PER CORRIDOR

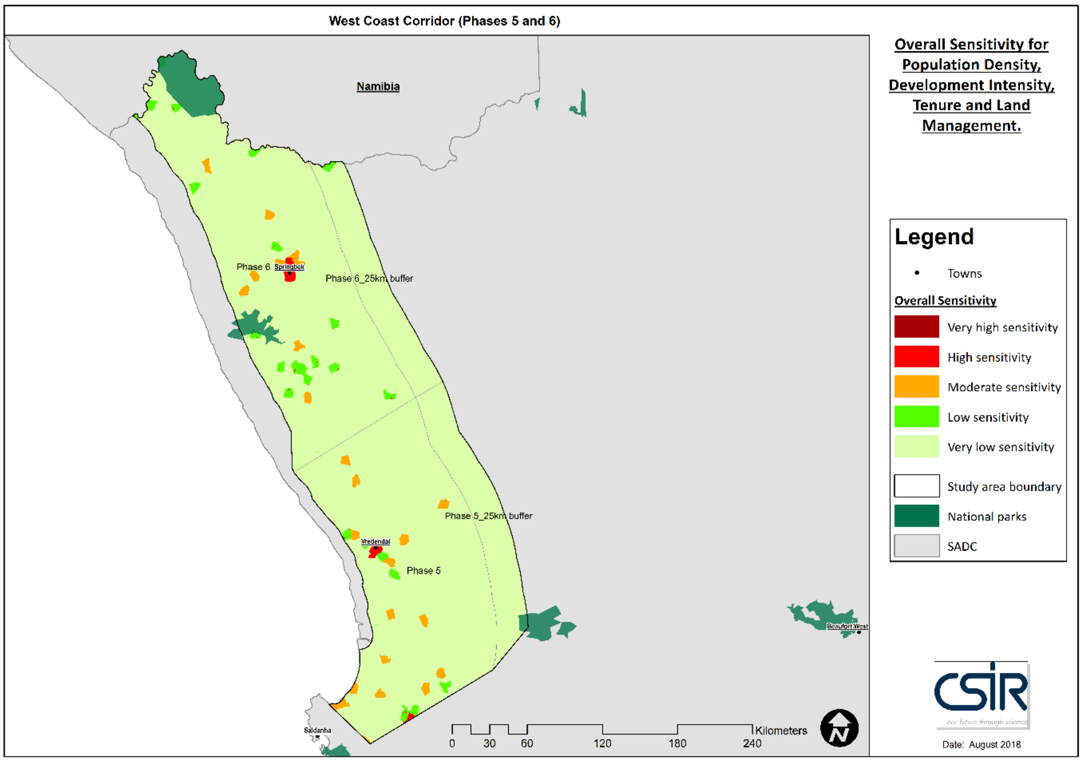


Figure D 1: Overall sensitivity in terms of population density, development intensity and land tenure in Gas Pipeline Corridor (West Coast Corridor (Phases 5 and 6))

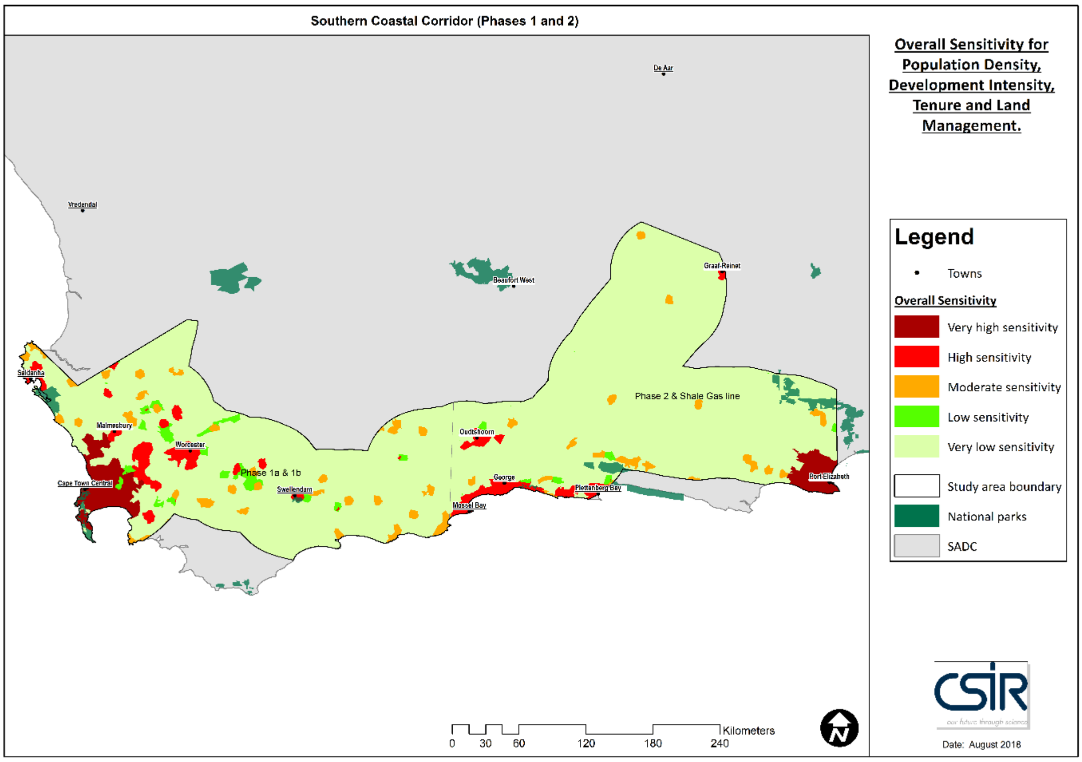


Figure D.2 Overall sensitivity in terms of population density, development intensity and land tenure in Gas Pipeline Corridor (Southern Coastal Corridor (Phases 1 and 2))

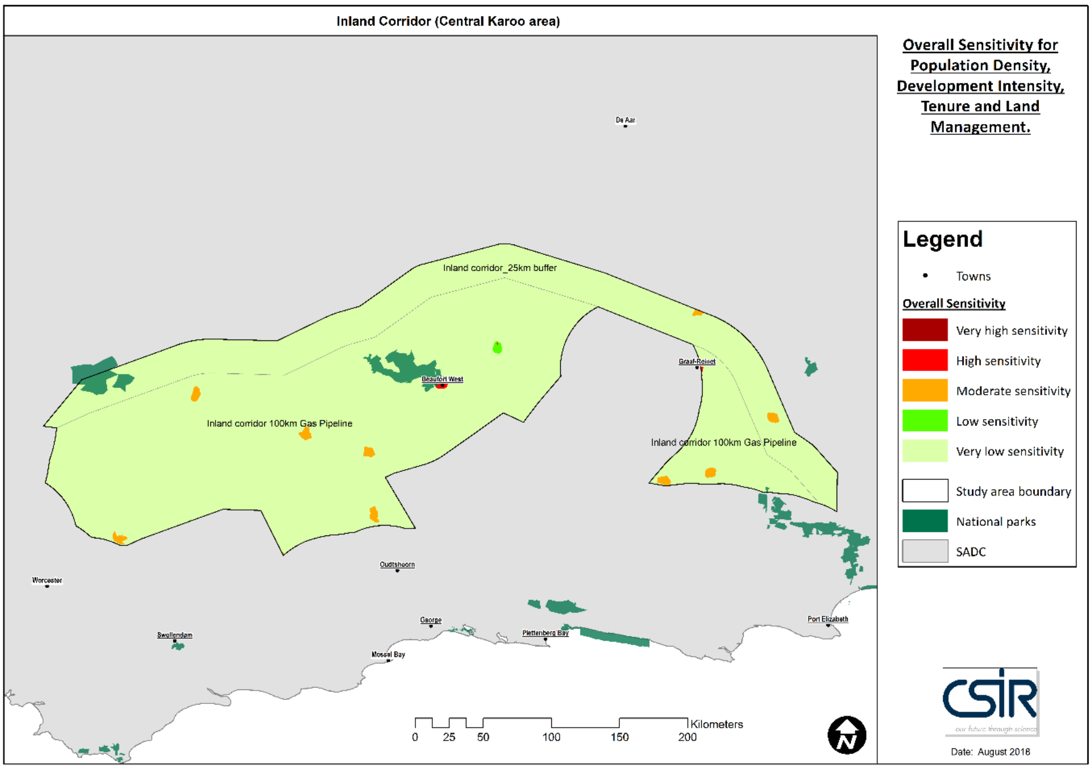


Figure D.3: Overall sensitivity in terms of population density, development intensity and land tenure in Gas Pipeline Corridor (Inland Corridor (Central Karoo area)

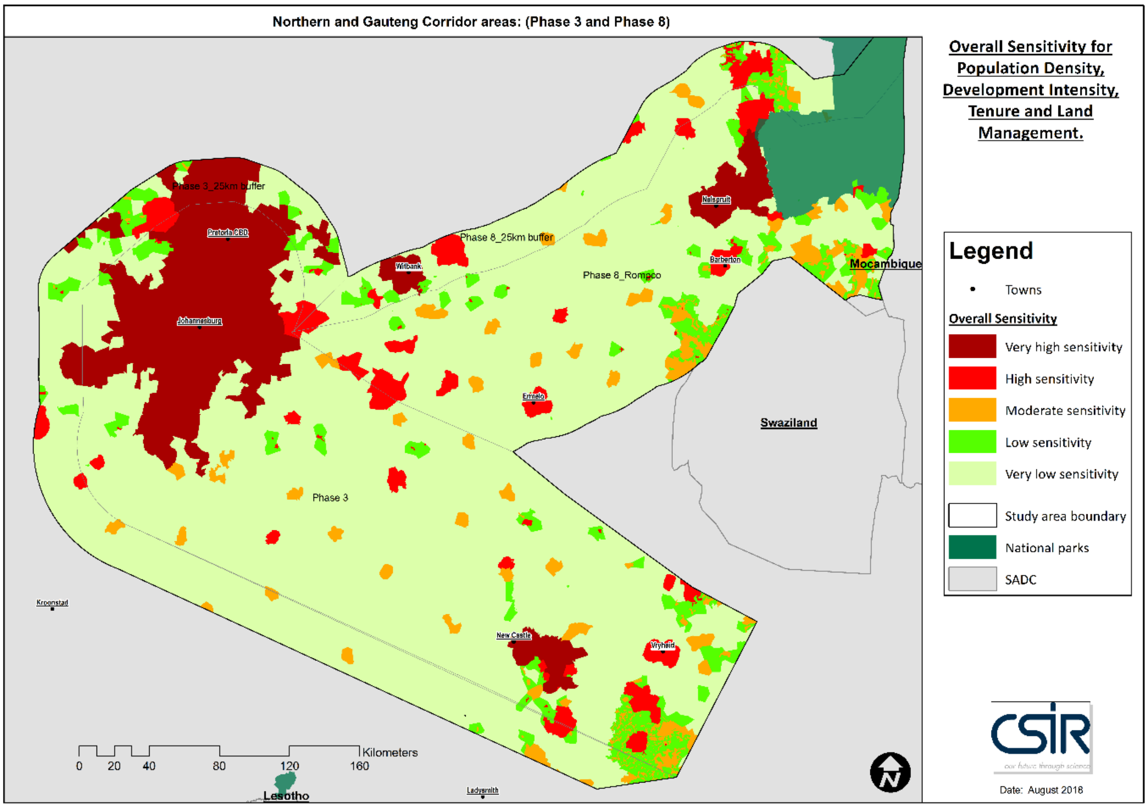


Figure D.4: Overall sensitivity in terms of population density, development intensity and land tenure in Gas Pipeline Corridor (Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)

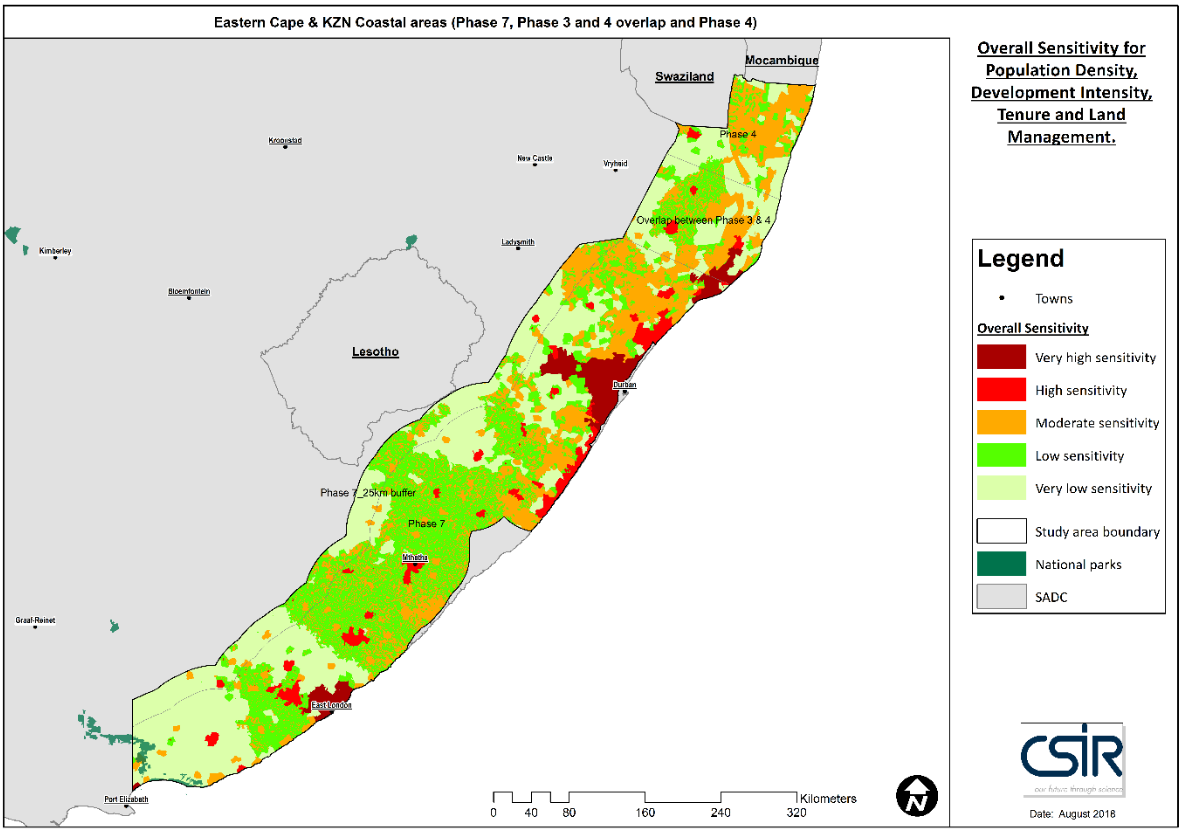


Figure D.5: Overall sensitivity in terms of population density, development intensity and land tenure in Gas Pipeline Corridor (Eastern Cape & KZN Coastal areas: (Phases 7, 3 and 4)

APPENDIX E – FUNCTIONAL TOWN TYPOLOGY

E.1 The creation of the settlement footprints for South African towns and settlements and description of the South African Functional Town Area Typology

Creation of a more defined boundary layer for settlements (Open settlement footprint layer)

May 2018
Author: G Mans, J Maritz & D McKelly
CSIR, BE, SPS

TECHNICAL DOCUMENT

South Africa's main spatial frameworks:
South Africa's frameworks for representing spatial data (particularly economic and demographic data) are made up of a combination of enumerator and large administrative zones. The following figure lists the main spatial units (zones) applied. These spatial units are mostly created by the Municipal Demarcation Board and Statistics South Africa. Currently Local Municipalities (LMs) are the lowest (most detailed) demarcation used for administrative management. Most data (or information) relating to municipal management as well as strategic planning and investment documents are done per municipality.

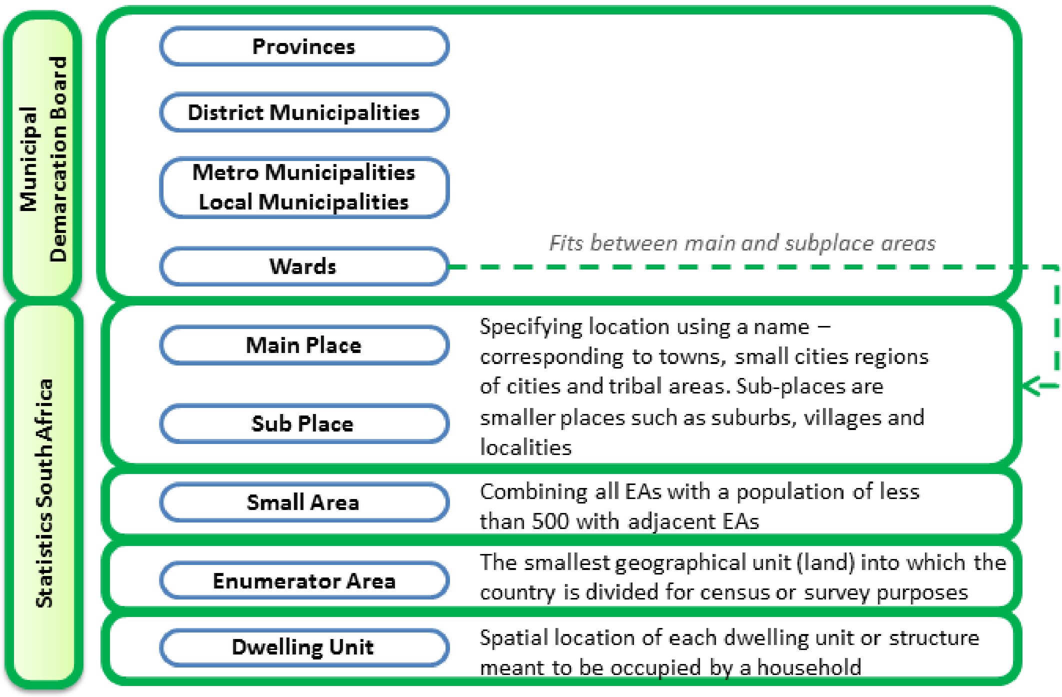


Figure E.1: South Africa's main spatial units.

The StatsSA census data does provide users with more detailed spatial data within municipalities such as Main-Place, Sub-Place, and Small Areas. Enumerator units were developed for a particular purpose and designed to represent fixed sets of people or households per zone and were suited to purposes of enumeration. Similarly other units (wards) were created to represent geopolitical subdivisions of local municipalities used for electoral purposes. These units do not accurately represent the extent of settlements.

Constraints of spatial frameworks:
Although these units nest seamlessly within the local municipal boundaries, at a larger scale they do not accurately represent the extent of settlements. The constraint can be illustrated using the following

example; using the town of Ventersdorp and surrounds. Both the Main- and Sub-place layers extend deep into the surrounding area which does not contain settlement similar to the town of Venterdorp. As can be deduced from the image these outlying areas, which forms part of the "town" demarcations, is actually commercial farming or other non-residential areas. This is not an isolated case and the same situation can be found in many other settlements across South Africa - there are many such spatial demarcations within a LM which cuts across, or includes portions of built up areas and outlying lower density land uses like commercial farming, small holding, mining or vacant land, to name the most common occurrences. **This therefore misrepresents the true extent of the town or settlement.** Additionally these units do not keep track of the growth experienced by towns. There often exists a mismatch between the boundaries of Main-Place, Sub-Place and Wards compared to the extent of settled areas (as can be observed when compared to more recent satellite imagery).

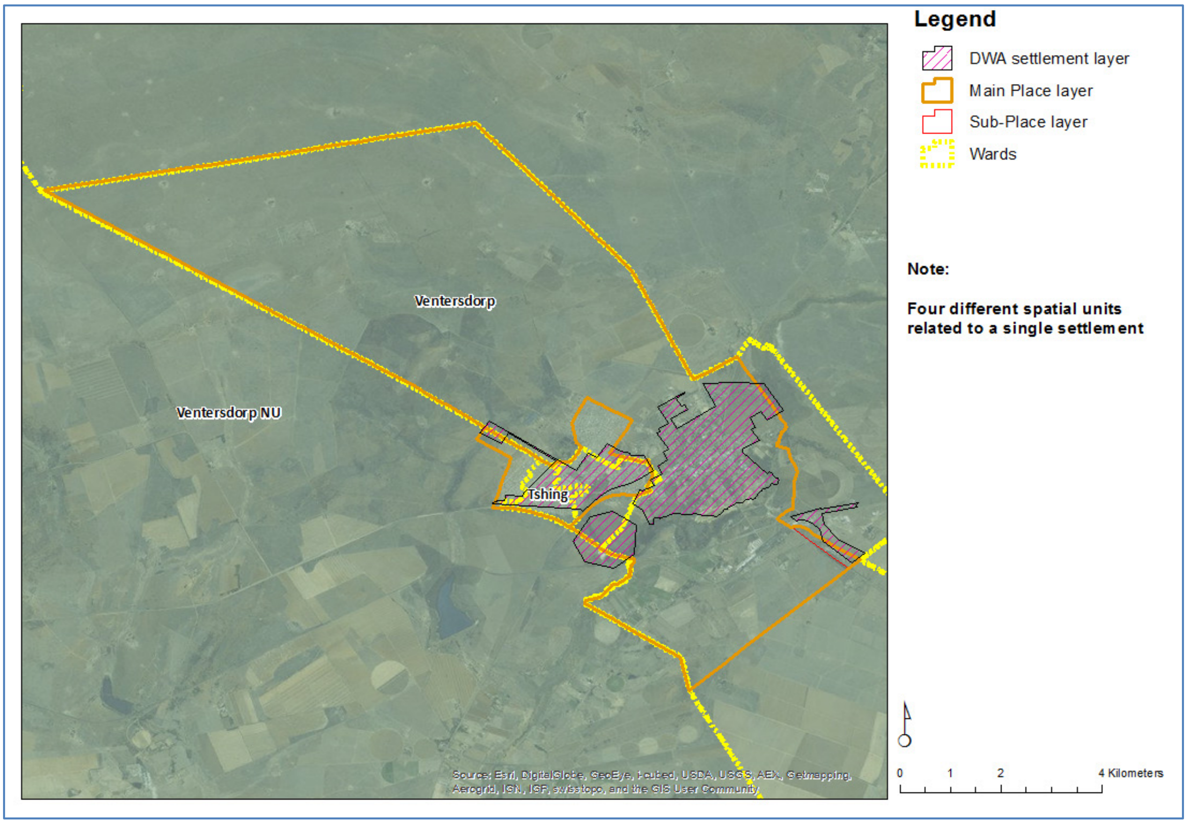


Figure E.2: Comparison of several spatial units.

Other spatial layers such as the mesozones (developed by CSIR) also represent settlements but they do so more from the point of broad differentiation across space than as accurate features. This is also largely due to their scale of application which is not localised but used at the meso (intermediate) scale.

<u>**What do we mean with settlement?**</u>

Settlement geography is an established branch of geography that investigates where humans have settled. The nature and scale of this settlement varies but central to all settlement is that they represent spaces where people live (reside) and also interact through a range of activities, from personal interaction such as trading or economic activity, employment, and accessing services. Larger and more organised (formal / proclaimed) settlement also has governance and management functions administered though elected representatives, or traditional structures. Settlements according to Bunce (1983, p23) can also be categorised or classified considering a number of factors such as groupings of building, morphology, location, size and functions.

There have been efforts to demarcate settlement areas in more detail such as the Department of Water Affairs' Settlement layer. The purpose of this layer should be noted; it consists of a grouping of structures (in clusters) that often coincides with 'villages'. These represent users of water and sanitation infrastructure and forms 'local planning units' when considering the extent of water service provision as well as future services. Because these units also do not combine to form the extent of a coherent village, town, city or large settlement, it does not always serve to define settlement boundaries. Although this dataset have proven extremely useful for spatial planning and locational purposes, it does not always succeed in defining settlement boundaries. In South Africa there exists currently two broad types of settlements; those created through a formal town establishment process and those created within traditional authority areas, mostly created through decisions taken by traditional leadership (preceded by homeland governments in some cases).

In the case of settlement data layers no hard categorisation is applied, instead the aim is:

- to encapsulate settlement footprints of both formal and traditional types, that are mostly continuous areas of human settlement and activities,
- that would be in need of services such as water and electricity,
- that could contain non-residential functions that contribute to the existence of the settlement such as commerce, industry, retail etc.

Why are more refined settlement layers needed?

As indicated above, when portraying information per settlement it can be distorted due to the particular spatial framework used and could also misrepresent items such as densities from both a computational as well as visual interpretation perspective. It becomes even more important when the scale of analysis is more localised. The effect of zone size distortions becomes more noticeable when working with data on a more detailed level. Apart from more accurately representing the settlement, this is also relevant when it is about controlling development and managing the use of land. Settlement dynamics is a wide field where many factors could influence or determine settlement. For the purpose of this exercise we will not be going into details. Neither is the objective to attach labels such as 'Urban' or 'Rural' due to the connotations these terms carry.

From a spatial planning point of view it is, however cardinal to have your settlements - with all the internal supporting functions associated with that settlement - clearly differentiated from the 'rest'. The 'rest' referred to includes land with uses like commercial- or subsistence farming, mining, vacant land, small holdings, conservations areas, etc. Divisions such as a river or ridge might create a natural divide but in terms of being part of a community/ or considering the interaction, such areas could be contained within the boundary of a particular settlement.

Do we need to define land uses to demarcate the settlement boundary line?

When following formal planning processes space/land is often identified based on its function its intended or actual land use. Although ideal this information is not always available particularly in non-formalised towns or settlements that fall outside typical land use management practices. What is practically available across all of South Africa is satellite imagery that provides a background to land cover information though that can be used to create or modify settlement boundary layer. It is also hoped that people's knowledge of a settlement could contribute towards its belter defined boundary.

How was the current draft (formal) Settlement layer created?

The main input dataset used in the process of identifying the settlement footprints was the EAs produced by StatsSA for the 2011 census. The reason for using the EAs are due to the high resolution of the dataset and therefore it is fairly homogenous in its land use and socio-economic characteristics. The EA dataset is classified as indicated in Figure E.3 below. The figure also indicates how the classes were grouped together to come up with a new classification of built-up areas (types of footprints). There were certain classes (industrial, vacant and small holdings) which were split between those EAs classified as being part of a settlement and whether it falls on the outside of a particular settlement. Mining is one of the sub-classes within the industrial class. Mines that sit isolated on the far outskirts of a town or city with now residential development linked to it was not included in the settlement footprints. Small holdings, especially in Gauteng, which are completely surrounded by built-up areas were included in the settlement footprint, due to the high probability that these small holdings will get redeveloped as residential, commercial or industrial areas. Some EAs were classified as vacant land (no development on it). Again if such an EA was completely surrounded by built up areas, it was included in the settlement footprint as it either functions as a public open space for recreation or it also stands a high chance of being developed to some form of built-up area.

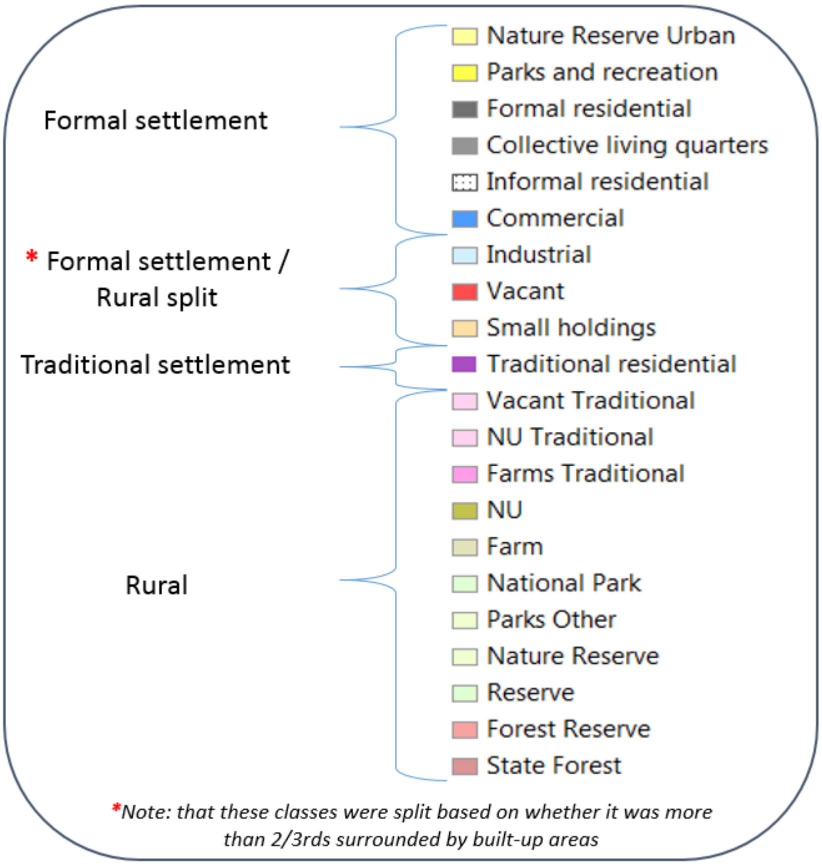


Figure E.3: EA re-classification to settlement footprint categories

The identified settlement footprints were further classified into two categories: formal settlements and traditional settlements. The settlement footprints classified as traditional are settlements that closely coincide with Traditional Authority areas.

After the EAs were re-classified as indicated in Figure E.3, a manual editing process was used to identify and edit EAs that should have been inside or outside a settlement footprint. This was followed by another manual editing process where the actual boundaries of EAs were adjusted if the EA had a significant split between undeveloped and built-up areas whilst this EA is situated on the outskirts of a settlement footprint.

The result was the classification of EAs (few with manually adjusted boundaries) representing the settlement footprints of the country. The next step was to aggregate these EAs into a functional settlement and link a name to such a settlement.

The latter process was done in three steps. The first was to aggregate the selected EAs based on the sub-place names as indicated in the 2011 spatial database provided by StatsSA. These area sub-place (SP) areas therefore have a strong resemblance to StasSA 2011 SPs, however the extent do differ as large undeveloped areas, which many times form prat of StatsSA SPs, have been removed. The naming convention was also adjusted and multi-part polygons removed. The next level in the hierarchy of the settlement layer was to follow the same process as discussed using the SPs, but in this instance using the StatsSA main-places (MPs). Lastly, the continuous settlement footprints were identified. This is in cases where several MPs adjacent to each other forms a continuous built-up footprint. In cases where such a footprint stretched across a local municipal boundary, the 2016 official local municipal boundaries (as published by the Demarcation Board) was used to define the boundary. The result of the settlement demarcation is therefore a three tier hierarchy (T1 is a continues built-up footprint only broken where is crosses a local municipal boundary; T2 is based on StatsSA MPs, but only built-up areas and no multi part polygons; T3 is based on StatsSA MPs, but only built-up areas and no multi part polygons). Figure E.4 below shows an example of the settlement footprint hierarchy that was created during this process.

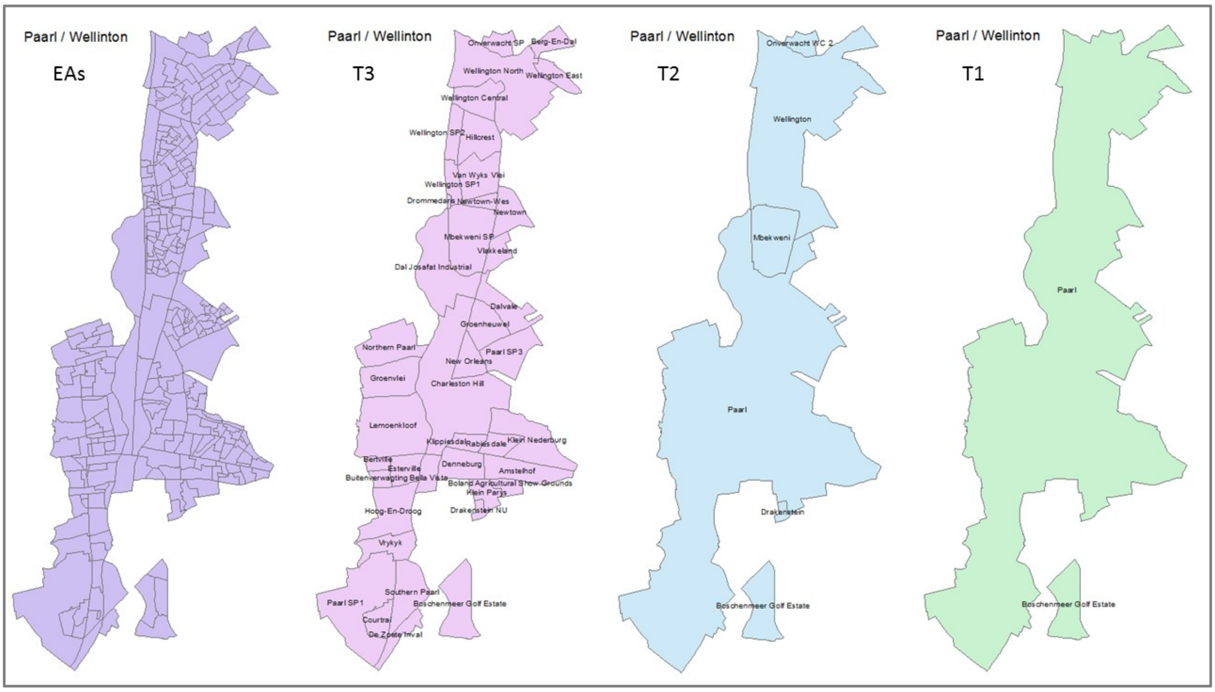


Figure E.4: Spatial hierarchy of the settlement footprint layer

Some point to guide the boundary adjustment process:

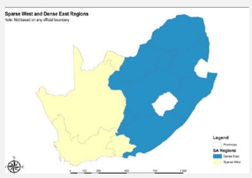
Given South Africa's settlement makeup it is quite difficult to distinguish the footprints of settlements. The following can serve as items for consideration when editing the settlement layers.

- Often settlements (particularly those that are formalised) would have a central business area. Such a point is surrounded by residential, commercial, industrial functions.
- Open spaces such as parks or undeveloped land could occur adjacent of in-between these activities.
- Areas such as small holdings that are slowly being taken up for expansions of the settlement should be included in such a boundary layer (In the process to prepare the provided settlement layer such areas were included where possible). Small holdings in close proximity to the settlement housing commercial or industrial functions could be included.

Editable open feature

Creating and modifying up to date settlement boundary layers requires a collaborative effort. As a result the approach will be an ***open data approach***. This means that anyone can freely contribute to the item. This item can also be shared and used by users at no cost. This item is made publically available under the Open Database License. The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Database while maintaining this same freedom for others. (see https://opendatacommons.org/licenses/odbl/1.0/) Due to the collaboration with other users the process to update the item will be easier and less reliant on a single entity to undertake.

South African Functional Town Area (FuTA) TYPE 2018 - CSIR 2018

RSA Settlement Landscape	SA Functional Town Area Type	*Description of Functional Town Area Types / Sub-types Based on urban function in surrounding region and urban area size*
Metropolitan Areas & Cities	**City Regions**	*Metro's and cities with more than 1 million people in large conurbations. Service related economic output estimated as average R188 000 mill and total economic output above R40 816mill in 2013*
	Cities and Large Regional Centres	*City Area (City) - More than 500 000 people in city and functional hinterland areas. Service related economic output estimated as average R14 192mill and total economic output above R7 900mill in 2013 for team understanding*
		Large Regional Centre (RC1) Cities and large regional nodes with more than 300 000 people in interconnected settlements and direct hinterland. Service related economic output estimated as average R5 500mill and total economic output above R4 000mill in 2013
Regional Service Centres & Service Towns (Urban core areas and surrounding functional town areas)	**Regional Service Centres**	*Big Regional Service Centre (RC2) - Regional nodes and corridors with 100 000-300 000 people in interconnected settlements and hinterland, playing a significant social and economic service role in region. Service related economic output estimated as average R3 400mill and total economic output above R 1400mill in 2013*
		Regional Service Centre (RC3) - Smaller Regional nodes and corridors with less than 100 000 people in interconnected settlements and hinterland, playing a significant social and economic service role in region. Total economic output in all cases above R1 100mill (2013) but service related economic output estimated as average R1 660mill
Formal Small Towns	**Service Town**	*Service Town - Towns of various sizes, providing an economic and social service anchor role in hinterland. Population variation between 15 000 to 100 000 population, with total economic output more than R270mill (2013) in all cases. Service related economic output estimated as average R670mill per town*
	Small Service Town	*Small Service Town - Towns of which economies and/or population smaller than that of Service towns. Playing an* ***anchor role as social service poin*** *t, serving a large number of people within 30km from the town in denser areas and within 50km from the town in sparser areas. Government and community services significant in local economy. Identified as priority service centre to people in towns and hinterland based on CSIR & DRDLR research & spatial profiling.*
	Small Town	*Small Town - Small towns of which economies and/or population smaller than that of Service towns. Primarily serve local population and/or 'niche' economic activity such as mining, tourism or fisheries. (Monocentric small towns, often apartheid landscape double centre towns)*
Rising Small Towns - Nodes of Consolidating in dense rural settlements	**Rural Service Settlement**	*Rural Service Settlement - Dense Rural Settlements that are strategically located to play an* ***anchor role as social service point,*** *serving a large number of people within 30km from the town in denser areas and within 50km from the town in sparser areas. Identified based on priority nodes for social service delivery in areas without formal towns and multiple settlement nodes, from DRDLR & CSIR research*
Rural Settlement Areas (Formal & Traditional)	**Smaller towns/ villages/ dorpies & nodal places in rural areas**	*Nodal settlement with limited population and economy but forming part of the South African group of towns. May be found in both sparse or densly settled areas. Small nodal places (any- not forming part of above)*
	Dense Rural Settlements	*This area incroprates both (i) Formal Rural settlement area - EA's and Settlements Footprint classified as formal as well as (ii) Traditional Authority Rural Settlement Area - EA's and Settlement Footprint areas classified as traditional. Both have very small formal service economy activities. Within such areas Rural Service Settlements and smaller nodal places have been identified for location of socail services as applicable based on the population threshold and characteristsics.*
Sparsely Populated	**Sparsely Populated**	*Sparsely populated areas (meso zone areas without rural settlements) Sparse East (more than 10 persons per sq km) while in the Sparse west this is defined as less than 10 persons per sq km and has an impact on the accestable travel access distance and threshold of certain social services.* 

Reference: Maritz, J., van Huyssteen, E. Green, C. and Sogoni, Z. South African Functional Town Typology (CSIR 2018 v2). Available at www/stepsa.orga.za.

E.2 Town and settlement population characteristics by Corridor Groupings

The town and settlement population characteristics have been sourced from the South African Functional Town Typology (Maritz *et al*, 2018) and Settlement Footprint Layer (Mans *et al*, 2017).

Table E.1: *Population numbers and growth West Coast Corridor –Phase 5 &6*

WEST COAST Corridor : Phase 5 & 6		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Phase 5		
Service Towns(2)		
Vredendal	18 070.13	13.76
Piketberg	11 947.50	29.92
Small Service Towns & Settlements(2)		
Clanwilliam	7 567.89	26.17
Citrusdal	7 022.01	(4.95)
Small Towns(13)		
Velddrif	10 921.38	49.28
St Helena Bay	8 341.25	50.92
Klawer	6 115.25	29.57
Van Rhynsdorp	5 954.34	41.76
Luizville	5 235.00	12.84
Graafwater	2 254.89	22.15
Nieuwoudtville	2 018.53	43.18
Eendekuil	1 531.00	54.50
Dwarskersbos	667.00	87.69
Nuwerus	651.00	21.40
Aurora	576.00	61.47
Redelinghuys	573.00	(3.51)
Bitterfontein	545.76	8.80
Dense Rural Settlements(4)		
Rural Settlement Area	5 627.53	7.03
Sparsely Populated Area(2)		
Sparse Rural	371.05	98.92
Phase 6		
Service Towns(1)		
Springbok	18 635.96	18.83
Small Service Towns & Settlements(1)		
Steinkopf	7 780.86	7.63
Small Towns(7)		
Concordia	4 960.11	18.47
Nababeep	4 297.04	(9.45)
Komaggas	3 115.00	(6.00)
Garies	2 074.32	25.57
Carolusberg	960.09	(0.99)
Kamieskroon	893.00	(1.32)
Eksteenfontein	528.00	17.26

WEST COAST Corridor : Phase 5 & 6		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Dense Rural Settlements(19)		
Rural Settlement Areas	9 581.22	6.84
Sparsely Populated Areas(3)		
Sparse Rural Areas	1 560.59	45.59
Phase 6_25km buffer		
Dense Rural Settlements(1)		
Rural Settlement Area	168.00	482.62

Table E.2: *Population numbers and growth Southern Coastal Corridor –Phases 1a &b and 2*

Southern Coastal Corridor: (Phases 1 a &b and Phase 2&Shale Gas line		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Phases 1 a &b		
Cape Town City Regions (CCR)	**3 811 934.80**	**28.42**
City of Cape Town	3 708 427.81	28.83
Stellenbosch Cape Winelands CCR area	103 506.99	28.01
West Coast CCR area	4 739.00	108.49
Regional Service Centres(3)		
Paarl/Wellington	201 459.84	29.58
Vredenburg	75 227.02	42.05
Worcester	99 857.44	18.25
Service Towns(9)		
Ceres	39 292.50	16.94
Franschhoek	18 576.25	29.73
Grabouw	31 269.81	18.42
Malmesbury	39 631.98	54.03
Montagu	14 892.90	35.53
Moorreesburg	12 184.39	39.48
Robertson	27 449.01	17.20
Swellendam	18 458.89	30.46
Wolseley	12 131.00	50.75
Small Service Towns & Settlements(9)		
Barrydale	3 899.38	14.34
Darling	10 400.29	24.53
Genadendal	5 642.21	25.93
Heidelberg-WC	7 870.88	13.16
Ladismith	6 461.79	8.40
Riversdale	15 183.31	28.49
Riviersonderend	5 203.17	44.59
Ashton	13 093.27	12.87
Riebeek West	4 524.10	59.23
Small Towns(26)		

Southern Coastal Corridor: (Phases 1 a &b and Phase 2&Shale Gas line		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Albertina	6 350.72	35.37
Boggomsbaai	71.00	(57.23)
Bonnievale	8 722.66	37.84
Calitzdorp	3 638.31	9.82
Gouritsmond	514.00	13.22
Greyton	2 780.73	7.97
Herbertsdale	661.46	5.76
Hopefield	5 770.80	30.39
Kleinmond	6 330.88	3.76
Koringberg	1 214.61	244.62
McGregor	2 783.65	31.12
Op-die-Berg	1 529.00	60.79
Paternoster	1 955.74	31.92
Porterville	6 967.30	20.45
Riebeek-Kasteel	4 465.14	72.85
Saron	7 831.68	(3.21)
Stilbaai	6 378.28	37.41
Suurbraak	2 106.15	13.30
Tulbagh	8 973.00	20.32
Villiersdorp	10 002.13	31.95
Vleesbaai	195.00	(21.09)
Yzerfontein	1 132.53	99.79
Zoar	4 648.10	14.55
Pringle Bay	2 299.00	50.41
St Helena Bay	3 085.16	20.24
De Doorns	10 452.21	(31.09)
Dense Rural Settlements(4)		
Rural Settlement Area	7 294.45	25.90
Sparsely Populated Area(7)		
Sparse Rural	2 244.66	35.21
Phase 2 and Shale Gas line		
Nelson Mandela Bay City Region Area (1)	**1 123 382.82**	**12.96**
Nelson Mandela Bay NMCR	1 123 382.82	12.96
Regional Service Centres(4)		
George	170 580.83	31.73
Knysna	50 881.36	26.85
Mossel Bay	80 700.32	29.87
Oudtshoorn	73 635.66	8.82
Service Towns(2)		
Graaf-Reinet	35 151.73	12.10
Plettenberg Bay	39 484.84	64.47
Small Service Towns & Settlements(7)		
Aberdeen	7 138.26	13.27

Southern Coastal Corridor: (Phases 1 a &b and Phase 2&Shale Gas line		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Hankey	11 328.55	17.07
Joubertina	6 215.95	6.77
Kirkwood	13 723.25	28.00
Murraysburg	5 061.50	14.67
Willowmore	7 551.51	21.13
De Rust	3 540.33	27.07
Small Towns(12)		
Barsheba	2 157.00	52.94
Buffelsbaai	70.00	(40.17)
Friemersheim	1 202.62	30.36
Haarlem	2 375.00	0.39
Karatara	502.25	169.19
Loerie	2 785.00	24.48
Louterwater	4 830.00	29.96
Patensie	4 855.50	11.28
Steytlerville	4 010.57	10.79
Thornhill	2 459.00	88.80
Uniondale	4 454.75	9.82
Krakeel River	1 932.00	12.78
Dense Rural Settlements(3)		
Rural Settlement Area	8 339.69	48.79
Sparsely Populated Area(8)		
Sparse Rural	3 842.94	91.16

Table E.3: Population numbers and growth Inland Corridor

Inland corridor		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Service Towns(1)		
Beaufort West	34 012.79	10.16
Small Service Towns & Settlements(2)		
Jansenville	5 419.69	13.39
Prince Albert	7 013.73	19.13
Small Towns(7)		
Klipplaat	2 952.91	1.91
Merweville	1 579.39	38.18
Sutherland	2 700.79	43.04
Touwsrivier	7 670.11	15.03
Leeu Gamka	2 568.12	22.06
Nieu-Bethesda	1414.57	52.13
Pearston	4474.48	10.90
Dense Rural Settlements(1)		

Inland corridor		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Rural Settlement Area	1 530.60	105.53
Sparsely Populated Area(1)		
Sparse Rural	417.08	10.44

Table E.4: *Population numbers and growth: Eastern Cape and KZN Coastal areas (Phase 7, Portion of Phase 3 and Phase 4)*

Eastern Cape and KZN Coastal areas (Phase 7, Overlap of Phase 3 & 4 and Phase 4)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Phase 7		
eThekwini City Region (ECR) (1)	**3 479 924.45**	**16.35**
eThekwini City ECR	3 440 670.50	11.39
iLembe ECR	23 170.01	30.44
Umgungundlovu ECR	16 083.94	7.22
Cities and Large Regional Centres(3)		
Pietermaritzburg	654 975.65	12.92
East London	537 603.36	11.74
Richards Bay	302 815.57	16.56
Regional Service Centres(7)		
Mthatha	199 151.42	25.90
Stanger	187 434.35	41.15
Port Shepstone/Margate	169 339.86	23.97
King Williams Town	138 513.75	1.84
Butterworth	73 005.26	(4.38)
Pennington/Scottburgh	71 531.39	8.92
Grahamstown	66 963.81	1.75
Service Towns(16)		
Mandini	74 436.93	17.76
Kokstad	51 419.75	38.87
Umzinto	37 680.82	35.48
Dimbaza	33 473.26	(14.79)
Richmond	32 852.53	20.72
Howick	26 726.21	45.23
Stutterheim	26 121.92	3.99
Port Alfred	25 766.39	22.14
Flagstaff	22 574.59	18.46
Idutywa	20 223.58	47.47
Clydesdale	19 743.12	31.50
Greytown	19 314.00	13.08
Eshowe	18 463.28	24.55
Engcobo	15 419.18	36.67
Mount Frere	14 768.00	27.31

Eastern Cape and KZN Coastal areas (Phase 7, Overlap of Phase 3 & 4 and Phase 4)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Bizana	10 151.06	65.23
Small Service Towns & Settlements(21)		
Maclear	10 499.19	9.83
Ixopo	10 302.08	23.66
Keiskammahoek	10 293.77	(8.68)
Harding	9 378.01	53.60
Nqamakwe	8 692.00	2.17
Peddie	8 314.00	6.42
Libode	8 067.00	12.65
Mount Ayliff	7 874.00	26.74
Melmoth	7 751.27	12.45
Bathhurst	6 224.07	2.35
Willowvale	6 107.74	(3.53)
Paterson	5 560.15	26.73
Dalton	4 066.00	35.79
Nkandla	3 406.91	27.85
Ngqeleni	3 378.00	19.60
Centane	3 354.69	11.23
Kei Mouth	2 357.00	(11.63)
Elliotdale	2 010.66	126.48
Kranskop	1 509.00	78.80
Creighton	860.30	89.69
Highflats	542.00	72.32
Small Towns(39)		
Alice	19 211.00	35.39
Addo	16 933.98	4.43
Tabankulu	15 817.31	2.45
Kwarela	13 747.09	5.34
Mt Fletcher	13 256.00	30.46
Kenton on sea-Boesmans	11 270.33	5.97
Hopewell	11 118.00	13.46
Alexandria	10 063.62	17.10
Qumbu	10 053.89	16.95
Tsolo A	9 724.00	9.70
Tsolo B	8 129.00	(18.08)
Komga	8 043.61	17.13
Donnybrook	7 806.67	(3.20)
Mqanduli	6 481.05	12.68
Middeldrift	5 013.00	35.34
Albert Falls	4 534.00	23.61
Cedarville	4 413.00	76.45
Lidgetton	4 365.07	57.57
Tsomo	3 569.54	30.48

Eastern Cape and KZN Coastal areas (Phase 7, Overlap of Phase 3 & 4 and Phase 4)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
New Hanover	3 172.00	45.76
Clarkebury	2 967.00	(7.84)
Braemar	2 849.42	(31.79)
Colchester	2 057.55	70.91
Hamburg	1 935.00	(8.19)
Franklin	1 844.03	256.04
Kei Road	1 649.00	2.55
Wesley	1 634.00	(0.49)
Kayser's Beach	1 416.02	49.92
Ginginlovu	1 110.00	(5.71)
Hogsback	930.84	31.43
Wartburg	906.00	(0.85)
Riebeek east	727.64	15.24
Taweni	694.00	(13.52)
Boknes Strand	528.32	8.40
Amatikulu	513.00	(30.20)
Kidd's Beach	500.00	10.34
Haga Haga	370.00	(39.46)
Seafield	290.30	1.88
Zigagayi	97.00	35.40
Dense Rural Settlements(2131)		
Rural Settlement Area	3 822 411.82	(5.19)
Sparsely Populated Area(25)		
Sparse Rural	10 463.16	(9.78)
Phase 7_25km buffer		
Service Towns(2)		
Fort Beaufort	26 997.93	7.92
Mooirivier	17 645.26	33.04
Small Service Towns & Settlements(8)		
Nababeep	14 667.00	(9.98)
Matatiele	12 399.17	21.19
Adelaide	12 090.72	(9.68)
Cofimvaba	11 878.32	44.84
Cathcart	7 201.44	(7.68)
Seymour	3 088.00	15.38
Tugela Ferry	1 811.30	37.92
Bulwer	1 319.00	40.08
Small Towns(6)		
Maluti	25 543.00	42.54
Ugie	12 917.66	58.59
Dumasini	5 395.00	9.18
Nottingham Road	1 784.00	31.82
Mt Fletcher	1 480.00	(6.87)

Eastern Cape and KZN Coastal areas (Phase 7, Overlap of Phase 3 & 4 and Phase 4)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Pomeroy	577.57	86.17
Dense Rural Settlements(275)		
Rural Settlement Area	275 081.47	(4.40)
Sparsely Populated Area(12)		
Sparse Rural	2 223.88	5.73
Overlap between Phase 3 & 4		
Cities and Large Regional Centres(1)		
Richards Bay	53 706.62	15.23
Service Towns(3)		
Mtubatuba	24 378.42	53.67
Nongoma	14 438.59	105.65
Ulundi	49 729.74	10.56
Small Service Towns & Settlements(5)		
Babanango	2 343.00	48.15
Hlabisa	2 470.00	84.76
Hluhluwe	3 643.50	72.03
Melmoth	1 105.77	34.86
Ntambanana	10 528.97	26.60
Small Towns(2)		
St Lucia	1 103.00	27.37
Khula Village	9 602.59	48.38
Dense Rural Settlements(209)		
Rural Settlement Area	649 173.06	1.99
Sparsely Populated Area(5)		
Sparse Rural	1 480.67	78.04
Phase 4		
Service Towns(1)		
Pongola	18 362.00	(2.83)
Small Service Towns & Settlements(5)		
Ndumu	5 631.00	(1.02)
Mkuze	5 609.11	73.43
Jozini	2 847.34	(0.61)
Mbazwana	2 899.43	26.36
Ingwavuma	1 303.92	17.99
Dense Rural Settlements(33)		
Rural Settlement Area	399 520.22	5.61
Sparsely Populated Area(2)		
Sparse Rural	687.00	(10.77)

Table E.5: *Population numbers and growth Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)*

Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Phase 3		
Gauteng City Region (GCR)(1)	**7 573 308.23**	**27.95**
City of Johannesburg GCR	4 413 405.57	37.63
Ekurhuleni GCR	3 147 764.04	27.54
City of Tshwane GCR	2 717 810.70	36.42
Sedibeng GCR	834 857.30	15.55
West Rand GCR	665 099.80	17.65
Fezile Dabi GCR	139 197.20	30.83
Bojanala GCR	68 579.19	30.04
Cities and Large Regional Centres(1)		
Newcastle	427 732.37	5.95
Regional Service Centres(4)		
Brits	2 741.69	41.11
Secunda	119 867.36	22.87
Standerton	84 371.35	21.50
Vryheid	132 634.16	2.68
Service Towns(9)		
Balfour	25 962.97	28.99
Delmas	2 908.30	136.45
Dundee	34 148.59	23.57
Frankfort	26 066.93	22.48
Leandra	596.00	62.28
Nqutu	17 651.05	35.72
Parys	48 062.08	9.72
Paul-Pietersburg	31 684.28	8.91
Volksrust	24 246.94	18.55
Small Service Towns & Settlements(8)		
Amersfoort	12 228.50	46.96
Heilbron	27 368.95	7.82
Louwsburg	4 034.41	31.86
Memel	7 143.00	20.98
Morgenzon	7 596.67	72.11
Utrecht	6 948.00	34.39
Villiers	17 316.00	(5.01)
Vrede	17 574.37	1.60
Small Towns(17)		
Charlestown	3 916.49	30.79
Cornelia	2 885.67	(14.63)
Coronation	11 724.27	30.71
Devon	9 572.00	33.21
Dunnhauser	5 370.22	11.40
Enyati	1 074.00	22.60

Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Nondweni	10 482.00	(0.46)
Oranjeville	5 145.16	47.60
Perdekop	5 030.18	51.57
Pumalanga	2 067.22	47.79
Tweeling	6 446.76	30.22
Wakkerstroom	5 257.00	7.66
Charl Cilliers	769.00	259.01
Holly County	588.00	(3.74)
Vaal Marina	1 876.00	98.11
Dense Rural Settlements(79)		
Rural Settlement Area	168 609.68	2.04
Sparsely Populated Area(6)		
Sparse Rural	996.62	(35.57)
Phase 3_25km buffer		
Gauteng City Regions (GCR) (1)	**413 857.77**	**14.42**
Bojanala GCR	225 809.95	19.82
City of Tshwane GCR	121 350.96	37.59
West Rand GCR	66 696.86	(14.14)
Cities and Large Regional Centres(7)		
Rustenburg	54 442.02	65.87
Regional Service Centres(2)		
Brits	104 671.84	46.19
Potchefstroom	143 181.82	27.23
Service Towns(3)		
Delmas	27 545.60	68.74
Dundee	16 699.96	19.78
Vredefort	14 563.41	25.07
Small Service Towns & Settlements(3)		
Koppies	13 797.23	57.95
Warden	10 406.25	57.82
Petrus Steyn	511.21	102.22
Small Towns(1)		
Wasbank	2 520.14	58.50
Dense Rural Settlements(42)		
Rural Settlement Area	325 535.60	2.50
Sparsely Populated Area(1)		
Sparse Rural	225.00	119.53
Phase 8_Rompco		
Cities and Large Regional Centres(1)		
Nelspruit	474 503.15	25.06
Regional Service Centres(5)		
Hazyview	131 312.47	11.51
Ermelo	83 658.64	52.58
Secunda	66 916.60	53.85

Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Bethal	59 254.59	37.28
Bushbuckridge	14 307.44	14.05
Service Towns(7)		
Matsulu	49 868.51	29.21
Barberton	48 634.43	31.39
Leandra	32 967.00	49.34
Kriel	29 230.82	45.59
Carolina	16 751.86	38.67
Kamaqhekeza	16 303.83	15.69
Sabie	15 612.19	27.17
Small Service Towns & Settlements(7)		
Nhlazartshe	40 292.03	20.43
Driekoppies	22 852.66	8.00
Hendrina	22 771.97	28.52
Belfast	16 313.57	67.09
Lothair	5 924.44	(8.85)
Komatiepoort	4 755.63	14.76
Ngodwana	1 177.00	169.00
Small Towns(17)		
Schoemansdal	45 071.00	23.85
Kamhlushwa	26 122.26	89.09
eMangweni	22 949.00	18.13
Masibeleka	21 552.02	(0.60)
Glenmore	19 326.01	(12.44)
Breyten	14 345.00	17.24
Mgobode	14 115.00	10.15
Empuluzi	13 542.00	7.88
Machadodorp	8 398.13	54.87
Badplaas	6 921.00	21.92
Vanwylsdrif	6 213.77	43.46
Waterval Boven	5 871.54	0.99
Davel	4 975.00	34.18
Chrissiesmeer	4 010.11	(18.71)
Malelane	3 877.20	8.32
Hectorspruit	3 084.72	36.06
Kaapmuiden	268.00	(32.74)
Dense Rural Settlements(59)		
Rural Settlement Area	289 267.22	13.01
Sparsely Populated Area(11)		
Sparse Rural	6 182.38	20.86
Phase 8_25km buffer		
Cities and Large Regional Centres(1)		
Witbank	295 712.79	52.45
Regional Service Centres(3)		

Northern and Gauteng Corridor areas: (Phase 3 and Phase 8)		
Towns by Typology category	Population 2011	% growth/decline (2001-2011) *Negative growth indicated in brackets*
Bushbuckridge	173 918.15	5.41
Middelburg	163 139.04	76.55
Hazyview	86.00	(17.34)
Service Towns(4)		
Acornhoek	81 093.35	20.20
Ogies	33 118.07	14.05
Delmas	24 472.00	19.10
Lydenburg	14 541.68	129.14
Small Service Towns & Settlements(2)		
Lillydale	24 550.00	9.65
Dullstroom	5 183.93	51.08
Small Towns(3)		
Graskop	3 833.47	14.24
Skukuza	1 603.00	284.02
Pilgrim's Rest	1 594.57	315.25
Dense Rural Settlements(27)		
Rural Settlement Area	81 380.39	6.38
Sparsely Populated Area(2)		
Sparse Rural	588.25	16.58

E.3 Infrastructure projects based on a review of Provincial SDF documents

A review of the Provincial SDF documents in the affected provinces noted planned infrastructure projects. All projects were checked and most fall within towns/OR are not geographic specific. This is shown both in a map (Figure E.5) and in a table below (Table E.6).

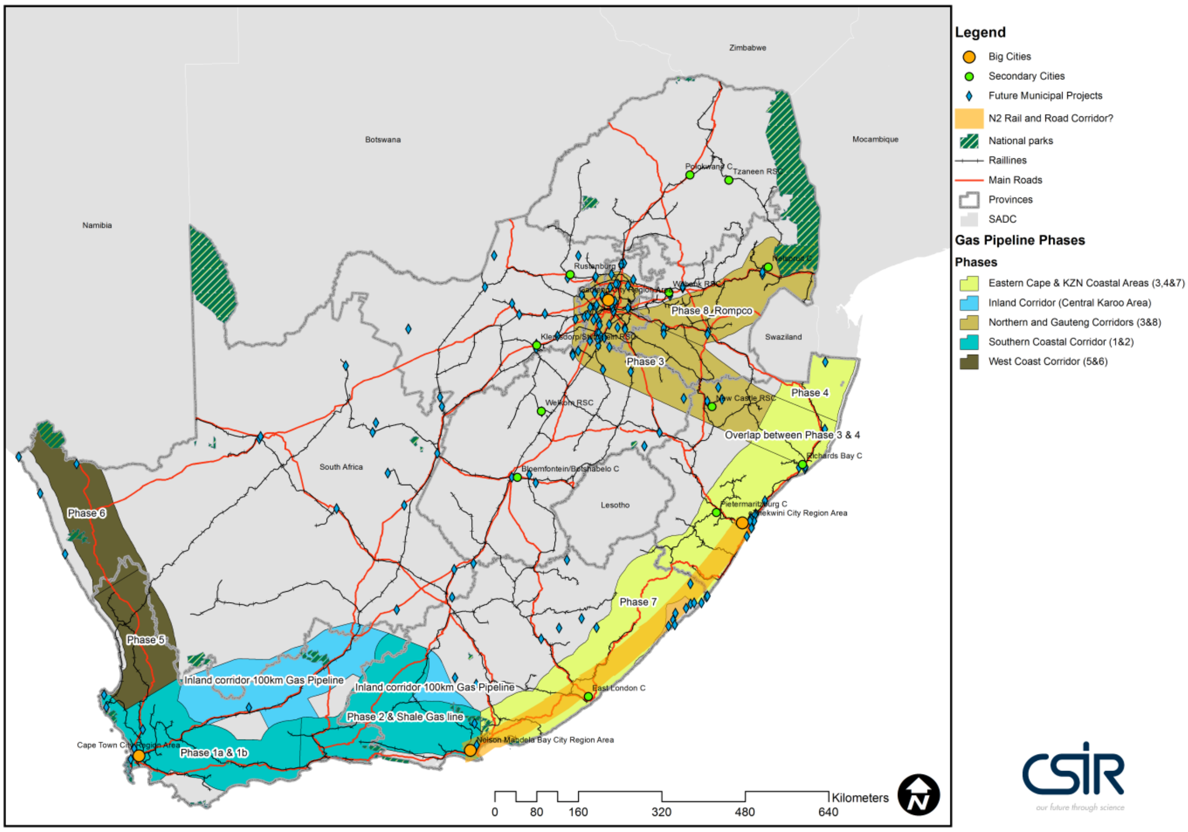


Figure E.5: Infrastructure projects as listed in Provincial SDF documents

Table E.6: *List of Infrastructure projects based on a review of Provincial SDF documents*

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
Western Cape							
WESCAPE Mixed Land Use Development (Note: WESCAPE is no longer considered as part of the future plans in terms of the City of Cape Town MSDF 2018)	20km outside Cape Town up the west coast, along the N7 Ward 104 City of Cape Town	-Residential Development	Yes	Long Term	Yes		City of Cape Town Spatial Development Framework (2012)
Cape Town Port upgrade and future expansion	Cape Town port	-Industrial development	Yes	Medium Term	No		Western Cape Provincial Spatial Development Framework (2014)
Saldanha Bay Port upgrade and future expansion	Saldanha Port	-Industrial development	Yes	Medium Term	No		Western Cape Provincial Spatial Development Framework (2014)
Saldanha Renewable energy industrial growth	Saldanha Port	-Industrial development	Yes	Medium Term	Yes		Western Cape Provincial Spatial Development Framework (2014)
Laingsburg Renewable energy industrial growth	Laingsburg Town	-Industrial development	No	Medium Term	Yes		Western Cape Provincial Spatial Development Framework (2014)
N7 Upgrading	Malmesbury - Philadelphia intersection	-Road corridor	Occurring	Present	Yes		City of Cape Town Spatial Development Framework (2012)
Mines and Quarries	-City of Cape Town -Saldanha -Oudtshoorn -Bredasdorp -Mossel Bay -Malgas - Albertina	Industrial Activity	Occurring	Present	No	There are a number of Mining and quarry activities which the project should avoid. The majority are found within the City of Cape Town metropolitan, however there are also three significantly sized quarries/mines found in Saldanha and a few others along the coast from Bredasdorp towards Mossel Bay and one in Oudtshoorn.	Western Cape Provincial Spatial Development Framework (2014)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
Priority Tourism Nodes	Table Mountain National Park	Tourist Attractions	Occurring	Present	No	The Gas Pipeline should avoid established areas of touristic interests.	Western Cape Provincial Spatial Development Framework (2014)
	Tsitsikamma National Park -Karoo National Park -West Coast National Park - Wilderness National Park -De Hoop National Park						
Agricultural Activities	-Swellendam -Brede Valley -Stellenbosch -Constantia -Knysna -Bitou	Farming Constraints	Occurring	Present	No	Western Cape has a plethora of farming activities across province most of which can be traversed by an active Gas Pipeline. However areas shown for deep rooted and long term produce i.e. vineyards and forestry should be avoided.	Western Cape Provincial Spatial Development Framework (2014)
Free State							
Industrial Corridor Bloemfontein and Botshabelo	-Bloemfontein to Botshabelo	Industrial Corridor	Yes	Medium Term	Yes	Bloemfontein and Botshabelo fall outside of the affected area by the Proposed Gas Pipeline, however it may increase Gas demand within the province.	Free State Province Provincial Spatial Development Framework (2014)
Proposed Industrial restructuring and expansion	-Phuthaditjshaba	Industrial Development	Yes	Medium Term	Yes		Free State Province Provincial Spatial Development Framework (2014)
Harrismith New Regional Airport	-Harrismith	Industrial Development	Yes	Long Term	Yes		Free State Province Provincial Spatial Development Framework (2014)
Welkom New Regional Airport	-Welkom	Industrial Development	Yes	Long Term	Yes		Free State Province Provincial Spatial Development Framework (2014)
Mineral and Mining Activities	-Frankfort -Heilbron -Sasolburg -Vredefort	Industrial Development	Occurring	Present	No		Free State Province Provincial Spatial Development Framework (2014)
Priority Tourism Nodes	-Memel	Tourism Nodes	Occurring	Present	No		Free State Province Provincial

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
	-Vaal Dam -Parys						Spatial Development Framework (2014)
Agriculture Activities	-Vaal Dam	Agricultural Scheme	Yes	Medium Term	Yes	The forms of agriculture found throughout the Province are traversable by the Proposed Gas Pipeline where it is mostly maize farming. However, the presence of the dam could present engineering constraints for the gas pipeline.	Free State Province Provincial Spatial Development Framework (2014)
Eastern Cape							
Port St Johns Proposed Renewable Energy Zone	-Port St Johns	Industrial Development	Yes	Long Term	Yes		Eastern Cape Provincial Spatial Development Plan (2010) Eastern Cape Infrastructure Plan 2013 (August 2016)
Urban Infilling Project	-Bizana -Sterkspruit	Residential Development	Yes	Medium Term	Yes		Eastern Cape Provincial Spatial Development Plan (2010)
Karoo Shale Gas optimisation	-Queenstown	Industrial Development	Yes	Very Long Term	Yes	This development would be a pull factor for this project as it would facilitate gas related development derived from Shale Gas should it ever occur.	Eastern Cape Provincial Spatial Development Plan (2010)
Wild Coast Road Development	-Ndwalane -Mntafufu -Lusikisiki -Msikaba	N2 Corridor Development	Occurring	Present	Yes	The Wild Coast Development Zone which looks to unlock the tourism potential along the coast through new road networks.	Eastern Cape Provincial Spatial Development Plan (2010) Eastern Cape Infrastructure Plan 2013 (August 2016)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
	-Holy Cross/ Mkambati						
	-Mtentu -Mzamba -Port Edward						
Upgrade of dedicated Mineral Rail Link	-Coega -Kirkwood (Addo) -Somerset East -Pearston -Nieu- Bethsdal	Rail Corridor Development	Yes	Long Term	Yes	Proposed upgrade of dedicated Mineral Rail Link from Coega and entering Northern Cape towards Colesburg.	Eastern Cape Provincial Spatial Development Plan (2010)
Proposed mIning Projects	-Xolobeni	Industrial Development	Yes	Medium Term	Yes		Eastern Cape Provincial Spatial Development Plan (2010)
Priority Tourism Nodes	-Addo National Park -Tsitsikamma National Park -Mountain Zebra National Park -Camdeboo National Parks	Tourism Nodes	Occurring	Present	No		Eastern Cape Provincial Spatial Development Plan (2010)
Priority Agricultural Areas	-Sakhisizwe - Engcobo -Emalahleni,	Agricultural Nodes Development	Yes	Medium Term	Yes		Eastern Cape Provincial Spatial Development Plan (2010)
North West							
Residential Housing Projects	-Rustenburg -Klerksdorp -Brits	Residential Development	Yes	Medium Term	Yes		North West Province Provincial Development Plan (2013)
Mining Corridor Consolidation (Road Expansions)	-Mafikeng -Lichtenburg	Corridor Development	Yes	Long Term	Yes		North West Province Provincial Development Plan (2013)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
	-Coligny						
	-Ventersdorp -Dovesdale -Potchestroom						
Mining Projects	-Carletonville -Klerksdorp	Industrial Development	Yes	Medium Term	Yes		North West Province Provincial Development Plan (2013)
Priority Tourism Areas	-Sun City -Magaliesburg -Hartbeespoort -Madikwe	Tourism Nodes	Occurring	Present	No		North West Province Provincial Development Plan (2013)
Proposed Potential Tourism Areas	-Borakalalo -Vredefort Dome -Vaalkop Dam -Ganyesa/Kalahari	Tourism Potential Nodes	Yes	Medium Term	Yes		North West Province Provincial Development Plan (2013)
Priority Agricultural Areas	Brits Agricultural Node	Agricultural Node Development	Yes	Medium Term	Yes		North West Province Provincial Development Plan (2013)
Mpumalanga							
Urban Expansion Projects	-Ermelo -Secunda -Emalahleni -Nelspruit -Middelburg	Residential Development	Yes	Medium Term	Yes		Mpumalanga Economic Growth and Development Plan (2011)
Urban Corridors between Developing Industrial Hubs	- Ermelo - Secunda	Industrial Development	Yes	Long Term	Yes		Mpumalanga Economic Growth and Development Plan (2011)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
	- Emalahleni						
	- Nelspruit - Middelburg						
Primary Mining Town Expansion	-Secunda -Emalahleni	Industrial Development	Yes	Medium Term	Yes		Mpumalanga Economic Growth and Development Plan (2011)
Northern Cape							
Vioolsdrift Dam Project	-Vioolsdrift	Industrial Development	Yes	Medium Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Kimberly University	-Kimberly	Occurring	Yes	Present	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Kimberly University (Upington Campus)	-Upington	Educational Development	Yes	Medium Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Food Production Corridor	-Hartswater -Jan Kempdorp -Prieska -Hopetown -Douglas	Food Corridor	Yes	Long Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Upinton Airport Cargo Hub	-Upington	Industrial Development	Yes	Long Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Mining Corridor	-Lime Acres -Danielskuil -Hotazel	Industrial Development	Yes	Long Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
Tourism Potential Nodes	-Lake Gariep -Colesburg -Richmond	Residential Development	Yes	Medium Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Agrilutural Potential Nodes	-Port Nolloth -Hondeklip Bay -Alexander Bay	Industrial Development	Yes	Long Term	Yes		Northern Cape Provincial Development and Resource Management Plan/ Provincial Spatial Development Framework (2012)
Gauteng							
Urban Expansion Projects	-Westonaria -Randfontein -Heidelberg -West Capital -East Capital -African Gateway -Lanseria Lion Park -Steyn City -Waterfall -Modderfontein -Linksfield -Masingita -Gauteng Highlands -Savanna City -Vaal River	Residential Developments	Yes	Medium to Long Term	Yes		Gauteng Spatial Development Framework 2030 (2016)
Infilling Development	-Tembisa -Germiston -Daveyton	Node Development	Yes	Medium Term	Yes		Gauteng Spatial Development Framework 2030 (2016)
	-Mogale City						

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
Industrial Corridor Developments	-Vereeniging -Vanderbijlpark -Sebokeng	Corridor Development	Yes	Medium Term	Yes		Gauteng Spatial Development Framework 2030 (2016)
Westonaria Airfield Development	-Westonaria	Industrial Development	No	Long Term	Yes		Gauteng Spatial Development Framework 2030 (2016)
Rail way Development areas	-Chamdor -Ennerdale -Sandton -Lanseria -Fourways -Tshwane -Hammanskraal -Mabopane	Transport Development	No	Long Term	Yes		Gauteng Spatial Development Framework 2030 (2016)
Tourism Nodes	-Cullinan -Dinkokeng -Magaliesburg -Craddle of Humankind -Vereeneging -Vaal River -Heidelberg -Suikersobrand	Tourism Developments (Accommodation)	Yes	Medium Term	Yes		Gauteng Spatial Development Framework 2030 (2016)
KwaZulu-Natal							
Durban Aerotropolis Development	-King Shaka Airport	Mixed Used Development	Yes	Long Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011)
							KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
Inkululeko Development Initiative	-Ndumo	Educational Development	Yes	Medium Term	No		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Proposed Newcastle University	-Newcastle	Educational Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Richards Bay 2000MW Gas to power Station	-Richards Bay	Industrial Development	Yes	Long Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Cornubia Integrated Human Settlement	-Mt Edgecombe	Mixed Use Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Emadlangeni Agri-Village	-Emadlangeni	Agricultural Development	Yes	Medium Term	No		KwaZulu-Natal Provincial Spatial Development Framework (2011)
Groenvlei Agri-Village	-Groenvlei	Agricultural Development	Yes	Medium Term	No		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Empangeni Housing	-Empangeni	Agricultural Development	Yes	Medium Term	No		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Greater Amaoti Housing Project	-Amaoti	Residential Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011)
							KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)

Project	Location	Activity	Likelihood	Timeframe	Rapid Population Growth	Comment	Documents Used
Greater Dukuduku Project	-Dukuduku	Residential Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Greater Kwamashu Bridge City	-Kwa-Mashu	Residential Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Development of Aluminium Hub	-Richards Bay	Industrial Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Development of Auto Supply Park	-Durban South	Industrial Development	Yes	Medium Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)
Fast Rail Line Development	-Kwadukuza -Dube Trade Port -Gateway -Durban	Transport Development	Yes	Long Term	Yes		KwaZulu-Natal Provincial Spatial Development Framework (2011) KwaZulu-Natal Provincial Growth and Development Plan 2035 (2018)

APPENDIX F – ADDITIONAL INFORMATION RELATED TO DISASTER MANAGEMENT

F.1 What happens during a gas pipeline accident?

In 2010, a conflagration in San Bruno, California, showed a true worst case scenario of the potential threat natural gas has. A high pressure natural gas pipeline suffered a leak and eventually ignited explosively without warning. In the end, 37 homes were destroyed, nearly 300 others evacuated, and unfortunately eight civilians perished (Krusen 2011). In 2014, a series of explosions resulted from a leakage of propylene from an underground pipeline resulted in 32 fatalities and 321 injuries in Kaohsiung, Taiwan. These explosions resulted in several major fires and property damage such as overturned vehicles and substantial roadway damage (Liaw 2016:228).

There are various reasons why human error, related to Pipeline Developer staff, can lead to disasters. Typically, companies use advanced computer-based devices from a centralized control room. Accidents at these plants typically start with equipment malfunction, process upset or operator error; but they are aggravated and propagated through the system by a series of factors that could be attributed to human, organizational, and safety factors within the system. Also, most complex systems' accidents resemble an "unkind work environment"; that is, an environment in which once an error has been made, it is not possible for the person to correct the effects of inappropriate variations in performance before they lead to unacceptable consequences. This is because the effects of the errors are neither observable nor reversible. Research has shown that operator error is an attribute of the whole technological system—a link in a chain of concatenated failures — that could result in accidents. The most important lesson to be learned from past accidents is that the principal cause tends to be neither the isolated malfunctioning of a major component nor a single gross blunder, but the unanticipated and largely unforeseeable concatenation of several small failures, both engineered and human. Each failure alone could probably be tolerated by the system's defences. What produces the disastrous outcome is their unnoticed and often mysterious complex interaction.

Human errors may be exacerbated by workplace factors, such as poor workstation and workplace designs, unbalanced workload, complicated operational processes, unsafe conditions, faulty maintenance, ineffective training, lack of motivation and experiential knowledge, nonresponsive managerial systems, poor planning, non-adaptive organizational structures, rigid job-based pay systems, and haphazard response systems (Meshkati 2006:81).

Staff workloads increases substantially during an event of system upset, such as a leak or equipment malfunction (e.g. valve or pump breakdown). Leak detection requires a good understanding of the physical characteristics of the product, the "profile" of the pipeline system and its hydraulic characteristics (pressure and flow), the terrain, and environmental conditions (temperature) (Meshkati 2006:85). This is very demanding on the staff.

Although rare, emergencies involving gas pipelines are the most catastrophic and most dangerous because of the high operating pressures and large volumes of escaping gas. Natural gas transmission lines are high-volume, high-pressure delivery systems. Finding the leak is often the most urgent challenge. The damage to the immediate area, including structures, can be severe even when no ignition of escaping gas occurs. Failures on transmission pipelines will almost always cause escaping gas to excavate a large crater at the point of damage.

The accumulation of natural gas in the air creates an explosive atmosphere. If the escaping gas ignites during the resulting pressure-release explosion, the heat release will be tremendous, creating life-safety and fire-exposure problems (Parsley and Schwab 2000). Fires on transmission lines are extremely large, hot fires that release large amounts of energy in the form of radiant heat. These incidents may last many hours, or perhaps days.

This is different from normal fires. Dealing with a natural gas is more like defusing a bomb than putting out a fire. Additionally, the "bomb" (accumulating gas) and the ignition source might not be readily apparent, and therefore it may be very difficult to anticipate where such an explosion may take place (Munthe 2005).

The goals of managing emergencies on transmission pipelines start with the basics: Establish A command and a safe staging area, effect viable rescues, eliminate ignition sources (if gas has not ignited), and protect exposures. In populated areas, anticipate exposure fires; in rural areas, anticipate wildfires.

A natural gas incident should be treated as a hazmat (hazardous materials) incident. It is the role of the first responders to handle it as such, and hopefully mitigate the incident before it progresses. Typically, these calls end without any incidents, and quite often are treated as though they pose no threat to the responder or the community. However, *a lack of understanding and complacency will eventually lead to disaster*. Well defined guidelines and proper training will help prevent incorrect operations by response personnel, and properly mitigate the leak.

The environment can also create problems for gas pipelines. In particular, electricity outages can have a dire impact on pipeline operations. During Hurricane Sandy (2012), in the US, for example, oil and gas industries suffered severe outages due to the loss of commercial power through cascading failures. Backup power was only of minor help and could not prevent disruptions in gas and petrol distribution. This bottleneck led to further outages in backup power, which then brought cascading failures to further infrastructures. The interdependency of oil and gas and power infrastructure was among the most critical interdependencies due to its downstream consequences on the entire infrastructural system (Comes and Van de Walle 2014:8).

F.2 Pipelines, "critical Infrastructure" and physical planning to reduce risks

Critical infrastructure often forms part of a "lifeline system" – typically referring to electric power, gas and liquid fuels, telecommunications, transportation, waste disposal, water supply, agriculture and food systems, the defence-industrial base, energy systems, public health and health care facilities, national monuments and icons, banking and finance systems, drinking water systems, chemical facilities, commercial facilities, dams, emergency services, nuclear power systems, information technology systems, telecommunications systems, postal and shipping services, transportation systems, and government facilities Taken individually, or in the aggregate, all of these systems are intimately linked with the economic well-being, security, and social fabric of the communities they serve (O'Rourke 2007:23).

Critical infrastructure in crowded urban and suburban areas are subject to increased risk from proximity. Damage to one infrastructural component, such as a cast-iron water main, can rapidly cascade into damage to surrounding components, such as electric and telecommunications cables and gas mains, with system-wide consequences (O'Rourke 2007:23).

Pipeline planning processes need to be sufficiently careful not to compromise existing infrastructure, particularly if it is located underground. A pipeline rupture in 2010 in San Bruno, California, referred to earlier in the report, released over 1.3 million m^3 of natural gas, resulting in a fire that destroyed thirty-seven homes. Remarkably, the homes destroyed in the transmission pipeline explosion had been planned and built several years *after* the construction of the pipeline, illustrating the relevance of planning that addresses pipeline hazards (Osland 2015:1064). In the 2014 Taiwanese gas explosion, a gas pipeline ran alongside a water drainage channel. Since the drainage channel was built after the propylene pipeline, its construction represented a substantial change in the environment of the pipeline. Corrosion of the pipeline resulting from moisture in the drainage channel housing the pipeline was never considered in planning, or in subsequent maintenance (Liaw 2016:229).

Regulatory frameworks affect land uses near transmission pipelines. In the United States, local governments lack authority to address pipeline operations; and pipeline operators lack authority to regulate land uses close to the pipeline. In the United States, land-use practices surrounding pipelines vary widely by community, and there are no federal government regulations to guide local decisions about appropriate land-use practices. In contrast to the United States, European Union transmission pipeline operators must adhere both to local and to international legal frameworks (Osland 2015:1065).

F.3 A multi-pronged approach to building resilience

Disaster planning includes developing a set of activities and systems to prepare for and predict disasters. Forecasting and warning systems, community education, emergency operations centres, and medical and food stockpiles are part of the preparation. This can be difficult in underdeveloped localities, where basic infrastructure and municipal services are lacking. Funding infrastructure and activities in these areas for events that may never occur may seem to local decision-makers like a waste of precious financial resources (Quarantelli 2003:219).

Once a disaster strikes, the overwhelming majority of search and rescue activities are carried out by friends, relatives, and neighbours. It is impossible to predict how people will respond, but knowing of risks and preparing communities to face them can help to improve their response.

In many countries, the military is often the key respondent to a disaster. Ironically, however, military organisations are often not been systematically approached for an analytical perspective on disaster response. Neither are religious organisations, even though relief provided by churches and organized religious groups frequently ranks very high as a major source of aid (Quarantelli 2003:220), but are seldom involved in disaster planning.

Municipal officials in disaster zones should ensure that equipment and trained crews are available (Quarantelli 3003:220). Even though some communities have put disaster management plans in place, difficulties in implementing them can be illustrated by the following observations made in Ecuador, Peru, and Bolivia during 1997 and 1998: While the civil defence organisations in the respective countries were the nominal “national emergency organizations” ... each was rapidly pushed to the sidelines by one or more new but temporary governmental organization charged with supposedly managing the response. The result was confusion and duplication at the institutional level, and a serious loss of credibility and morale in each country’s civil defence structure. Local agencies knowledgeable about an area should assume a lead role, especially if they have prepared for such an event. The strengthening of their capacities for all levels of a crisis means that “fewer crises will become emergencies, fewer emergencies will become disasters, and fewer disasters will become catastrophes” (Quarantelli 2003:220).

Without adequate disaster management planning, an emergency can escalate into a disaster. The core emergency and response facilities may be destroyed. In recent catastrophes in developing countries, small towns have had their medical and police personnel wiped out. Outside agencies later responded, though their response times were longer, they were unfamiliar with the area, and there were “turf wars” as agencies staked out their territories (Quarantelli 2003:221). Significantly, the core capacity of local agencies should be maintained, if at all possible, and this requires various measures to promote resilience – as argued below.

A real challenge is the lack of information about possible risks and appropriate responses (Mitchell 1999:139). The effective flow of information across organizational boundaries – before and during a disaster - is critical for an organization’s ability to remain effective in a dynamic disaster environment. Valid and timely information sharing is critical in emergency response operations. Institutional networks need to be created before disasters happen (Kapucu 2006:208). This is particularly important for cross-sectoral collaboration.

The key element of effective responses to disaster is to build *resilience,* for both physical and social systems. Resilience includes four main qualities:

- *Robustness:* the inherent strength or resistance in a system to withstand external demands without degradation or loss of functionality.
- *Redundancy:* system properties that allow for alternate options, choices, and substitutions under stress.
- *Resourcefulness:* the capacity to mobilize needed resources and services in emergencies.
- *Rapidity:* the speed with which disruption can be overcome and safety, services, and financial stability restored (O’Rourke 20007:25).

Table F.1. The concept of resilience has technical, organizational, social and economic dimensions (O'Rourke 2007:27).

TABLE 1 Matrix of Resilience Qualities with Examples Pertaining to the Technical, Organizational, Social, and Economic Dimensions of Infrastructure

Dimension/Quality	Technical	Organizational	Social	Economic
Robustness	Building codes and construction procedures for new and retrofitted structures	Emergency operations planning	Social vulnerability and degree of community preparedness	Extent of regional economic diversification
Redundancy	Capacity for technical substitutions and "work-arounds"	Alternate sites for managing disaster operations	Availability of housing options for disaster victims	Ability to substitute and conserve needed inputs
Resourcefulness	Availability of equipment and materials for restoration and repair	Capacity to improvise, innovate, and expand operations	Capacity to address human needs	Business and industry capacity to improvise
Rapidity	System downtime, restoration time	Time between impact and early recovery	Time to restore lifeline services	Time to regain capacity, lost revenue

According to O'Rourke (2007:28), four main interventions are required to build resilience:

- Awareness, public education and knowledge, at all levels of society – from schools to business and politics
- Effective leadership, making informed decisions at the right time
- Planning for potential disasters and breakdowns, based on analyses of realistic risk factors
- Resource allocation to systems, to build alternative systems of provision ("resource redundancy"). For example, keeping secondary and tertiary roads in good condition is as important as maintaining the main highways.

F.4 Urban fire-fighting - Fire Brigade Services Act, 1987

An important piece of legislation is the *Fire Brigade Services Act, 1987* [Act 99 of 1987], which still appears to be in force. In 2010, the Minister of COGTA still used this piece of legislation to issue regulations.

This Act defined the functions of a fire brigade service as:

1. Preventing the outbreak or spread of a fire
2. Fighting or extinguishing a fire
3. The protection of life or property against a fire *or other threatening danger*
4. The rescue of life or property from a fire *or other danger*
5. Subject to the provisions of the Health Act of 1977, to render an ambulance service as an integral part of the fire brigade service.

Those Local Authorities who did establish Fire Brigades had to appoint a person with prescribed qualifications and experience, as chief fire officer, to be in charge of this service. Additional people, with the prescribed qualifications and experience, may be appointed to assist the chief fire officer. A local authority may also establish a fire brigade reserve force, consisting of temporary members. The powers of the members of the service includes, pursuant to implementing their functions: (a) closing any road or street, (b) enter any premises, (c) damage or destroy any property, (d) forcibly remove any person who is in danger, or obstructs the brigade in performing its duties, and (e) take material or objects from any person, who would be compensated subsequently.

A local authority may levy fees, payable by a person on whose behalf the fire service was applied. This would include the service, equipment, and material consumed.

Significantly, the Administrator could, after consultation with the Fire Brigade Board, pay grants-in-aid to local authorities, to establish or maintain their service. The local authority would be required to submit annual reports on expenditures.

Local authorities may make agreements (create partnerships) with one another, to co-operate with regards to fire services. They could also make agreements with other persons or institutions.

Municipalities were therefore the front-line agencies for fire services. Provincial administrations were tasked with guiding and evaluating them. The Provincial Administrators could give written notices to local authorities, requiring them to comply with requirements or standards. If a local authority failed to do so, the Administrator could take steps to enforce such requirements.

The national Minister (of Local Government) also played a role. He/she could make regulations regarding employment procedures, uniforms, safety requirements, the use of flammable materials (**including petroleum and gas),** equipment, materials, and the qualifications and experience of chief fire officers. The Minister could also establish a Training Institution for fire officers.

F.5 Rural fire-fighting - National Veld and Forest Fire Act, no. 101 of 1998

This Law is implemented by a different sectoral department – the Department of Agriculture, Forestry and Fisheries (DAFF). The Fire Protection Associations must be registered with the national Ministry, and the Minister could provide a loan or grant to Associations. In contrast, the Fire Brigade Services Act is administered by the national department responsible for municipalities (now COGTA, or the Department of Co-operative Governance and Traditional Affairs).

Municipalities are *required* to join such a local or district fire association. Any State landowner in the area is *required* to join the association. These measures give the Fire Protection Associations a fair degree of power. Several Associations may work together and establish an umbrella organisation. Clearly, the main impetus of this legislation was private initiative and civil society, not municipal control.

The Associations *are required to* implement at least these functions:

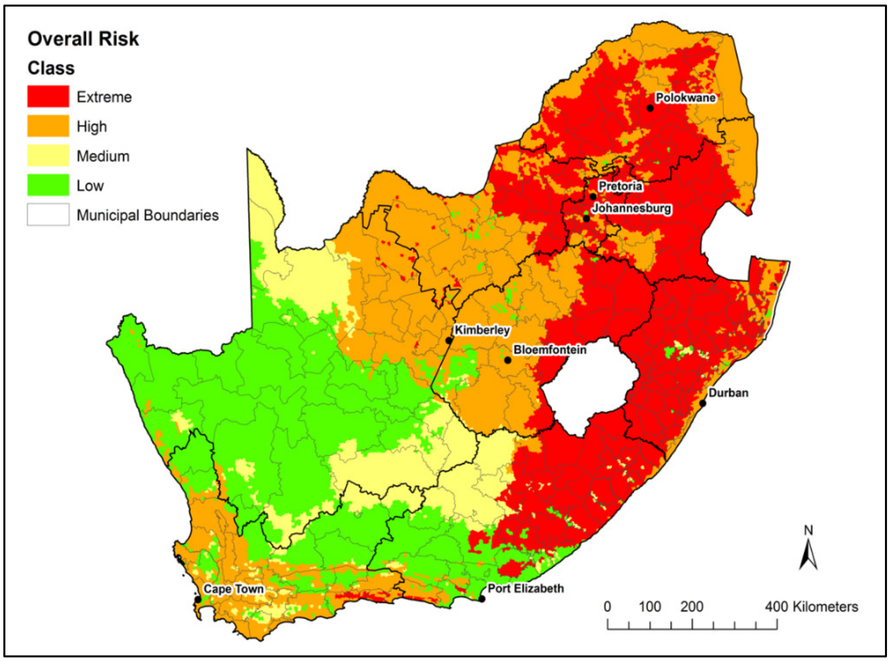
1. Develop and apply a veldfire management strategy for the area
2. Devise mechanisms to co-ordinate actions with adjoining Associations, in the event of a fire crossing boundaries
3. Make rules which bind its members
4. Identify the ecological conditions that affect the fire danger
5. Regularly communicate the fire danger rating
6. Organise and train its members in fire fighting, management and prevention
7. Inform its members of equipment and technology for preventing and fighting veldfires
8. Provide management services, training and support for communities in their efforts to manage and control veldfires
9. Supply the Minister at least once every 12 months with statistics about veldfires in its area
10. Furnish any information requested by the Minister in order to prepare or maintain the fire danger rating system
11. Exercise the powers and perform the duties delegated to it by the Minister,
12. And appoint a fire protection officer, unless a municipality is a member (presumably, the fire protection officer would then be that official employed by the municipality).

There is a link between the Fire Associations and the Municipalities' Fire Brigade function. In this law, "Chief Fire Officer" refers to those officials appointed in terms of the *Fire Brigade Services Act, 1987.*

The *National Veld and Forest Fire Act* (1998) also provides that the Department must prepare and maintain a fire rating system for the entire country. For each region, this would include the topography, vegetation, seasonal climatic cycle, and weather conditions. For each region, the fire danger in different periods can be rated, and dangerous activities identified. The Minister can then issue public warnings if these dangers are imminent, and public activities (such as lighting fires) can be prohibited.

All owners of land need to prepare and maintain firebreaks. They also need to maintain equipment, protective clothing and trained staff to extinguish fires. Typically, fire protection officers would take over a fire-fighting operation, as soon as they arrive on the scene. In the absence of a fire protection officer, a forest officer may take over control of the fighting of a fire within 10 km of a state forest.

Any fire protection officer, or a person functioning in that capacity, may, in controlling a fire, enter any land, destroy trees or crops, enter any premises, remove vehicles, or forcibly remove any person who is in danger or who obstructs the fire-fighting operation.



National Veld Fire Risk profile (COGTA n.d.)

F.6 Disaster Management Act, Act 57 of 2002

This Act created a new institutional architecture. At the apex of the DM system is an Intergovernmental Committee on Disaster Management **(ICDM),** established by the President. The ICDM consists of the Cabinet members involved in Disaster Management, as well as relevant Provincial MECs, and members of municipal councils, as selected by SALGA. The ICDM must promote co-operative governance with regards to Disaster Management; report to Cabinet on such co-ordination; and advise Cabinet about the creation of a national Disaster Management framework.

Like the Fire Brigades Act, the relevant Minister is the one who co-ordinates provincial and local government – i.e. COGTA. This Minister chairs the ICDM.

The Minister must establish a **National Disaster Management Advisory Forum**, consisting of the Head of the National Centre; a senior representative of each national department and each provincial department represented on the ICDM; municipal officials nominated by SALGA; and representatives of other stakeholders – notably, organised business, the Chamber of Mines, organised labour, the insurance industry, organised labour, traditional leaders, religious and welfare organisations, medical organisations, organisations representing DM professions in South Africa, institutions of higher education, technical institutions, DM experts chosen by the Minister, and any other relevant organisations.

Other staff may be seconded to the Centre. Its main tasks are to monitor compliance with the Disaster Management Framework across the government system, collect relevant information on disasters, advise government and non-state actors, promote the recruitment of volunteers, promote Disaster Management training in schools, and promote research. The National Centre must report annually to the Minister on its activities, the monitoring of prevention and mitigation initiatives, disasters in each province, impacts of these disasters, and particular problems that were experienced in dealing with these disasters. It can also make recommendations.

The Centre must establish a **directory of all role-players** relevant to Disaster Management, including their contact details. These role-players may include government agencies, NGOs, experts, private sector specialists, and foreign organisations. It must also create an electronic data-base on previous and future disasters, risk factors, prevention, mitigation, early warning systems, vulnerable areas, emergency response resources, police stations, medical institutions, useful public buildings, fire-fighting services, airports and railway stations. This data-base must be available to any person, free of charge.

F.7 Critiques of the Fire Brigade Services: 1999-2013

In 1999, a study of fire services was undertaken by the South African Insurance Association. Several problems were identified (COGTA 2013:26):

- Lack of compulsory national standards
- Inappropriate employment practices
- Inadequate accountability at some municipalities for this function
- Lack of effective management
- Poor maintenance of equipment
- Fire safety challenges, and
- Inadequate funding.

By 2013, the *Fire Brigade Services Act, 1987* (FBSA) was still the primary piece of legislation regulating fire services. COGTA identified the need to review FBSA. This was intended to be followed by a White Paper and a new Bill and Act, to establish a clear policy framework.

The Discussion Document then lists several important problems with current legislation (COGTA 2013:16):

- The FBSA does not sufficiently provide for fire safety, fire prevention and community fire safety education.
- The FBSA does not clearly outline national norms and standards in the provision of a fire service.
- After 1987, a myriad new pieces of legislation have impacted on the FBSA, in a chaotic manner.
- The FBSA established the Fire Brigade Board, which has not functioned well. The Secretariat of the Board, working as a directorate in the National Disaster Management Centre, is under-capacitated and under-funded.
- The FBSA does not clearly provide for support, oversight and capacity-building of municipalities.
- There are ambiguities in interpretations of Section 84(1) of the *Local Government Municipal Structures Act, 1998*, which led to complex and varied division of fire functions between DMs and LMs. The division of functions between Local and District Municipalities often results in a wasteful duplication of resources and efforts.
- The *National Veld and Forest Fire Act* and FBSA are not well integrated, and the division of functions between municipalities and Fire Protection Associations remained unclear. This resulted in jurisdictional contests between municipal fire services and other functions such as veldfire management. There was also a lack of clarity on the jurisdiction of Chief Fire Officers.
- Inadequate statistics regarding fires, injuries, property losses, and deaths.

There is overarching role confusion between two central departments. Whereas the National Veld and Forest Fire Act is administered by the Department of Environmental Affairs, the FBSA is administered by COGTA. Within COGTA, the National Disaster Management Centre (NDMC) is responsible for the administration and oversight of the FBSA.

Other agencies also play an important role in firefighting, but they have not been sufficiently integrated in Disaster Management Planning. These agencies include (COGTA 2013:39):

- South African Police Service (SAPS): Joint incident command during incidents; assists fire prevention units with fire investigation, especially arson; incident access control and evacuation; support of Urban Search and Rescue (USAR) ; traffic and crowd control at emergencies
- Emergency Medical Services: Joint incident command during incidents; provision of emergency medical services; provision of equipment; provision of support in hazardous materials incidents; provision of support in rescue efforts
- South African National Defence Force: Support local fire services; Support USAR and other special incidents; training of firefighters;
- State-owned Entities: Performing fire safety functions; Performing fire risk assessments; emergency planning.

Critically, firefighting requires water. This is a municipal function, and it requires careful planning (COGTA 2013: 52). There are three sources of piped water supply for firefighting:

- Public supply usually delivered by municipal infrastructure
- Private supply wherein National Building Regulations require building owners to install tanks and pumps
- Operational supply, such as water tankers.

In fact, the water current provision problems faced by many municipalities may well affect their firefighting capability.

The Discussion Document noted that South Africa has lost many experienced firefighters during the transitional years. While there is training of new firefighters, there has been a loss of capacity and skills (COGTA 2013: 63). "The quality assurance of training and training institutions remains problematic and open to untoward activity" (COGTA 2013:63).

F.8 The 2016 Draft White Paper on Fire Services

Since 2014, COGTA has worked on building a partnership between the National Disaster Management Centre (NDMC) and the South African Local Government Association (SALGA) to develop a disaster management capacity building programme for local government. The overall aim of the project is to ensure full understanding and application of disaster management in local government to facilitate well-informed developmental decisions that impact positively on sustainable development.

One outcome was the recent *Draft White Paper on Fire Services*, which was gazetted for public comment in December 2016. The Draft White Paper provided a good overview of the problems facing the fire services sector and noted that the *Fire Brigade Services Act* of 1987 was still the primary piece of legislation regulating fire services. It does not seem that this has subsequently been taken forward. It seeks to reposition the country's municipal fire services from a response-oriented approach towards a greater emphasis on fire prevention and risk reduction. The White Paper admits: "It is clear that traditional methods of providing fire services have not enabled the country to adequately manage the evolving fire risk faced by communities. Following extensive interactions between the National Disaster Management Centre and stakeholders involved in fire services, this White Paper seeks to entrench fire safety and prevention as core components of fire services. This requires a paradigm shift from response-oriented methodologies of providing fire services towards an approach that primarily strives to reduce fire risk through fire safety and prevention initiatives."

Gazetted in accordance with the *Fire Brigade Services Act of 1987*, among the draft document's policy proposals are a clear definition of the roles and responsibilities of the three spheres of government, the professionalisation of the fire service, the introduction of a risk-based approach in the provision of fire services, the introduction of a funding strategy for fire services, and the establishment of a national fire research and data centre.

There were 16 key policy proposals set out in the 2016 *White Paper on Fire Services:*

1. Amend the legislation to reposition the fire services into the 21st century
2. Provide a clear definition of roles and responsibilities of all spheres of government
3. Establish national and provincial Fire Services Directorates
4. Locate fire services within the broader development agenda of the country
5. Development of a National Fire Services Framework
6. Professionalisation of the fire services
7. Alignment of applicable regulatory and legislative frameworks so as to provide comprehensive and unified legislation for fire services
8. Establishment of a national fire research and data centre
9. Development of a uniform risk assessment model
10. Develop various categories of designated services
11. Develop a national education and training strategy
12. Introduce a risk-based approach in the provision of fire services
13. Entrench fire safety and prevention as core deliverables of the fire services
14. Introduce a funding strategy for fire services
15. Make provision to adopt applicable South African National Standards (SANS) to provide benchmarks for the delivery of fire services
16. Introduce and implement a new Fire Services Act.

Significantly, many of these goals had been discussed before, but had never been effectively addressed.

The White Paper admits that this old legislation had a number of weaknesses –

- The Act did not make adequate arrangements or place explicit focus on fire safety and *prevention*, particularly community fire safety education.

    - The Act did not clearly outline *national norms and standards* that can be utilised as benchmarks in the provision of a fire service. In addition, aspects related to research and development, as well as mechanisms for dealing with quality assurance, are not addressed.
- The Act had been promulgated in 1987 and the advent of the new democratic dispensation in 1994 resulted in new legislation that significantly impacts on local government functions and institutional arrangements. This necessitated a review of the Act to harmonise it with other key legislation that impacts on the provision of fire services.
- The Act established the *Fire Brigade Board (FBB*) as a forum to be consulted on various matters relating to the oversight, regulation and administration of fire services. However, it met infrequently which *makes its functioning ineffective* and the administration of fire services weak. Political oversight is not achieved as the platform to achieve this vital function is not functioning.
- The Act assigned the administrative work of the FBB to a *secretariat.* The secretariat, established as a Directorate in the National Disaster Management Centre, was *under-capacitated and under-funded* to perform the assigned function.
- The current Act did not provide clear provisions for the support, oversight and *capacity-building roles of provinces and national government* as outlined in the Constitution, the 1998 White Paper on Local Government and other applicable legislation.

The White Paper addressed the ongoing problem of role confusion between national, provincial and local government in fire services. It argued for expanding the municipal fire-fighting function to include new roles and responsibilities, inter alia,

- *integrated development planning* towards uniform fire services
- *coordination* and regulation of local authority fire services, designated fire authorities and volunteer fire associations
- development of *specialised capacity* to deal with fire risks prevalent in the area such as veld fires, *chemical fires*, and informal settlements fires
- development of *specialised dangerous goods incident response* capacity
- coordination of the *standardization* of infrastructure, vehicles, equipment and operational procedures
- facilitation and coordination of the *training* and development of practitioners
- development and facilitation of the implementation of *standardised municipal by-laws*
- the coordination of planning for the provision of *fire safety and prevention*
- the development, implementation and maintenance of *mutual aid agreements* amongst local fire services, designated fire authorities, fire protection associations and volunteer fire associations
- development, support and implementation of *community-based fire safety* and prevention programmes
- establishment and maintenance of a *District Fire Service Coordination Forum*
- preventing the outbreak and spread of a fire, by making arrangements for the provision of *information, publicity, training, education* and encouragement in respect of the steps to be taken to prevent fires and death or injury by fire and by conducting regular and random fire safety inspections at any premises where the chief fire officer deems necessary
- conducting *fire risk assessments.*

Once again, the White Paper fell into the temptation of dealing with municipal problems by actually *increasing* their portfolio of functions, without clarifying how they would be supported in practice.

At the same time, the White Paper also highlighted the problematic division of powers and functions between various categories of municipalities. Fire-fighting is listed as a local government function in Schedule 4 Part B of the Constitution. Although Section 156(1)(a) of the Constitution does not differentiate between district and local municipalities, the service delivery model emanating from the two-tier system is beset with challenges such as *fragmentation in the delivery of services, duplication of efforts and resources, and jurisdictional contestation.*

In view of the complexity involved in addressing this matter, GoGTA identified the following fundamental principles as critical to the allocation of powers and functions –

- A *clear definition of roles* and responsibilities is necessary to avoid duplication of efforts and resources which is costly and wasteful

- Recognition that *district municipalities have an inherent responsibility to support* local municipalities in their area of jurisdiction
- Recognising the importance of a *differentiated approach* as opposed to a one-size-fits-all approach that fails to appreciate the specific contextual variables of each municipality
- Appreciating that the function can be delivered as a *shared service* as long as roles and responsibilities are clearly defined
- An approach to division of powers must be underpinned by the principles of a risk-based approach to the provision of fire services.
- The allocation of powers, especially for local municipalities, must recognise the role played by fire services in building plan approvals, and land and township development initiatives
- Municipalities must act in accordance with the constitutional requirement of *cooperative government.*

Most local municipalities have fire services by-laws which are used to manage various aspects of their fire services. CoGTA must ensure that applicable legislation is aligned and harmonised to create a unified legislative framework which provides clarity on the division of powers and functions between the various categories of municipalities. While a metropolitan municipality has the powers to render all functions outlined above, a provincial MEC may adjust powers between a district and a local municipality in terms of the Municipal Structures Act.

The draft White Paper also proposed that:

- Chief fire officers and service members must have prescribed *qualifications and experience* to perform their respective functions. Although appointment of members of service will remain a prerogative of the municipality or designated service, the national government must ensure that the qualifications and experience required for such appointments are prescribed appropriately. National government must also develop a career path for fire services personnel.
- The proposed fire services legislation must make provision for the recruitment and utilization of *reservists in fire services*, with powers similar to those enjoyed by member of service.
- Because the infrastructure needed for *call-taking and dispatch* is expensive and complex, and requires significant management input, most municipal fire services have made little progress towards installing and using systems such as two-way radio communications networks, computer-aided dispatch systems and resource tracking systems. The envisaged fire service legislation must provide adequate mechanisms for this critical component of the fire service.
- Fire services must determine their level of capacity to discharge their legal mandate. To strengthen this capacity, they must enter into *mutual aid agreements* with neighbouring fire services, the private sector and any other agency involved in the provision of fire services.
- *While fire services play a fundamental role in the safe storage and transportation of dangerous goods, there is no single policy or legislative framework dealing with thus function.* The roles and responsibilities of fire services must be clearly defined to minimise confusion, costly overlapping and the wasteful duplication of efforts and resources which is costly and wasteful. Furthermore, it is critical that fire services must enter into partnerships with other role players involved in dangerous goods management.

The White Paper also recognised that the funding of fire services is problematic. Generally, local government bears most of the financial responsibility for funding fire services. This funding model is, however, strongly linked to municipal viability, with municipalities that are financially viable able to adequately and sustainably fund the function, while those that are not viable struggle to finance fire activities in any meaningful way. Fire services are not defined as a basic service and this to a large extent often results in inadequate allocation of resources to the function.

The fact that fire services are *capital and resource-intensive, coupled with its low revenue-generating capacity,* is a disincentive for decision-makers to provide adequate funding for the function. In short, the competition for limited resources by all basic services such as electricity, sanitation and water often means that fire services is not able to receive priority.

It is important that *future funding models* put measures in place to support resource-poor municipalities in providing the service sustainably. While financially viable municipalities have been able to allocate resources for the function, an analysis of their expenditure patterns indicates that the bulk of resources expended has been to support fire services operations (fire-fighting and procurement of equipment, etc.). Very little investment has been made by fire services to support fire safety, prevention and protection activities especially community-based fire risk-reduction initiatives.

Future funding arrangements must provide for the funding of fire services across the entire value chain of the function. This will require a *combination of sources* found at all levels of government to adequately fund the fire service.

F.9. Municipal overview of Disaster Management capacity

Eastern Cape

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Alfred Nzo District Municipality			**main**	1				
Umzimvubu	Mount Ayliff	Alfred Nzo	Satellite			1		
Matatiele	Matatiele	Alfred Nzo	Satellite			1		
Mbizana	Bizana	Alfred Nzo	Satellite			1		
Ntabankulu	Ntaban-kulu	Alfred Nzo	Satellite			1		
Amathole District Municipality			**Main**	1		0		
Mbhashe	Idutywa	Amathole	Satellite			1		
Mnquma	Butterworth	Amathole	Satellite			1		
Great Kei	Komga	Amathole	Satellite			1		
Amahlathi	Stutterheim	Amathole	Satellite			1		
Ngqushwa	Peddie	Amathole	Satellite			1		
Nkonkobe	Alice	Amathole	Satellite			1		
Raymond Mhlaba[9]	Fort Beaufort	Amathole	Satellite			1		
Nxuba	Adelaide	Amathole	Satellite			1		
Buffalo City Metro			**Main**		1			
Sarah Baartman District Municipality			**Main**		1			
Dr Beyers Naude[10]	Graaff-Reinet	Sarah Baartman	Main		1			
Blue Crane Route	Somerset East	Sarah Baartman	Main			1		
Makana	Grahamstown	Sarah Baartman	Main			1		
Ndlambe	Port Alfred	Sarah Baartman	Main		1			
Sundays River Valley	Kirkwood	Sarah Baartman	Main			1		
Kouga	Humansdorp	Sarah Baartman	Main	1				
Kou-Kamma	Kareedouw	Sarah Baartman	Main		1			
Chris Hani District Municipality			**Main**		1			
Enoch Mginjima[11]	Queenstown	Chris Hani	Satellite				1	
Intsika Yethu	Cofimvaba	Chris Hani	Satellite			1		
Engcobo	Engcobo	Chris Hani	Satellite			1		

[9] This is an amalgamation of the erstwhile Nkonkobe and Nxuba Local Municipalities.
[10] This is an amalgamation of the erstwhile Camdeboo, Ikwezi and Baviaans LMs.
[11] Previously Lukhanji LM.

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Inxuba Yethemba	Cradock	Chris Hani	Satellite			1		
Sakhisizwe	Elliot	Chris Hani	Satellite				1	
Joe Gqabi			**Main**				1	
Elundini	Mount Fletcher	Joe Gqabi	Satellite			1		
Nelson Mandela Bay Metro			**Main**	1				
O.R. Tambo District			**Main**		1			
Ngquza Hill	Flagstaff	O.R. Tambo	Satellite				1	
Mhlontlo	Qumbu	O.R. Tambo	Satellite				1	
King Sabata Dalindyebo	Umtata	O.R. Tambo	Satellite				1	
Nyandeni	Libode	O.R. Tambo	Satellite				1	
Port St Johns	Port St Johns	O.R. Tambo	Satellite				1	

Free State

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Fezile Dabi District Municipality			?[12]					1
Moqhaka	Kroonstad	Fezile Dabi	?					1
Ngwathe	Parys	Fezile Dabi	?					1
Metsimaholo	Sasolburg	Fezile Dabi	?					1
Mafube	Frankfort	Fezile Dabi	?					1
Thabo Mofutsanyane District								1
Phumelela	Vrede	Thabo Mofutsanyane	?					1
Nketoana	Reitz	Thabo Mafutsanyane	?					1
Maluti a Phofung	Qwa-Qwa	Thabo Mafutsanyane	?					1

[12] "?" means that the information is not clear in the IDP. This, in turn, reflects the deep underlying confusion regarding powers and functions – so that even the IDPs have not attempted to clarify the matter.

Gauteng

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Johannesburg Metro	Johannesburg	Johannesburg Metro	Main	1				
Tshwane Metro	Pretoria	Tshwane Metro	Main	1				
Ekurhuleni Metro	East Rand	Ekurhuleni Metro	Main	1				
Sedibeng District Municipality			**Main**			1		
Emfuleni	Vereeniging	Sedibeng	Main	1				
Midvaal	Meyerton	Sedibeng	Main	1				
Lesedi	Heidelberg	Sedibeng	Main	1				
West Rand District Municipality			**Main**	**1**				
Merafong	Carletonville	West Rand	Satellite				1	
Mogale City	Krugersdorp	West Rand	Satellite				1	
Randfontein	Randfontein	West Rand	Satellite				1	
Westonaria	Westonaria	West Rand	Satellite				1	

KwaZulu-Natal

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Amajuba District Municipality			**Satellite**					1
Newcastle	Newcastle	Amajuba	Main					1
Emadlangeni	Utrecht	Amajuba	Main	1				
Dannhauser	Durnacol	Amajuba	Main		1			
Ethekwini Durban Metro			**Main**	**1**				
iLembe District Municipality			**Main**			1		
Mandeni	Mandeni	iLembe	Satellite				1	
KwaDukuza	Stanger	iLembe	Main	1				
Ndwedwe	Ndwedwe	iLembe	Satellite				1	
Maphumulo	Maphumulo	iLembe	Satellite				1	
Harry Gwala District Municipality			?			1		
Umzimkhulu	Umzimkulu	Harry Gwala	?			1		
Dr Nkosazana Dlamini-Zuma[13]	Creighton	Harry Gwala	?					1
Greater Kokstad	Kokstad	Harry Gwala	?				1	
Ubuhlebezwe	Ixopo	Harry Gwala	?				1	
Ugu District Municipality			?		1			
Vulamehlo	Dududu	Ugu				1		
Umdoni	Scottburgh	Ugu	Main	1				
Umzumbe	Umzumbe	Ugu	Main?			1		
UMuziwabantu	Harding	Ugu	satellite			1		
Ray Nkonyeni[14]	Izinqolweni	Ugu	satellite			1		
Ray Nkonyeni[15]	Port Shepstone	Ugu	Main		1			
uMgungundlovu District Municipality			?			1		
uMshwathi	Wartburg	uMgungundlovu	?					1
uMngeni	Howick	uMgungundlovu	satellite			1		

13 This Municipality is an amalgamation of the Ingwe and Kwa Sani Local Municipalities.
14 This Municipality was previously the Ezingoleni LM.
15 This Municipality was previously Hibiscus Coast LM.

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Mpofana	Mooirivier	uMgungundlovu	?				1	
Impendle	Impendle	uMgungundlovu	?				1	
The Msunduzi	Pietermaritz-burg	uMgungundlovu	Main	1				
Mkhambathini	Camperdown	uMgungundlovu	?					1
Richmond	Richmond	uMgungundlovu	?					1
uMkhanyakude District Municipality			**Main**		**1**			
Umhlabuya-lingana	Emangusi	uMkhanyakude	Satellite					1
Jozini	Mkuze	uMkhanyakude	Satellite					1
The Big 5 Hlabisa	Hluhluwe	uMkhanyakude	Satellite					1
Mtubatuba	Mtubatuba	uMkhanyakude	Satellite					1
uMzinyathi District Municipality			**Main**		**1**			
Endumeni	Dundee	uMzinyathi	Main		1			
Nqutu	Nqutu	uMzinyathi	Satellite				1	
Msinga	Pomeroy	uMzinyathi	Satellite				1	
Umvoti	Greytown	uMzinyathi	Main	1				
King Cetshwayo District Municipality			**Main**				1	
Mfolozi	KwaMbonambi	King Cetshwayo	Satellite					1
uMhlathuze	Richards Bay	King Cetshwayo	Main	1				
Ntambanana	Ntambana	King Cetshwayo	Satellite					1
uMlalazi	Eshowe	King Cetshwayo	Main		1			
Mthonjaneni	Melmoth	King Cetshwayo	?					1
Nkandla	Nkandla	King Cetshwayo	?					1
Zululand District Municipality			**Main**	**1**				
eDumbe	Paulpietersbur g	Zululand	Satellite			1		
UPhongolo	Pongola	Zululand	Satellite				1	
Abaqulusi	Vryheid	Zululand	Main			1		
Nongoma	Nongoma	Zululand	Satellite				1	
Ulundi	Ulundi	Zululand	Satellite				1	

Mpumalanga

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Ehlanzeni District Municipality			?			1		
Bushbuckridge	Bushbuckridge	Ehlanzeni	Main			1		
Thaba Chweu	Sabie	Ehlanzeni	Main					1
Mbombela	Nelspruit	Ehlanzeni	Main	1				
Umjindi	Barberton	Ehlanzeni	Main		1			
Nkomazi	Nkomazi	Ehlanzeni	Main			1		
Gert Sibande District Municipality					**1**			
Albert Luthuli	Carolina	Gert Sibande	Main		1			
Msukaligwa	Ermelo	Gert Sibande	Main	1				
Mkhondo	Piet Retief	Gert Sibande	Main				1	
Lekwa	Standerton	Gert Sibande	Main				1	
Dipaleseng	Balfour	Gert Sibande	Main				1	
Govan Mbeki	Highveld Ridge	Gert Sibande	Main	1				
Nkangala District Municipality			**Main**			1		
Victor Khanye	Delmas	Nkangala	Main	1				
Emalahleni	Witbank	Nkangala	Main		1			
Steve Tshwete	Middelburg	Nkangala	Main		1			
Emakhazeni	Belfast	Nkangala	Main	1				
Thembisile	KwaMhlanga	Nkangala	Main			1		

Northern Cape

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Pixley ka Seme DM			**Main**		**1**			
Ubuntu LM	Victoria West	Pixley ka Seme	satellite			1		
Namakwa District Municipality			**Main**	1				
Richtersveld	Port Nolloth	Namakwa	?		1			
Nama Khoi	Springbok	Namakwa	Main					1
Hantam	Calvinia	Namakwa	Satellite			1		
Karoo-Hoogland	Williston	Namakwa	satellite			1		
Kamiesberg	Garies	Namakwa	Main					1

North-West Province

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Bojanala District Municipality			**Main**?		**1**			
Madibeng	Brits	Bojanala DM	main		1			
Moretele	Unclear	Bojanala DM	Satellite?		1			
Rustenburg	Rustenburg	Bojanala DM	main	1				
Dr Kenneth Kaunda DM						1		
JB Marks[16]	Potchefstroom	Dr K Kaunda	Main	1				

[16] Previously the Tlokwe Local Municipality.

Western Cape

Local Municipality	Centre	District Municipality	Main or Satellite	Good	Fair	Marginal	None	No info available
Cape Winelands District Municipality				1				
Witzenberg	Ceres	Cape Winelands	Main	1				
Drakenstein	Paarl	Cape Winelands	Main	1				
Stellenbosch	Stellenbosch	Cape Winelands	Main					1
Breede Valley	Worcester	Cape Winelands	Main					1
Langeberg	Robertson	Cape Winelands	Main	1				1
City of Cape Town Metro			**Main**	**1**				
Eden District Municipality			**Main**	**1**				
Kannaland	Ladismith	Eden	Satellite; wants to be Main		1			
Hessequa	Riversdal	Eden	Main?		1			
Mossel Bay	Mossel Bay	Eden	Main?				1	
George	George	Eden	Main	1				
Oudtshoorn	Oudtshoorn	Eden	Main	1				
Bitou	Plettenberg Bay	Eden	Main?				1	
Knysna	Knysna	Eden	Main	1				
Overberg District Municipality			**Main**	**1**				
Theewaters-kloof	Caledon	Overberg	Main?				1	
Overstrand	Hermanus	Overberg	Main?				1	
Cape Agulhas	Bredasdorp	Overberg	Main?				1	
Swellendam	Swellendam	Overberg	Main				1	
West Coast District Municipality			**Main**	**1**				
Matzikama	Vredendal	West Coast	Main?				1	
Cederberg	Citrusdal	West Coast	Main?				1	
Bergrivier	Velddrif	West Coast	Satellite?				1	
Saldanha Bay	Saldanha Bay	West Coast	Satellite				1	
Swartland	Malmesbury	West Coast			1			
Central Karoo DM			**Main**				1	
Beaufort West	Beaufort West	Central Karoo	main		1			
Laingsburg	Laingsburg	Central Karoo	main		1			
Prince Albert	Prince Albert	Central Karoo	main			1		

APPENDIX G – PEER REVIEW AND SPECIALIST RESPONSE SHEET

Peer Reviewer: Peter Magni; Independent Consultant

EXPERT REVIEW AND SPECIALIST RESPONSES: Settlement Planning, Disaster Management and related Social Impacts - Gas					Change has been effected in the report No change has been effected in the report (i.e. not required and supported by response by Specialist)
Expert Reviewer Name	**Page Range**	**Line/s**	**Table/ Figure**	**Expert Reviewer Comments**	**Author(s) Response**
Peter Magni	3	3		define significance of gas pipeline as part of summary - (i.e. replace current phrase with "...development of a gas pipeline network for South Africa)"	Amended
Peter Magni	3	6-11		Single sentence paragraph is too long, reader loses sense of meaning. Suggested replacement paragraph: "The study seeks to refine and optimise the location of the proposed corridors that compose the gas pipeline network based on the initial proposal. It considers the planning of the pipeline network from a social, spatial planning and disaster management perspective identifying issues and opportunities in determining the project's final extent.	Amended
Peter Magni	3	14		Economic growth from gas is not sustainable given that the resource is finite. Economic growth derived from gas will peak and decline over time, even if the development of the resource is phased. Rather refer to "economic growth"	Amended
Peter Magni	3	14 - 15		"as well as realising national development objectives related to achieving a more sustainable energy mix for the Country."	Amended
Peter Magni	3	15-18		Break bolded sentence: **"However, construction of a gas transmission pipeline has the potential to cause substantial disruption to lives and livelihoods should it be constructed in close proximity of existing settlements.** The Pipeline could have a negative impact if it does not take due precaution to limit disruption to existing settlements and developments.	Amended
Peter Magni	3	22-25		Negative impacts of a gas transmission pipeline manifest in land-use (e.g. alienation of existing land uses making these uses untenable), tenure management considerations (e.g. expropriation of land), the potential need for resettlement, restriction in future development potential of a parcel of land and negative impacts on service delivery and local economies.	Amended
Peter Magni	3	35		Should read "finalising the alignment of the proposed corridors"	Amended

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Peter Magni	5	13 - 15		"Land-use planning is therefore an important dimension of disaster management and it is critically important that relevant authorities have infrastructural maps to guide maintenance workers." There is an inconsistency in this sentence. What is referred to here is not land use management schemes, or spatial development frameworks but infrastructure masterplans or infrastructure asset management plans relevant to the infrastructure type, which are removed to an extent, from land use planning tools. Then there is the subjective statement that land use planning is a dimension of disaster management, when the alternate assertion could also be true. The sentence should be altered so that it is consistent and that subjectivity is removed.	Changed to The availability of Infrastructure masterplans is deemed an important dimension of disaster management and it is critically important that relevant authorities have infrastructural maps to guide maintenance workers
Peter Magni	5	21 -22		Add: "Disaster management therefore requires collaboration between public agencies and private sector pipeline developers **and operators"**.	Added

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Peter Magni	5	35 -37		"The fire-fighting capabilities of the affected municipalities were considered as a proxy for the DisM capability of a municipality and, where available, were reviewed as part of this study." Why has a broader consideration of EMS capability within municipalities been excluded? Is it difficult to disaggregate municipal from provincial ambulance services for instance?	Given the large geographic area, and the numerous municipal jurisdictions, it was necessary to identify adequate criteria comparing them along a standard benchmark, with available documentation. Fire-fighting is the most standard EMS service available, and even for that basic measurement, data is not always available. Ambulance services vary between: 1. Provincial service delivery 2. District municipal service delivery – usually in the erstwhile Cape Province areas (now Western, Eastern and Northern Cape) 3. Metros service delivery, and 4. Private ambulance services. The available documentation is very limited (mostly on municipal government, and even that is very uneven, as the report shows). Any finer detail would require a field work process, which in this instance would not be very useful, for two reasons: (a) It would soon be outdated (b) Such data-collection should be done as part of a preparation for a gas pipeline project, so that the institutional relationships between the pipeline project and the various municipal and provincial agencies are created – i.e. the process of research is as important as the substance of research. The crucial point in this study is that (a) service delivery is highly varied and uneven, and (b) available documentation is highly uneven.
Peter Magni	5	37 - 39		"The review of the DisM capabilities of district municipalities within the gas corridors to respond to a disaster is shown in Figure B below." The highlighted sentence prior to this one speaks to local municipalities. Figure B though, speaks to district municipalities. This is not in keeping to the proposed focus on local municipalities. Why was the representation done for district and not local municipalities?	Figure has been changed, as well as the paragraph

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Peter Magni	6	1	Figure B	Figure B needs to be captured at the local municipality level. I think it would be a very sobering map.	Figure has been changed
Peter Magni	6	4 to 6		Sentence needs correction as follows: "The overall suitability of the proposed corridors for the development of a gas transmission pipeline in relation to settlement planning and disaster management is summarised below (Table A)."	Amended
Peter Magni	6 -7		Table A	Southern Coastal Corridor and Inland Corridor, and potentially the western corridor are areas where extraction of gas is to take place, or where the gas is to be brought onshore. As such, do the settlements in these corridors not have a higher employment potential than settlements in the other corridors, and by extension greater potential to grow in population?	The assessment did not consider the employment opportunities to be created downstream by the establishment of a gas corridor since the details regarding employment opportunities are not clear at this stage and would be too speculative. It must also be noted that corridors are assessed individually and are not compared to each other (i.e. not ranked). The calculated assumption regarding buffers was based on past development trends, and the current size of the settlement to cater for future growth. If and when development happens, there would have to be a local detail assessment. Human and Settlement development are not linked to rules of behaviour that are easily predicted. In addition, it was assumed the same growth in all directions. This may not happen and all growth may go in another direction due to ground conditions, cost of development, political decisions, cost of land etc.
Peter Magni	8		Additional Figure	Suggestion: Include a map that highlights the major urban areas in South Africa overlaying this information with icons, or a graph which shows the urban settlements that have shown significant economic growth in the past ten years.	Please see Figure 3 which shows where there is population growth. The economic opportunities are captured within a separate assessment of the SEA
Peter Magni	8	11 - 13		Meaning of sentence unclear, change to: "While the proposed gas transmission pipeline is intended to be kept outside cities and towns, these areas, due to population and economic agglomeration, form the anchor points for future gas demand."	Amended
Peter Magni	8	17 - 18		Add sentence that states: Alternatively, the expansion of the gas network to urban areas may stimulate the growth of associated industry and business which may increase the demand for industrial land and servitudes associated with local gas reticulation networks.	Sentence has been added.

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Expert Reviewer Name	Page Range	Line/s	Table/ Figure	Expert Reviewer Comments	Author(s) Response
Peter Magni	8	38 - 39		Section should read: " whilst at the same time protecting ecologically sensitive areas and critical ecological infrastructure	Amended
Peter Magni	8	41 - 45		Alter as follows: "At a national and regional scale, it is pertinent that the proposed gas transmission pipelines are designed in such a way that the investment in large scale infrastructure is done in support of current and planned future economic nodes and corridors for South Africa in the most effective and sustainable way. To achieve this, national and regional design considerations would need to include:"	Amended
Peter Magni	8	48		In relation to private sector investment, consideration must not only be of future gas related energy demands, but also of the existing gas related industries and how the imposition of the new gas network may benefit or negatively impact these industries.	The economic opportunities are captured within a separate assessment of the SEA
Peter Magni	9	12 - 18		The proposed national pipeline will traverse diverse settlement and socio-economic contexts, often within ambit of cities, towns and settlements. The proposed corridor includes the sparsely populated and arid western areas of the country, through the developed, heavily populated Southern Corridor, and the densely populated rural traditional authority areas of the country which are also the country's most critical water resource areas.	Amended
Peter Magni	9	20 -24		At national, provincial and sub-regional scale consideration of the different contexts of which the corridors consist will be critical to ensure the greatest development return, for the most sustainable long term infrastructure investment. It is imperative that, irrespective of whether the pipeline is developed or not, careful, coordinated and integrated planning must take place.	Amended
Peter Magni	9	25		There needs to be a sentence that guides the reader to 1.1, and defines what is to be covered, otherwise the reader is uncertain. The narrative jumps from speaking to the South African experience and the gas project to a US example with no explanation. Add a sub-section titled: "International Gas Pipeline Development Planning Experience"	Added sub-headings

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Peter Magni	9 - 10	27 - 30		The international gas pipeline experience in the draft chapter draws solely on developed world examples of the United States and Canada. This chapter should consider developing country examples, and the lessons that these countries might have in relation to gas pipelines in circumstances where planning systems are fragmented, where more than one tenure system is in operation, and where informal/illegal land occupation is a legitimated form of land holding. There is a significant body of literature to draw from. Countries that should be considered in this regard include: Venezuela, Brazil, Peru, Argentina, Trinidad and Tobago and Bolivia as the largest South American natural gas exploiting countries with gas pipelines (https://en.wikipedia.org/wiki/Natural_gas_in_Bolivia). South American countries also have experience in dealing with trans-national gas pipeline if the South African Gas Pipeline needs to consider export to SADC. See Gasoducto Argentina (Yabog pipeline) and Gasoducto Bolivia-Brazil (GASBOL pipeline). For example in the case of Bolivia see: (https://en.wikipedia.org/wiki/Bolivian_gas_conflict) (https://www.nytimes.com/2006/05/02/world/americas/02bolivia.html). The Bolivia experience is particularly informative as to the importance of careful planning in designing gas pipelines and the exploitation of the natural gas resource. In the mid-2000s the perception that the exploitation of natural resources was not benefitting the local population, a view particularly held in urban areas, was a key reason for political change and the election of President Evo Morales and the subsequent nationalisation of the resource. (https://openknowledge.worldbank.org/bitstream/handle/10986/17953/ESM3220Gas0Pipelines01PUBLIC1.pdf;sequence=1). This article covers major development planning considerations related to the GASBOL project. (e.g. See page 24 for standards for right of way servitudes used.	Added text to the Chapter to try and support the comment See section 1.1.1)
Peter Magni	10	32		The document jumps abruptly to the South African planning experience. Please can sub-headings be used to denote such shifts to help the reader? Call the subsection: "Relevant South African Planning Related Policy"	Added sub-headings

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Peter Magni	11	24		Section 19-20 of the Spatial Planning and Land Use Management Act (2013) makes provision for a Regional Spatial Development Framework (RSDF). At the time of promulgation there was contention as to when, how and why such a spatial planning document would need to be used in circumstances where, Regional Planning and Development was seen as a Concurrent National and Provincial Legislative Competence in terms of Schedule 4 Part A , while municipal planning was a local government competence under Schedule 4 Part B of the Constitution (1996). It is suggested that the Chapter promote the drafting of a RSDF be the correct spatial planning vehicle to use in relation to the proposed bulk gas pipe-line where there is: 1) uncertainty as to the phasing and the timing of the project which may be implemented over decades;2) the need for provinces and municipalities to apply consistent criteria for the assessment of development applications in a situation where most municipalities would not have had to deal with a bulk gas pipeline applications before; 3) there is a need to bridge the planning gap between an environmental assessment that focuses on the status quo and an Environmental Impact Assessment that is reactive to a particular development application. In this manner an environmental sustainability focus can be embedded in the spatial planning considerations for the initiative. This would also address the concern that environmental considerations are not adequately dealt with in spatial planning policy; 4) the geographical area under consideration includes a number of provinces and municipalities; 5) the nature of servitudes, development criteria for bulk, distribution, point gas facilities and gas reticulation consideration for related facilities (e.g. industrial, residential retail uses) can be included in the framework; 6) bulk gas servitudes need to be preserved for an extended period of time from urbanisation; 7) There are differing capacities within municipalities to undertake SDFs. This would be a means of ensuring that the correct safety measures (e.g. LP Gas Safety Regulations) are included in developments from the planning phase.	Added text in Section 10.1. to support this comment

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Peter Magni	12	15 - 19		The existing Guidelines for Human Settlement Planning and design (2000)(Red Book) considers biogas, 'town gas' (gas pipeline) as used on a limited scale in Johannesburg, Durban, Cape Town and Port Elizabeth, and Liquid Petroleum Gas (portable gas canisters - Eezi Gas, CADAC etc.) in Chapter 12. No guidelines are provided for servitudes for bulk and associated distribution networks and facilities associated to natural gas (It is not known whether more detail has been provided on this matter in the revised Red Book). It would be useful if the Chapter gave the reader an idea as to the servitude sizes used for such bulk and distribution networks, and what the land use considerations would be for required point facilities (e.g. access points, storage facilities, depots etc.). This would assist in defining the detailed land use considerations. A diagram showing the cross-section of such a servitude would be useful.	This is addressed in the SEA Report (Introduction and Background) and not within this Chapter

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Peter Magni	1 - 144 specifically 16 / 17	10 -11 & 16 - 25		"There is insufficient evidence and information available to asses any benefit to a community at this stage": This is a contested statement. What the chapter needs to do is identify those industries that currently exist that would benefit from having ready access to a bulk gas line. The chapter, from a development planning perspective, also needs to identify the existing gas pipelines and related facilities in the country. This means understanding the products that can be manufactured from natural gas, or which industries could use a reliable bulk source of energy (e.g. It is surprising that SASOL as a major player in the gas/coal/oil space in the Country is not referenced in this chapter or the overview to the SEA) . Given that this is a high level assessment, the chapter does not have to identify every land use in this respect; rather it needs to identify clusters of land uses (i.e. industries and businesses) that meet these criteria. Most of these land uses will be located within or adjacent to an existing settlement. It is in these areas that the opportunities for economic expansion and employment creation will be greatest, where existing skills and institutions would benefit from the proposed gas infrastructure. The Chapter's primary weakness at the moment is that the focus on settlement population and density as the primary determinants in considering location sensitivity creates no-go areas for a bulk gas pipeline in cities and towns. This effectively excludes, or makes it very difficult to motivate for an expansion and intensification of gas distribution networks within existing settlements which would, by extension, be deemed too sensitive to be undertaken in settlements, and to benefit from locations where the skills and industry exist to make the greatest economic benefit from the infrastructure. In identifying cities and large towns as being highly sensitive when considering the location of the bulk gas servitude, one prioritises the pipe-line corridors that avoid settlement and facilitate the direct export of the resource. One needs to consider the political ramifications of a multi-billion rand project that is unable to show that it is benefitting as large a portion of the South African urban population as possible both as source of energy and in terms of job creation. It is strongly advised that a more detailed review of land use, focusing on existing gas industries and allied industries be undertaken so as to show the symbiotic relationship between dense settlement and the proposed gas pipeline.	The economic opportunities are captured within a separate assessment of the SEA. Existing industrial developments and gas transmission pipelines have been considered in the engineering constraints analysis and future intensive energy users are considered in the demand mapping that will be used when refining the proposed corridors, to ensure that while environmental and social considerations have been incorporated, the benefits of gas accessibility is also taken into account.

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Peter Magni	17	36		The CSIR did analysis for certain of the metropolitan municipalities to determine gaps in emergency services. Could this work not add to the methodology used in the Chapter?	The assessment did not include a gap analysis but rather considered the status-quo based on: 1. Their status as "main" or "satellite" fire-fighting offices. 2. Number of fires and incident call-outs. 3. Number of fire fighters, disaster management volunteers and volunteers. 4. Number of vacancies (unfilled posts). 5. Number of "appliances" (vehicles and specialised equipment). 6. The repairs expenditure, to show municipal commitment to Operations and Maintenance. This gap analysis was only done for 4 metros, is mostly out of date, and highly dependent on the final road network and settlement layout which is yet to be developed.

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Peter Magni	20	20		Please elaborate with a sentence or two on: 1) What analysis is required to provide a detailed perspective of fire-fighting capacity?; 2) Capacity required in the event of a Gas incident from a broader Emergency Management Service needs to be elaborated upon (e.g. ambulance, policing considerations)	1) Amended in the text. 2) The aim of this assessment was to provide a high level indication of municipalities on a strategic level that may be of risk in terms of their capacity to respond to a disaster. In addition, the broader Emergency Management Services required would need to be prepared on a project level. The provision of these measures is outside the scope of this assessment. Furthermore, a gas incident can range from small to large. We might have to conclude that a municipality has enough ambulances for a small incident, but not for a medium and large incident. Different types and scales of incident would require different types of services, ranging from (say) 2 ambulances to 50 ambulances, of from (say) 20 policemen to 50 policemen. This is incredibly fine empirical detail which is not feasible in the current study. And all of this would be outdated in (say) 2 years, due to staff changes, financial factors and political dynamics. The point made in the study is that any proposed gas pipeline will have to do a detailed consultation with each municipality, using a proper rubric of comparison, according to each service. That would then require a proper process of methodological planning, engagement, and fieldwork.
Peter Magni	20 / 21	41 / 42		Editing error. Sentence is split over two pages. Needs to be corrected.	Amended
Peter Magni	22	1	Table 1	One needs to be careful not to add policy to the table indiscriminately, so the following proposed policy additions need to be considered selectively. The national policy regarding displacement for emergency housing and the relocation of informal settlements (relevant to pipe line construction) is located in the Housing Code (2009) under chapter 4, in the Sections relating Emergency Programme and the Informal Settlement Upgrading Programme. The Housing Code is policy undertaken in terms of the Housing Act (1996).	Included in the relevant literature table.

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Peter Magni	22	1	Table 1	Further to the above policy. It would be important when expropriating land for the gas pipeline servitude to detail the existing legislative elements that define and might affect this process, while mentioning that there is a process to review the existing process of land expropriation. Below is the list of legislation that needs to be considered for inclusion that interfaces directly with SPLUMA (Refer to Planning Law Second Edition, Jeannie van Wyk (2012) for detail on the legislation and jurisprudence in question): Constitution 25 Sections(5)-(9), Expropriation Act (1975), Land Survey Act (1997), Deeds Registries Act (1937), Land Tenure Security Act (1989), National Heritage Resources Act (1999), Prevention of Illegal Eviction from and Unlawful Occupation of Land Act (1998)(PIE).	Expropriation of land is not applicable to this project.
Peter Magni	22	1	Table 1	It is important that the distinction to own land for particular land uses as defined in SPLUMA, the Land Survey Act and Deeds Registries Act sits side by side with a complementary perspective on access to land in the country that says that people have a right to be respected as human beings and that occupation of land by a certain group of people, at a given point of time needs to follow due process. This principal is defined in the PIE (1998) Act and upheld by a number of court cases (e.g. Grootboom vs Oostenberg Municipality and Others 2000(3) BCLR). PIE needs to be considered when removing informal settlements or expropriating land. The issue of land rights in Traditional Authorities is a contentious where adopted legislation has not been implemented as intended (e.g. Communal Property Associations Act (1996), Extension of Security of Tenure Act (1997), with different pieces of legislation applicable in different provinces (Ingonyama Trust Act (1994).	See Section 7.1.2 for an inclusion of PIE.

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Peter Magni	27		Figure 2	The general application is that Phase 1 will be the start of a given project, followed by Phase 2 and so on. If this is not going to be the case please can a different means of referencing the Gas Pipeline Project geographical components be used? In its current form the labelling will create confusion in the minds of the public.	The way in which the corridors are referenced has been provided by the Project Team and a suitable description will be included in the main body of the SEA report. The Phase numbering originated from Operation Phakisa and does not necessarily reflect the order in which the pipeline may be constructed. The proposed project phases are independent of each other and each one will be based on its own business case. It is estimated that one gas transmission pipeline will be constructed within each corridor, as the pipeline will be driven by finding a gas reserve and will only be constructed based on a viable business case.
Peter Magni	27	4		Edit required: 'Although is it is highly unlikely that everyone'	Amended
Peter Magni	29	16-17		At present the general thesis of this chapter is that cities and towns are the most sensitive areas, which need greatest care when constructing and maintaining the gas infrastructure. This thesis is agreed too. But this chapter also needs to highlight the critical role played by dense cities and towns in realising the success of the bulk gas network from not only a socio-economic and political perspective as detailed previously but from a physical perspective. These settlements have the highest concentration of existing linear publicly owned servitudes in the Country. During the detailed planning phases the viability of using these existing servitudes needs to be explored with the responsible departments and entities.	Existing servitudes (road, water pipelines etc.) will be taken into consideration when planning the route for a proposed gas transmission pipeline. These, where applicable, will also be used as "pull" factors when optimising the location of the proposed corridors. It must however be noted that the gas pipeline needs to be located about 5 - 10 km away from railway lines (excluding those lines running on diesel) and power lines due to an induced current created in the pipeline, which causes corrosion issues. Public owned servitudes within settlements would form part of the distribution network which out of the scope of this SEA.
Peter Magni	30	4-12		Why is it that District Municipalities have greater fire fighting capacity than local municipalities? How is that capacity proportioned to the local municipalities?	The analysis of District Municipalities outline their ability or provision to support local municipalities in DiSM
Peter Magni	31	2	Figure 7	Why is it that there is no disaster management information available for eThekwini Metro? They are usually forthright with information. Unless what is being said by the map, is that eThekwini is particularly unprepared for a disaster. Then this finding must be highlighted. It is noted that the other Metros have been treated and District Municipalities.	No information was available, this is shown on the maps

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Peter Magni	32	2	Figure 8	Figure 8 includes eThekwini's information. Please ensure that this information is captured in Figure 7	Updated
Peter Magni	34		Table 5	Table 5 should include a section for each of the regions identifying where the clusters of existing industrial and gas related land uses exist which would benefit from the construction of the pipeline. These land use clusters should be captured on a map in the chapter.	Refer to the Economic opportunities study as part of the SEA repot.
Peter Magni	37	34		7.1.1. The danger of accepting the sensitivity analysis at face value is that the gas pipe lines that intersect major urban areas will not be prioritised, in favour for a strategy that promotes bulk export of natural gas, with no gas related beneficiation being realised in South African Urban Centres where over 60% of the population reside. The socio-economic and political dangers of such prioritisation are too high. This section and the following section need to include the servitude and land benefits of bringing a bulk gas pipeline to urban areas.	The economic opportunities for gas are captured within a separate study. This SEA is only looking at transmission gas pipelines, which are high pressure pipelines for industrial centres. In addition, the viability of such a project (development of a Transmission gas pipeline) would generally require a large customer, such as a power station. Beyond that, supply to industry would be required, followed by supply to homes. This SEA does not address supplying gas to urban or rural households, therefore benefits for bringing bulk gas pipelines to urban areas cannot be considered at this stage. There is no promotion of "bulk export" of natural gas.
Peter Magni	38	41		There needs to be a paragraph that reiterates the current requirements under the land expropriation act, and the ramifications of the Prevention of Illegal Evictions Act for the finalisation of the pipeline servitudes in question	Expropriation is not anticipated. PIE has been added to this section.
Peter Magni	38 - 39	49 - 5		Clarity needs to be provided on how the Emergency Housing Programme of the Department of Human Settlements relates to a Resettlement Action Plan as required by DEA.	Added text
Peter Magni	39	43		add: "and applicable municipal infrastructure masterplans.."	Amended
Peter Magni	39	45 - 49		The following sentence does not make sense and needs to be re-written: "The need for gas would probably require the pipeline to be able to service, but at the same time very sensitive design with a much more detailed impact assessment within high density population and economic nodes within the bigger eThekwini, Cape Town, Nelson Mandela Bay and Gauteng city region areas for the gas transmission pipeline."	Amended

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Peter Magni	40	5-11		The following sentence does not make sense and needs to be split into two sentences and rewritten: " The same requirements than above will need to be considered in future when increased or specific needs might be identified for increase access to gas as energy resource in fast growing and high density cities including Mbombela/Nelspruit, New Castle, Vryheid, Mthatha, the South Coast Corridor (east of Durban) and the North Coast corridor (north of Durban), the Durban-Pietermaritzburg corridor area and nodes, the coastal corridors of Plettenberg Bay and George, and smaller development concentrations and footprints in the various inland service towns.	Amended
Peter Magni	40	28 - 29		Replace "is too complex to be assessed further (i.e. attach a risk level) as part of this high level SEA." with "requires further investigation."	Amended
Peter Magni	40	31 - 37		Mention the Expropriation Act as the reason why compensation is not paid.	Expropriation of land is not applicable to this project.
Peter Magni	40	45		Add bullet which reads: "Use existing infrastructure servitudes where viable and agreed to."	Added text
Peter Magni	41	8		Does 'segment' as used in this context mean 'Phase'?	A segment refers to a section of the pipeline that will be constructed, not a Phase
Peter Magni	41	38		"through" not "though"	Amended
Peter Magni	42	31		Add Bullet: Location of servitude should not exclude existing or potential business or industry that uses or would benefit from access to a high volume, regular source of natural gas.	Added
Peter Magni	43	7 - 24		Would it be possible to reference an academic study as well as the DEA, 2016 SEA document when associating construction workers, as a specific group, with criminal activity? The accusation is too much of a generalisation and needs to be better supported than it is now.	Added references to DEA 2016 SEA and Energy Sector Management Assistance Program (ESMAP) (2006). Best Practices in Mainstreaming Environmental & Social Safeguards into Gas Pipeline Projects. These are generic impacts/risks that are typically associated with construction phase of large project.
Peter Magni	43	29 - 45		As with construction workers, please find an alternative academic reference in relation to the generalisation made regarding work seekers, other than the DEA study. What is being said about work seekers is discriminatory.	Refer to response above.

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Peter Magni	43 - 45	47 - 2		Are the management actions proposed in this list compliant with Department of Labour Legislation and associated regulations? How are the rights of the employees affected by these proposals? This section needs to be better referenced, and more carefully considered.	These mitigation measures have been recommended in various Social and Environmental Assessments undertaken in South Africa, which have been approved and implemented. Additional recommendations have been included regarding compliance with the Department of Labour's requirements, as applicable. In addition, relevant management measures will be included in the EMPr. The Report has also been updated to include reference to IFC PS2.
Peter Magni	47			Please rectify formatting errors on page, and embed the information boxes	Amended
Peter Magni	48			Please rectify formatting errors on page, and embed the information box	Amended
Peter Magni	55		Table 6	Formatting - Table lines have gone missing, and need to be added	Amended
Peter Magni	56 - 58		Table 8	It is difficult to read this table. Inserting table lines might help. What the table would communicate, does reinforce the position that towns and cities should not be priorities for a gas pipe-line given the sensitivities and complexities associated with providing a bulk servitude and installing the infrastructure. The benefits of a bulk supply of gas to a city or a town are absent from this assessment.	Amended. The economic opportunities are captured within a separate assessment of the SEA. In general, the need for the gas **transmission** pipeline would require a large customer, such as a power station. Beyond that, supply to industry would be required, followed by supply to homes via distribution and reticulation networks. This project is only looking at transmission of gas, which are high pressure pipelines, mainly for the industrial centres. This SEA does not address supplying gas to urban or rural households, although distribution and reticulation networks will subsequently emanate from the transmission pipeline (take offs).
Peter Magni			Table 9	Table 9 is much easier to read and understand than Table 8. It would benefit from the addition of table lines.	Amended

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Peter Magni	60	5 - 7		Edit sentence to read: "Regarding potential negative impacts of future gas transmission pipeline within approved corridors, the potential impact on existing mining rights (especially in Gauteng) except from certain requirements of the Mineral and Petroleum Resources Development Act (2002) has been identified as a potential issue to be mitigated through the routing of any future gas pipelines." In the case of Gauteng Mining Companies who hold the mineral rights, they use these rights to allow/direct/ prevent/stall development relative to their surface land holdings.	It is noted that when mineral rights were issued prior to 2002, these may fall outside the jurisdiction of the current permit system but these must still be considered a real right held by company/individual in question when defining the servitude for the gas pipeline. Under the 2002 Act the right to prospect and extract minerals is a limited real right that is maintained by a permit system. As such comments on a development application must be requested from the mineral rights holder as defined on the title deed.
Peter Magni	60	27		At the very least this chapter needs to have identified the clusters of existing industries and business land uses by city and town within South Africa that would benefit from a bulk gas pipe-line.	The economic opportunities are captured within a separate assessment of the SEA
Peter Magni	60	35 - 40		Move paragraph to section above, as it relates to spatial planning and land use considerations and not to disaster management concerns. Insert academic references to validate assertions.	Section moved however, no references included since this is a statement made by the contributing author based on the findings of the material researched
Peter Magni	61	9 - 15		"Such negotiations will inevitably drag on for months, as it will involve two major aspects, namely, spatial co-ordination according to municipal SDFs, which may well have to be adjusted to cater for the pipeline (e.g. urban residential expansion) and administrative capacity, particularly regarding disaster management capacity-building, i.e. assessing current capacity, determining what additional capacity (staff, finances, skills) will be required to deal with potential pipeline problems, and determining the source of such financial support." Provide references to the assertions made in this sentence.	No references included since this is a statement made by the contributing author based on the findings of the material researched
Peter Magni	61 - 62	37 - 32		Instead of a Municipal IDP and SDF approach as currently envisaged, propose a Regional Spatial Development Framework specifically for the bulk gas network that all affected provinces and municipalities would adhere to. In this way the SEA will be realised as a planning tool and can in turn directly assist in EIA assessment, and municipalities will not have to alter their spatial planning and land use instruments just to facilitate a gas pipeline.	Added text to support this statement

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Peter Magni	62	36 - 37		Delete bullet. Cities and towns are meant to benefit from the gas pipe-line; they should be the primary beneficiaries of the natural gas resource. The political ramifications of not ensuring that the majority of South Africans benefit from their natural resources are great. We must learn from our previous mistakes with gold and platinum and from the experiences of Countries such as Bolivia.	Previous notes about this SEA focusing on high pressure transmission lines and not distribution or reticulation lines stand. The Gas transmission Pipeline is aimed to supply large industrial areas and as such, it is a recommendation that high density population areas should be avoided, as best as possible. While the proposed gas transmission pipeline corridor is intended to be kept outside cities and towns, these areas, due to population and economic agglomeration, also form the anchor points for future gas demand. The subsequent expansion of the gas network to urban areas (via distribution networks) may stimulate the growth of associated industry and business which may increase the demand for industrial land and servitudes associated with local gas reticulation networks. However where it cannot be avoided then various measures will need to be followed, for example ensuring the pipeline has a thicker wall in proximity to settlements.
Peter Magni	72		Appendix A2	Under "Small Towns and Small Service Centres" add sentence that reads. "Planning Capacity may be lacking, and may negatively impact on timeframes in finalising servitudes"	Added
Peter Magni	114		Table E6	"Saldanha Renewable energy industrial growth": What does this project entail? What does it mean for the gas pipe-line? Is this project forming part of the SEA discussions? If so how? If not why not? Is this a future industry cluster that would benefit from bulk gas?	A review of development projects contained in available PGDSs (January 2018) in the corridor area can be found in Appendix E of this report. Given that time lines, phasing, scale, funding and spatial specific implications are not clearly evident from these studies and is subject to change, relevant local and provincial plans will have to be reviewed for each sector closer to the time of final construction. Available planning for the N2 road corridor and possible rail linkages in the same corridor in future is illustrated in Figure 6 to inform future alignment of the gas corridor servitude. A Gas opportunity study and a demand mapping
Peter Magni	114		Table E6	"Laingsburg Renewable energy industrial growth" What does this project entail? What does it mean for the gas pipe-line? Is this project forming part of the SEA discussions? If so how? If not why not? Is this a future industry cluster that would benefit from bulk gas?	
Peter Magni	116		Table E6	"Port St Johns Proposed Renewable Energy Zone" What does this project entail? What does it mean for the gas pipe-line? Is this project forming part of the SEA discussions? If so how? If not why not? Is this a future industry cluster that would benefit from bulk gas?	

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Peter Magni	117		Table E6	Karoo Shale Gas optimisation? A future province supported location for gas industry.	exercise have been undertaken to identify the main current and future energy intensive users (including SEZ, IDZ, intensive agriculture, mining etc.). These will form anchor points and will be considered when optimising the location of the proposed corridors, to ensure that economic benefits are looked at.
Peter Magni	123		Table E6	"Richards Bay 2000MW Gas to power Station". This project needs bulk gas. The project is not mentioned or defined in the chapter. Should this not be a reason to prioritise a gas pipe line that affects Richards Bay? What does this project entail? What does it mean for the gas pipe-line? Is this project forming part of the SEA discussions? If so how? If not why not? Is this project part of a future industry cluster that would benefit from bulk gas (e.g. the Aluminium Hub)?	