STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT IN SOUTH AFRICA

Biodiversity and Ecological Impacts (Terrestrial Ecosystems and Species) - Succulent and Nama Karoo Biomes

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

Draft v3 Specialist Assessment Report for Stakeholder Review

NAMA KAROO, SUCCULENT KAROO AND DESERT BIOMES

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ABBREVIATIONS AND ACRONYMS

AIS	Alien Invasive Species
BOTSOC	Botanical Society of South Africa
CBA	Critical Biodiversity Area
CESA	Critical Ecological Support Area
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEADP	Department of Environmental Affairs and Development Planning
DWA	Department of Water Affairs
ECPAES	Eastern Cape Protected Area Expansion Strategy
EMP	Environmental Management Plan
EMPr	Environmental Management Programme
EN	Endangered
ESA	Ecological Support Area
IUCN	International Union for Conservation of Nature
LM	Local Municipality
NBA	National Biodiversity Assessment
NFEPA	National Freshwater Ecosystem Priority Areas
NPAES	National Protected Area Expansion Strategy
ONA	Other Natural Area
PA	Protected Area
REDZ	Renewable Energy Development Zone
SANBI	South African National Biodiversity Institute
SAPAD	South African Protected Areas Database
SCC	Species of Conservation Concern
SEA	Strategic Environmental Assessment
UCT	University of Cape Town
VU	Vulnerable
WCBSP	Western Cape Biodiversity Spatial Plan

1 SUMMARY

This assessment aims to identify the potential impacts of constructing and maintaining gas pipeline infrastructure in the Nama and Succulent Karoo biomes, as well as the Desert biome of South Africa.

Key environmental attributes of the Nama and Succulent Karoo biomes (including the Desert biome) in the proposed Phased Gas Pipeline corridors include:

- High diversity and endemism for succulent plants;
- High diversity and endemism for fauna, especially reptiles;
- Extensive degradation due to overgrazing (e.g. sheep, goats and ostrich);
- Habitat destruction due to large scale crop cultivation and surface mining;
- Increased desertification due to unsustainable land use and climate change; and
- Establishment of alien invasive (plant) species.

The activities associated with gas pipeline construction and maintenance may pose a risk of habitat destruction and degradation, establishment and spread of invasive plants, increased soil erosion, faunal displacement, poaching of rare and endangered fauna and flora, as well as cumulative impacts on broad-scale ecological processes.

2 INTRODUCTION

The purpose of this assessment is to identify the potential impacts of gas pipeline construction and maintenance to the Nama Karoo, Succulent Karoo and Desert biomes of South Africa. Furthermore, it recommends management actions and best practice mechanisms to avoid and minimise any potential impacts to sensitive Karoo and Desert ecosystems.

This assessment forms part of an overarching Strategic Environmental Assessment (SEA) which ultimately aims to guide sustainable development and environmental decision-making on proposed phased gas pipeline construction and maintenance in South Africa.

3 SCOPE OF THIS STRATEGIC ISSUE

3.1 Data Sources

This analysis has made extensive use of data resources arising from the following datasets listed below in Table 1:

Table 1. Available spatial datasets used to assess terrestrial ecological features in this assessment.

Data Source	Summary
Northern Cape Department of Nature and Conservation (DENC). (2016). Critical Biodiversity Areas (CBAs) of the Northern Cape. http://bgis.sanbi.org/.	The Northern Cape CBA Map identifies biodiversity priority areas, CBAs and Ecological Support Areas (ESAs), which, together with Protected Areas, are important for the persistence of a viable representative sample of all ecosystem types and species, as well as the long-term ecological functioning of the landscape as a whole.
CapeNature. (2017). Western Cape Biodiversity Spatial Plan 2017. http://bgis.sanbi.org/.	The Western Cape Biodiversity Spatial Plan (WCBSP) is the product of a systematic biodiversity planning assessment that delineates CBAs and ESAs which require safeguarding to ensure the continued existence and functioning of species and ecosystems, including the delivery of ecosystem services, across terrestrial and freshwater realms. These spatial priorities (i.e. CBAs and ESAs) are used to inform sustainable development in the Western Cape Province.
Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (DEDEAT). (2017). Eastern Cape Biodiversity Conservation Plan Handbook. DEDEAT: King Williams Town. Compiled by G. Hawley, P. Desmet and D. Berliner. Draft version, December 2017.	Significant strides have been made with respect to refining the spatial representation of biodiversity pattern and biodiversity processes, as well as establishing standardised minimum requirements for spatial biodiversity planning that ensure a level of consistency throughout the country (SANBI, 2017). The Eastern Cape Biodiversity Conservation Plan 2017 is a tool that guides and informs land use and resource-use planning and decision-making in the Eastern Cape by a full range of sectors whose policies, programmes and decisions impact on biodiversity, in order to preserve long-term functioning and health of priority areas, i.e. CBAs and ESAs.
Department of Environmental Affairs (DEA). (2018). South African Protected Areas Database (SAPAD). Q2, 2018. https://egis.environment.gov.za/.	Protected areas as defined in the National Environmental Management: Protected Areas Act, (Act 57 of 2003) (NEM:PAA). Protected areas: • Special nature reserves; • National parks; • Nature reserves; • Protected environments (1-4 declared in terms of the National Environmental Management: Protected Areas Act, 2003); • World heritage sites declared in terms of the World Heritage Convention Act; • Marine protected areas declared in terms of the Marine Living Resources Act; • Specially protected forest areas, forest nature reserves, and forest wilderness areas declared in terms of the National Forests Act, 1998 (Act No. 84 of 1998); • Mountain catchment areas declared in terms of the Mountain Catchment Areas Act, 1970 (Act No. 63 of 1970).

Data Source	Summary
SANParks. 2010. National Protected Areas Expansion Strategy: Focus Areas for Protected Area Expansion. http://bgis.sanbi.org/.	The goal of the NPAES is to identify focus areas for land-based protected area expansion and to achieve cost effective protected area expansion for improved ecosystem representation, ecological sustainability and resilience to climate change. It sets protected area targets, maps priority areas for protected area expansion, and makes recommendations on mechanisms to achieve this.
South African National Biodiversity Institute (SANBI). (2018). Vegetation Map of South Africa, Lesotho and Swaziland. http://bgis.sanbi.org/.	Update of the Vegetation Map of South Africa, Lesotho and Swaziland (Mucina & Rutherford 2006) based on decisions made by the National Vegetation map Committee and contributions by various partners.
RAMSAR Sites Information Services www.ramsar.wetlands.org	Distribution and extent of areas that contain wetlands of international importance in South Africa.
Geoterraimage. (2015). 2013-2014 South African National Land-Cover. DEA. Geospatial Data. https://egis.environment.gov.za/.	Recent global availability of Landsat 8 satellite imagery enabled the generation of new, national land-cover dataset1 for South Africa, circa 2013-14, replacing and updating the previous 1994 and 2000 South African National Landcover datasets. The 2013-14 national land-cover dataset is based on 30x30m raster cells, and is ideally suited for ± 1:75,000 - 1:250,000 scale GIS-based mapping and modelling applications. Land cover are categorised into different classes, which broadly include: • Bare none vegetated • Cultivated • Erosion • Grassland • Indigenous Forest • Low shrubland • Mines/mining • Plantation • Shrubland fynbos • Thicket /Dense bush • Urban • Water • Woodland/Open bush
Nel *et al.* (2011). Technical Report for the National Freshwater Ecosystem Priority Areas (NFEPA) project. Pretoria: Water Research Commission, WRC Report No. K5/1801.	The NFEPA coverages provide specific spatial information for rivers according to the Department of Water and Sanitation (DWS) 1:250 000 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).
Nel and Driver, A. (2012). South African National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. Stellenbosch: Council for Scientific and Industrial Research. CSIR Report Number: CSIR/NRE/ECO/IR/2012/0022/A.	A vector layer was developed during the 2011 NBA to define wetland vegetation groups to classify wetlands according to Level 2 of the national wetland classification system. The wetland vegetation groups provide the regional context within which wetlands occur, and are the latest available classification of threat status of wetlands that are broadly defined by the associated wetland vegetation

Data Source	Summary
	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.
Collins, N. (2017). National Biodiversity Assessment (NBA) 2018 Wetland Probability Map. https://csir.maps.arcgis.com/apps/MapJournal/index.html?appid=8832bd2cbc0d4a5486a52c843daebcba#	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 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.
DEA (2011). South African Government Gazette. National Environmental Management: Biodiversity Act: National list of ecosystems that are threatened and in need of protection. Government Gazette, 558(34809). http://bgis.sanbi.org/.	The Biodiversity Act (Act 10 of 2004) provides for listing of threatened or protected ecosystems, in one of four categories: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or protected. The purpose of listing threatened ecosystems is primarily to reduce the rate of ecosystem and species extinction. This includes preventing further degradation and loss of structure, function and composition of threatened ecosystems. The purpose of listing protected ecosystems is primarily to preserve witness sites of exceptionally high conservation value.
Holness *et al*. (2016). Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/	Terrestrial and aquatic ecosystem sensitivities specific to Karoo ecology and biodiversity, including fauna and flora that were mapped in the Shale Gas Strategic Environmental Assessment (SEA) are specific to that SEA and Shale Gas development as such, and these are not considered directly transferrable to the current Gas Pipeline Corridor study. But areas that were mapped as Very High sensitivity are considered in this study to represent biodiversity priority areas and are also used here within the area of overlap of these two assessments.
Skowno *et al*. 2015. Terrestrial and Aquatic Biodiversity Scoping Assessment. In: Van der Westhuizen, C., Cape-Ducluzeau, L. and Lochner, P. (eds.). (2015). Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa. Department of Environmental Affairs, 2015. CSIR Report Number: CSIR/CAS/EMS/ER/2015/0001/B. Stellenbosch. Available at https://redzs.csir.co.za/wp-content/uploads/2017/04/Wind-and-Solar-SEA-Report-Appendix-C-Specialist-Studies.pdf	Terrestrial and aquatic ecosystems sensitivities specific to Karoo ecology and biodiversity, including fauna and flora that were mapped in the Wind and Solar SEA (REDZ) are specific to that SEA and renewable energy development as such, and these are not considered directly transferrable to the current gas pipeline corridor study. But areas that were mapped as **Very High** sensitivity are considered in this study to represent biodiversity priority areas and are also used here within the area of overlap of these two assessments.
Child *et al.* (2016). (Eds). The 2016 Red List of Mammals of South Africa, Swaziland and Lesotho. SANBI & EWT: South Africa	Known spatial locations for recorded Red Listed mammals in South Africa.
Bates *et al*. (2014) (Eds). Atlas and red data list of the reptiles of South Africa, Lesotho and Swaziland. SANBI: Pretoria (Suricata series; no. 1).	Known spatial locations for recorded Red Listed reptiles in South Africa.
Minter, L.R. (2004). Atlas and red data book of the frogs of South Africa, Lesotho, and Swaziland. Avian Demography Unit: UCT.	Known spatial locations for recorded Red Listed amphibians in South Africa.
Raimondo *et al.* (2009, as updated in 2018). Red list of South African plants 2009, 2018 update. SANBI.	Known spatial locations for recorded Red Listed terrestrial and aquatic plant species in South Africa.
International Union for Conservation of Nature (IUCN). (2017). The IUCN Red List of Threatened Species, 2017. http://www.iucnredlist.org/	Distribution data for selected fauna and flora 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 Quarter Degree Grid distributions.

Data Source	Summary
University of Cape Town (UCT). (1997). The Southern African Bird Atlas 1 (SABAP1). Animal Demography Unit, UCT.	The Southern African Bird Atlas Project (SABAP) was conducted between 1987 and 1993.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. 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.
University of Cape Town (UCT). (2007) - Present. The Southern African Bird Atlas 2 (SABAP2). Animal Demography Unit, UCT.	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). The current project is a joint venture between the Animal Demography Unit at the University of Cape Town, BirdLife South Africa and 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. 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 of latitude by five minutes of longitude, squares with sides of roughly 9km.

3.2 Assumptions and Limitations

The following assumptions and limitations are relevant to this study:

- This is a strategic-level desktop assessment of the sensitivity of the terrestrial ecosystems, including fauna, flora and ecological processes, characteristic of the Nama Karoo and Succulent Karoo, as well as Desert biomes of South Africa, to potential gas pipeline construction and maintenance. No field assessment was undertaken.
- The scale of input data used in these maps was variable ranging from occurrence points for species populations to graded data at different special resolutions (e.g. 30 m x 30 m for land cover to units mapped at approximately 1:250 000 scale such as vegetation types). This heterogeneity is inappropriate for fine-scale analysis and interpretation such as provisional routes.
- Species of least conservation concern or widely distributed species were excluded due to the paucity in their occurrence data i.e. their distributions are considered too broad to usefully inform the sensitivity mapping.
- The potential presence of fauna species, in particular terrestrial invertebrate groups in each of the assessed biomes was evaluated based on existing literature and available databases. However, data contained within some of these species databases are coarse and insufficient to be able to identify endemics with any certainty, and the threat status of most invertebrate groups has not been assessed according to the IUCN criteria. A further limitation was that some datasets are outdated, or lacking data for certain areas of ecological importance within each biome.

3.3 Relevant Regulations and Legislation

Table 2. Key legislation, policies and plans pertaining to conservation management and planning in the Northern, Western and Eastern Cape provinces.

Year	Legislation
International	
1971	Convention on Wetlands of International Importance (Ramsar Convention)
1975	Convention on Trade in Endangered Species of Wild Fauna and Flora (CITES)
1993	Convention on Biological Diversity, including the CBD's Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets
1994	United Nations Framework Convention on Climate Change (UNFCC)
National	
1970	Mountain Catchment Areas Act (No. 63 of 1970)
1970	Subdivision of Agricultural Land Act (No. 70 of 1970)
1983	Conservation of Agricultural Resources Act (No. 43 of 1983)
1998	National Forest Act (No. 84 of 1998)
1998	National Water Act (No. 36 of 1998)
1998	National Forests Act (No. 84 of 1998)
1998	National Environmental Management Act (No. 107 of 1998)
1999	National Heritage Resources Act (No. 25 of 1999)
2002	Mineral and Petroleum Resources Development Act (No. 28 of 2002)
2003	National Environmental Management: Protected Areas Act (No. 57 of 2003, as amended)
2004	National Environmental Management: Biodiversity Act (No. 10 of 2004)
2004	National Environmental Management: Air Quality Act (No. 39 of 2004)
2008	National Environmental Management: Waste Act (No. 59 of 2008, as amended)
2013	Threatened or Protected Species Regulations of 2013 (ToPS)
2013	Spatial Planning and Land Use Management Act (No. 16 of 2013)
2016	Alien and Invasive Species Regulations of 2016 (AIS)
2017	National Environmental Management Act, Environmental Impact Assessment 2014 Regulations, as amended in 2017
In progress	Draft National Biodiversity Offset Policy

Year	Legislation
Provincial	
1974	Eastern Cape Nature and Environmental Conservation Ordinance (No. 19 of 1974)
1974	Cape Nature Conservation Ordinance, No. 19 of 1974 (still in force)
1987	Ciskei Nature Conservation Act 1987
1987	Land Use Regulation Act (No. 15 of 1987) (governing former Ciskei)
1985	Land Use Planning Ordinance (Ordinance 15 of 1985) (governing former old Cape Province)
1992	Transkei Environmental Conservation Decree (No. 9 of 1992)
1998	Western Cape Nature Conservation Board Act, 1998 (Act 15 of 1998)
2000	Western Cape Nature Conservation Laws Amendment Act, 2000. (Act 3 of 2000)
2007	Provincial guideline on biodiversity offsets (Western Cape DEA&DP)
2009	Northern Cape Nature Conservation Act (Act No. 9 of 2009)
2010	Eastern Cape Parks and Tourism Agency Act (No. 2 of 2010)
Regional / Municipal	
2000	Municipal Systems Act (No. 32 of 2000)

4 BASELINE DESCRIPTION

4.1 Demarcation of study areas

The six gas pipeline corridors that contain elements characteristic of the Nama and Succulent Karoo, as well as Desert biomes are shown in Table 3 and Figure 1 below.

Table 3. Distribution of the Nama Karoo, Succulent Karoo and Desert biomes in each of the six gas pipeline corridors relevant to this assessment, where applicable.

Phase	Biome	Province	Relevant Local Municipalities
Inland	Nama Karoo Succulent Karoo	Eastern Cape Northern Cape Western Cape	Hantam, Witzenberg, Karoo Hoogland, Laingsburg, Prince Albert, Beaufort West, Ubuntu, Camdeboo, Blue Crane Route and Ikwezi
Phase 1	Nama Karoo Succulent Karoo	Northern Cape Western Cape	Hantam, Witzenberg, Breede Valley, Langeberg, Laingsburg, Swellendam, Kannaland and Prince Albert
Phase 2	Nama Karoo Succulent Karoo	Eastern Cape Western Cape	Oudtshoorn, George, Prince Albert, Beaufort West, Baviaans, Camdeboo, Ikwezi, Blue Crane Route and Sundays River Valley
Phase 5	Succulent Karoo	Northern Cape Western Cape	Hantam, Matzikama, Cederberg, Bergrivier, Saldanha Bay and Witzenberg
Phase 6	Desert Nama Karoo Succulent Karoo	Northern Cape Western Cape	Kamiesberg, Nama Khoi, Richtersveld and Matzikama
Phase 7	Nama Karoo	Eastern Cape	Blue Crane Route, Makana and Sundays River Valley

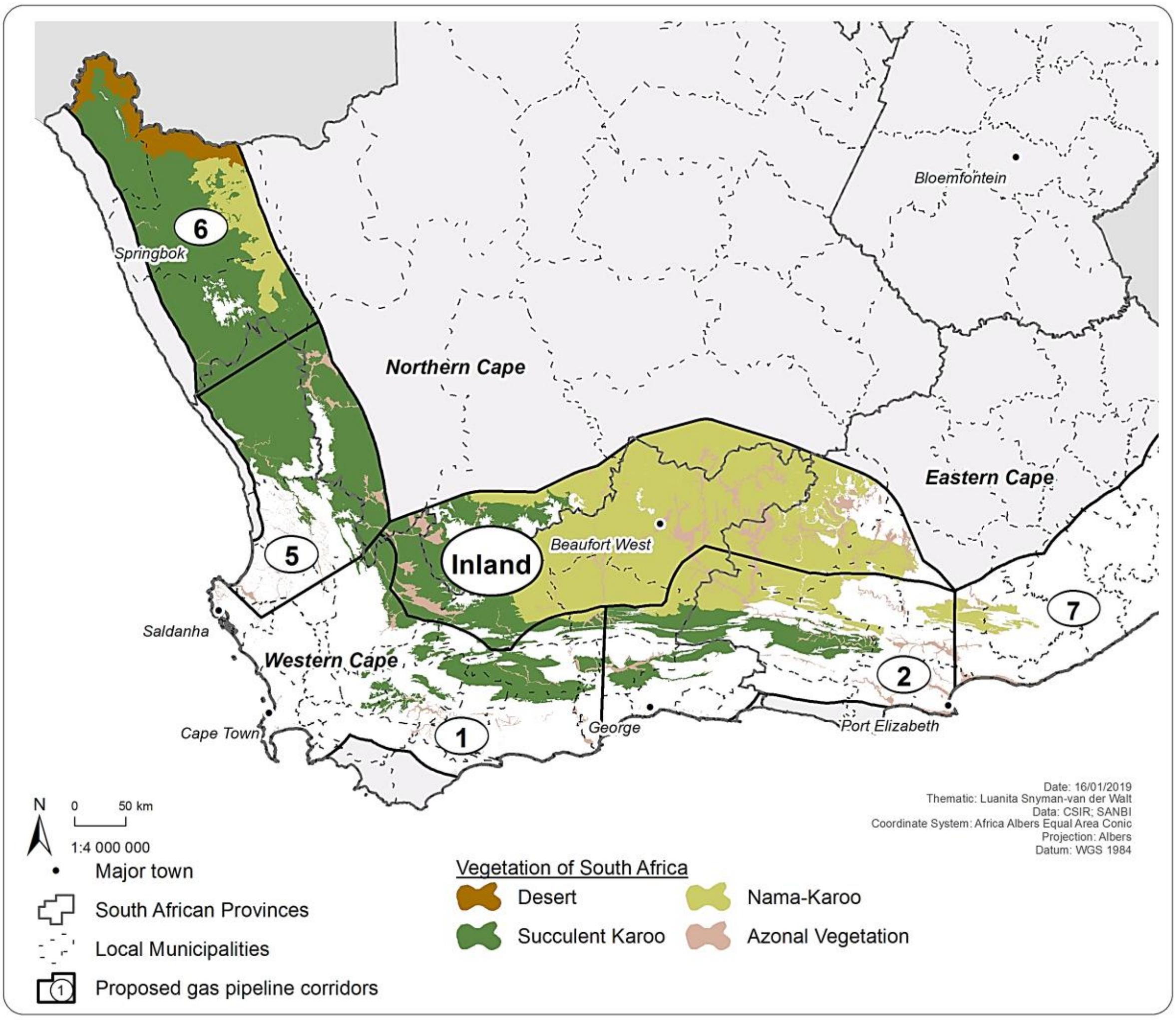

Figure 1. Map showing the distribution of the Nama Karoo, Succulent Karoo and Desert biomes in each of the six gas pipeline corridors relevant to this assessment.

4.2 Baseline environmental description of the Nama Karoo biome

4.2.1 What and where is the Nama Karoo biome in South Africa?

The Nama Karoo biome occurs on the central plateau of the western half of South Africa and is the largest of the three biomes that comprise the semi-arid Karoo-Namib Region covering about 23% of the interior of southern Africa (Ndhlovu *et al.*, 2011; Walker *et al*., 2018). The word 'Karoo' comes from the Khoi-San word *kuru* which means dry, an apt description for this vast, open, arid thirstland. The Nama Karoo interfaces with the Succulent Karoo biome to the west, the Desert biome in the extreme northwest, the Savanna biome to the north and northeast, the Fynbos and Albany Thicket biomes in its southern and south-eastern extremities, and the Grassland biome infringing on its eastern border (Mucina *et al.*, 2006a).

The geology underlying the Nama Karoo biome is exceptionally varied and consists of a 3 km thick succession of millennia old sedimentary rocks rich in fossils (Lloyd, 1999; Mucina *et al.*, 2006a). Shallow, weakly developed lime-rich soils with high erodibility cover more than 80% of the Nama Karoo landscape (Watkeys, 1999). The climate is typically harsh with considerable fluctuations in both seasonal and daily temperatures. Droughts are common with frost a frequent occurrence during winter. Rainfall is highly seasonal, peaking in summer with a mean annual precipitation (MAP) ranging from 100 mm in the west to about 500 mm in the east, decreasing from east to west and from north to south (Palmer and Hoffmann, 1997; Desmet and Cowling, 1999; Mucina *et al.*, 2006a; Walker *et al*., 2018).

The Nama Karoo is mostly a complex of extensive, flat to undulating gravel plains dominated by grassy, dwarf shrubland vegetation of which its relative abundances are dictated mainly by rainfall and soil type (Cowling and Roux, 1987; Palmer and Hoffmann, 1997; Mucina *et al.*, 2006a). Towards the Great Escarpment in the south and west, a much dissected landscape exists characteristic of isolated hills, koppies, butts, mesas, low mountain ridges and dolerite dykes supporting sparse dwarf Karoo scrub and small trees (Dean and Milton, 1999; Mucina *et al.*, 2006a; Jacobs and Jangle, 2008).

Nama Karoo vegetation is not particularly species-rich and the biome does not contain any centres of endemism (Van Wyk and Smith, 2001). There are also very few rare or endangered indigenous plant species occurring in the biome. Dwarf shrubs (generally <1 m tall) and grasses dominate the current vegetation that is intermixed with succulents, geophytes and annual forbs. As a result, the amount and nature of the fuel load is insufficient to carry fires and fires are rare within the biome. Grasses tend to be more common in depressions and on sandy soils, whereas small trees occur mainly along drainage lines and on rocky outcrops (Palmer and Hoffmann, 1997; Mucina *et al.*, 2006a).

Some of the more abundant shrubs include species of *Drosanthemum, Eriocephalus, Galenia, Lycium, Pentzia, Pteronia*, *Rhigozum*, and *Ruschia*, while the principal perennial grasses are *Aristida, Digitaria, Enneapogon*, and *Stipagrostis* species. Trees and taller woody shrubs are mostly restricted to watercourses such as rivers and wetlands, and include *Boscia albitrunca, B. foetida, Diospyros lycioides, Grewia robusta, Searsia lancea, Senegalia mellifera, Tamarix usneoides* and *Vachellia karroo* (Palmer and Hoffmann, 1997; Mucina *et al.*, 2006a).

4.2.2 Vegetation types of the Nama Karoo

The Nama Karoo biome originally contained five distinct veld types in its entirety as described by Acocks (1953), namely Central Upper Karoo, Central Lower Karoo, Orange River Broken Veld, Arid Karoo and False Arid Karoo. However, large parts of the False Upper Karoo and Karroid Broken Veld, as well as smaller portions of four more arid veld types with similar climatic and floristic characteristics were enclosed in this biome. In 1996, Low and Rebelo regrouped these veld types into only six different vegetation types. Then in 1997, Palmer and Hoffmann reclassified the Nama Karoo biome into three geographically distinct bioregions; (i) the Griqualand West and Bushmanland, (ii) the Great Karoo and Central Lower Karoo, and (iii) the Upper Karoo and Eastern Cape Midlands.

The main drivers for defining these bioregions were rainfall, temperature and topography. Mucina *et al.* (2006a) have subsequently approximated these bioregions into the (i) Bushmanland – a region dominated by arid grass- and shrublands; (ii) Lower Karoo – which mainly consists of grassy scrub, arid shrubland and riparian woodland along drainage lines; and (iii) Upper Karoo – which comprises montane shrubland at higher elevations with grassy and succulent dwarf shrublands dominating the vast, open plains (Figure 2). These three bioregions collectively boast 14 unique Nama Karoo vegetation types, nine of which are present in the proposed gas pipeline corridors (Figure 3).

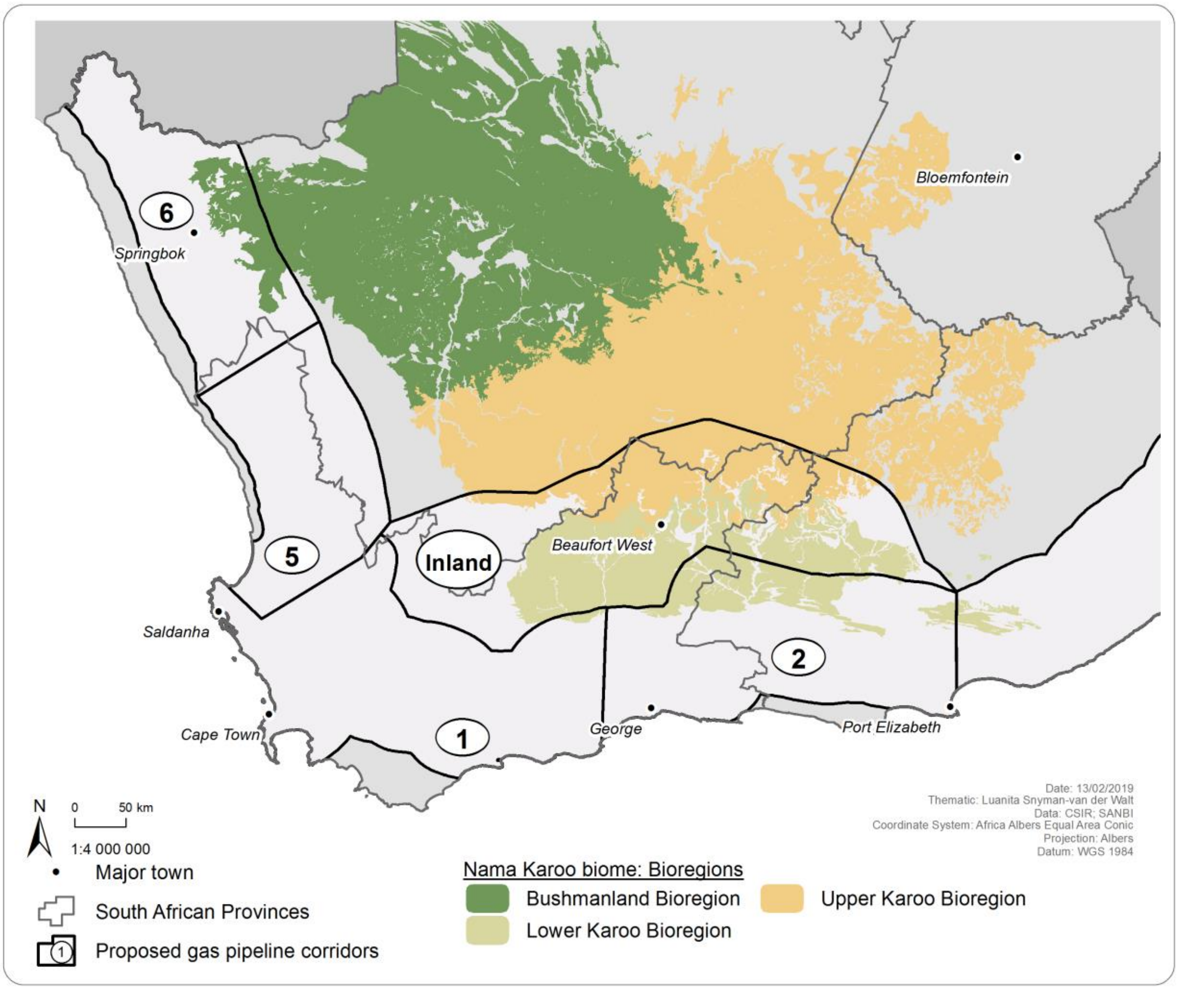

Figure 2. The Nama Karoo biome consists of three different bioregions.

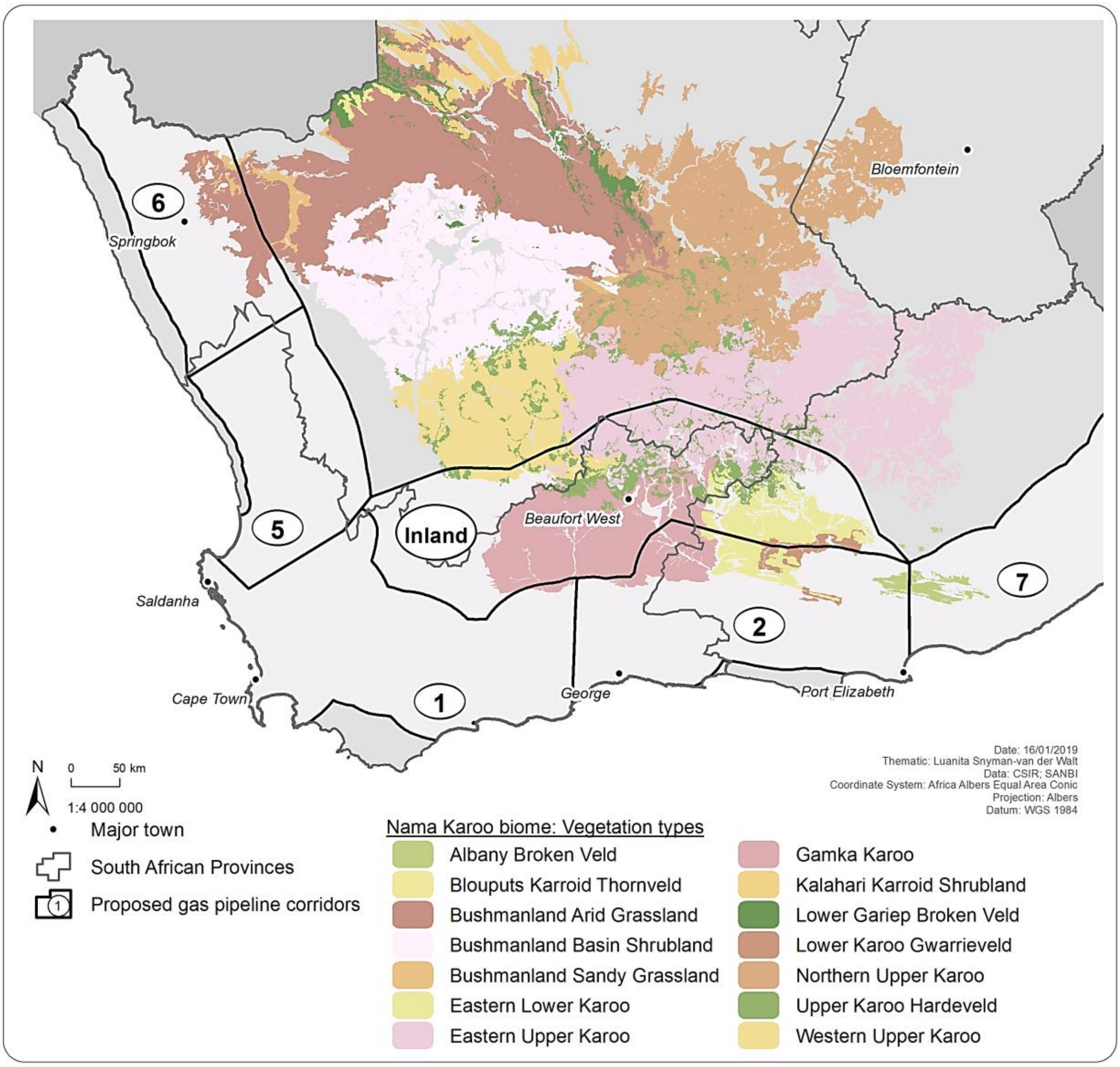

Figure 3. The Nama Karoo biome consists of 14 unique vegetation types.

4.2.3 What is the state of the Nama Karoo?

The Nama Karoo biome, considered the third largest biome in South Africa after the Grassland and Savanna biomes, comprises an area of approximately 248 278 km² of which only approximately 1.6% is formally protected in statutory reserves such as the Augrabies and Karoo National Parks (Hoffmann *et al.,* 2018). About 5% of the Nama Karoo has been transformed by human impact relative to other biomes in South Africa, leaving the majority of the land still in a state classified as Natural (Mucina *et al.*, 2006a; Hoffmann *et al.,* 2018). However, according to Hoffmann and Ashwell (2001) approximately 60% of the Nama Karoo landscape is characterised by moderately to severely degraded soils and vegetation cover (Mucina *et al.*, 2006a). Despite the increasing impact of mainly soil erosion and overgrazing (Atkinson, 2007), the ecosystem threat status of all 14 Nama Karoo vegetation types are considered least threatened (South African Government Gazette, 2011).

The large historical herds of Springbok (*Antidorcas marsupialis*) and other game native to the Nama Karoo no longer exist as most of the Nama Karoo has been converted to fenced rangeland for livestock grazing during the past century, in particular sheep and mohair goats (Hoffmann *et al.,* 1999). Although the habitat is mostly intact, heavy grazing has left certain parts of the Nama Karoo seriously degraded (Lloyd, 1999; Milton, 2009; Ndhlovu *et al.,* 2011; Ndhlovu *et al.,* 2015). Vegetation recovery following drought can be delayed due to increased stocking rates that in turn exacerbate the effects of subsequent drought periods. Under conditions of overgrazing many indigenous shrubs may proliferate, while several grasses and other palatable species may be lost (Mucina *et al.*, 2006a), contributing to the gradual increase of land degradation in the Nama Karoo (Milton and Dean, 2012; Walker *et al*., 2018).

In addition to pastoralism, alien plant infestation, anthropogenic climate change, agricultural expansion, construction of linear structures, urban sprawl, the collection of rare succulents and reptiles for illegal trade, as well as the construction and failure of dams also threaten the Nama Karoo's biodiversity (Lovegrove, 1993; Lloyd, 1999; Rutherford *et al.*, 1999; Mucina *et al.*, 2006a; Milton, 2009; Dean *et al.,* 2018). The introduction of a number of alien, drought-hardy ornamental and forage plants have the potential to seriously alter the biome's ecology and hydrology (Milton *et al.* 1999). Alien invasive plants currently common in the Nama Karoo region include *Argemone ochroleuca*, *Arundo donax*, *Atriplex* spp., *Limonium sinuatum*, *Opuntia* spp., *Pennisetum setaceum*, *Phragmites australis, Prosopis* spp., *Salsola kali and Schkuhria pinnata,* as well as various members of the Cactaceae family such as *Echinopsis* spp. and *Tephrocactus articulates* (Van Wilgen *et al.,* 2008; Walker *et al*., 2018).

The Nama Karoo is also threatened by increased mining activities such as open-cast zinc mining at Black Mountain and the Gamsberg near Aggeneys, as well as the potential threat of uranium mining around Beaufort West and the greater Lower Karoo region. The possibility of large scale shale gas fracking presents a further threat to the Nama Karoo biodiversity (Khavhagali, 2010; Milton and Dean, 2012; Cramer, 2016). An increased need for renewable energy has already seen the impact of several wind farms being developed in the Karoo region and along its margins, as well as planning and construction of a number of solar power projects (Walker *et al*., 2018).

Furthermore, the increased clearing of natural vegetation for cultivation along the lower Orange River destroys the natural habitat of many Nama Karoo fauna and flora. Pesticides used to control Brown Locust (*Locustana pardalina*) and Karoo Caterpillar (*Loxostege frustalis*) outbreaks also impact wildlife habitat severely, with the highest concentration of pesticides particularly within the avifauna, specifically raptors (Lovegrove, 1993; Khavhagali, 2010; Walker *et al*., 2018).

The overall improvement of ecosystem health and to ensure ecological sustainability of the Nama Karoo biome will require a dedicated effort and strategic collaboration from a wide range of stakeholders to achieve the preservation, conservation and management of its biodiversity.

4.2.4 Value of the Nama Karoo

4.2.4.1 Biodiversity value

a) Flora

The Nama Karoo biome does not boast the same level of plant diversity and species richness that is unique to the adjacent Succulent Karoo biome (see Section 4.3.4) and yet, the Nama Karoo flora consists of nearly 2 200 plant species of which about 450 are distinctive to the region (Milton, 2009). The level of endemism in the biome is very low with the majority of endemic species occurring in the Upper Karoo Hardeveld vegetation type. Plant families dominating the Nama Karoo veld are *Asteraceae* (daisies), *Fabaceae* (legumes) and *Poaceae* (grasses). Where the Nama Karoo interfaces with the Fynbos and Succulent Karoo biomes to the south and west, taxa in the *Aizoaceae* (vygies) and *Asteraceae* families are prominent, while elements of summer rainfall floras typical of the Grassland and Savanna biomes become prevalent in the north and east (Mucina and Rutherford, 2006). The presence of succulent taxa representative of the plant families *Aizoaceae*, *Crassulaceae* and *Euphorbiaceae* adds to the species richness of Nama Karoo vegetation.

b) Fauna

The Nama Karoo never had the variety of wildlife that can be found for example in the Savanna biome; however, before pastoralism brought along fenced rangelands, vast herds of Springbok used to migrate through the region in search of water and grazing. Today, these free roaming herds are mostly replaced with livestock and game ranching. The majority of mammals in the Nama Karoo are species with a widespread distribution that originate in the Savanna and Grassland biomes (Dean *et al.,* 2018). The Nama Karoo boasts a mammal diversity of approximately 177 species of which more than 10 threatened species are known to occur in this biome. Common animals include the Bat-Eared Fox, Black-Backed Jackal, Spring Hare, Springbok, Gemsbok, Kudu, Eland and Hartebeest. Most noteworthy is the Critically Endangered Riverine Rabbit (*Bunolagus monticularis*) which is an endemic species of the central Nama Karoo (Holness *et al*., 2016; UCT, 2018a).

Other mammal species of conservation concern include the Endangered Southern Tree Hyrax (*Dendrohyrax arboreus*), as well as the Vulnerable Hartmann's Zebra (*Equus zebra hartmannae*), Cheetah (*Acinonyx jubatus*), Leopard (*Panthera pardus*), Black-footed Cat (*Felis nigripes*) and White-tailed Mouse (*Mystromys albicaudatus*). The Grey Rhebok *(Pelea capreolus*), Mountain Reedbuck (*Redunca fulvorufula* subsp. *fulvorufula*), Brown Hyena (*Hyaena brunnea*) and the Southern African Hedgehog (*Atelerix frontalis*) are all listed as Near-Threatened (UCT, 2018a).

The avifauna of the Nama Karoo is characterised by typically ground-dwelling species of open habitats, although watercourses with prevalent riparian vegetation have allowed several tree-living species to penetrate the interior of this biome (Walker *et al*., 2018). Up to 217 bird species have been recorded to occur in the Nama Karoo of which 23 species are considered threatened (Taylor and Peacock, 2018). Birds such as the Black-headed and White-throated canaries, Red Lark and Sclater's Lark, Karoo Chat, Karoo Korhaan, Layard's Tit-babbler and the Cinnamon-breasted Warbler are characteristic of this arid, harsh landscape. Many of the bird species occurring in the Nama Karoo are highly nomadic and are able to respond quickly to rainfall events and insect irruptions such as Brown Locust outbreaks (UCT, 2007 – Present; Dean *et al.,* 2018).

Reptile diversity of the Nama Karoo is moderately high with nearly 221 species that can be found in this arid to semi-arid environment (UCT, 2018b). Important tortoise species include the Vulnerable Speckled Padloper (*Chersobius signatus*) and the Near-Threatened Karoo Padloper (*Chersobius boulengeri*). The Plain Mountain Adder (*Bitis inornata*), which is restricted to the Nuweveldberge, is the only snake species that is endemic to the Nama Karoo and it is categorised as Endangered. Also, the Elandsberg Dwarf Chameleon (*Bradypodion taeniabronchum*) is currently listed as endangered and the Braack's Pygmy Gecko (*Goggia braacki*) is considered Near-Threatened. Three other lizard species, the Dwarf Karoo Girdled Lizard (*Cordylus aridus*), the Karoo Flat Gecko (*Afroedura karroica*) and Thin-skinned Gecko (*Pachydactylus kladaroderma*) have much of their distribution in the Karoo.

The Nama Karoo boasts a fairly moderate diversity of Amphibia with about 50 frog species that could be found in this biome. Noteworthy species include the endemic Karoo Caco (*Cacosternum karooicum*) and the Near-Threatened Giant Bull Frog (*Pyxicephalus adspersus*) (Minter, 2004).

Terrestrial invertebrate diversity in the Nama Karoo is considerably high with up to 575 species of Lepidoptera (moths and butterflies), 84 species of dragonflies, 115 species of lacewings and more than 80 different species of dung beetle. Five butterfly species are wholly endemic to the Central Karoo (*Aloeides pringlei, Lepidochrysops victori, Thestor compassbergae, T. camdeboo* and *Cassionympha camdeboo*). The butterfly species, *Lepidochrysops victori* is categorised as Vulnerable (Mecenero *et al.* 2013; Holness *et al.,* 2016). Nearly 40 species of scorpions could occur in the Nama Karoo region (Holness *et al.,* 2016).

4.2.4.2 Socio-economic value

The Nama Karoo provides natural resources for a wide array of business activities; however, social wellbeing and economic viability of these enterprises greatly rely on the availability and spatial distribution of water. The main industry sectors underpinning economic growth in the Nama Karoo are agriculture (including game and livestock ranching, and crop cultivation), mining (including diamonds, granite, heavy metals and marble, as well as the potential for shale gas and uranium) and tourism (including ecotourism). All three of these sectors have potential to contribute to socio-economic growth of the region but are heavily dependent on sustainable water resources to exist (Hoffmann *et al.*, 1999; Mucina *et al.*, 2006a; Milton, 2009; Walker *et al*., 2018).

Other economic opportunities characteristic of the Nama Karoo relates to the development and commercial exploitation of medicinal plants (such as *Hoodia gordonii*), horticulture, manufacturing, biodiversity conservation (e.g. National Parks, Nature Reserves, game farms) and the significance of cultural heritage (Milton, 2009; Todd *et al.*, 2016; Dean *et al.,* 2018; Walker *et al*., 2018). A recent increase in renewable energy installations (solar and wind) in the Nama Karoo has shown a total land cover of about 3.6% to date (Hoffmann *et al.,* 2018).

4.3 Baseline environmental description of the Succulent Karoo biome

4.3.1 What and where is the Succulent Karoo biome in South Africa?

The Succulent Karoo biome covers an area of approximately 103 000 km² and extends from the coastal regions of southern Namibia through the western parts of the Northern Cape and Western Cape provinces of South Africa, as well as inland of the Fynbos biome to the Little Karoo in the south (Rundel and Cowling, 2013). The Succulent Karoo biome interfaces with the Albany Thicket to the east, the Nama Karoo to the north and west, and the Desert biome to the north (Jonas, 2004; Mucina *et al.*, 2006a).

The Succulent Karoo biome is a semi-desert region that is characterised by the presence of low winter rainfall, with a mean annual precipitation of between 100 and 200 mm, and daily temperature maxima in summer in excess of 40°C the norm. Fog is a common occurrence in the coastal region and frost is infrequent. Desiccating, hot berg winds may occur throughout the year (Desmet and Cowling, 1999; Jonas, 2004; Mucina *et al.*, 2006b; Walker *et al*., 2018).

Topographically the Succulent Karoo varies from flat to gently undulating plains at altitudes generally below 800 m that are situated to the west and south of the escarpment and are typical of the Knersvlakte and Hantam/Roggeveld/Tanqua Karoo, towards a more hilly and rugged mountainous terrain characteristic of the Namaqualand, Robertson Karoo and Little Karoo at higher elevations reaching up to 1 500 m in the east. The geology of the Succulent Karoo is ancient and complex with weakly developed, lime-rich sandy soils that easily erode and are derived from weathering of sandstone and quartzite (Allsopp, 1999). An unusual but abundant feature of the Succulent Karoo soils are low, circular mounds called 'heuweltjies' which were created by harvester termites thousands of years ago (McAuliffe *et.al*., 2018; McAuliffe *et.al*., in press). Their rich soils support an entirely different vegetation from the surrounding land cover making them truly unique (Jonas, 2004; Mucina *et al.*, 2006b; Jacobs and Jangle, 2008).

The Doring, Olifants and Tanqua rivers are the major drainage systems in the west, with the Breede and Gouritz rivers and its relevant tributaries in the south-east of the biome, all derived from catchments located within the bordering Fynbos biome. The majority of other river courses are small, short-lived and seasonal west-flowing systems, including a relatively short section of the lower Orange River in the north (Jonas, 2004; Mucina *et al.*, 2006b; Le Maitre *et al.* 2009).

The Succulent Karoo is an arid to semi-arid biome which is known for its exceptional succulent and bulbous plant species richness, high reptile and invertebrate diversity, as well as its unique bird and mammal life (Rundel and Cowling, 2013). It is also recognised as one of three global biodiversity hotspots in southern Africa with unrivalled levels of diversity and endemism for an arid region (Cowling *et al.*, 1999; Desmet, 2007; Hayes and Crane, 2008). The Succulent Karoo vegetation is dominated by dwarf leaf-succulent shrublands with a matrix of succulent shrubs and very few grasses, except in some sandy areas. Species of the plant families *Aizoaceae* (formerly the *Mesembryanthemaceae*), *Crassulaceae* and *Euphorbiaceae*, as well as succulent members of the *Asteraceae*, *Iridaceae* and *Hyacinthaceae* are particularly prominent. Mass flowering displays of annuals (mainly *Asteraceae* species), often on degraded or fallow agricultural lands are a characteristic occurrence in spring.

The varied Succulent Karoo landscape lends itself to the adaptation of a diversity of plant growth forms, ranging from extensive plains often littered with rocks or pebbles such as the Knersvlakte to rocky areas occasionally dotted with solitary trees and tall bush clumps (e.g. *Ficus ilicina, Pappea capensis, Searsia undulata, Schotia afra* and *Vachellia karroo*) often found in deeper valleys and along drainage lines. In some higher altitude areas of the Succulent Karoo, particularly on rain shadow mountain slopes, the vegetation contains elements similar to an arid daisy-type fynbos (Mucina *et al*., 2006b; Jacobs and Jangle, 2008).

4.3.2 Vegetation types of the Succulent Karoo

In 1991, the then Succulent Karoo Floristic Region was divided by Jürgens into two distinct sub-regions, namely the Namaqualand-Namib Domain, which extends north from the west coast of South Africa into Southern Namibia, and the Southern Karoo Domain that lies inland of the great escarpment. Key drivers motivating this subdivision were rainfall patterns and temperature regimes, with the Namaqualand-Namib mainly characterised by winter rainfall and the Southern Karoo by summer rainfall (Low & Rebelo, 1996).

Subsequently the Succulent Karoo biome was further diversified into six broadly defined bioregions (Figure 4) comprising a total of 63 vegetation types (Figure 5). The six bioregions constitute the Richtersveld (with 19 vegetation types), Namaqualand Hardeveld (with six vegetation types), Namaqualand Sandveld (with 13 vegetation types), Knersvlakte (with eight vegetation types), Trans-Escarpment Succulent Karoo (with three vegetation types) and the Rainshadow Valley Karoo (with 14 vegetation types) (Mucina *et al.*, 2006b). Forty-six of these 63 Succulent Karoo vegetation types are all, or partly present within the proposed gas pipeline corridors. Despite a general lack of structural diversity, plant species diversity at both the local and regional scales in the Succulent Karoo is undoubtedly the highest recorded for any arid region in the world (Cowling *et al.,* 1999).

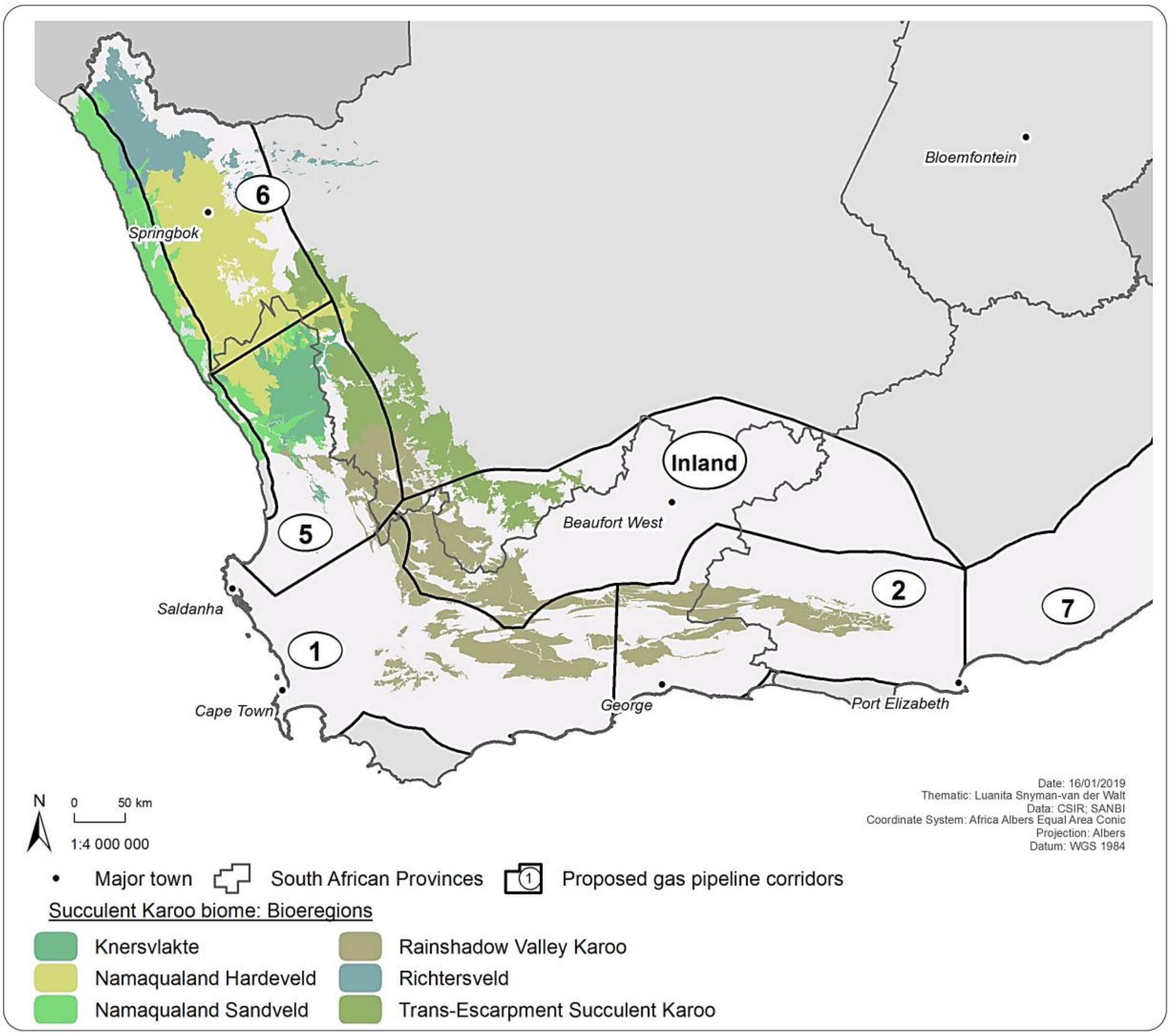

Figure 4. The Succulent Karoo biome consists of six different bioregions.

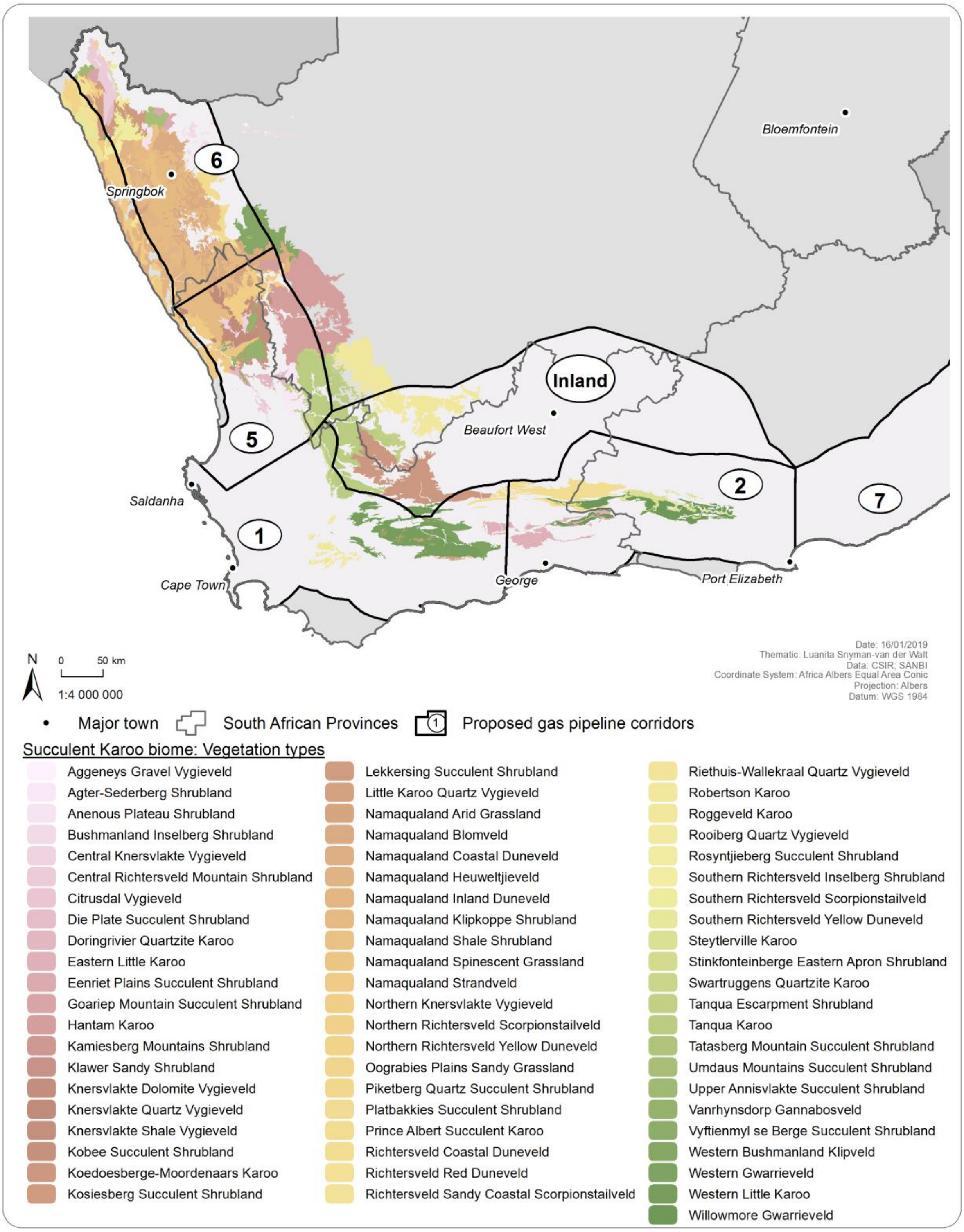

Figure 5. The Succulent Karoo biome comprises a total of 63 unique vegetation types.

4.3.3 What is the state of the Succulent Karoo?

The Succulent Karoo biome is recognised as one of 25 internationally acclaimed biodiversity hotspots due to its exceptional abundance and rich diversity of unusual succulent plants and animal life (Myers *et al.,* 2000; Jonas, 2004; Noroozi *et al.,* 2018). Despite its amazing ecological and socio-economic diversity, the hotspot is a vulnerable ecosystem with about 8% of the Succulent Karoo biome formally protected in statutory and non-statutory reserves, including the Richtersveld, Namaqua and Tankwa Karoo National Parks, as well as the Goegap, Nababieps and Oorlogskloof Provincial Nature Reserves (Mucina *et al.*, 2006b; Hoffmann *et al.,* 2018).

The predominant land use is agriculture with about 90% of the region subjected to livestock grazing (mainly sheep, goats and ostrich farming). Although crop farming is limited due to nutrient-poor soils with low agricultural potential and the lack of sufficient irrigation water, severe overgrazing and unsustainable cultivation practices have contributed to widespread loss of topsoil through sheet erosion and the accelerated degradation of veld condition reducing the overall species diversity in this arid environment (Mucina *et al.*, 2006b; Le Maitre *et al.*, 2009; Walker *et al*., 2018).

Mining for diamonds, gypsum and heavy metals, although an important economic driver which is only affecting about 1% of the biome, is another major threat to biodiversity in the Succulent Karoo as it irreversibly transforms landscapes making ecological restoration extremely challenging (Jonas, 2004; Milton and Dean, 2012). An increase in urban settlements due to a growing population, in addition to overharvesting of fuel wood and the illegal harvesting of plants for the medicinal and horticultural trades, further threatens conservation efforts of the Succulent Karoo biome (Milton *et al.*, 1999; Walker *et al*., 2018).

Cropping, mining, linear structures such as fences, roads, railways and power lines, and the eutrophication of water further exacerbate the spread and establishment of alien invasive plant species in the Succulent Karoo such as *Arundo donax*, *Atriplex lindleyi*, *Atriplex nummularia*, *Nerium oleander*, *Pennisetum setaceum*, *Prosopis glandulosa* and *Tamarix ramossissima* (Van Wilgen *et.al.,* 2008; Rahlao *et.al.,* 2009; Le Maitre *et.al.,* 2016; Dean *et al.,* 2018; Walker *et al*., 2018). The invasion of members of the Cactaceae family such as the Bilberry cactus (*Myrtillocactus geometrizans*) is becoming an increasing conservation concern especially in the southern Karoo (Dean and Milton, 2019).

Furthermore, climate change has been identified as one of the most significant threats to biodiversity as increasing temperature levels and decreasing rainfall over the next five decades could exacerbate desertification of the Succulent Karoo biome (Hoffmann *et al.*, 1999; Rutherford *et al.,* 1999; Walker *et al*., 2018). Also, a recent increase in renewable energy developments (solar and wind) in the Succulent Karoo has seen approval of about 160 applications for environmental authorisation to date of which another almost 50 are currently in process (DEA, 2019). Notwithstanding the effect of the aforementioned impacts on Succulent Karoo ecosystems, to date approximately 4% of the biome has been transformed (Mucina *et al.*, 2006b).

4.3.4 Value of the Succulent Karoo

4.3.4.1 Biodiversity value

a) Flora

The Succulent Karoo biome claims its place amongst the world's biodiversity hotspots housing an extraordinarily high floral diversity exceeding 6 356 plant species in more than 1 000 genera and representative of almost 170 plant families. Of this number about 450 taxa are considered threatened i.e. species that are facing a high risk of extinction, and a further 816 species that are of conservation concern i.e. species that have a high conservation importance in terms of preserving South Africa's rich floristic diversity (SANBI, 2017).

Nearly 40% (~2 535 species) are considered endemic to the Succulent Karoo vegetation of which the majority are either succulents or geophytes (Jonas, 2004; Mucina *et al.*, 2006b). Some 269 endemic taxa are threatened and a further 536 endemic species are of conservation concern (SANBI, 2017). Many endemics have very limited spatial ranges and are vulnerable to extinction through localised habitat damage. Also noteworthy is the occurrence of approximately 16% (~1 590 species) of the world's 10 000 succulent species within this biome (Cowling and Hilton-Taylor, 1999; Mucina *et al.*, 2006b).

Species of the plant families *Aizoaceae* (formerly the *Mesembryanthemaceae*), *Crassulaceae* and *Euphorbiaceae,* as well as succulent members of the *Asteraceae*, *Iridaceae* and *Hyacinthaceae* are particularly prominent in this biome (Mucina *et al.*, 2006b). This exceptional plant diversity, combined with high levels of endemism and intense land use pressures means the biome is also a recognised conservation priority as per the objectives and conservation targets of the Succulent Karoo Ecosystem Programme (SKEP) (Hayes and Crane, 2008).

SKEP focuses on eight geographic priority areas within the Succulent Karoo biome that contain important habitats vulnerable to land use pressures and are in need of conservation (Table 4) (Hayes and Crane, 2008).

Table 4. A summary of the floristic value of each of the eight SKEP priority focus areas

SKEP Priority Focus Area	Area (ha)	# of Plant Species	# of Endemic Plant Species	# of Red Data Plant Species
Greater Richtersveld	2 071 054	2 700 (>80% succulents)	560	194
Bushmanland Inselbergs	31 400	429	67	87
Namaqualand Uplands	361 127	1 109	286	71
Central Namaqualand Coast	372 587	432	85	74
Knersvlakte	522 234	1 324	266	121
Bokkeveld-Tanqua-Roggeveld	932 717	1 767	357	102
Central Breede River Valley	206 808	1 500	115	19
Central Little Karoo	548 430	1 325	182	73

Adding to the Succulent Karoo's exceptional high level of plant diversity, it boasts five centres of plant endemism (Table 5); one centre typical of the Cape Floristic Region with elements characteristic of fynbos, and four more centres characterised of the Succulent Karoo Region dominated by dwarf, succulent shrubland with the stem- and leaf succulent species particularly prominent (Van Wyk and Smith, 2001).

Table 5. The five centres of plant endemism contained within the Succulent Karoo biome

Region	Cape Floristic	Succulent Karoo	Succulent Karoo	Succulent Karoo	Succulent Karoo
Centre	*Kamiesberg*	*Knersvlakte*	*Little Karoo*	*Worcester-Robertson Karoo*	*Hantam-Roggeveld*
Approximate location	Entire Kamiesberg Mountain Range east of Kamieskroon	Low-lying plain north of Vanrhynsdorp	Broad intermountain valley from Montagu to Uniondale	Middle Breede River Valley from Worcester to Swellendam	High-lying plateau between Loeriesfontein and Sutherland
Number of vascular plant spp.	±1 000	±1 000	±2 000	±1 500	±2 500
Number of endemics	>80	>150	>250	>115	>250
Percentage succulents among endemics	~7.5%	~74%	~82%	~78%	~23%

b) Fauna

The fauna of the Succulent Karoo biome does not reflect the same level of diversity or endemism shown by the flora (Vernon, 1999; Mucina *et al.*, 2006b; Rundel and Cowling, 2013).

Mammal diversity in the Succulent Karoo biome is relatively high with about 75 species of mammals (UCT, 2018a) of which two are endemic, namely the Critically Endangered De Winton's golden mole (*Cryptochloris wintoni*) and the Namaqua dune mole rat (*Bathyergus janetta*). Another important species of conservation concern in the region is the Critically Endangered riverine rabbit (*Bunolagus monticularis*), the Near-

Threatened brown hyena (*Hyaena brunnea*), the Vulnerable Hartmann's mountain zebra (*Equus zebra hartmannae*), the Vulnerable Cape leopard (*Panthera pardus*) and the Vulnerable Grant's golden mole (*Eremitalpa granti*) (Rundel and Cowling, 2013; Child *et al.* 2016).

Major concentrations of large mammals, including the African elephant (*Loxodonta africana*), the Critically Endangered black rhinoceros *(Diceros bicornis*), the hippopotamus (*Hippopotamus amphibious*) and the African buffalo (*Syncerus caffer*), used to roam the riverine forests along major rivers in the Succulent Karoo, but these populations have now all disappeared from this hotspot. Today, only smaller herds of gemsbok (*Oryx gazella*), mountain zebra (*Equus zebra*) and springbok (*Antidorcas marsupialis*) are commonly found mainly within the confines of formally protected areas and privately owned game farms (Williamson, 2010; Walker *et al*., 2018).

The avifauna of the Succulent Karoo includes nearly 230 species (UCT, 2007–present) with 13 threatened birds, one of which are endemic to the region, namely the Barlow's lark (*Certhilauda barlowi*). Other notable species of conservation concern in the region include the Endangered black harrier (*Circus maurus*), which has the most restricted range of the world's 13 harrier species, and the Endangered Ludwig's bustard (*Neotis ludwigii*), as well as the Lanner Falcon (*Falco biarmicus*), Southern Black Korhaan (*Afrotis afra*), Secretarybird (*Sagittarius serpentarius*) and the Verreaux's Eagle (*Aquila verreauxii*), all of which are considered Vulnerable (Rundel and Cowling, 2013; Taylor and Peacock, 2018; Arcus, 2018).

Reptile diversity is relatively high in the Succulent Karoo with approximately 94 species of which about 15 are endemic (UCT, 2018b). All of the endemics are geckos and lizards, representing about 25% of the nearly 60 gecko and lizard species in the biome. These endemics include seven species of girdled lizards of the genus *Cordylus*, including the armadillo girdled lizard (*Cordylus cataphractus*) that is endemic to the region. Tortoise diversity is very high in the Succulent Karoo with seven taxa of which two are endemic, namely the Namaqualand tent tortoise (*Psammobates tentorius trimeni*) and the Namaqualand speckled padloper (*Homopus signatus signatus*) (Bates *et al.,* 2014).

Amphibians are poorly represented in the Succulent Karoo with just over 20 species (UCT, 2018d). All of these species are frogs of which one is endemic, namely the Desert Rain Frog (*Breviceps macrops*). This frog species occurs along the Namaqualand coast of South Africa northwards to Lüderitz in the coastal south-west of Namibia. Also noteworthy is the Namaqua Stream Frog (*Strongylopus springbokensis*) that has a Near-Threatened status (Minter, 2004).

Invertebrate diversity is quite high in the Succulent Karoo biome and evidence suggests that more than half of the species in some insect groups are endemic to this biodiversity hotspot. These include amongst others monkey beetles (*Clania glenlyonensis*), bee flies, long-tongued flies and bees, as well as a variety of masarid and vespid wasps (Rundel and Cowling, 2013). The Succulent Karoo also boasts 50 scorpion species of which nearly 22 species are endemic to the biome (Rundel and Cowling, 2013; UCT, 2018c).

4.3.4.2 Socio-economic value

Historically, the Succulent Karoo biome has mainly supported livestock farming, mostly sheep and goats, but it was not until the late 1700's that land occupation and urban settlement by colonial pioneers expanded throughout most of the area. By late 1800's both cattle and ostrich farming also became an important agricultural revenue stream and today almost 90% of the Succulent Karoo supports commercial and subsistence pastoralism, in addition to cropland farming in areas where irrigation water is readily available (Hoffmann *et al.*, 1999; Smith, 1999; Jonas, 2004; Hoffmann *et al.,* 2018; Walker *et al*., 2018).

A study by Jonas in 2004 revealed the following economic land uses in the Succulent Karoo:

- Agriculture – Livestock farming (e.g. sheep, goats, cattle and ostrich);
- Agriculture – Cropland farming (barley, lucern, dates, vineyards, etc.);
- Conservation (e.g. National Parks and Nature Reserves);
- Fuel wood (e.g. *Prosopis* spp).

- Game farming (e.g. trophy hunting, live game sales, venison sales, etc.);
- Horticulture (e.g. succulents);
- Medicinal bioprospecting (e.g. cancer bush and kougoed);
- Mining (e.g. diamonds, copper, zinc, etc.); and
- Tourism (including ecotourism).

Recent statistics have shown that wind and solar energy installations cover approximately 5.2% of land in the Succulent Karoo of which the largest percentage of affected areas is situated in the Namaqualand bioregions (Hoffmann *et al.,* 2018).

All life and economic activities occurring within the Succulent Karoo are highly driven by the availability of water. Both surface and groundwater are generally very limited and often of naturally poor quality, especially in the driest regions of the biome. Exacerbated by climate change and compounded by increased pressure from human demand, sufficient water quality and quantity pose serious challenges to current and future land use and development opportunities in the Succulent Karoo (Hoffmann *et al.*, 2009; Le Maitre *et al.,* 2009; Milton, 2009; Hoffmann *et al.,* 2018; Walker *et al*., 2018).

4.4 Baseline environmental description of the Desert biome

4.4.1 What and where is the Desert biome in South Africa?

The Desert biome of South Africa is broadly divided into two bioregions, namely (i) the Southern Namib Desert bioregion and (ii) the Gariep Desert bioregion. The former comprises the desert areas stretching from the Atlantic coast near the mouth of the Orange River penetrating inland along the course of the lower Orange River to Sendelingsdrift and is characteristic of winter rainfall. The Gariep Desert is characterised by summer rainfall and includes the desert areas from Sendelingsdrift further east to the vicinity of Onseepkans and Pofadder in northern Bushmanland. The Desert biome borders the Nama Karoo biome to the east, and the Succulent Karoo biome in its western parts (Jürgens, 2006).

This arid environment is characteristic of extreme ecological conditions with erratic rainfall across the area (MAP <70 mm), high maximum daily temperatures (>48°C), high incidence of coastal fog, strong winds and frequent sandstorms. The desert landscape is highly dissected ranging from tall, rugged mountains with deep gorges to broad, sloping valley plains. The desert substrate is generally very rocky with little to no soil present. Desert soils, where present, are slow-forming, shallow alluvial sands created from a variety of rock types that are easily eroded by wind and high-impact rainfall from thunderstorms (Jürgens, 2006).

The Southern Namib Desert vegetation is characteristic of stem- and leaf-succulent trees and shrubs such as the Quiver tree (*Aloidendron dichotomum*) and the Giant Quiver tree (*Aloidendron pillansii*), with species from key genera including *Euphorbia, Fenestraria, Mesembryanthemum* (formerly *Brownanthus*)*, Monsonia* (formerly *Sarcocaulon*), *Salsola, Stoeberia* and *Tylecodon* dominating the desert plains and rocky hilly landscape. The Gariep Desert, in addition to the presence of stem- and leaf-succulents such as *Aloidendron dichotomum, Commiphora* species*, Euphorbia* species and *Pachypodium namaquanum* ('halfmens'), is typified by non-succulent woody perennials such as *Boscia albitrunca* (Shepherds tree), *Parkinsonia africana* (Green-hair thorn tree) and *Schotia afra* (Karoo boer-bean tree) with grasses like *Stipagostis* and *Enneapogon* species being distinctive of the sandy plains (Van Jaarsveld, 1987; Jürgens, 2006).

4.4.2 Vegetation types of the Desert biome

Rutherford and Westfall (1986) and Rutherford (1997) have differentiated between arid conditions characteristic of the eastern and western parts of the Karoo biomes, respectively, which led to the recognition of various types of deserts present in north-western South Africa by Jürgens in 1991. The Desert biome was subsequently defined by including a wide arid zone along the lower Orange River stretching from the Richtersveld in the west to the surrounds of the Pofadder region in the east. This biome was further demarcated into two bioregions (Figure 6), namely the Gariep Desert (located mostly within the borders of South Africa) and the Southern Namib Desert (Jürgens, 2006). The Gariep Desert includes a tally of 10 different vegetation types, whereas the Southern Namib Desert is characterised by only five distinct vegetation types (Figure 7). Eleven of these Desert vegetation types are wholly or partly present in the proposed gas pipeline corridors.

The Gariep Desert flora is dominated by ephemeral plants, often annual grasses and non-woody forbs, especially after a good rainy season. Normally the vast desert plains appear barren and desolated with aboveground vegetation persisting underground in the form of seed, but following abundant rainfall in winter the desert plains and lower mountain slopes can be covered with a sea of short annual grasses and striking mass flowering displays of short-lived forbs and succulents in spring. Perennial plants such as stem- and leaf succulent trees and shrubs, including some non-succulent plants, are usually encountered in specialised habitats associated with local concentrations of water, like dry river beds, drainage lines and rock crevices. Lichen fields are also a conspicuous marvel of the open coastal belt utilising the moisture-filled fog originating from the adjoining Atlantic Ocean (Van Jaarsveld, 1987; Jürgens, 2006).

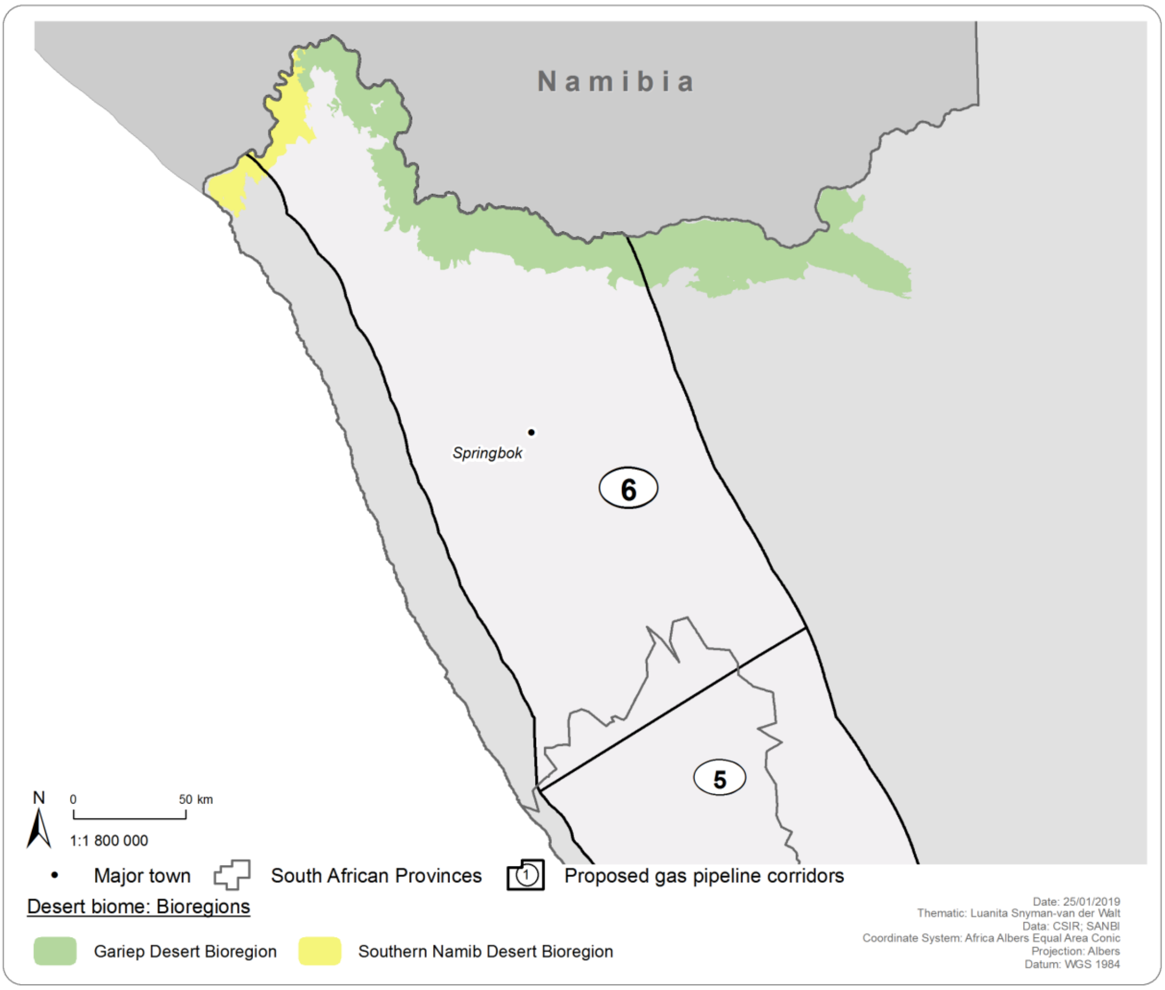

Figure 6. The Desert biome consists of two different bioregions.

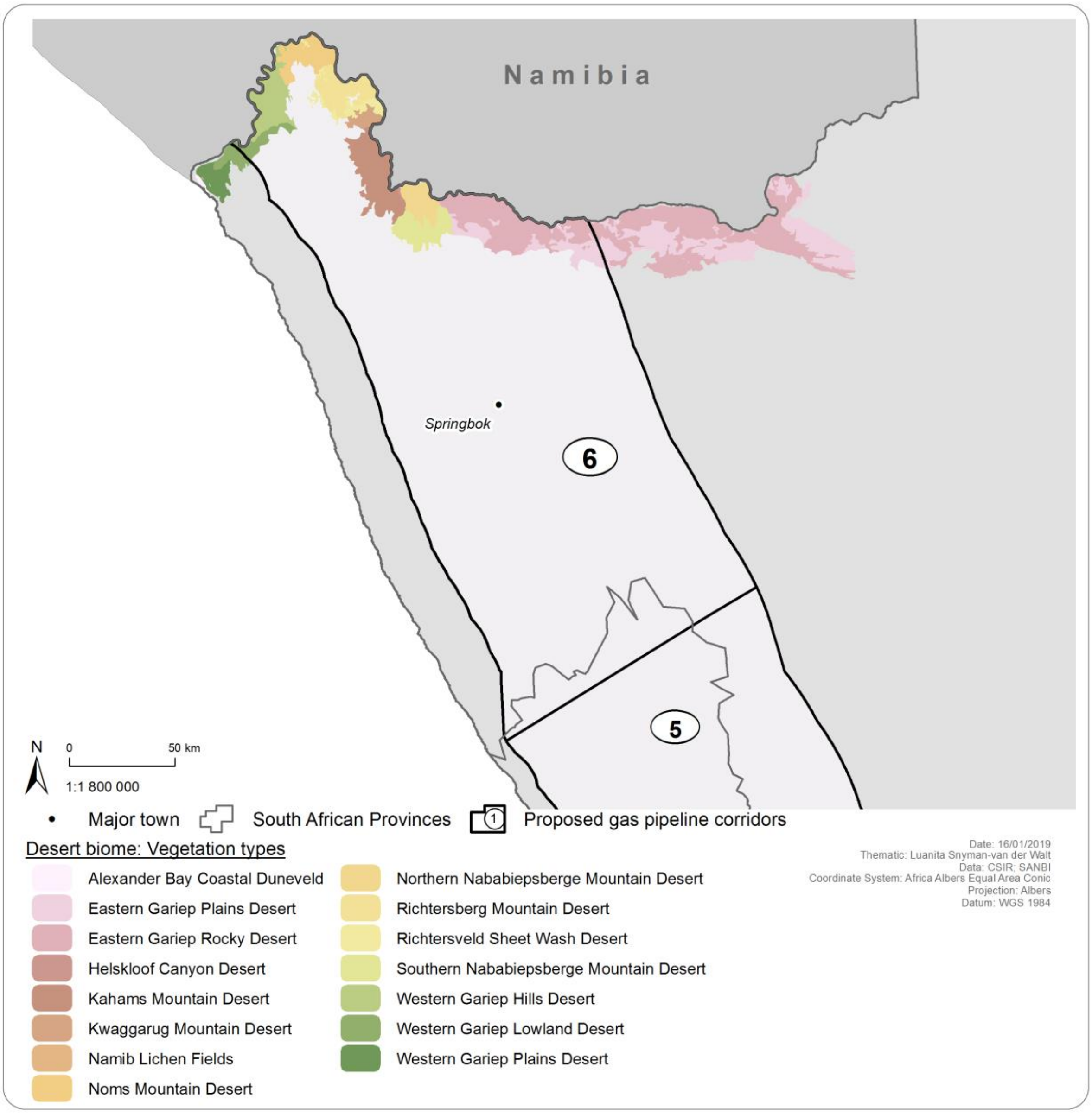

Figure 7. The Desert biome consists of 15 different types of desert habitat.

4.4.3 What is the state of the Desert biome?

The Desert biome, interfacing with the highly diverse and species-rich Succulent Karoo biome, is considered to be one of the most biologically diverse and environmentally sensitive deserts in the world. Although the region is sparsely populated with only few small villages, communal livestock farming (mainly sheep and goats) across large areas of the biome has had a significant impact on vegetation cover. Overgrazing due to overstocking, intensified by extended periods of drought, especially surrounding some permanent settlements in the Richtersveld, resulted in severe deterioration of veld condition, and in some places total desertification (Hoffmann *et al.*, 1999; Jürgens, 2006; Hoffmann *et al.,* 2014).

Commercial scale crop farming along the lower Orange River has also substantially increased during the past century now having extensive areas cultivated with inter alia vineyards, dates and subtropical fruit orchards. In addition to irrigation agriculture, open-cast diamond mining and exploration activities, mostly along the lower Orange River from Alexander Bay to Swartwater, have largely scarred the desert landscape adding to the human impact on this sensitive ecosystem. Although alien invasive plants such as *Prosopis* spp., *Nicotiana glauca, Ricinus communis* and *Atriplex lindleyi* are a common phenomenon of dry river beds, drainage lines and around human settlements, its distribution has been limited by the lack of subsurface water in the greater desert area (Milton *et al.*, 1999; Jürgens, 2006). Unfortunately, unique species richness and high levels of endemism associated with the Desert biome have also seen the illegal removal of succulents by collectors and traders (Van Wyk and Smith, 2001).

So far, only approximately 22% of the Desert biome is formally protected in statutory and non-statutory reserves of which the Richtersveld National Park, the Nababieps Provincial Nature Reserve and the Orange River Mouth Provincial Nature Reserve constitute the largest area of conservation (Jürgens, 2006; Taylor and Peacock, 2018). The average conservation target for vegetation types in the Desert biome is 32%. Other efforts to preserve this unique desert ecosystem include the Richtersveld Community Conservancy and two proclaimed National Heritage Sites, namely (i) the lichen field near Alexander Bay and (ii) the renowned population of *Aloidendron pillansii* on Cornellskop (Jürgens, 2006).

Transformation of the Desert biome has so far been relatively limited transformed despite the effect of the aforementioned impacts on desert ecosystems (Jürgens, 2006). However, rising temperatures and decreasing rainfall as a direct result of climate change could intensify desertification of the Desert biome over the next 50 years (Hoffmann *et al.*, 1999; Rutherford *et al.,* 1999).

4.4.4 Value of the Desert biome

4.4.4.1 Biodiversity value

a) Flora

Plant species richness of the vegetation types included in the Desert biome is exceptionally high when compared to other desert environments with similar aridity levels globally (Jürgens, 2006). The most profound feature of the Desert biome is the Gariep Centre of Endemism which covers the northern most part of the biome stretching inland along the Lower Orange River Valley. The Richtersveld forms the core of the centre boasting a total of approximately 2 700 vascular plant species of which more than 560 species are endemic and near-endemic to the Gariep Centre. More than 80% of species among these endemics are succulents (Van Wyk and Smith, 2001). Also, the Orange River Mouth is located at South Africa's coastal border with Namibia and contains two threatened vegetation types which are both highly disturbed, namely the Arid Estuarine Salt Marshes that is a National Freshwater Ecosystem Priority Area (NFEPA) and Endangered Wetland, as well as the Critically Endangered Alexander Bay Coastal Duneveld (SANBI, 2011; Driver *et al.,* 2012; Holness and Oosthuysen, 2016).

b) Fauna

More than 60 different mammal species are known to occur in the Desert biome (UCT, 2018a). Three species are considered Vulnerable, namely the Hartmann's zebra (*Equus zebra hartmannae*), the Black-footed cat (*Felis nigripes*) and the Cape leopard (*Panthera pardus*). A further three mammals have a Near-Threatened status including the Brown Hyena (*Hyaena brunnea*), the African Clawless Otter (*Aonyx capensis*) and Littledale's Whistling Rat (*Parotomys littledalei*). Antelope species common to the desert plains include Gemsbok (*Oryx gazella*), Springbok (*Antidorcas marsupialis*), Steenbok (*Raphicerus campestris*) and Kudu (*Tragelaphus strepsiceros*) (Williamson, 2010; Child *et al.*, 2016; Walker *et al*., 2018).

The Desert biome has a relatively high bird diversity with a total of 133 species of which 12 are listed as threatened species. A tally of 212 species have been recorded in the Richtersveld National Park (UCT, 2007-present; Taylor and Peacock, 2018). An Important Bird Area (IBA) for avifauna diversity is the Orange River Mouth which is regarded as the second most important estuary in South Africa in terms of conservation importance (Taylor and Peacock, 2018). This coastal wetland near Alexander Bay received Ramsar status in June 1991 and supports more than 250 recorded bird species of which 102 are waterbirds (BirdLife SA, 2015; SARS, 2016).

The reptile diversity of the Desert biome is fairly high with about 84 species (UCT, 2018b), three of which are of conservation concern. These include the Near-Threatened Richtersveld Pygmy Gecko (*Goggia gemmula*), the Critically Endangered Namib Web-footed Gecko (*Pachydactylus rangei*) and the Vulnerable Speckled Padloper (*Chersobius signatus*) (Bates *et al.,* 2014).

A total of 13 frog species can potentially occur in the Desert biome (UCT, 2018d) of which two species are listed as being Vulnerable, namely the Desert Rain Frog (*Breviceps macrops*) and the Namaqua Stream Frog (*Strongylopus springbokensis*) (Minter, 2004).

The Desert Biome includes an abundant insect fauna which includes many Scarabaeidae and Tenebrionidae beetles. Its insect diversity further includes about 69 species of moths and butterflies, 20 species of dragonflies and 32 species of lacewings (Mecenero *et al.,* 2013). Up to 24 scorpion species could potentially be found in this desert environment (UCT, 2018c).

4.4.4.2 Socio-economic value

The Desert biome is not particularly rich in natural resources, hence providing employment to a relatively small number of people. The main economic drivers in this arid area are commercial scale crop cultivation and mining activities along the Lower Orange River Valley, whereas small stock farming is the main agricultural land use practised in most of the remaining biome. Ecotourism and conservation, as well as collection of plants for the horticultural trade, specifically succulents, add to the economic value of the Desert biome (Hoffmann *et al.*, 1999; Jonas, 2004; Jürgens, 2006).

Due to the ecologically sensitive nature of this biome, not all of the aforementioned land uses are sustainable. Clearance of vegetation and removal of topsoil for irrigated croplands as well as large scale surface mining along the Orange River have resulted in total biodiversity loss and increased soil erosion. In addition to overstocking of small livestock, which leads to overgrazing, unsustainable land use exacerbated by global climate change is causing desertification which could have a negative impact on the socio-economic value of the Desert biome (Hoffmann *et al.*, 1999; Jonas, 2004; Jürgens, 2006; Milton, 2009).

5 FEATURE SENSITIVITY MAPPING

5.1 Methodological approach to sensitivity mapping

The sensitivity mapping approach, takes as a starting point, the distribution of Protected Areas and CBAs as Very High sensitivity features. The whole study area has been subject to recent fine-scale conservation planning and this represents an important biodiversity input layer for the mapping. Such fine-scale conservation planning identifies CBAs which represent biodiversity priority areas which should be maintained in a natural to near natural state. The CBA maps indicate the most efficient selection and classification of land portions requiring safeguarding in order to meet national biodiversity objectives. As such, development in such areas is not considered desirable as this may compromise the ability to meet conservation targets or impact on biodiversity patterns or processes within the CBA. Furthermore, as these have been derived in an efficient manner and taking competing land uses into account, to compensate for habitat loss within CBAs even greater areas are required to meet the same targets. Both Protected Areas and CBAs are considered to represent Very High sensitivity areas.

Building on from the above features, another process-level feature used is the drainage features of the area. These are based on the NFEPA layer and buffered from 100 m to 1 000 m, depending on the stream order, with larger rivers being buffered by increasingly large amounts. As there can be extensive floodplains associated with some large drainage systems, this was also supplemented by the azonal vegetation types layer derived from the VegMap for the study area, which maps riparian vegetation types associated with wetlands and drainage systems. These areas are also considered Very High sensitivity.

Plant and faunal species-level biodiversity information was vetted and checked before being used to inform the sensitivity mapping as the data sets contained various errors as well as some species localities of poor accuracy. Rather than buffer the point localities by a set distance, a more ecologically sound approach was considered to be allocating sensitivity to a quinary sub-catchment, based on species occurrence within the sub-catchment. These represent relatively small and localised quinary catchments with similar climatic and environmental conditions likely to be more widely suitable for fauna species of concern present elsewhere within the basin.

A number of additional modifiers were also used to inform the sensitivity mapping, with the presence of threatened ecosystems and National Protected Area Expansion Strategy (NPAES) Focus Areas being used to increase sensitivity levels where appropriate. Custom sensitivity layers used include a custom specialist interpretation of the new 2018 VegMap beta layer, whereby each vegetation type in the study area was allocated a sensitivity category based on the inherent sensitivity of the vegetation type due to the diversity, ecological function, faunal value or abundance of species of conservation concern within the vegetation type. An additional layer of sensitive areas identified by the specialist, as well as from the Shale Gas Strategic Environmental Assessment (SEA) and the Renewable Energy Development Zones (REDZ) SEA, were also used to identify higher sensitivity areas.

In addition, the old fields' layer and croplands layer were used to drop the sensitivity of degraded areas to low. A number of layers were either selectively used or not used at all due to the issues with data quality. This includes the land cover layer which was not used as experience with this layer indicates that it is not sufficiently reliable in the arid parts of the country. This is largely because many bare areas which correspond in the field to pans or other low-vegetation habitats are often classified as degraded or transformed habitats. In addition, wetland features present in the Nama Karoo, Succulent Karoo and Desert biomes were captured using the 2018 wetlands layer.

5.2 Biodiversity features and classification of sensitivity criteria

The biodiversity sensitivity values are adapted from the CBA classifications, as based on the provincial systematic conservation plans for the Northern, Western and Eastern Cape provinces. This is summarised in Table 6.

The biodiversity feature data and critical biodiversity classification rules for Gas Pipeline Corridor Phases 7, Inland and part of 2; were adapted from the draft Eastern Cape Biodiversity Conservation Plan (2017); while the biodiversity feature data and critical biodiversity classification for Gas Pipeline Corridor Phases 1 and part of 2 falling into the Western Cape was obtained from the Western Cape Biodiversity Spatial Plan (2017). Biodiversity feature data and critical biodiversity classification for Gas Pipeline Corridor Phases 6 and part of 5 falling into the Northern Cape was obtained from the CBAs of the Northern Cape (2016).

Additional detail and data sources relevant to the biodiversity features used and the rules to derive the sensitivity classifications are also provided in Table 6.

Table 6. Biodiversity feature classes and sensitivity ratings derived from CBA classifications used in this assessment.

Feature Class, Data Source and Date of Publication	Sensitivity Feature Class	Sensitivity Rating & Buffer	Data Description, Preparation and Processing
2017 Western Cape Biodiversity Framework - CBAs	CBA 1	Very High	High value and irreplaceable areas.
	CBA 2	High	Degraded areas of high value.
	ESA	Low	Data generally taken as is.
2016 Northern Cape CBA Map	CBA 1	Very High	These areas also overlap with the Northern Cape Protected Area Expansion Strategy Focus Areas and as such, the latter is not used as this is already captured in the CBA mapping.
	CBA 2	High	Data generally taken as is.
	ESA	Low	Data generally taken as is.
2017 Eastern Cape CBAs	CBA 1	Very High	Data generally taken as is.
	CBA 2	High	CBA2 areas are over-mapped in the Eastern Cape and are used to capture broad corridors where there are currently no major threats. Possibly these areas should be dropped to Medium sensitivity.
	ESA	Low	Data generally taken as is.
Protected Areas from latest (2018 Q3) SAPAD Database	DEA Protected Areas	Very High	Formal protected areas all classified as Very High.
2010 NPAES	NPAES Focus Areas	**Medium**	This is considered a useful layer as it is aligned with the more recent provincial plans which are seen as the current benchmark in conservation planning for each province.
Old Fields Layer	Old Fields	Old fields = **Low**	The old fields' layer is used to downgrade the sensitivity of CBA areas from High and Very High to Medium.
		CBA 1 + Old Fields = **Medium**	
		CBA 2 + Old Fields = **Medium**	
Croplands Layer	Croplands	**Low**	All active croplands are listed as Low sensitivity regardless of CBA or other status
SANBI (2006-2018). The Vegetation Map of South Africa, Lesotho and Swaziland, Mucina, L., Rutherford, M.C. and Powrie, L.W. (Editors), Online, http://bgis.sanbi.org/Projects/Detail/186, Version 2018	All vegetation types within the study area were categorised into sensitivity classes based on their vulnerability to disturbance or ecological value.	Azonal Vegetation Types = Very High except for extensive non-wetland related types which are generally classified as **High**	This is a specialist interpretation of the VegMap types which is aimed at capturing sensitive features that have not been captured via other means.
		Other Veg types which have a high abundance of Species of Conservation Concern = **High**	
		Veg types which are considered vulnerable to disturbance (dunes) = **High**	

Feature Class, Data Source and Date of Publication	Sensitivity Feature Class	Sensitivity Rating & Buffer	Data Description, Preparation and Processing
Western Cape Threat Status from WCBSP2017	Threat Status	Critically Endangered – **Very High** Endangered- **High** Vulnerable - **Medium**	Data generally taken as is.
Wetlands Layer 2018 NBA Layer	Wetlands	High in Succulent Karoo **Low** in Nama Karoo	Data generally taken as is.
Rivers from the NFEPA – 1:250 000 layer (Note that these features are considered in the Freshwater Assessment and are included for information purposes here. Refer to the separately attached Freshwater Assessment Report for feedback on sensitivity ratings in this regard).	Stream Order 1-3 4-5 6-7	Stream Order was buffered as follows: 1-3: 100 m 4-5: 500 m 6-7: 1000 m All classified as Very High	This is aimed at highlighting riparian areas. While the VegMap should capture riparian vegetation as an Azonal Veg type, this does not always occur as many riparian areas are poorly mapped.
Fauna Layers	Fauna of conservation concern (CR/EN/VU)	Quinary catchments where SCC were present were mapped as **High**	Not all data points could be used as the older data is not georeferenced well as the data is from 1:50 000 or 1:250 000 map centroids. In addition, it is not appropriate to buffer the localities as most of these species are also present between the observations. The best approach was seen to allocate sensitivity to quinary catchments based on the presence of SCC. Where species are known to occupy specific habitats, intervening quinaries between observations were also included. Widespread more generalist species were excluded.
SANBI Plant Habitats	Mapped areas of occurrence of Plant SCC	SANBI Plant habitats classified as Very **High** Occurrence classified as **High**	Data generally taken as is.
Specialist identified sensitive areas in Karoo and Desert ecosystems	Areas of high biodiversity significance based on the specialists own experience or gained from working on the REDZ and Shale Gas SEAs	Classified as **High**	Custom layer based on the specialists' own knowledge and experience.
Shale Gas SEA	Very High sensitivity areas	Classified as **High**	Sensitivities mapped in the Shale Gas SEA are specific to the SEA and Shale Gas development as such, these are not considered directly transferrable to the current study. But areas mapped as Very High are considered to represent biodiversity priority areas and are also used here within the area of overlap of these two assessments.

5.3 Four-Tier Sensitivity Mapping

5.3.1 Gas Pipeline Corridor - Phase 1

Within Phase 1, important features present include the Tanqua Karoo, which includes the Tanqua Karoo National Park as well as several areas where the Riverine Rabbit is known to occur (Figure 8). The Riverine Rabbit is also known to occur more widely within the corridor, from Touws River, through to the Robertson area and Sanbona Private Nature Reserve and northwards towards Anysberg Nature Reserve. The Worcester-Robertson Succulent Karoo region is also considered to be an area of high plant diversity and endemism and the vegetation in this area is considered fairly high sensitivity (Figure 9). In the east the corridor also includes the area around Calitzdorp as well as the open plains between Laingsburg and Prince Albert, where the major features are the larger drainage systems present including the Dwyka, Gamka, Groot and Touws Rivers. The mountains in this area are generally important areas for the Grey Rhebok, as well as potential habitat for the Cape Mountain Zebra, Cape Leopard and fauna more generally.

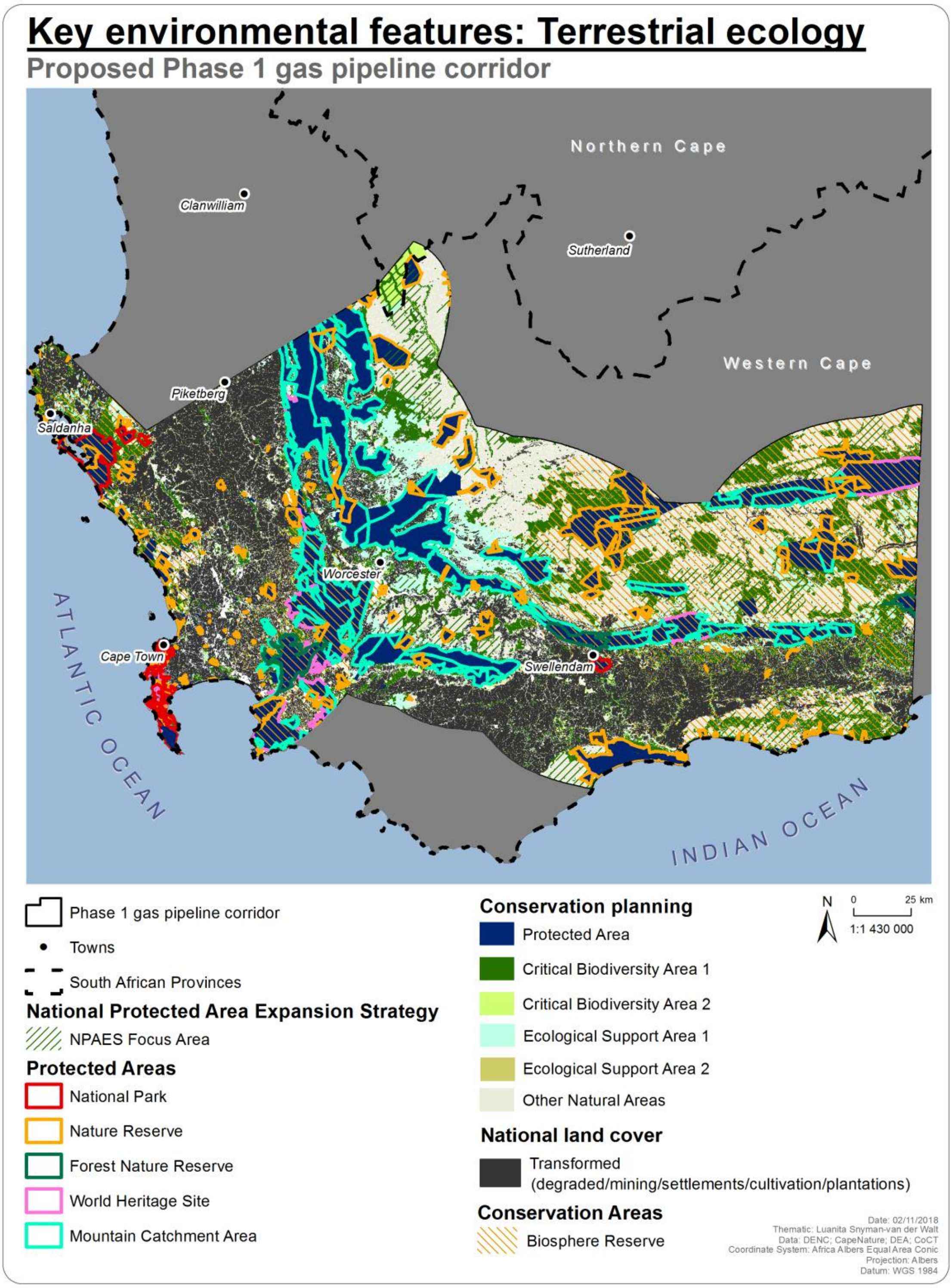

Figure 8. Key environmental features in the proposed Gas Pipeline Phase 1 corridor.

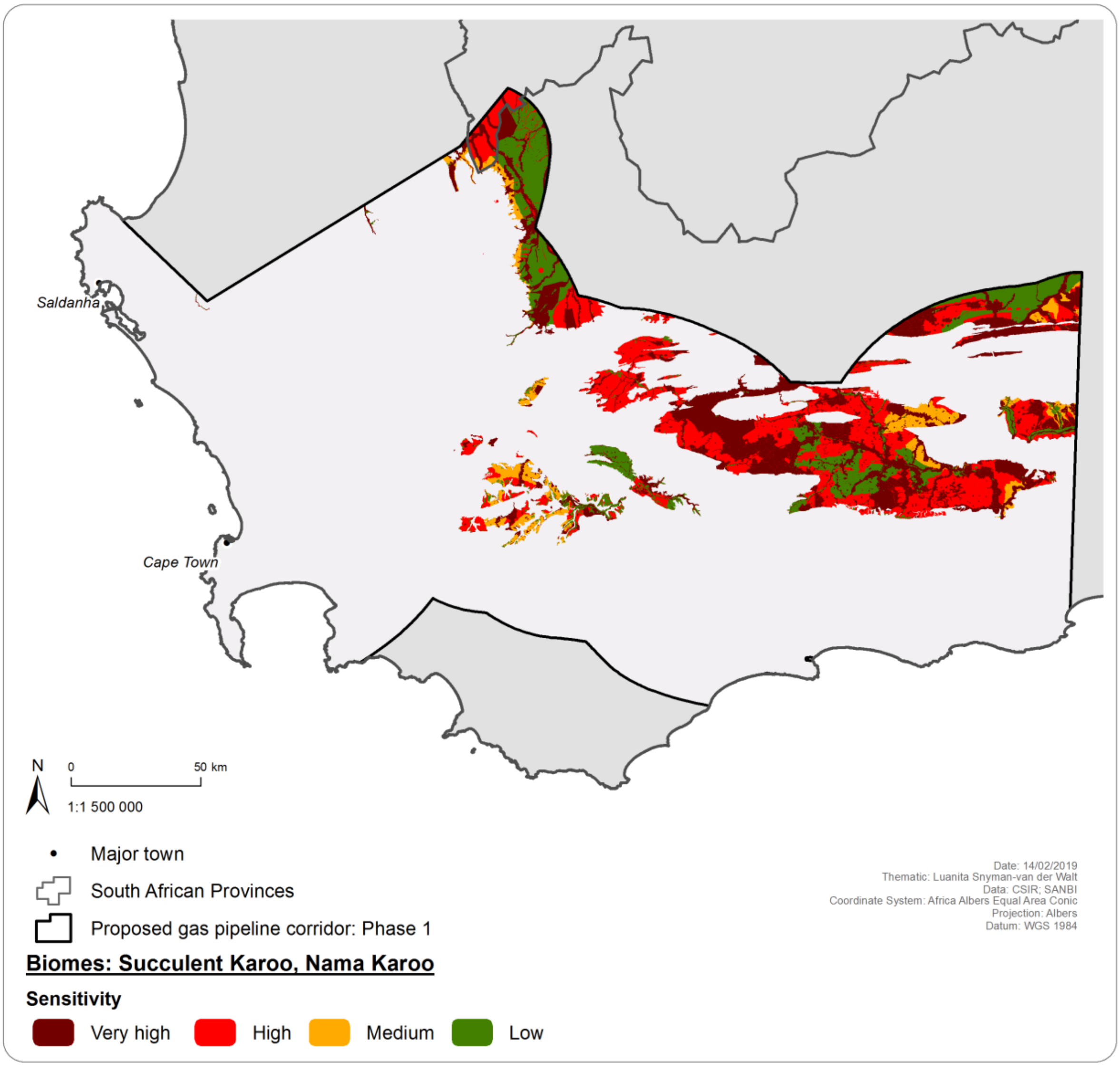

Figure 9. Sensitivity of Karoo ecosystems in the proposed Gas Pipeline Phase 1 corridor.

5.3.2 Gas Pipeline Corridor - Phase 2

The arid sections of Corridor Phase 2 are bounded by various mountain ranges in the south such as the Swartberg and Baviaanskloof (Figure 10). The arid Karoo plains from Prince Albert in the west to Steytlerville and Jansenville in the east are generally of moderate sensitivity, but there are occasional high to very high sensitivity areas present including the major features such as the Kariega, Sout and Groot Rivers, as well as the transition areas between the plains of the Nama Karoo and the thicket communities present on the slopes and hills of the area (Figure 11). In terms of fauna, this is generally a low sensitivity area with few fauna of conservation concern present across this area, apart from the Black-footed Cat which occurs at a low density across this area as well as the South African Hedgehog, which is known from the eastern margin of this corridor. The mountains are also home to the Near-Threatened Mountain Reedbuck and Grey Rhebok.

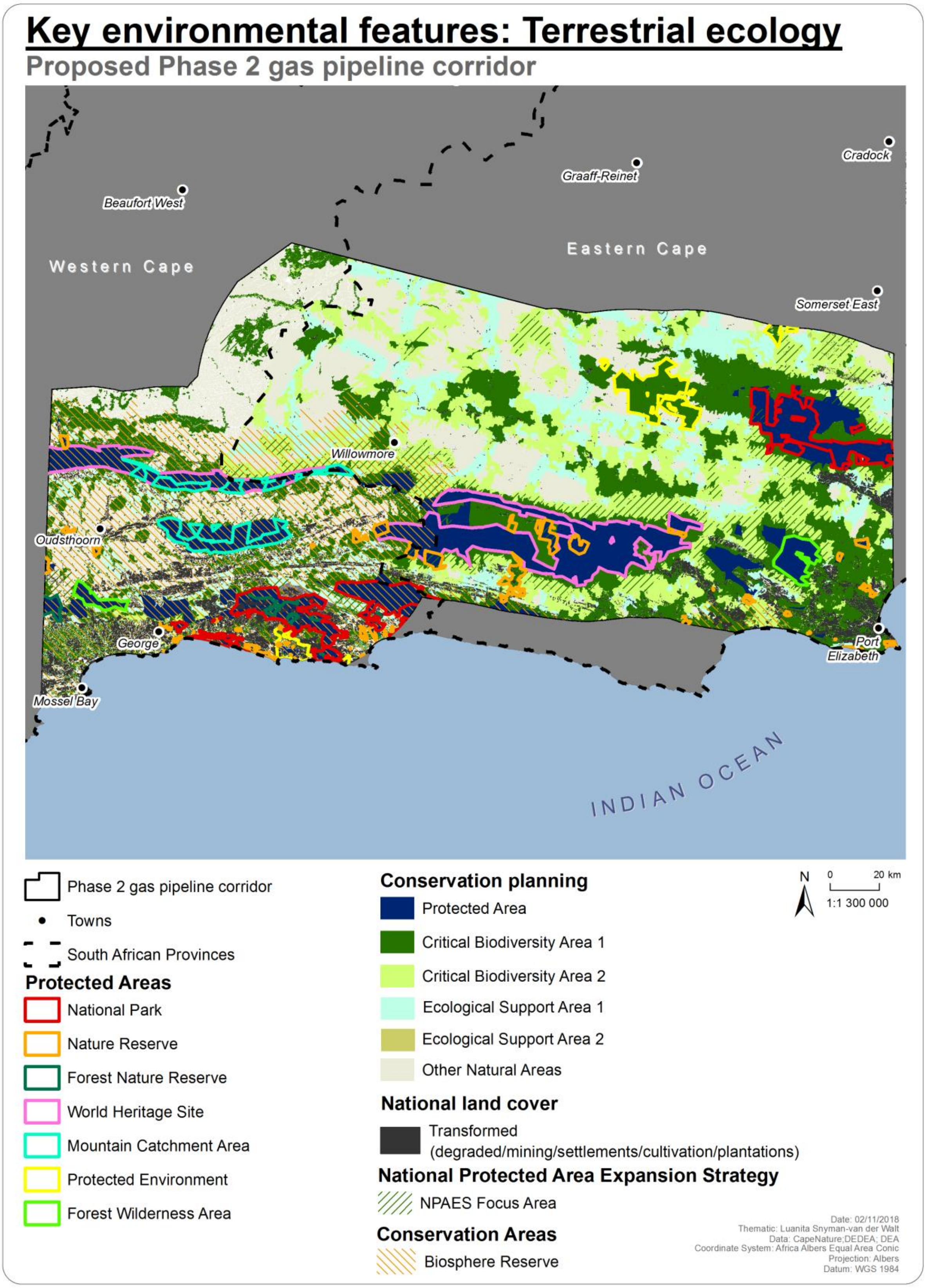

Figure 10. Key environmental features in the proposed Gas Pipeline Phase 2 corridor.

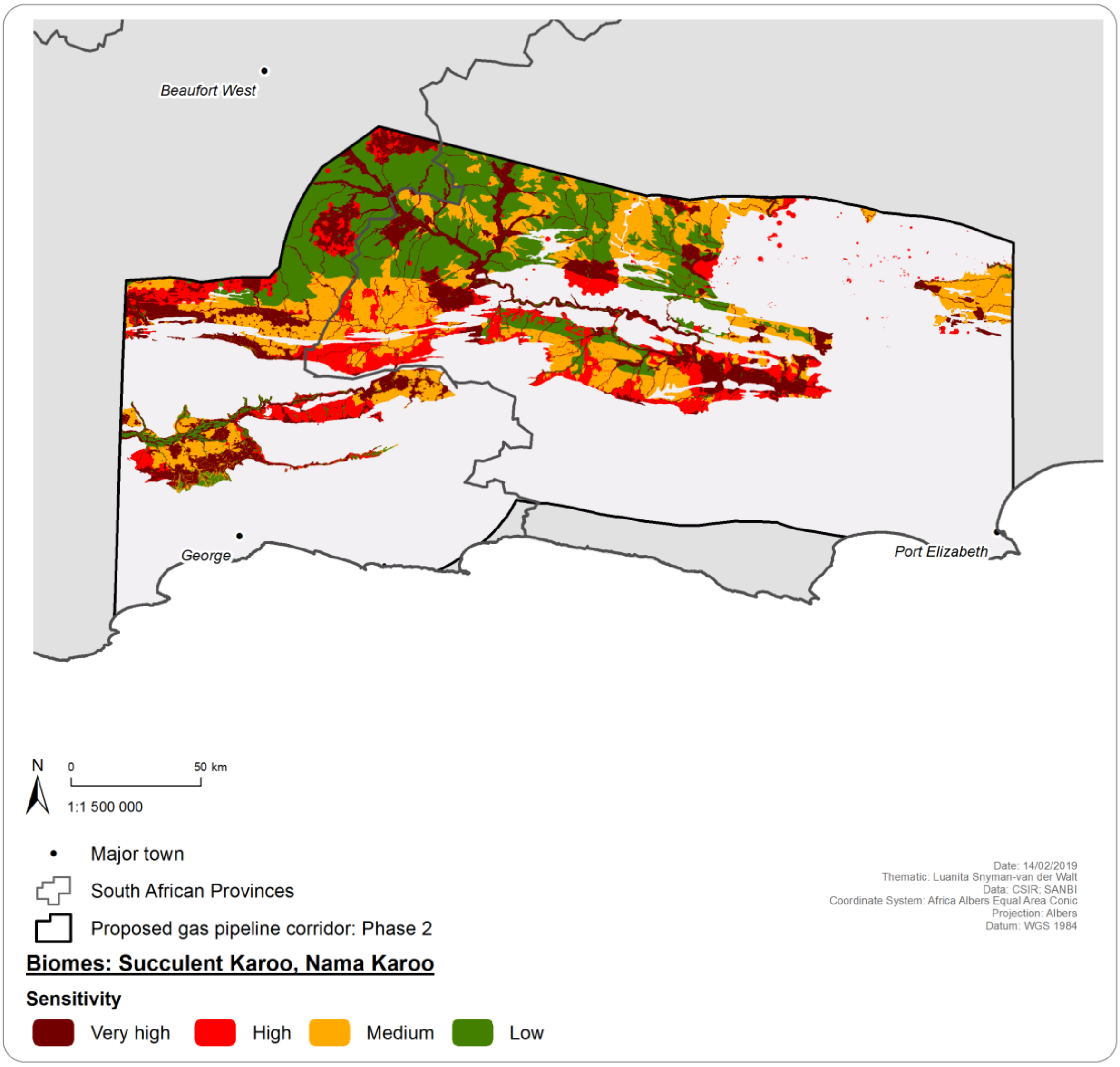

Figure 11. Sensitivity of Karoo ecosystems in the proposed Gas Pipeline Phase 2 corridor.

5.3.3 Gas Pipeline Corridor - Phase 5

Phase 5 of the Gas Pipeline Corridor includes the transition from the arid Knersvlakte in the north to the wetter Swartland and Cedarberg Mountains in the south (Figure 12). Within the Karoo study area, the most significant features of this phase include the various parts of the Knersvlakte Nature Reserve along the N7 as well as the Bokkeveld Escarpment in the east. The Knersvlakte is considered especially sensitive due to the exceptional levels of endemism which characterise this area as well as its arid nature and associated difficulty in effectively rehabilitating disturbed areas (Figure 13).

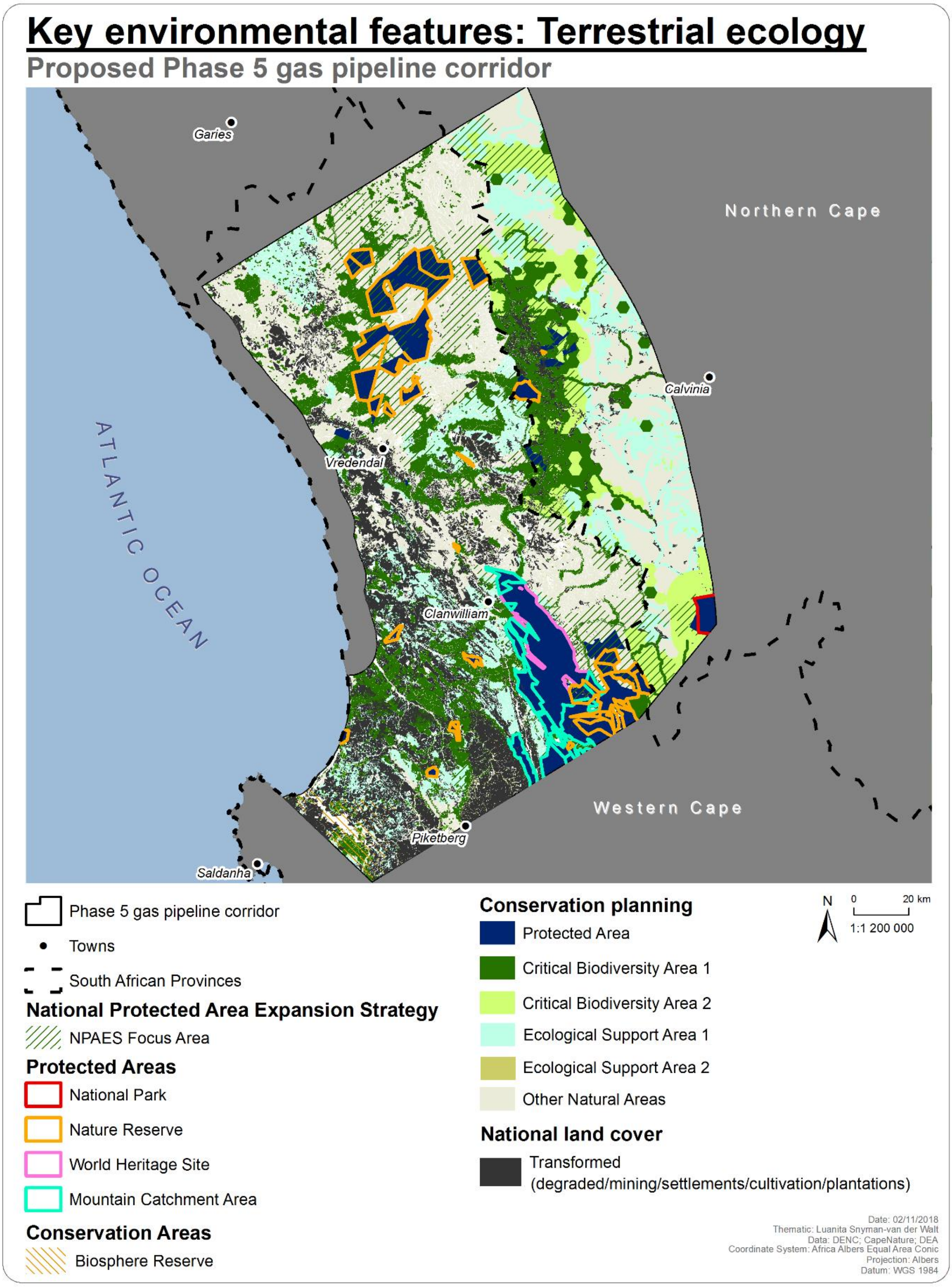

Figure 12. Key environmental features in the proposed Gas Pipeline Phase 5 corridor.

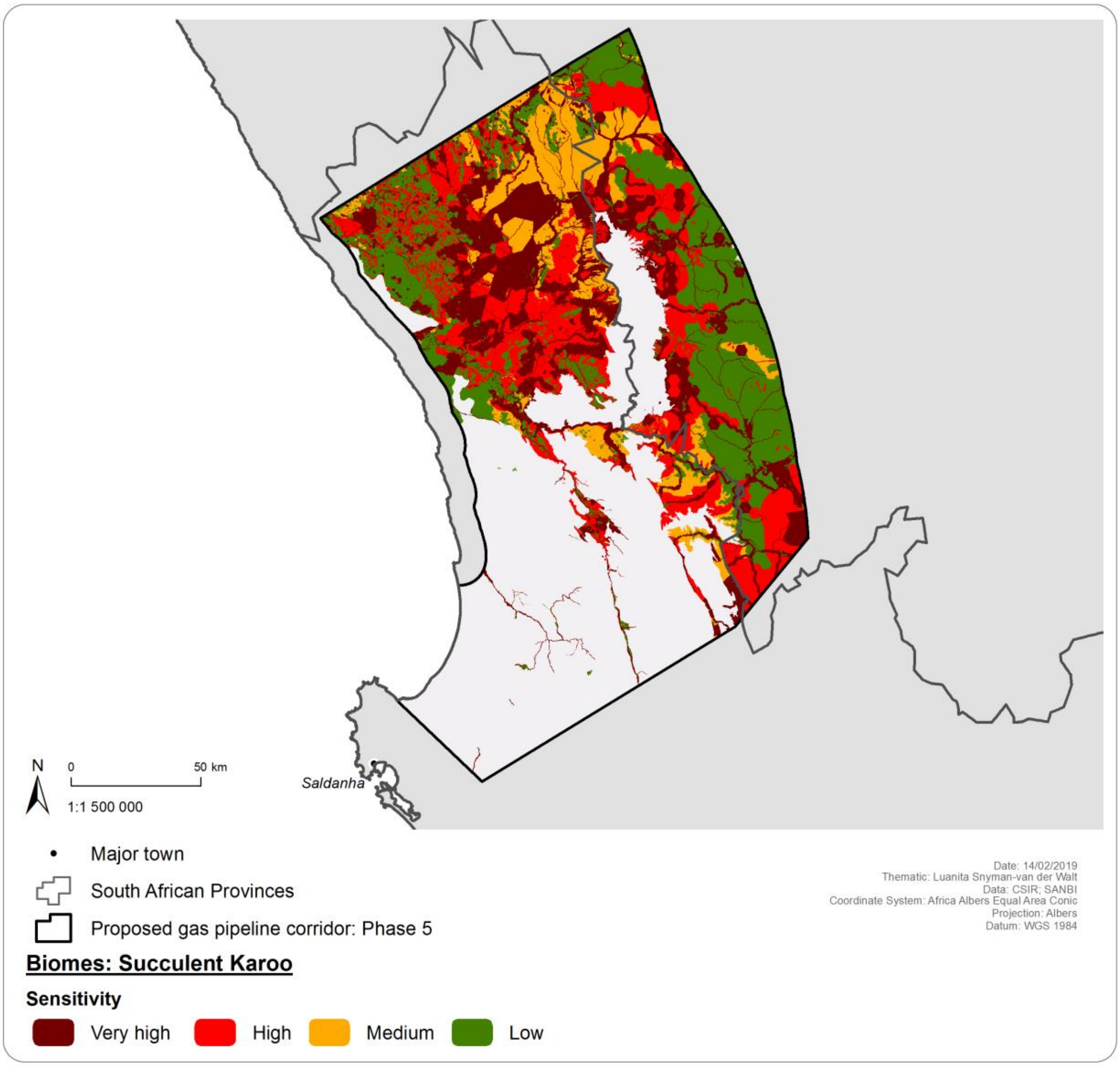

Figure 13. Sensitivity of Karoo ecosystems in the proposed Gas Pipeline Phase 5 corridor.

5.3.4 Gas Pipeline Corridor - Phase 6

The dominant features of the Phase 6 corridor are the large Protected Areas present in the northern section of the corridor, which includes the Richtersveld National Park and the Richtersveld World Heritage Site, as well as the Orange River Mouth and the Nababieps Provincial Nature Reserves (Figure 14). The Orange River Mouth Nature Reserve also includes a Ramsar wetland. This arid environment is typified by Desert and Karoo vegetation rich in succulents with a high level of species richness and endemism, many of which are of conservation concern such as the Endangered Giant Quiver tree (*Aloidendron pillansii*) and the 'halfmens' (*Pachypodium namaquanum*). The abundance of fauna of conservation concern in this corridor is also quite high, with numerous locally-endemic gecko species present along the mountains of the Orange River valley. Along the coast, there are also several fauna of concern including the Namib Web-footed Gecko and Grant's Golden Mole.

The central section of the corridor is characterised by several Protected Areas including the Goegap Provincial Nature Reserve and the Namakwa National Park. Other sensitive areas include the Kamiesberg Mountains which are considered largely unsuitable for pipeline construction due to the rugged terrain as well as diversity of this area. Also, elements of sensitive Fynbos ecosystems can be found in this corridor as isolated fragments located mostly on mountain tops in the Kamiesberg (central), Richtersveld (north) and Bokkeveld (south), or on the coastal plain (west). The Knersvlakte Nature Reserve is an important Protected Area located in the southern section of the corridor.

In general, this Phase of the pipeline corridor is considered generally fairly high sensitivity due to the diversity of the underlying Succulent Karoo and Desert vegetation, and the high abundance of features and fauna of conservation concern within this area (Figure 15). In the north, along the Orange River, as well as in the west, along the coast, there is little scope for avoidance of very high and high sensitivity areas. Also, both the Namaqualand Hardeveld and the Namaqualand Sandveld, as well the Knersvlakte in the south are considered areas of conservation concern. However, some areas in a southerly direction along the centre of the corridor have a medium sensitivity due to the presence of extensive degraded rangeland. The far eastern section of the corridor located within Bushmanland is typified by Nama Karoo vegetation with very few species of conservation concern and are thus generally considered to be of low sensitivity.

Although there are these low sensitivity areas situated in the far eastern parts of the corridor, within Bushmanland, it is not likely that this area can be easily accessed by the pipeline route given that the Bushmanland plains are situated on the inland plateau, which are separated from the western section of the corridor by the escarpment. Also, it is recommended that this Gas Corridor is extended westwards towards the coast as there are some less sensitive as well as transformed areas located in the Sandveld along the coast where the topography and soils are also far more conducive for pipeline construction than through the rugged mountains within the current corridor alignment.

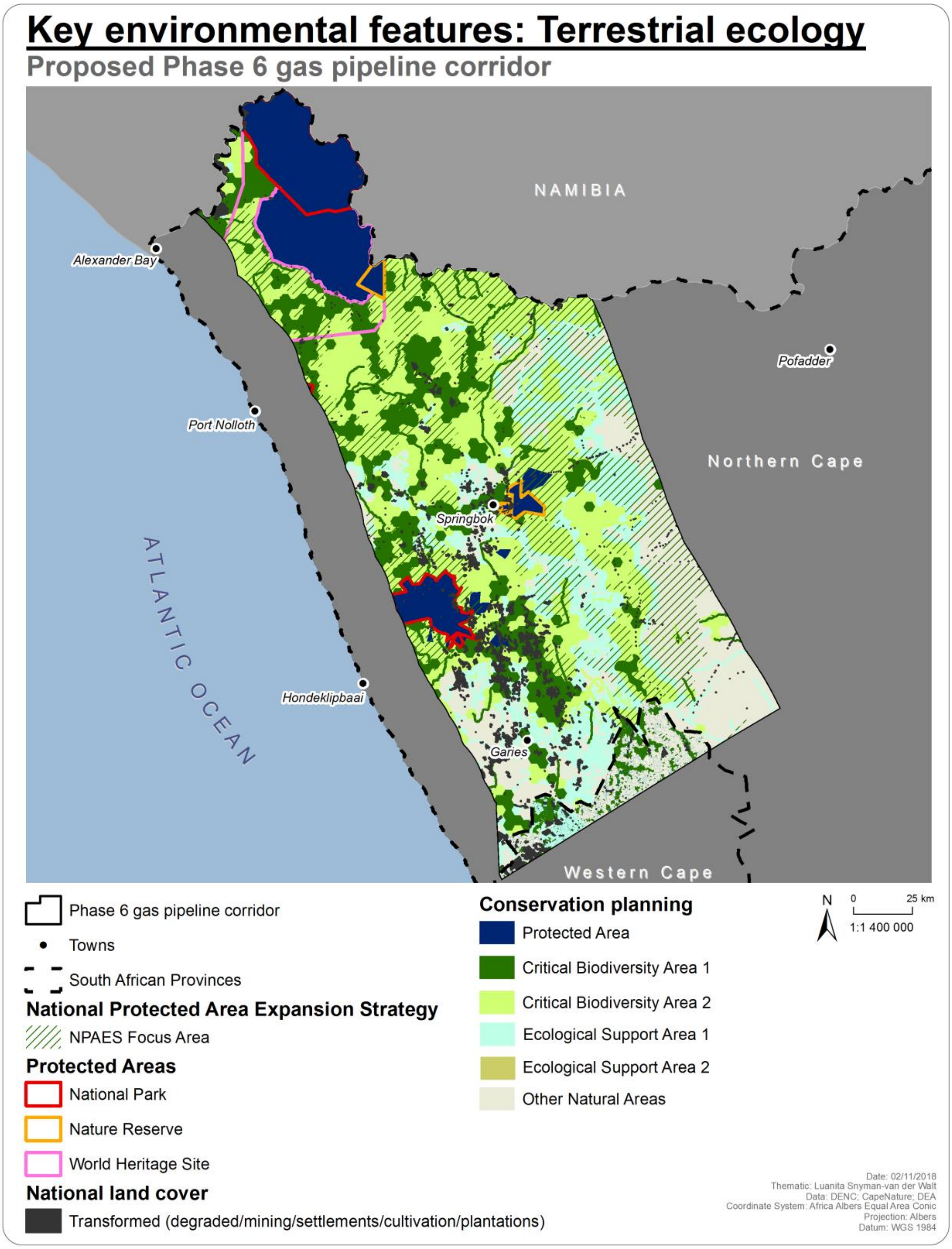

Figure 14. Key environmental features in the proposed Gas Pipeline Phase 6 corridor.

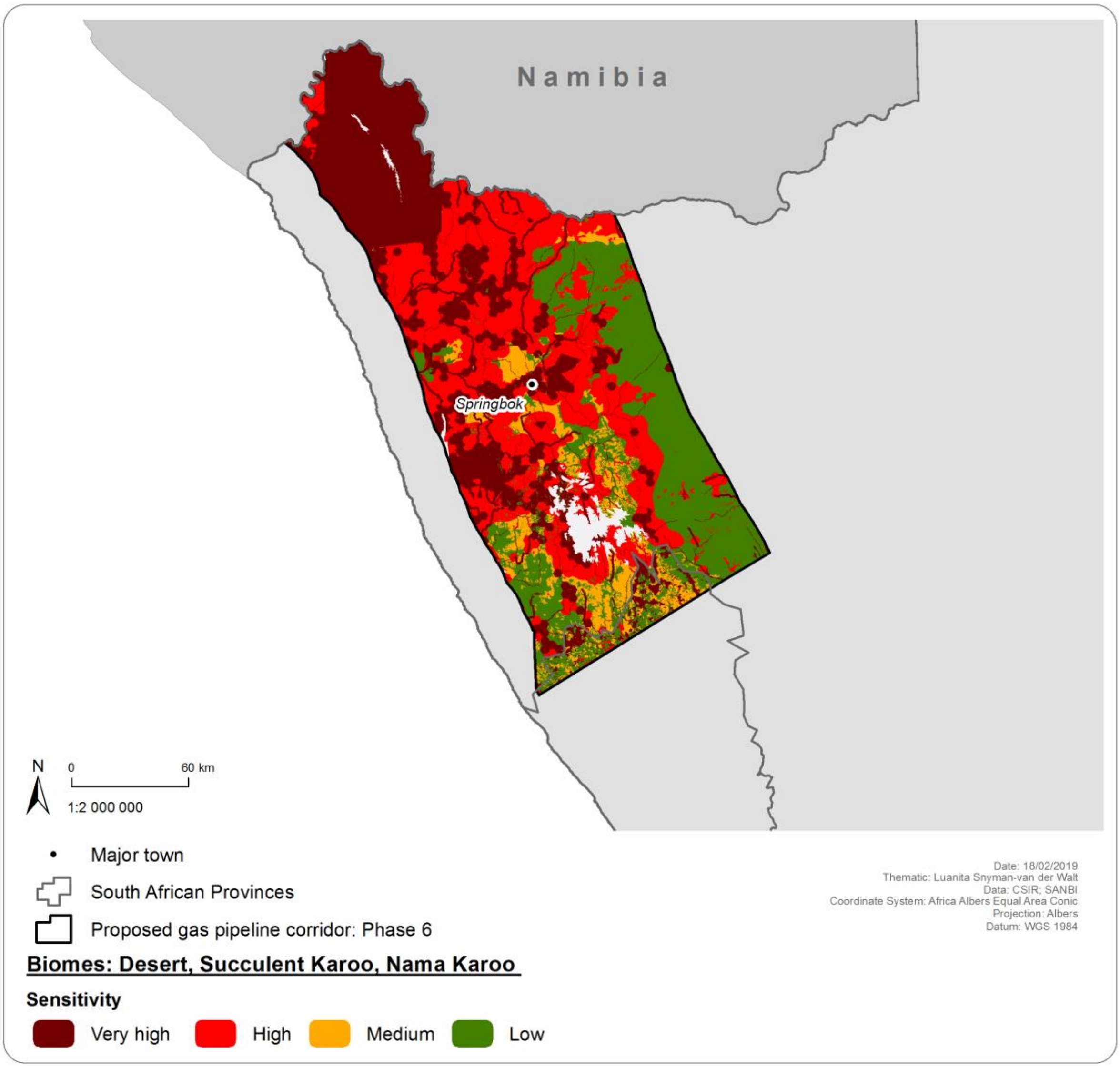

Figure 15. Sensitivity of Desert and Karoo ecosystems in the proposed Gas Pipeline Phase 6 corridor.

5.3.5 Gas Pipeline Corridor - Phase 7

There is very little Karoo habitat within the Phase 7 corridor, with a small extent of Albany Broken Veld in the western section of the corridor (Figure 16). The vegetation type is transitional between the low grassy shrublands of the open plains and the thickets on the slopes of the hills of the area. The majority of species and features of conservation concern within this area are associated with the adjacent areas of thicket, grassland or small pockets of Afromontane forest that occur in moist positions along the mountains of the area (Figure 17). There are numerous private as well as public nature reserves in this area.

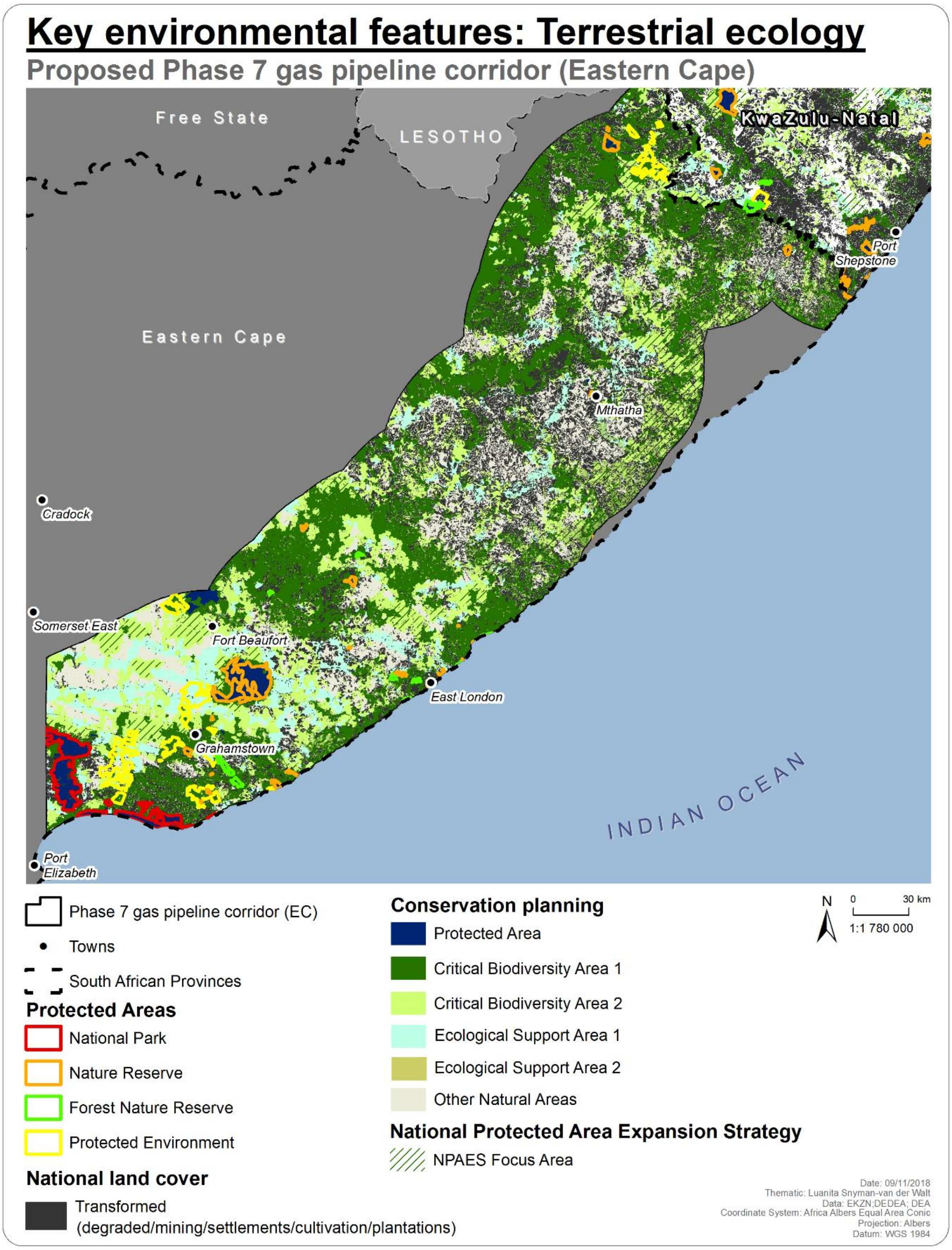

Figure 16. Key environmental features of the Nama Karoo ecosystem in the proposed Gas Pipeline Phase 7 corridor.

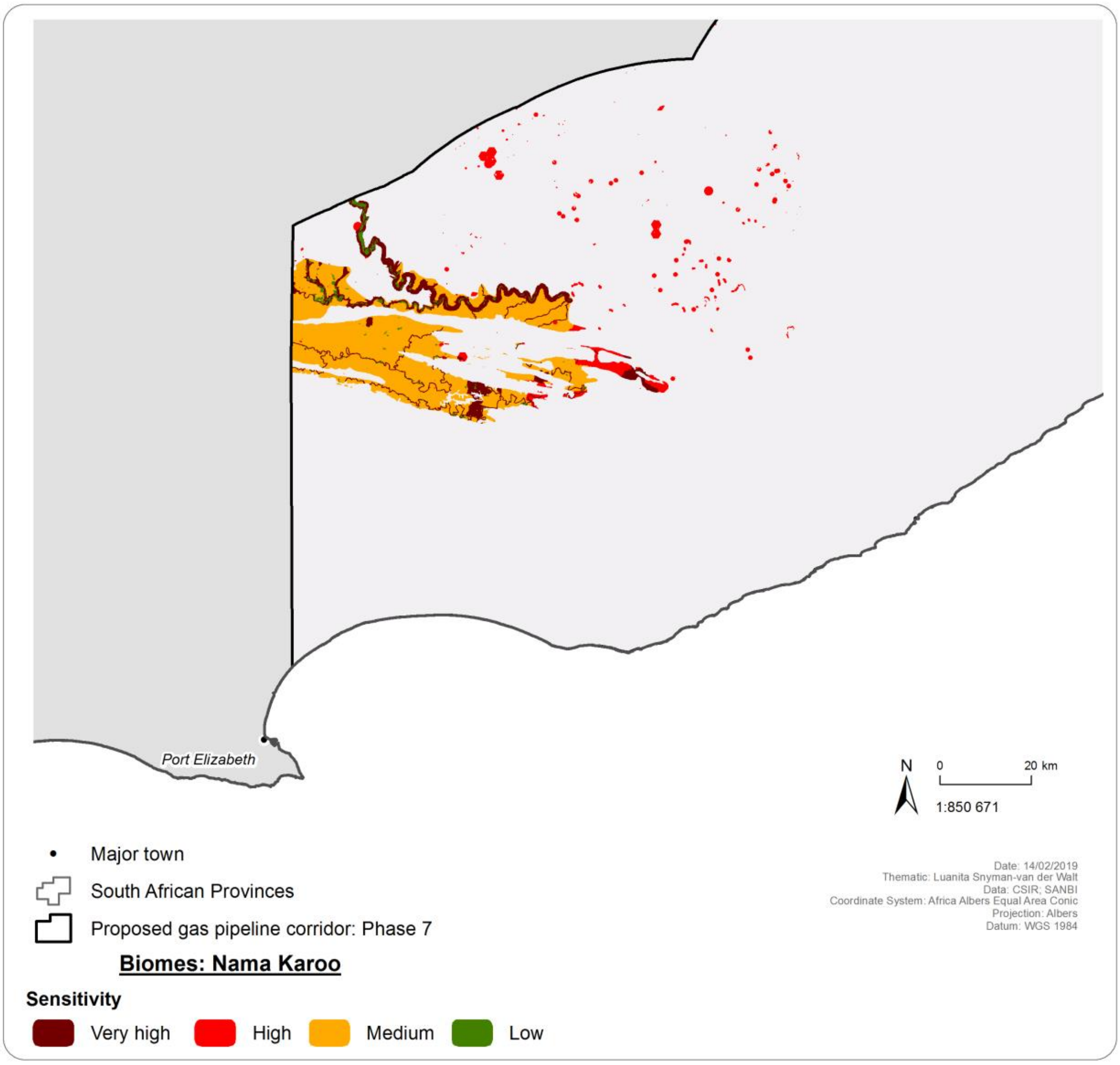

Figure 17. Sensitivity of the Nama Karoo ecosystem in the proposed Gas Pipeline Phase 7 corridor.

5.3.6 Gas Pipeline Corridor - Inland

The inland corridor consists of the plains of the Lower Karoo in the south, which gives way to the Roggeveld and Nuweveld mountain ranges in the north (Figure 18). In general, at a broad level the areas of Lower Karoo are considered less sensitive than the mountains and Upper Karoo in the north. Important features of the Inland Corridor include the Tanqua Karoo National Park in the west, the Roggeveld Mountains which lie within the Roggeveld-Hantam centre of endemism, as well as the Karoo National Park near Beaufort West and the Camdeboo National Park near Graaff-Reinet in the east (Figure 19). Diversity of the rugged northern sections of the inland Corridor is considered high and these areas are considered generally unsuitable for a pipeline. The area from Sutherland across Beaufort West and up towards Loxton and Victoria West is also home to the Critically Endangered Riverine Rabbit. The open plains to the south of the mountains are however generally of lower diversity with the key biodiversity feature present being the major drainage features such as the Gamka, Buffels, Dwyka, Kariega and Sundays Rivers.

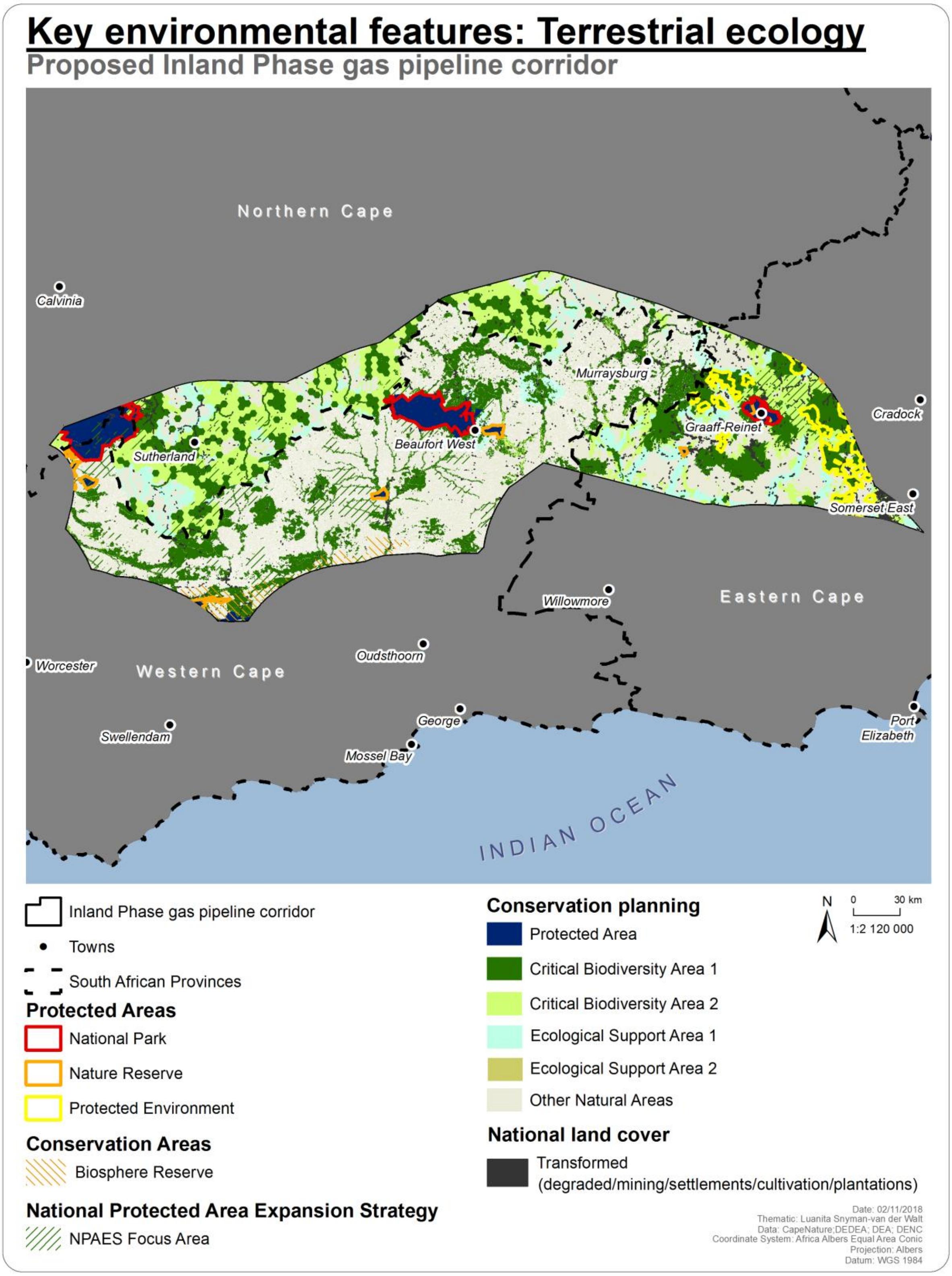

Figure 18. Key environmental features in the proposed Gas Pipeline Inland Phase corridor.

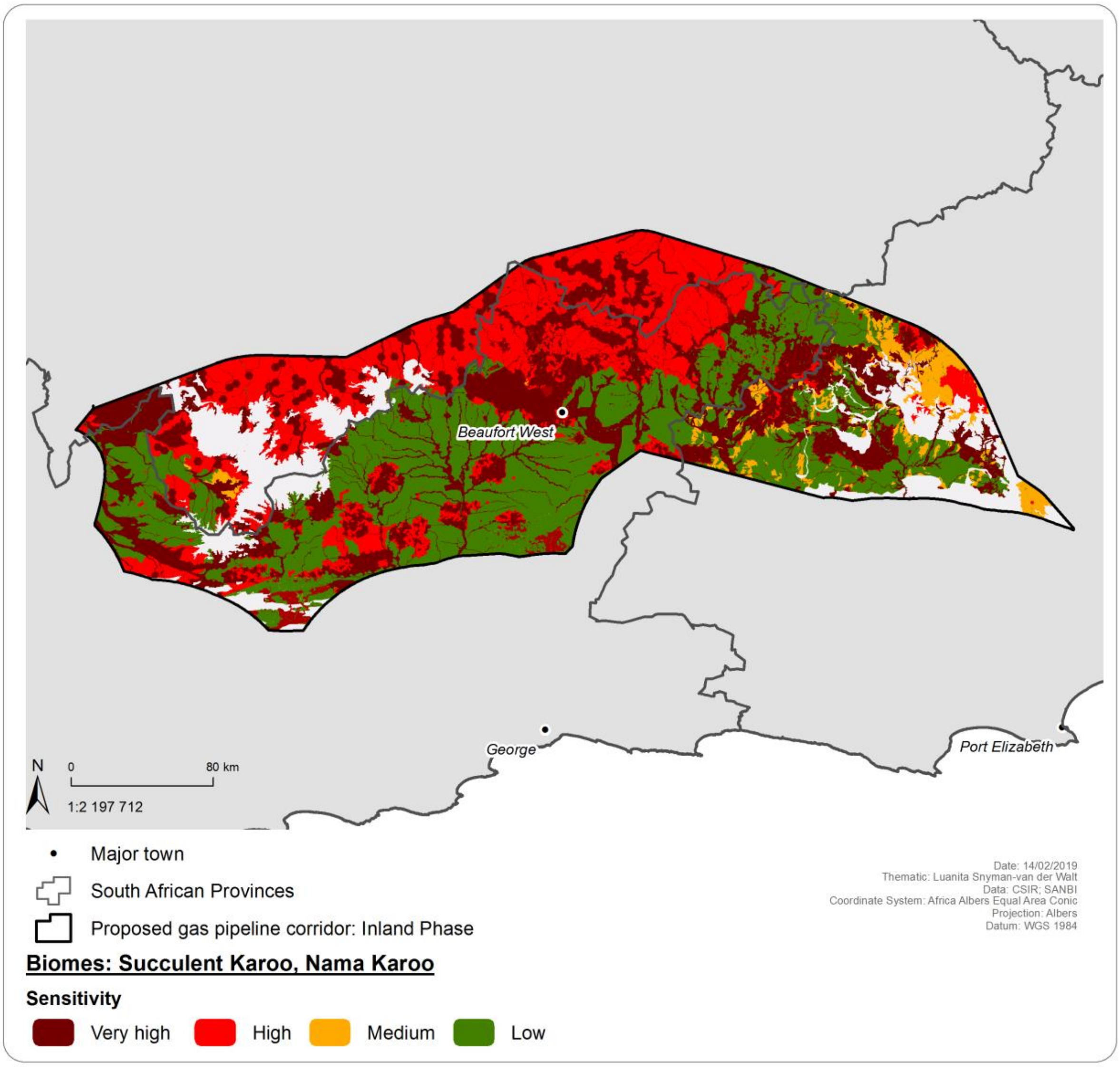

Figure 19. Sensitivity of Karoo ecosystems in the proposed Gas Pipeline Inland Phase corridor.

5.4 Environmental suitability of gas pipeline corridors

The largest constraints on the construction of the gas pipeline appear to be operating within the Desert region along the Orange River Valley and the broader Succulent Karoo, in particular the Richtersveld, the Knersvlakte and the Namaqualand sections of the corridor. This stems from the higher general sensitivity of these areas as well as the particular ecological features and high diversity of locally endemic species that are present within the Phase 6 Gas Corridor. These numerous high and very high sensitivity areas that are dominating across the corridor are generally associated with areas of conservation concern including formal Protected Areas, CBAs, ESAs and areas earmarked for protected area expansion. These areas, in addition to the mountainous upland terrain of the Kamiesberge and the Richtersveld, which could pose serious engineering constraints, can all be considered 'no-go' areas that should largely be avoided.

However, despite the high and very high sensitivity of the coastal plains along the western extremities of the corridor, in addition to the numerous mining rights that are active in this region, there are much improved opportunities for the gas pipeline routing to follow based on more detailed mapping and corridor refinement as the overall undulating to flat topography, soils and poor ecological state of this area are more conducive to gas pipeline construction. Also, it is further recommended that the lower sensitive areas located to the far eastern and south-eastern sections of the corridor be considered for gas pipeline construction.

6 KEY POTENTIAL IMPACTS AND PROPOSED MANAGEMENT ACTIONS

Impacts associated with gas transmission pipelines may occur during the construction, operation or maintenance of the pipeline (Table 7). Typical impacts during construction are related to the removal of vegetation and the disturbance of soils within the pipeline servitude, constructing access roads and installing the pipeline. Gas pipeline servitudes and other linear developments like transmission lines, roads, seismic lines and trails can increase human access into new, undisturbed areas; damage sensitive ecosystems and destroy plant SCC; displace fauna from their natural habitat; act as barriers to wildlife movement and also affect faunal migration routes. Such servitudes may cross different ecosystems and can fragment habitats, lead to the clearance of sensitive vegetation and create pathways for the spread of invasive species. Servitude stream crossings can result in significant bio-physical as well as engineering problems. The scope and magnitude of any gas pipeline project requires proper mitigation and management actions to protect natural biological diversity, especially in areas of high and very-high ecological sensitivity.

Maintenance of gas pipeline servitudes often involves the chemical or mechanical control of vegetative growth (specifically of deep-rooted species and alien invasive plants) within the servitude contributing to the loss of natural plant species diversity. Cleared servitudes may also be a continued source of sedimentation, due to possible soil erosion, into nearby watercourses. Frequent maintenance could further result in soil compaction, alteration of natural landscape topography and drainage patterns, and the disruption of normal groundwater flows. Repair and maintenance activities can also disturb wildlife, result in spills and contribute to continued habitat loss.

Table 7. Key potential impacts on terrestrial Karoo and Desert Biome ecosystems associated with gas pipeline construction and operation with proposed management actions.

Key Impact/impact driver	Description and possible effect	Proposed management actions
Vegetation destruction, habitat loss and impact on plant species of conservation concern as a result of servitude clearance	Removal of vegetation cover will result in: • Increased risk of threatened, protected and endemic species loss; • Decline in ecosystem resilience; • Disruption of ecosystem services; • Increased habitat fragmentation; • Change in terrain morphology; • Change in water surface runoff; • Loss of topsoil; • Increased noise levels and dust deposition; • Increased risk of illegal collection of indigenous medicinal plants and other valuable plants by collectors e.g. cycads, rare succulents and orchids, etc. and • Increased risk of illegal harvesting of timber and/or firewood.	<u>**Avoid**</u> *<u>Planning</u>:* • Use of environmental sensitivity maps and least cost in routing design; • Design and layout of infrastructure to avoid highly sensitivity areas; • Ground assessments and pre-construction walk-through by specialist to further refine the layout and further reduce impacts on sensitive habitats and protected species through micro-siting of the development footprint; • Placement of infrastructure should be done in such a way that no threatened SCCs are affected; • Design to use as much common/shared infrastructure as possible with development in nodes, rather than spread out; • Avoid any construction on steep slopes (>25 degrees). *<u>Construction</u>:* • Avoid any unnecessary vegetation clearance; and • No collection of 'fuelwood' should be allowed on site. <u>**Minimise**</u> *<u>Construction</u>:* • Minimise construction footprint with careful planning; • Construction footprint should be clearly demarcated; • Use existing roads as far as possible for access; • Construction outside of peak rain season as much as possible; • Soil compaction should be kept to a minimum by restricting driving to designated roads; • Use plant rescue to remove rare plants in construction footprint; • If roads or structures are fenced, use plain strands and not jackal proof fencing to ensure animals can still move through fences; and

Key Impact/impact driver	Description and possible effect	Proposed management actions
		• Excessive dust can be reduced by spraying water onto the soil to control dust generation. Other suitable dust control mitigation measures can also be considered. **<u>Rehabilitate</u>** *<u>Construction</u>:* • During construction maintain topsoil for later rehabilitation; • Revegetate all cleared areas as soon as possible following construction; • Rehabilitate using locally indigenous plant species. Where feasible translocate savage plants. Where not feasible use a seed mix that includes both annuals and perennials. • Stabilise all slopes and embankments of water courses; and • Where fragmentation of key habitats has occurred use landscape design methods to re-establish ecological connectivity such as green bridges or wildlife crossings, establishment of conservation corridors, underpasses for migrating animals, use of indigenous seeds and plants for landscaping, creation of riparian strips and revitalisation of flowing waterbodies.
Impact on faunal SCC	• Loss of faunal habitat and consequently loss of SCC; • Open deep trenches can trap certain ground-dwelling animals with no shelter, water or food. Also, if the trenches fill with water, animals that cannot escape, drown; • Possible ensnarement of animals or ingestion waste due to materials such as cables and plastic left lying around on site; • Increases in noise, vibrations, dust and light levels could potentially cause changes in behavioural patterns of animals and cause them to flee the area; • Increase in road traffic and associated road kills; • Faunal mortalities as a result of soil compaction and construction activities; • Soil compaction and open trenches may hamper overland and subsoil movement (e.g. mole rats) of some	**<u>Avoid</u>** *<u>Planning</u>:* • Avoid identified areas of high fauna importance, including SCC. *<u>Construction</u>:* • Avoid poaching of animals, or illegal collection of rare species. All instances of illegal collection should be reported to the applicable provincial Nature Conservation Authorities; • No dogs or other pets should be allowed on site; • Proper waste management procedures should be in place to avoid waste lying around and where possible to remove all waste material from the site. • Avoid road kills as far as possible; and • No construction should be done at night, as far as

Key Impact/impact driver	Description and possible effect	Proposed management actions
	animals • Increased human activities may cause animals to migrate away from their natural habitat; and • Increased risk of poaching due to an increase in human activities and road access to formerly remote and inaccessible areas. • Electrocution on ground as tortoises and other small fauna that get stuck underneath or against electrical fences, should such electrified fencing be installed.	possible. **Minimise** *Planning:* • Appropriate design of roads and other infrastructure where appropriate to minimise faunal impacts and allow fauna to pass through or underneath these features. *Construction:* • Search and rescue for reptiles and other vulnerable species during construction, before areas are cleared, as well as fauna that become trapped in trenches; • Access to the construction site should be strictly regulated and limited, and ensure that construction staff and machinery remain within the demarcated construction areas during the construction phase; • Environmental training for all staff and contractors on-site to increase their awareness of environmental concerns; • Night driving should be limited on site; • Appropriate lighting should be installed to minimize negative effects on nocturnal animals; • Speed limits should be set on all roads on site; and • Electrical fences, if installed, should be erected at least 30 cm from the ground or according to relevant the norms and standards of the Nature Conservation Authorities in the Western, Northern and Eastern Cape provinces. **Rehabilitate** *Operation:* • An Open Space Management Plan is required for the development, which makes provision for favourable management of the infrastructure and the surrounding area for fauna.
Alien plant invasion	• Removal of vegetation cover and topsoil can create pathways for the spread of invasive species; and • Altered soil structure and moisture promotes the establishment of alien invasive plants and animals.	**Avoid** *Construction:* • Avoid unnecessary disturbance of plant cover and topsoil;

Key Impact/impact driver	Description and possible effect	Proposed management actions
		• Use existing roads as far as possible; and • Do not use soil sources contaminated with alien invasive plant seeds for bedding of the pipe or for construction work. **Minimise** *Construction:* • Remove alien invasive plants occurring on or in vicinity of the construction site, preferably before they set seed. Dispose of all the cut plant material from site immediately using carefully considered and suitable methods that are in compliance with relevant legislation and based on consultation with experts, as required **Rehabilitate** *Construction:* • Remove all alien vegetation and re-vegetate disturbed areas as soon as possible after construction with perennial local fast-growing vegetation. Dispose of all the cut plant material from site immediately using carefully considered and suitable methods that are in compliance with relevant legislation and based on consultation with experts, as required. *Operation:* • Keep all livestock out of rehabilitated areas; • Avoid off road driving in rehabilitated areas; • An Alien Invasive Species (AIS) Management Plan to be implemented during the operational phase of the development, which makes provision for regular alien clearing and monitoring.
Soil disturbance and increased erosion	• Increased soil erosion and water run-off due to vegetation loss; • Potential siltation of drainage lines and watercourses.	**Avoid** *Construction:* • Avoid areas of high erosion vulnerability as much as possible; and • Clearing of vegetation, compaction and levelling should be restricted to the footprint of the proposed development.

Key Impact/impact driver	Description and possible effect	Proposed management actions
		<u>**Minimise and Rehabilitate**</u> *<u>Construction</u>:* • Revegetation of cleared areas with monitoring and follow-up to ensure that rehabilitation is successful; • Use barriers, geotextiles, active rehabilitation and other measures during and after construction to minimise soil movement at the site; • Roads should be provided with run-off structures; and • Roads should not be built on steep inclines.
Impact on CBAs and broad-scale ecological processes	• Changes in local habitat features and ecological processes; • Transformation of intact habitat within a CBA. Such CBAs are areas required to meet biodiversity targets for ecosystems, species or ecological processes and as such development in these areas is discouraged; • Transformation of habitat within an ESA. ESAs are areas that are not essential for meeting biodiversity targets, but play an important role in supporting the ecological functioning in a CBA; and • May affect the suitability of certain areas for inclusion in NPAES.	<u>**Avoid**</u> *<u>Planning and Construction</u>:* • Avoid CBAs as far as possible; and • Avoid impact to restricted and specialised habitats such as cliffs, large rocky outcrops, quartz, pebble patches and rock sheets. <u>**Minimise**</u> *<u>Planning and Construction</u>:* • Minimise construction in ESAs as far as possible. • Minimise the development footprint as much as possible and rehabilitate cleared areas after construction; and • Locate temporary-use areas such as construction camps and lay-down areas in previously disturbed areas as far as possible. <u>**Rehabilitate**</u> *<u>Operation</u>:* • Ensure that management of the pipeline development occurs in a biodiversity-conscious manner in accordance with an Open Space Management Plan for the development.
Cumulative impacts on habitat loss and broad-scale ecological processes	• Cumulative habitat loss; • Impact on broad-scale ecological processes; • Biodiversity loss; • Risk of explosions and/or gas leaks to aquatic and terrestrial ecosystems, including soil-dwelling fauna; and • Loss of wilderness character; ecotourism opportunities and the potential of unspoilt conservation areas.	<u>**Avoid**</u> *<u>Planning and Construction</u>:* • Avoid CBAs as far as possible. <u>**Minimise**</u> *<u>Planning and Construction</u>:* • Minimise construction in ESAs as far as possible.

Key Impact/impact driver	Description and possible effect	Proposed management actions
		• Ensure proper design and planning for demolition activities, with an emphasis on using delayed explosion methods, if blasting is required; • Minimise blasting operations to mid-day, where required; and • Minimise the development footprint as much as possible and rehabilitate cleared areas after construction is completed. **Rehabilitate** *Operation:* • Ensure that management of the pipeline development occurs in a biodiversity-conscious manner in accordance with an Open Space Management Plan for the development; • Ensure that gas pipeline infrastructure is regularly inspected for signs of corrosion or any potential perforation of the pipeline walls that could result in gas leaks and subsequent explosions

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7 RISK ASSESSMENT

7.1 Consequence levels

Consequence levels used in the risk assessment, with thresholds for species, ecosystems and ecological processes are presented in Table 8 below. Thresholds for species are linked to thresholds used in IUCN Red List assessments, and those for ecosystems and ecological processes are linked to thresholds used in national assessments of ecosystem threat status and in biodiversity planning in South Africa.

Table 8. Consequence levels used in the risk assessment, with thresholds for species, ecosystems and ecological processes.

	Consequence level →	Slight	Moderate	Substantial	Severe	Extreme
	Impact ↓					
Species of special concern	Reduction in population or occupied area*	<20% (Least Concern LC)	20-30% (Near Threatened NT)	30-50% (Vulnerable VU)	50-80% (Endangered EN)	80-100% (Critically Endangered CR)
Ecosystems (habitat types)	Reduction in intact area**	<20% (Least Threatened LT)	20-40% (Least Threatened LT)	40-60% (Vulnerable VU)	60-80% (Endangered EN)	80-100% (Critically Endangered CR)
Ecological processes	Disruption of ecological functioning***	<20%	20-40%	40-60%	60-80%	80-100%

** In relation to national distribution (except for keystone species – in relation to study area)*

*** In relation to national distribution*

**** In relation to their functioning within the study area*

7.2 Risk assessment results

Biodiversity features do not necessarily share the same potential for mitigation after impact. This may depend on the extent, duration and severity of each impact, but also on the sensitivity of the receiving environment. Areas of very high and high ecological sensitivity, comprising both plant and animal SCC will be more vulnerable. The success of management actions may be variable.

Table 9. Impacts and risk assessment with and without mitigation applicable to all six gas pipeline corridor phases in this assessment.

Impact	Location	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Vegetation removal and habitat loss due to clearance and infrastructure development, including impact on plant SCC	Very High	Extreme	Very Likely	Very High	Severe	Very Likely	High
	High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
	Medium	Substantial	Very Likely	Moderate	Moderate	Likely	Low
	Low	Moderate	Very Likely	Low	Slight	Likely	Very Low
Impact on fauna due to habitat loss, including impact on fauna SCC	Very High	Extreme	Very Likely	Very High	Severe	Very Likely	High
	High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
	Medium	Substantial	Very Likely	Moderate	Moderate	Very Likely	Low
	Low	Moderate	Likely	Low	Slight	Likely	Very Low
Increased risk of alien plant invasion	Very High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
	High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
	Medium	Substantial	Very Likely	Moderate	Moderate	Likely	Low
	Low	Moderate	Likely	Low	Slight	Likely	Very Low
Impact of wind and water erosion	Very High	Severe	Very Likely	High	Substantial	Likely	Moderate
	High	Substantial	Very Likely	Moderate	Moderate	Likely	Low
	Medium	Moderate	Likely	Low	Slight	Not Likely	Very Low
	Low	Moderate	Likely	Low	Slight	Not Likely	Very Low
Impact on CBAs and broad-scale	Very High	Extreme	Very Likely	Very High	Severe	Very Likely	High

Impact	Location	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
ecological processes	High	Severe	Very Likely	High	Substantial	Likely	Moderate
	Medium	Substantial	Likely	Moderate	Moderate	Likely	Low
	Low	Moderate	Likely	Low	Slight	Not Likely	Very Low
Cumulative ecological impacts	Very High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
	High	Substantial	Likely	Moderate	Moderate	Likely	Low
	Medium	Moderate	Not likely	Low	Slight	Not Likely	Very Low
	Low	Slight	Not likely	Very Low	Slight	Very Unlikely	Very Low

7.3 Limits of Acceptable Change

Limits of acceptable change are defined as the variation that is considered acceptable by experts in the field (Stankey *et al.*, 1985) of a particular environmental indictor of a component or process of the ecological system in question. Potential limits of acceptable change for the Nama Karoo, Succulent Karoo and Desert biomes have been suggested by this author and are presented in Table 10.

Table 10. Suggested limits of acceptable change

Variable	Threat Status	Acceptable Change
Vegetation/Ecosystem Types	Critically Endangered	No Nett Loss of Vegetation/Ecosystem Type
	Endangered	No Nett Loss of Vegetation/Ecosystem Type
	Vulnerable	No more than 1% of the remaining extent of the vegetation type. No loss resulting in the vegetation type being elevated to a higher threat status
	Near-Threatened	No more than 5% of the remaining extent of the vegetation type No loss resulting in the vegetation type being elevated to a higher threat status
Plant SCC	Critically Endangered	No Nett Loss of plant SCC
	Endangered	No Nett Loss of plant SCC
	Vulnerable	No more than 1% of the remaining local population No loss resulting in a species being elevated to a higher threat status
	Near-Threatened	No more than 5% of the remaining local population No loss resulting in a species being elevated to a higher threat status
Fauna SCC	Critically Endangered	No nett loss of fauna SCC or resulting in a SCC being elevated to a higher threat status. Should sections of the planned Gas Pipeline routes transect the known Extent of Occurrence / distribution of a fauna SCC, a taxon-specific specialist should be appointed to confirm the sensitivity and assess the significance of potential impacts on that SCC. The impact assessment process must prove to the relevant competent authority that the proposed development will not have an unacceptable negative impact on SCC populations, both locally and regionally. Any identified impacts should be avoided or mitigated. All mitigation measures from the specialist study are to be incorporated into the EMPr. A South African Council for Natural Scientific Professions (SACNASP) accredited zoologist must conduct the impact assessment in accordance with the NEMA regulations.
	Endangered	
	Vulnerable	
	Data Deficient	
Alien plant invasion	All sensitivity categories	No invasion of adjacent natural habitats
Wind and water erosion activity	All sensitivity categories	No long-term soil erosion
Loss of CBAs	CBA1	No loss of irreplaceable CBAs No loss resulting in it no longer being possible to meet biodiversity targets

8 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

8.1 Planning phase

- Planning stage avoidance of high-threat status ecosystems, as well as fauna and flora species populations of conservation concern is required. In many areas, the known extent of occurrence (EoO) / distribution range of SCC are not well known and as such, the planning phase should make provision for flexibility in determining the final pipeline alignment to avoid locally sensitive features and populations of SCC. Should sections of the planned gas pipeline route transect the known EoO / distribution of an SCC, a taxon-specific specialist should be appointed to confirm the sensitivity and assess the significance of potential impacts on that SCC. The impact assessment process must prove to the relevant competent authority that the proposed development will not have an unacceptable negative impact on SCC populations, both locally and regionally. Any identified impacts should be avoided or mitigated. All mitigation measures from the specialist study to be incorporated into the EMPr. A SACNASP accredited botanist and zoologist must conduct the impact assessment in accordance with the NEMA regulations.
- Pre-construction walk-through and on-site assessment by a SACNASP accredited botanist and zoologist of the final pipeline route is mandatory to identify any features that should be avoided or buffered from impact, and to identify and locate any plant and animal SCC that should be subject to search and rescue prior to construction.
- The final gas pipeline route should be checked in the field by the appropriate accredited specialists and at the appropriate time of year. In the winter rainfall areas, all fieldwork for flora should take place from late July through to mid-September depending on the exact timing of rainfall. In the summer rainfall areas, fieldwork should take place following good rainfall and growth of the vegetation. In most areas this is usually late summer to early autumn (February to April).
- Where high sensitivity areas cannot be avoided and there is significant habitat loss in these areas, an offset study should be conducted to ascertain whether an offset is an appropriate mechanism to offset the impact on the high sensitivity area. This should include an identification of offset receiving areas as well as an estimate of the required extent of the offset and the degree to which the offset would be able to compensate for the assessed impacts.

8.2 Construction phase

- The construction operating corridor should be clearly delimited and demarcated with construction tape or similar markers to limit construction activity and disturbance to the pipeline corridor.
- Temporary lay-down areas should be located within previously transformed areas or areas that have been identified as being of low sensitivity. These areas should be rehabilitated after use.
- All construction vehicles should adhere to a low speed limit (30km/h for trucks and 40km/h for light vehicles) to avoid collisions with susceptible species such as snakes and tortoises.
- All hazardous materials should be stored in the appropriate manner to prevent contamination of the site. Any accidental chemical, fuel and oil spills that occur at the site should be cleaned up in the appropriate manner as related to the nature of the spill.
- Any trenches or holes that need to be dug should not be left open for extended periods of time as fauna may fall in and become trapped. Trenches which are standing open should have places where there are soil ramps allowing fauna to escape the trench.
- Measures should be taken to prevent and limit poaching of fauna and harvesting of flora by construction crews or other people accessing the pipeline route.

8.3 Operations phase

- If parts of the pipeline such as compressor stations (which is not part of the scope of the assessment) need to be lit at night for security purposes, this should be done with low-UV type lights (such as most LEDs), which do not attract insects.

- If any parts of the pipeline, or any work area in the vicinity of the pipeline need to be fenced, then no electrified strands should be placed within 30 cm of the ground as some species such as tortoises are susceptible to electrocution from electric fences as they do not move away when electrocuted but rather adopt defensive behaviour and are killed by repeated shocks.
- All vehicles accessing the pipeline should adhere to a low speed limit (30 km/h max) to avoid collisions with susceptible species such as snakes and tortoises.
- Oils, fuels and other hazardous materials required for machine and vehicle maintenance and repair are to be securely stored to prevent spill and contamination during operation and maintenance of the gas pipeline infrastructure.
- Regular alien clearing along the pipeline route is required. An annual check and clearing should be sufficient in most arid and semi-arid areas.
- Regular erosion monitoring and remediation. An annual check with follow-up rehabilitation and remediation should be sufficient in most areas. It is important to note that erosion can be severe in semi-arid environments due to the occasional occurrence of heavy showers and the lack of sufficient vegetation cover to protect the soil or slow runoff, with the result that occasional high-risk erosion events can cause large amounts of damage.
- Access to the pipeline servitude should be restricted to service and maintenance staff and affected landowners.

8.4 Rehabilitation and post closure

Arid areas are very difficult to rehabilitate with a variety of constraints limiting success. In most cases topsoil management is a key factor as the soils deeper down may have a very high pH, be salt- or metal-laden, be very nutrient poor or otherwise inhospitable to plant establishment. Furthermore, in most instances, the restoration of pre-construction levels of diversity is not a realistic goal and the rehabilitation should focus on the establishment of an ecologically functional cover of locally-occurring species to protect the soil and provide some cover for fauna. The following recommendations are provided for the rehabilitation and post closure phase:

- Clear rehabilitation targets should be set for each area based on the background perennial vegetation cover. A reasonable target would be 60% of the vegetation cover of adjacent indigenous vegetation achieved after five years.
- All species used in rehabilitation should be locally occurring perennial species. A mixture of different functional type species is recommended.
- No fertilizers or irrigation should be applied during rehabilitation as this is likely to lead to a green flush after rain and failure of perennial species to establish in competition with annuals and ephemerals.
- There should be annual monitoring and follow-up action on alien species occurrence and erosion.

8.5 Monitoring requirements

- Populations of key fauna and flora SCC, of which the known extent of occurrence or distribution range was identified and confirmed by a SACNASP accredited botanist and zoologist during the planning (pre-construction) phase and which are being transected by the planned gas pipeline route, should be monitored throughout construction and operation to ensure that these SCC are not being poached or otherwise negatively impacted by the presence and operation of the gas pipeline. Monitoring frequency depends to some extent on the longevity of a specific species, but should also be informed by its threat status and the consequences of not identifying unacceptable negative impacts beforehand. Any identified impacts should be avoided or mitigated. As such, the following basic monitoring schedule is proposed – Pre-construction, Post-construction and every 3-5 years during operation depending on the species.
- The successful establishment and persistence of plant species of high conservation concern translocated during the search and rescue should be monitored for at least five years after construction is completed. An appropriate frequency would be a year after translocation and every second year thereafter.

9 GAPS IN KNOWLEDGE

- A major gap in knowledge for the Karoo study area is that there is a paucity of baseline information as the area is generally poorly sampled and sparsely distributed with the result that extensive areas will have no records for fauna or flora in the existing biodiversity databases.
- Areas with generally good records include the national parks, along the main access roads and near to towns and other popular tourist destinations.
- As a result, all areas should receive detailed baseline data collection in the appropriate season to inform the final pipeline alignment.

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