Impacts on Heritage

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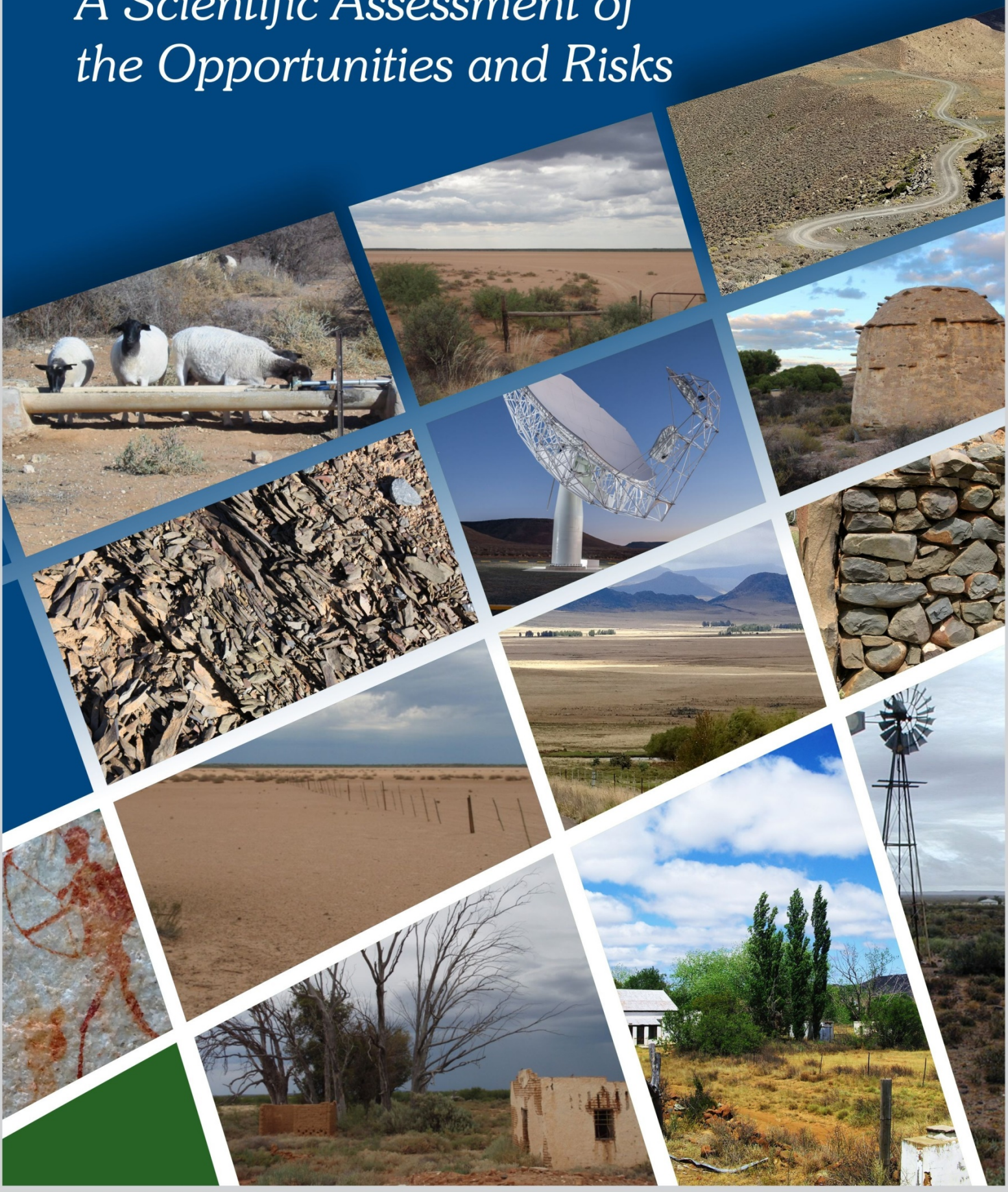
Shale Gas Development in the Central Karoo:

A Scientific Assessment of the Opportunities and Risks



Shale Gas Development in the Central Karoo:
A Scientific Assessment of the Opportunities and Risks

The Central Karoo is an arid, extensive landscape, experienced by many people as a sanctuary of austere but captivating beauty. At the same time, the people who live in the region are mostly poor - high levels of unemployment and inequality characterise the local economies and social fabric. South Africa is investigating the opportunities for introducing more natural gas into the predominantly coal-dominated energy mix. One option is to exploit naturally occurring methane, liberated from deep shale layers in the Central Karoo through horizontal drilling and hydraulic fracturing technologies ('fracking'). Very little is known about the distribution and magnitude of the gas resource, or whether it can be extracted at economically viable rates. If shale gas development were found to be economically viable, the economic and energy security opportunities of a medium to large shale gas resource would be substantial; as would be the social and environmental risks associated with a gas industry in the Central Karoo. This has been presented to the public and decision-makers as a stark choice between economic opportunity on the one hand and environmental protection on the other. It has become a highly divisive topic, but one which has been, up to now, poorly informed by publically-available and trusted evidence. To address this lack of critically-evaluated information, a Strategic Environmental Assessment (SEA) for shale gas development was commissioned in 2015 by five national government departments of the Republic of South Africa. Phase 2 of the SEA process was undertaken as an independent 'scientific assessment' and is reported in this book. The 18 chapters were drafted by 146 authors and peer reviewed by a further 75 independent experts and also by stakeholders involved in the process. It is the largest scientific assessment ever undertaken in South Africa and has set a national precedent on how strategic issues of great importance and consequence should be dealt with if critical development choices are to be guided by evidence-based policies.

Prof Robert (Bob) Scholes is a systems ecologist at the University of the Witwatersrand. He has led many assessments over the past 25 years, including parts of the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment, the South African Assessment on Elephant Management, and the global Land Degradation and Restoration Assessments.

Paul Lochner is an environmental assessment practitioner at the CSIR in Stellenbosch, with over 25 years of experience in a wide range of environmental assessment and management studies. His particular experience is in the renewable energy, oil and gas, and industrial and port development sectors. He has been closely involved in the application of Strategic Environmental Assessment in South Africa.

Greg Schreiner started work at CSIR in 2011. He is interested in innovative and novel approaches to environmental assessment and management; and the social processes which underpin good decision-making. He has a Masters Degree in Environment and Development from the University of Cambridge. He has for the past 2 years managed the day to day processes of the shale gas SEA.

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Shale Gas Development in the Central Karoo

A Scientific Assessment of the Opportunities and Risks

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Foreword

Much has been said and written about the importance of evidence-based policy-making, about the benefits that will accrue from decisions that are based on sound evidence, and from the ability to accurately compare the real to the expected results of our actions. As scientists we have welcomed these developments - this is of course the world with which many of us are intimately familiar, a world where the facts matter and our theories and inventions have to prove that they are able to deal with reality. However, this welcome development brings with it a great responsibility. The consequences of getting it wrong, of making mistakes, are no longer limited to our academic standing amongst our peers, or to the opportunities we spurn by following dead ends. Now, the consequences are potentially much more serious, and may involve the lives and livelihoods of entire communities, the shape and size of our economy and the very ability of our environment to sustain human life.

The question of whether or not South Africa should exploit, through hydraulic fracturing, its natural gas reserves trapped within the deep shale layers in the Karoo Basin emerged in 2010. This question is a clear example of both the importance and complexity of working in the policy environment - the stakes could not possibly be higher, with important long-term consequences, either environmentally or economically, for South Africa's future. It is to the great credit of both parties - the policy-makers who will take responsibility for our course of action and the scientists who have been asked to advise them - which neither has baulked at the task that has been placed before them.

The result of this collaboration, reported on in this document, is a meticulous and multi-disciplinary assessment which presents, in an objective and balanced fashion, the opportunities and risks associated with shale gas development in South Africa across different scenarios. Over 200 of the best national and international scientists have, over 18 months, contributed to this study, and through a process of rigorous peer-review ensured that we have made the best use of the evidence and insights at our disposal.

The process has included close collaboration with government, non-governmental organisations and research institutions, and consisted of an extensive stakeholder outreach programme using multiple communication mediums. It is the largest scientific assessment undertaken in South Africa in terms of material scope and participation, both scientific and stakeholder based.

As CEO of the CSIR, the organisation which led this scientific assessment, I am extremely proud of the manner in which such an important national issue has been addressed. I also am grateful to my contemporaries at the South African National Biodiversity Institute (SANBI) and the Council for Geosciences (CGS) for their collaboration through the project. Recognition must go to Government, for commissioning the CSIR, in collaboration with other national scientific bodies, to co-ordinate this independent process. I am grateful to the participating scientists who gave so willingly of their time and expertise.

Most of all, I am grateful to the South African public, for their participation in this landmark process and in exercising their civil rights and duties by contributing so diligently. The collaborative philosophy in which the scientific assessment process has been undertaken has been an astonishing success. I hope that, when confronted with equally important choices, our policy-makers can look back on this exercise as a model for their future actions.

Dr Sibusiso Sibisi

CEO, CSIR

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Reviewers

The process developed to generate the scientific material for this publication relied on a collaborative endeavour between authors, expert peer reviewers and stakeholders. This resulted in a 'co-production' of the evidence-base. The Editors would like to acknowledge and thank all the reviewers who made valuable contributions to the book. This includes the 75 national and international expert peer reviewers nominated to review specific First Order Draft chapters, indicated in the list below as [PR] (to denote 'peer reviewer') and the Chapter which they were responsible for reviewing. In addition, thanks are extended to the stakeholder reviewers who contributed to the Second Order Draft review process. They are also listed below with their affiliated institutions.

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CHAPTER 15

Impacts on Heritage

CHAPTER 15: IMPACTS ON HERITAGE

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Executive Summary

The study area contains a rich layering of heritage resources stretching over some 4.6 billion years. Geological heritage sites and meteorites are the oldest aspects of heritage considered here, while palaeontological resources cover more than 300 million years of prehistory. The archaeological record spans some 2 million years and covers the Early, Middle and Late Stone Ages, as well as the Iron Age and historical period. The latter is responsible for the bulk of the built heritage that occurs, including the well-known Karoo vernacular architecture. Ensembles of individual cultural heritage resources relate to one another in various ways to produce urban and rural cultural landscapes throughout the study area. Living heritage binds the physical resources together and provides much of the character that is so highly valued by a wide community of South Africans.

Heritage resources in the study area are part of the National Estate and thus belong to the people of South Africa. While most are of relatively low heritage significance, there are numerous sites of high significance scattered across the region, including many that are formally declared. Archaeological and palaeontological resources are found throughout the study area but, because of weathering and erosion of the land surface, the context, preservation, and academic value of much of this material is limited, especially in the case of archaeology. However, important sites will occur in most areas. Built heritage resources add much cultural value to the study area and comprise the vast majority of declared sites. Cultural landscapes are both rural and urban, and specific areas generally have high significance because of the spatial relationship between multiple individual resources. The entire study area, however, has seen some degree of human modification and thus can be considered part of the regional cultural landscape. Living heritage is a key element of the National Estate in the Karoo because the last vestiges of a number of communities are still represented there.

Shale gas development (SGD) will impact on heritage resources no matter where development occurs in the study area, but the risk would vary markedly depending on the specific locations of wellpads, access roads and related infrastructure, and the amount of induced seismic activity that occurs. Heritage resources are distributed in variable densities throughout the study area but, because of generally low survey coverage, the actual distribution of resources is poorly known. Small pockets of high coverage indicate that important resources of all types can occur anywhere in the landscape but that river valleys, rocky ridges and the undulating uplands tend to be more sensitive than the open plains for some categories of heritage, largely because of access to water. Seismic activity could affect heritage resources to varying degrees depending on their fragility, but built heritage is most at risk.

Due to the great variety of physical manifestations of the various types of heritage, the degree of risk relating to each is variable. Some aspects result in a low risk before mitigation, while others will result in high risk. Only one aspect produces a very high risk before mitigation, but this reduces to high with mitigation. The majority of post-mitigation risks are assessed to be of a low or very low level. Greater risks are generally an indication of those aspects of heritage that would experience residual impacts after mitigation.

When viewed from a heritage perspective, the limited SGD envisaged under Scenario 2 (Small Gas) and Scenario 3 (Big Gas) is feasible because the impacts would be confined to particular areas. However, the potential for extensive impacts from Scenario 1 (Exploration Only) is of concern because of the large area that might be impacted. Although it will not be possible to choose the exploration and/or development areas based on heritage resources, micro-siting of the infrastructure and the implementation of management and mitigation measures during all phases will help reduce the significance of the impacts. The most difficult aspects with which to deal in terms of mitigation are aspects relating to the cultural landscape and, along with minimising the amount of landscape scarring that occurs, effective closure phase rehabilitation will be key to the feasibility of the development.

CHAPTER 15: IMPACTS ON HERITAGE

15.1 Introduction and scope

15.1.1 What is meant by this topic?

15.1.1.1 The Karoo and shale gas development

The study area covers about 14% of South Africa, the greater portion of which falls within the Karoo, but a small portion in the southeast extends into the somewhat better watered Border Kei region. While the Karoo might mean different things for different people, the overriding sense is of a vast dryland. The very name 'Karoo' derives from a Khoekhoe word meaning 'hard' or 'dry' (Raper, n.d.). The unique sense of place and natural beauty of the Karoo derive from the expansiveness, remoteness and endless horizons that have inspired the creative genius in many of South Africa's cultural icons and more recently has become a centre for astronomical research. The region has cultural significance to the local communities who have lived and farmed there since at least the early 1700s. Its agricultural sector provides employment and it has considerable and growing value as an income-generating tourism resource (Atkinson, 2016). It contains one of the longest and most complete fossil records in the world, the consequence of 120 million years of continuous sedimentation into the Karoo basin (something that occurred nowhere else in the world). It also preserves a rich layering of early evidence of its precolonial inhabitants in the form of archaeological deposits, rock art and in the more recent historical past, various sites of confrontation, contestation and conflict. The history of the San, Khoekhoen, Trekboers, Basters and a section of the Xhosa nation is encapsulated in the rich layering of heritage resources, as is the more recent history of Dutch and British Colonialism and apartheid. Any loss of this will impoverish what is in effect a National Treasure – our largely intact, authentic and largely under-utilised Karoo heritage.

With such large areas and the great potential for ancillary development it is important that shale gas development (SGD) is properly managed in relation to heritage resources so as to ensure their preservation for future generations.

15.1.1.2 What is our heritage?

The broadest definition of heritage – itself a very broad topic – is simply 'that which is inherited'. Heritage includes physical objects and places, as well as the intangible aspects of culture and tradition that are passed down from earlier generations. This might be natural or cultural yet relates to the deepest past and is still being created, even as you read.

The protection of South Africa's cultural heritage is governed by the National Heritage Resources Act (NHRA) (No. 25 of 1999, 1999), which stipulates in Section 3(1) that any place or object is to be considered part of the National Estate if it has cultural significance or any other special value for current or future generations. Section 2(vi) of the NHRA mandates that something has cultural significance if it has aesthetic, architectural, historical, scientific, social, spiritual, linguistic or technological value or significance. These, then, are the qualities that allow something to fall within the ambit of the NHRA and hence heritage. Section 3(2) provides an extensive list of the types of heritage resources that might be included in the National Estate, while potential motivations are listed in Section 3(3). These sections of the NHRA (see Digital Addendum 15A) essentially provide a working definition for cultural heritage in South Africa and it is from them that this Chapter takes its lead. We describe the heritage resources under five sections, excluding aspects covered in other Chapters of this scientific assessment. Some aspects occur throughout the study area, while others have limited distributions. What follows is a brief overview of the five categories under assessment.

Grading of heritage resources

Section 7(1) of the NHRA provides for heritage resources to be assigned Grades I, II or III, while Section 7(2) provides for sub-categories of the latter two. Where Grades are referred to in this Chapter they follow the conventions established and applied by Heritage Western Cape (2016a) as follows:

- I: Sites of national significance.
- II: Sites of provincial or regional significance (no sub-categories).
- IIIA: Sites of high local significance (excellent examples of their kind or rare).
- IIIB: As for IIIA but at a slightly lower level of significance.
- IIIC: Significance is primarily contextual.
- NCW (Not Conservation-Worthy): Sites with little or no heritage value.

15.1.1.3 Built heritage (Section 34, Section 37)

Notwithstanding the definition of 'structures' as provided in the NHRA (see Digital Addendum 15A), here we take a broad view, so refer to 'built heritage' as also covering ensembles such as towns and farms, thereby not limiting the scope of what is included. The setting of individual built heritage resources, including monuments and memorials, as well as that of ensembles is of great importance and therefore incorporated. Military structures, which, according to the NHRA are also archaeological, are covered here, but precolonial structures are covered under archaeology.

Vernacular architecture?

The word vernacular (Latin: *vernaculus*) means 'domestic' or 'indigenous'. Vernacular architecture responds to local needs and the environment, reflects local cultural traditions and relies on local materials, technology and skills. It evolves in an organic manner in keeping with its historical context.

In the harsh, resource-scarce Karoo environment with its restricted range of materials, necessity often was the mother of invention when it came to constructing shelter, resulting in a unique regional vernacular building tradition that displays the creative and technical achievement required to fashion an existence there. This relied on both traditional and conventional artisanal skills since buildings were hand-crafted from sun-baked bricks, locally occurring timber and quarried or collected stone. The result was a variety of local styles that we refer to collectively as Karoo vernacular. This is an aesthetic valued by a wide community and, although its frequency diminishes towards the southeast, it is present throughout the study area. While 'Karoostyle', as described by Marincowitz (2006), typically incorporates flat roofs and parapets above a simple rectangular house (Figure 15.1), Karoo vernacular buildings tend to have evolved organically according to need or fashion and reflect much historical layering (Figure 15.2). Unique building typologies that occur in the study area are the corbelled houses (see text box) that developed as a direct response to the lack of available timber in the north-western part of the study area (Figure 15.3; Kramer, 2012) and the '*brakdak*' houses (Fagan, 2008) that employed locally available sticks, reeds and mud (traditionally mixed with chaff, animal manure, sedge or densely matted roots) in the creation of their flat roofs. Corbelled houses are poorly known because of their remote locations. Several are declared Provincial Heritage Sites (PHSs).

Figure 15.1: 'Karoostyle' houses: an abandoned rural dwelling near Williston that is being lost to neglect and a well maintained example from Victoria West.

Figure 15.2: Well-maintained Karoo vernacular dwellings: a cottage in Carnarvon and a farmhouse north of Matjiesfontein.

Figure 15.3: A small early corbelled house (likely 1820s or 1830s) may have originally been a kafhok, while a larger example has a square dome with a kitchen and wagon house added to the sides. Both are near Loxton.

Corbelled buildings – a unique and vulnerable vernacular resource

Corbelled buildings are built of blocks of flat stone. Each course of roof stones is laid in gradually smaller circles in two layers to create a dome-shaped roof. The floor diameter and roof height are directly related to one another to prevent collapse of the structure. They occur within the north-western part of the study area. Although corbelled buildings are found elsewhere in the world, the Karoo buildings are unique in displaying features related to the requirements of early Trekboer small stock pastoralists, both European and Basters (offspring of European/slave/Khoekhoen unions). Every structure is unique, thereby showing the level of proficiency and technological development of the builders and even their origins and social status. Karoo corbelled buildings (erected between about 1813 and 1870) are one of the first signs of permanent Trekboer or settler occupation of this harsh environment. As a physical statement of occupation they emphasised that the indigenous people had lost their land. Corbelled buildings are important examples of 'creolisation' (input from multiple sources, both European and indigenous) which was typical of frontier areas and they, along with their surrounding *werfs* (farmyards), allow us to understand early pastoralism in the area (Kramer, 2012).

The study area and surrounds have seen settlement by various cultures and has a diverse built heritage. The main activities that encouraged colonial settlement were pastoralism, religion, military and administrative needs, transport and infrastructural development and health care. Of late, astronomy (the South African Large Telescope [SALT] and the Square Kilometre Array [SKA]) has

introduced a new driver for development. Colonial occupation of the Karoo was initially by Trekboers who lived from their wagons and left no built traces. They relied on their skills of animal husbandry to be successful. Gradually, as local knowledge grew, they settled in simple vernacular homes and, with the need for some agriculture, water-related technology such as dams, water pits (*gorra*) and wind pumps became important (see also Section 15.1.1.4 below). Some of the earliest towns were established as mission stations (e.g. Carnarvon, Williston, Colesburg), while others, particularly on the frontier, were administrative centres (e.g. Graaff-Reinet, Beaufort West, Victoria West). Still others were established around Dutch Reformed Churches in response to local need (e.g. Sutherland, Loxton, Fraserburg).

In the east one finds Xhosa settlements characterised by vernacular architecture in the form of rondavels. This part of the study area is also home to mission settlements, such as Fort Beaufort (founded in the 1830s as the Kat River Settlement to provide a refuge and livelihood for freed slaves), military infrastructure, such as Fort Brown (constructed by British forces during their successive wars against the Xhosa) and the Martello Tower in Fort Beaufort (PHS; Figure 15.4; one of only two free standing dressed stone masonry structures typical of the type in use by the British between 1848 and 1869, a third was demolished), and important educational heritage sites such as Healdtown (one of several places with strong links to the origins of the Liberation movement in South Africa).

Figure 15.4: Martello Tower, Fort Beaufort.

During the late 19th century transport infrastructure, especially railways began to be built across the hinterland of the country. This was initially to service the Kimberley diamond fields, but also to connect the developing interior with coastal ports (Burman, 1984). Although now largely disused, a number of late 19th and early 20th century railway stations still survive. The road network also became more strongly established with time. The bridges, culverts, retaining walls, stations, mountain passes and provisioning infrastructure associated with transport routes all became part of the region's built heritage. The rail network later became crucial to the British efforts during the South African War, with blockhouses being built in a variety of materials to protect towns and key rail infrastructure, especially bridges and junctions. Many survive today as the most tangible testament to the war; some are PHSs. The health benefits of the clean, dry Karoo air became well-known, especially during the 19th century British occupation, with people relocating there from their cool, damp homelands in order to recover from a variety of ailments.

Built heritage resources occur in low densities throughout the study area and are emphatic features of the cultural landscape (see Section 15.1.1.7 below). Individual farmsteads and their associated agrarian landscape settings present ensembles of vernacular built heritage that include not only houses, barns and labourers' cottages but also features like packed stone walls (including the very long ostrich walls found in the western part of the study area), *kraals* (livestock enclosures), mills, *kafhokke* (chaff and grain stores), *trapvloere* (threshing floors), dams, *gorras* (pits), irrigation channels, wind pumps, livestock pens, crushes and dips (Figure 15.5). Historical werfs often also include refuse middens which are archaeological sites.

Figure 15.5: A corbelled kafhok and trapvloer, now fenced and in use as an animal pen.

The towns of the study area are unique, with both their constituent parts and their settings contributing cultural value. The historic core of Victoria West, for example, is made particularly special by its longitudinal orientation in a narrow valley setting. Because of the constraints of the valley, modern urban development has occurred away from the core resulting in well-preserved Karoo vernacular streetscapes that include some 86 heritage register buildings (Figure 15.6). The towns contain localised concentrations of built heritage with most retaining a historic core often centred on the church, the spire forming a beacon in the landscape. These central areas usually comprise many conservation-worthy structures that, as a direct result of not being commercialised, retain their historical character. Graaff-Reinet has an especially high density of heritage structures, often restored, with many being PHSs. Its historic core preserves many buildings of exceptional cultural value. Beaufort West also retains many significant buildings but, largely through commercialisation of the town centre, the historic urban landscape has become somewhat degraded. A lack of commercialisation can also lead to urban degradation because insufficient finances are available for building maintenance. Inequitable spatial planning policies from the apartheid era have also left a lasting legacy in these towns.

Figure 15.6: The well-preserved streetscape of Church Street, Victoria West.

The Karoo townscape

Most Karoo towns are typified by simple grid-iron street layouts with a centrally located steepled church, invariably Dutch Reformed, that serves a broad rural community. Many streets are fronted by single or sometimes double storeyed Karoo vernacular houses with whitewashed parapets and deep-set verandas with single or double *stoep-kamers* (rooms created by enclosing the end of a veranda). These are interspersed with corner trading stores and petrol garages, the latter sometimes retaining the Art Deco style. Due to apartheid planning policies these 'formal' resourced towns are twinned by former townships and informal settlements served by a mission church and school, and often removed by a linear barrier such as a major road or railway line. Much still needs to be done to redress these inherited inequities.

As a landscape of conflict (see Section 15.1.1.4 below), the study area also contains many memorials to wars and those who lost their lives through conflict. These include the century-long series of Frontier (or Xhosa) Wars in Eastern Cape, the Second South African ('Anglo-Boer') War and the two World Wars. There are also sites and memorials dedicated to the memory of the internment camps of the Second South African War. Memorials to other events occur in various places as well. Examples include the Slagtersnek Monument, near Cookhouse, which commemorates the uprising that is considered one of the factors that triggered the Great Trek (Von der Heyde, 2013), and the Burgersdorp Taal Monument with its peculiar history (PHS; Figure 15.7). Originally erected in 1893 in honour of the Dutch language, the monument was damaged and removed during the South African War by the British who supplied a replacement in 1907. It was moved to its current location in 1933 and declared a National Monument in 1937. The damaged original was only relocated (buried in the Department of Public Works yard in King William's Town) and installed alongside the replica in 1939 (Oberholster, 1972).

Figure 15.7: The original (centre) and replica (left) Burgersdorp Taal Monuments.

Karoo architecture has attracted considerable interest with a number of local (Bakker, 2006; Herholdt, 1990; Matthews, 1958; University of the Free State, 2013) or thematic (Fagan, 2008; Kramer, 2012) architectural studies having been produced. Many compendiums of heritage architecture list structures in the study area (e.g. Fransen, 2004), while some towns have published their own built heritage guides for tourism purposes. Among other things, buildings and towns are also culturally significant for their connections to religion, historical characters, slavery, indentured and unfree labour (Malherbe, 1991), scientific research (e.g. Wellwood Fossil Museum) and the liberation struggle (e.g. the serial nomination of the internationally significant 'Human Rights, Liberation Struggle and Reconciliation: Nelson Mandela Legacy Sites'), which is currently included in South Africa's United Nations Educational, Scientific and Educational Organisation (UNESCO) World Heritage Tentative list (UNESCO, 2016a), and includes Healdtown, located in the study area and the University of Fort Hare and Lovedale, just outside the study area. These are sites where Nelson Mandela and other prominent Liberation leaders were educated; they have intangible value representing "the fight for a multi-racial democracy such as freedom from tyranny, racial harmony, reconciliation and restorative justice from a notorious regime" (UNESCO, 2016a). The University of Fort Hare is also included in the tentatively listed 'Liberation Heritage Route' (UNESCO, 2016b). Many built heritage resources are declared PHSs (Bluff and Orton, 2016) and countless others are worthy of nomination or receiving Grade II or IIIA status.

15.1.1.4 Archaeology (Section 35) and graves (Section 36)

Archaeological residues in the study area are common and generally highly visible on the eroding landscape. These residues include material from the Early (ESA), Middle (MSA) and Late (LSA) Stone Ages and from the historical period (Figure 15.8). Iron Age residues may also occur in the southeast. As a key factor for occupation of the dry interior of South Africa, permanent and temporary water sources play a key role in understanding settlement, especially during recent millennia when the climate was more similar to that prevailing today. Overprinting would have occurred around water sources with more recent occupations obscuring evidence of earlier settlement.

Figure 15.8: Examples of the kinds of archaeological artefacts that might be found within the study area. The upper two rows are ESA and MSA stone artefacts respectively, while the following row has LSA stone artefacts, beads and pottery. At the bottom are historical glass and ceramics.

The earliest archaeological material is represented by Pleistocene stone artefacts that are variably distributed across the landscape. Because of the variations in climate and erosion since their deposition, these artefacts are not always strongly tied to present water sources. Seldom are they unusual or dense enough to engender significance and their spatial distribution is largely a product of natural forces. Because of this, the vast majority of this material is considered to be background scatter, but in the case of very extensive, denser scatters the material can be thought of as forming a precolonial cultural landscape (Orton, in press). While most artefacts are adiagnostic, the presence of certain types and the degree of surface weathering present can indicate the general age of the material. Hand-axes, for example, are a particularly obvious marker of the ESA. On rare occasions open scatters of older material with high research value are encountered, like an ESA site along the escarpment south of Sutherland (Hart et al., 2010) and those along the Orange River just outside the north-eastern part of the study area (Sampson, 1972). Excavations at the Cradock Springs yielded ESA material including hand-axes and cleavers, while the upper levels contained MSA artefacts (M. Opperman, pers. comm., 2016). ESA material is also sometimes encountered on floodplains and abandoned river terraces. Most artefacts found on the Karoo landscape date to the MSA. Such artefacts have also been found buried in open contexts along river valleys near Noupoort (Bousman, 1991) and along the Seacow River (Sampson, 1968), while rock shelter excavations in the eastern (Deacon, 1976) and north-eastern (Wallsmith, 1990) parts of the study area have also yielded MSA material.

Glossary of archaeological terms

Adiagnostic artefact: an artefact with no features that allow its age or function to be discerned.

Background scatter: a widespread, low density scatter of artefacts whose distribution is governed more by natural forces than by human agency.

Early Stone Age (ESA): an archaeological period between about 2 million and 200 000 years ago.

Ex situ: no longer in primary context, could be in secondary or tertiary context.

Hand-axe: a distinctive bifacial stone tool produced during the ESA.

Hominin: any one of the various species of humans and human ancestors.

In situ: in primary/original context.

Late Stone Age (LSA): an archaeological period encompassing the last 20 000 years.

Middle Stone Age (MSA): an archaeological period between 200 000 and 20 000 years ago.

Patina: a thin weathering rind that forms over rock (among other materials) as a result of chemical weathering.

Note: see also the definitions from the NHRA included in Appendix A. For geological time periods see Section 15.1.1.5.

The LSA is of greater consequence to this assessment because many significant surface sites are known to occur throughout the study area, although again in strongly variable densities. The majority

of LSA remains date to the Holocene, although the period from 8- 4 000 years ago is strongly under-represented in the radiocarbon record of the Karoo, presumably due to the warmer and drier climate of the early Holocene (Deacon, 1974; Meadows and Watkeys, 1999; Scott, 1993). Karoo populations likely increased during the late Holocene, particularly with the introduction of domestic livestock (sheep, goats and cattle) and pottery to the regional economy some 2000 years ago (Sadr, 2003; Sampson, 2010). In contrast to older sites, and largely because they have been subjected to far less erosion since their deposition, many LSA sites are in better context, sometimes preserving organic materials that yield far more information to the researcher than stone tools alone. These sites are largely tied to water sources, be they pans, stream beds or springs. Surface scatters preserving only stone artefacts are also found and can provide good research data (e.g. Brooker, 1977; Sampson, 1972). *In situ* occupation sites potentially containing subsurface archaeological deposits are very scarce in open contexts and of far greater value. Hart et al. (2010) found two such sites in protected valleys along the escarpment southeast of Sutherland and noted their vulnerability to disturbance due to their proximity to a road. In addition to flaked stone tools, such deposits may include grinding stones, pottery and organic remains like hearths, animal bones and ostrich eggshell fragments, beads and flasks. Piled stone structures such as kraals and windbreaks occur in various areas but are best known from the intensively studied and archaeologically rich Seacow River valley between Richmond and Middelburg where many structures likely attributable to late Holocene livestock-keepers of the last 2000 years have been documented (Figure 15.9; Hart, 1989; Sampson, 1985, 2010; Sampson, et al., 2015). Others have been identified near Sutherland (Hart, 2005; Hart et al., 2010; Orton and Halkett, 2011), some only from aerial photographs (Regensberg, 2016). Hart (1989) compiled a typology of their various forms and differentiated them from their more formally constructed historical counterparts. Rock shelters like Blydefontein (Figure 15.10) generally contain the debris of repeated occupations that demonstrate change in the archaeological record through time. Although rare in the study area, a number have been excavated in the north-eastern (e.g. Bousman, 2005; Hart, 1989; Plug, 1993; Sampson, 1967a, 1967b; Sampson et al., 1989), eastern (Deacon, 1976; Hewitt, 1931) and south-eastern (Hall, 1990) parts of the study area, while one small shelter near Sutherland has also been excavated (Evans et al., 1985). Many more likely exist, but research in the mountains of the Karoo and Border Kei areas has been relatively meagre. Research shows that LSA people were

Dolerite and archaeology

The presence of dolerite in the Karoo lends a particular character to the local archaeology for two reasons. Firstly, the closer one is to the area of dolerite outcrops the more likely it is that hornfels will dominate the stone artefact assemblages. This is a rock produced through thermal metamorphism of country rocks (usually shales) when molten dolerite intrudes from below. The second factor is that dolerite is the preferred rock type for engravings. This is because of its surface patina which, when removed reveals a light orange-brown colour (see Figure 15.11). The relative age of both artefacts and engravings can be discerned by the degree to which the patina has reformed.

adaptable and found ways to survive in the relatively dry Karoo, with much of their knowledge having been passed on to the communities of today.

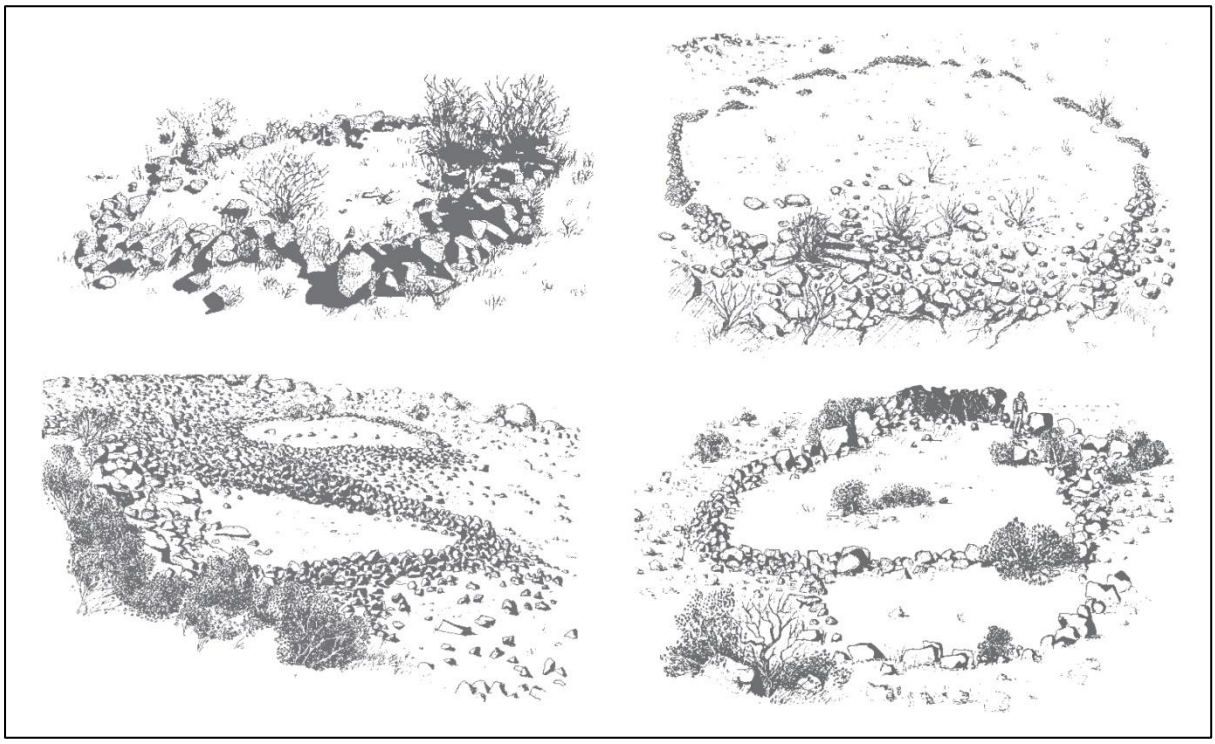

Figure 15.9: Examples of precolonial kraals from the Seacow Valley (original artwork by T. Hart, digital rendering by G. Sampson).

Figure 15.10: Blydefontein Rock Shelter near Noupoort.

There is no Iron Age archaeology known from the Karoo region because the climate did not allow the cultivation of summer rainfall crops. However, the 18th Century Frontier Wars of the Border Kei

region (Von der Heyde, 2013) indicate that Xhosa people were living as far west as Grahamstown and that Late Iron Age remains should be present in the extreme south-eastern corner of the study area.

Rock art is one of the more tangible aspects of archaeology and occurs throughout the study area wherever suitable canvases present themselves. The art takes two main forms whose distribution is dependent on the type of rock available. The northern half of the study area (Bushmanland and the central Karoo) is well-known for the engravings that occur on dolerite outcrops, while painted art is most common on the steeper rocks of the escarpment and other mountains, occurring more densely in the far eastern part of the study area than in the west. This is not a strict rule, however, with Hollman and Hykkerud (2004) documenting a dense cluster of painted sites on sandstone outcrops around Williston. Engravings may be incised, pecked or scraped (Parkington et al., 2008), while paintings are either brush or finger painted. Two main art traditions occur in the study area and were both painted and engraved (Figure 15.11). The fine-line tradition of the indigenous Bushmen (San) is characterised by human and animal figures and associated with Bushman symbolism, ritual and religion (Lewis-Williams and Challis, 2011; Lewis-Williams and Dowson, 1999). In contrast, geometric tradition art was made by the Khoekhoen and has a cruder appearance with largely symbolic imagery. Its distribution is focused strongly on water sources across the northern, central and western parts of South Africa (Eastwood and Smith, 2005; Orton, 2013; Smith and Ouzman, 2004). During historic times colonial images like wagons, horses and figures in European dress were added to the subject matter of both engravings and paintings. Although not art, rock gongs are identified from the characteristic markings left on the edges of dolerite boulders from being beaten to produce sound. Perhaps because they are difficult to identify, they are not well mapped, although they are known to occur within the study area (Parkington et al., 2008). Another rock art layer that should be considered is historical graffiti. Early travellers and farmers frequently left their names, dates or other inscriptions at places they visited. The graffiti can be painted (e.g. Figure 15.11) or engraved and would need to be older than 100 years to be protected under Section 35 of the NHRA.

Figure 15.11: Clockwise from top: A well-patinated snake-like engraving from near Beaufort West; a historical incised engraving from near Beaufort West; a complex rock art panel from near Noupoort displaying faded fine-line imagery (inset) overpainted by bolder, finger-painted geometric tradition art which, in turn, has been covered by painted and scratched historical markings; a row of fine-line eland from near Noupoort.

Until the turn of the 18th century, the western part of the study area was occupied solely by the San and Khoekhoen but from this time onwards runaway slaves and colonial fugitives began moving into the Cederberg, Tankwa Karoo and Roggeveld areas to escape the colony. They persecuted the San and Khoekhoen but the expanding colonial frontier brought even worse conditions as the farmers took control of the land and the frontier became characterised by violence and conflict. In combination with the growing economic, social, psychological and political pressure, the smallpox epidemic of 1713 wreaked havoc among the indigenous populace of the south-western Cape Colony and terrified the inland clans lest the disease should spread among them. The San and Khoekhoen were soon subjugated and many became farm labourers. Throughout the 18th century escapes northwards continued but now with indigenous peoples joining the bands of runaways (Penn, 1999; 2005).

Little researched until recently, 18th and 19th century archaeology in the Karoo is remarkably diverse and records much of what has shaped the local communities of today. The use of wagons to transport

people, food and goods and the introduction of the wind pump to South Africa in the mid-19th century (Walton and Pretorius, 1998) resulted in historical residues becoming more widely spread as time progressed. An important component is the domestic refuse middens associated with farmhouses and which contain large quantities of discarded material culture. An aerial photography survey in the south-western part of the study area has revealed the diversity of pastoralist settlement, both precolonial and historical (Regensberg, 2016). Changes in the visible built material culture identify the changing structure of pastoralist systems as land control and management changed. Merino sheep, and in places ostriches, became the focus of more commercialised farming practices and, during the latter half of the 19th century, wind pumps increasingly loosened the constraint of natural water sources on pastoralist management. Settler farmhouses became widespread across the Karoo and many of the earlier ones, sometimes now in ruin, have proximate ash heaps and rubbish dumps containing the material culture of the period. Traditional pastoralist practices would have been largely curtailed with the passing of the Fencing Act (No. 30 of 1883) which resulted in the enclosure of many farms, starting especially in the eastern part of the study area, and a switch to modern farming practices (Van Sittert, 2002). Recent work has demonstrated continuity in the cultural identity and practices of indigenous people in the Karoo and shown that these are deeply rooted in the precolonial past and continue to inform contemporary beliefs and values.

The Karoo and Border Kei regions have long been a landscape of conflict, originally between the indigenous San and migrant Khoekhoen. Later there was ongoing tension between these groups and the European settlers who sought to control the interior, all the while expanding the frontier of colonialism. The most recent archaeological layer derives from the influx of non-local groups like missionaries, Xhosas and other African migrants (Zachariou, 2013).

The Second South African War was an important event in South Africa's history. It started on 12 October 1899 after the British Government ignored an ultimatum from the Government of the South African Republic regarding what the South Africans felt was unlawful interference in the internal affairs of the Republic (Grobler, 2004). Although smaller skirmishes were common across much of the country, the larger battles were limited to the northern and eastern regions with only two having been fought within the study area: the Battle of Stormberg north of Molteno, and the Battle of West Australia Hill southeast of Colesburg (Von der Hyde, 2013). The Boer forces, supported by their African and Khoekhoen retainers, initially fared quite well, but by February 1900, after considerable reinforcements had been brought in from Britain, the Boers were on the defensive and switched to guerrilla tactics (Von der Hyde, 2013). The war eventually ended with a peace treaty signed on 31 May 1902 (Grobler, 2004). From an archaeological view point, camps where soldiers spent the night are marked by the presence of food tins, drink bottles and occasional other artefacts. Battlefields are

often less noticeable on the ground but they can have bullet cases, military buttons and other miscellaneous items on them.

Although protected by a separate section of the NHRA, graves, by their nature, form a subset of archaeological remains and can be found almost anywhere. Isolated precolonial graves are generally in areas where the substrate is more suited to hand excavation and are most often completely unmarked. This is not always the case, however, as demonstrated by graves with broken grindstones on them associated with Khoekhoe sites in the Roggeveld area (Hart et al., 2010). Historical graves are usually close to farmsteads, usually in formal walled or fenced graveyards. The graves of poor people and farm workers and older, often very isolated graves (perhaps from the early settlers who moved around the landscape on a seasonal basis) may just have natural rock slabs or cobbles as head and foot stones. Graves associated with the South African War and other conflicts could be in very remote locations, like Middelpos in the far west (Schoeman, 2013), although many slain soldiers were buried in formal municipal cemeteries in towns. In the Border Kei part of the study area there will certainly be many family graves associated with Xhosa homesteads. The most well-known grave in the study area is that of Dr Robert Mangaliso Sobukwe, in Graaff-Reinet, which is a declared National Heritage Site (NHS).

15.1.1.5 Palaeontology (Section 35), Meteorites (Section 35) and Geological heritage (National Estate)

What is a fossil?

Fossils are the traces of ancient life (animal, plant or microbial) preserved within consolidated rocks and other sediments and come in two forms:

- Body fossils preserve parts, casts or impressions of the original tissues of an organism (e.g. bones, teeth, wood, pollen grains); and
- Trace fossils such as trackways and burrows record ancient animal behaviour.

The Great Karoo region of South Africa is internationally renowned for its exceptionally rich fossil record of terrestrial and freshwater plants and animals from the ancient supercontinent Gondwana (MacRae, 1999; Rubidge and Hancox, 1999; McCarthy and Rubidge, 2005). Thousands of vertebrate fossils have been collected from the Great Karoo including early finds near Beaufort West in the 1820s, the first known dicynodonts (two-tusked mammal-like reptiles) from the Fort Beaufort area discovered by the pioneer geologist Andrew Geddes Bain in the 1830s, and some of the earliest known dinosaurs near Aliwal North collected by "Gogga" Brown in the 1870s (MacRae, 1999).

The Late Carboniferous to Early Jurassic fossil record is fairly continuous, spanning more than 100 million years. Karoo fossils have long played a central role in understanding the origins and evolution of several key groups of terrestrial vertebrates, such as amphibians, tortoises, early dinosaurs and

mammals. Both primitive and advanced therapsids ("mammal-like reptiles") are especially well represented here, ranging in body size from rats to rhinos. They dominated vertebrate life on land up to 40 million years before the first dinosaurs evolved. Trackways of crocodile-sized amphibians, therapsids and dinosaurs provide insights into the behaviour of extinct vertebrates, while studies of remarkably well-preserved fossil bones and teeth illuminate their development and physiology. Invertebrate fossils are poorly represented in the Karoo, but the main exceptions are freshwater bivalves and crustaceans. The wealth of fossil plant material from the ancient Karoo assemblages – including compressions of stems, leaves and fruiting structures, petrified woods, microscopic spores and pollens – is far more impressive. World-class fossil plant assemblages from the Coal Measures of the Ecca Group and younger carbon-rich rock horizons (e.g. Normandien and Molteno Formations) document the diversification and ecological turnover of vegetation on Gondwana in the Permian and Triassic Periods. Interestingly, the Middle Permian Whitehill Formation (Ecca Group) – the main target for SGD – is renowned for its exquisitely preserved fossils of intact mesosaurid reptiles, primitive bony fish and bottom-dwelling crustaceans as well as a range of fossil plants and microfossils. Identical fossils found in Brazil provided some of the most convincing early evidence for continental drift and the ancient supercontinent Gondwana. All-in-all, the sediments and fossils of the Karoo Supergroup provide us with the best available picture of how the first complex terrestrial and freshwater ecosystems developed on Earth. Also recorded in Karoo rocks is how these early ecosystems responded to dramatic environmental changes leading to a series of three catastrophic extinction events within or towards the end of the Permian and Triassic Periods, some 260, 250 and 200 million years ago respectively. The ever-changing wildlife of the ancient Karoo (e.g. Figure 15.12) is reflected in the series of eight successive fossil assemblages zones formally established for the Beaufort Group rocks of the Main Karoo Basin. These serve as international references for terrestrial biotas of the Middle Permian to Early Triassic time interval (Van der Walt et al., 2010; Smith et al., 2012).

Geological time

The following periods are relevant to archaeology and/or palaeontology in the Karoo:

Period	Age (years)
Holocene	0
Pleistocene	12 000
Neogene	2.5 million
Paleogene	23 million
Cretaceous	65.5 million
Jurassic	145.5 million
Triassic	201.6 million
Permian	251 million
Carboniferous	299 million
	359.2 million

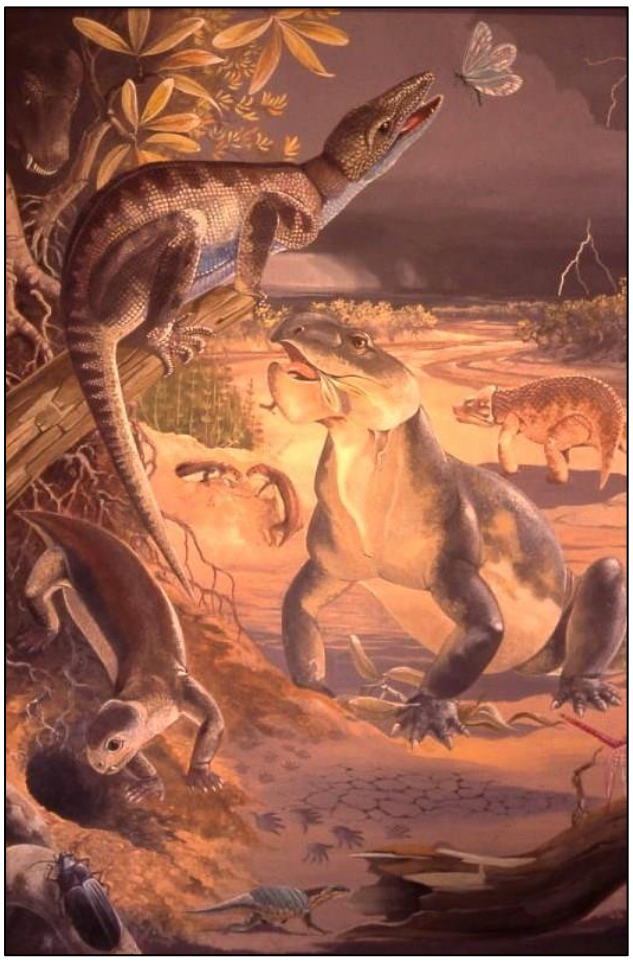

Figure 15.12: Reconstruction of Late Permian wildlife in the Main Karoo Basin (Source: Victoria West Museum, original artwork by Maggie Newman).

Locally the much younger superficial deposits mantling the ancient Karoo bedrocks - notably thick alluvial, spring or pan deposits and ancient cemented soils (pedocretes) – also contain a valuable but poorly-known fossil record. Examples spanning the last 20 million years or so include the bones, teeth and horn cores of extinct Pleistocene mammals, tortoise and snail shells, petrified termitaria as well as very rare examples of early *Homo sapiens* such as the so-called Hofmeyr skull discovered in the eastern part of the study area (Grine et al., 2007). Pollen and other records from springs, pans, valley alluvium or hyrax middens, for example, provide valuable information regarding late Pleistocene and Holocene palaeoenvironments (Holmes et al., 2003; Meadows and Watkeys, 1999; Scott, 1993) that complement and enrich archaeological research.

As a consequence of the exceptional scientific significance and abundance of Karoo fossils in the Beaufort Group (the thick sedimentary rock unit underlying the majority of the study area; Figure 15.13), its outcrop area is rated as very highly sensitive in palaeontological heritage terms on the South African Heritage Resources Information System (SAHRIS) Palaeosensitivity Map (Figure 15.14). There is, as yet, no comprehensive database of known or formally protected fossil sites within the Great Karoo, and most potentially fossiliferous areas have never been palaeontologically surveyed. Type areas for each of the various Beaufort Group fossil assemblage zones have been designated and are of international significance (Rubidge, 1995); each covers substantial portions of one or more Karoo farms. Prominent fossil sites of tourism importance include the Gansfontein palaeosurface near Fraserburg with its wealth of fossil trackways, therapsid fossils in the Gatsrivier near Nieu Bethesda (Kitching Fossil Exploration Centre), and the Grade I, 253 million year old dicynodont herd trackways at Asante Sana Nature Reserve near Graaff-Reinet (Figure 15.15; De Klerk, 2002).

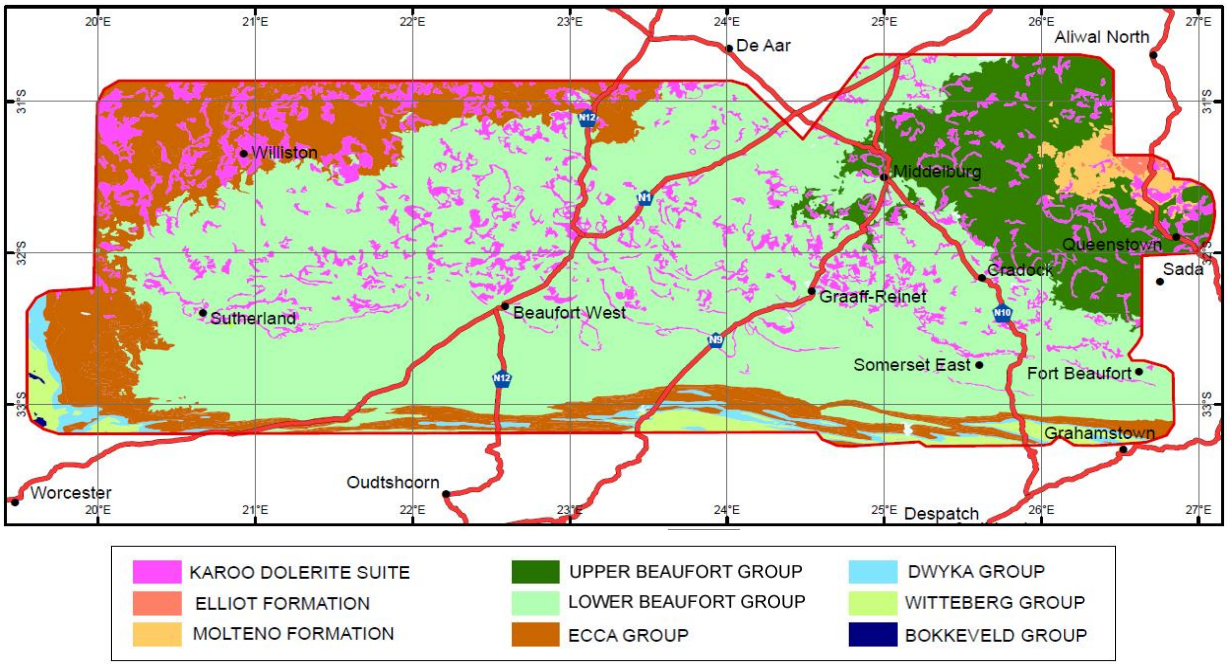

Figure 15.13: Geological map showing the outcrop areas of the main rock units represented within the study area (map provided by the Council for Geoscience (CGS), Pretoria). Note that almost all of these rock units are sediments of the Karoo Supergroup that are known to contain significant fossil heritage.

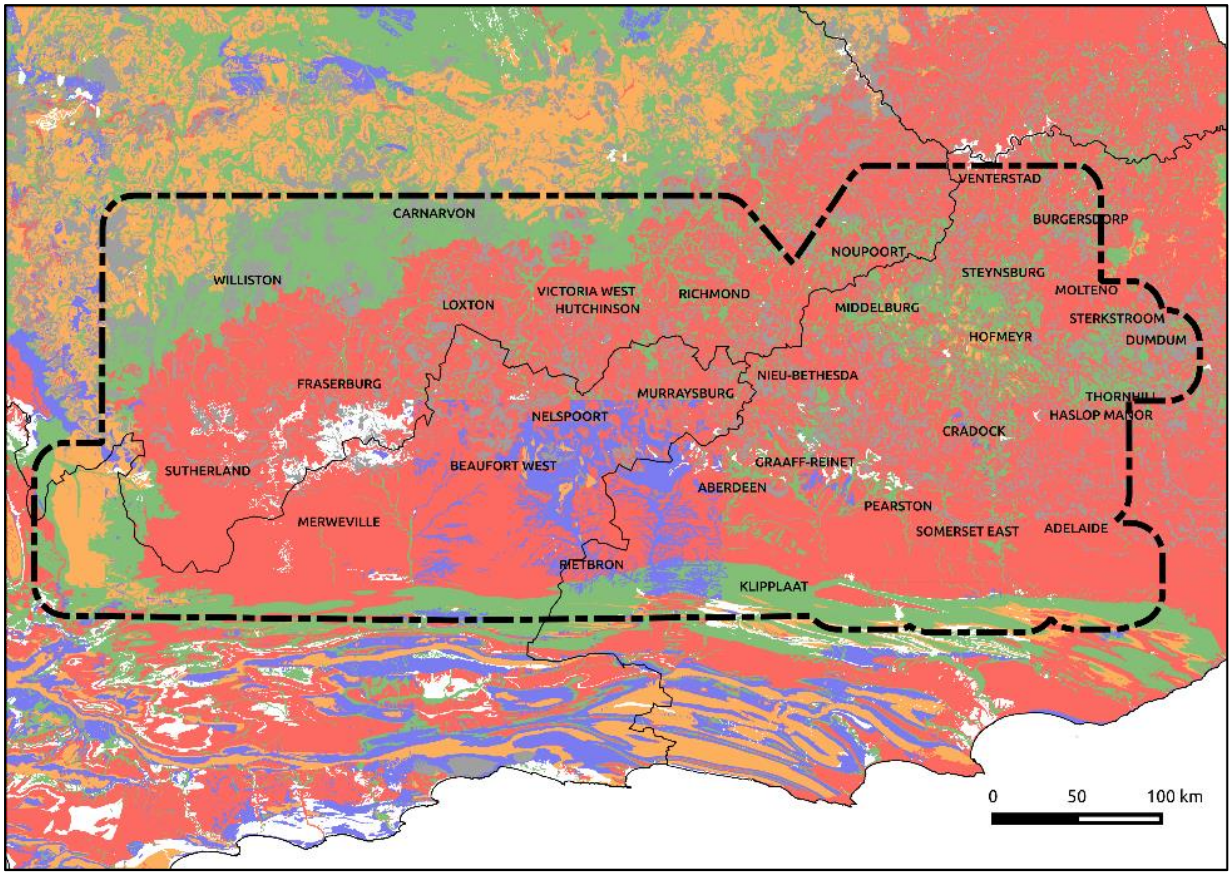

Figure 15.14: Extract from the SAHRIS Palaeosensitivity Map showing the study area. Red shading denotes 'very high palaeontological sensitivity', orange is 'high', green is 'moderate, blue is 'low', grey is 'zero' and

white is 'unknown'. Although several Karoo rock units are highly sensitive (including the potentially hydrocarbon-rich Whitehill Formation), the majority of the red shading within the study area represents the various formations making up the Beaufort Group.

Figure 15.15: Dicynodont footprints in Late Permian (c. 255 million year old) alluvial sediments of the Balfour Formation (Lower Beaufort Group) from near Graaff-Reinet (Source: SAHRIS, n.d.).

Most Karoo vertebrate fossils are variously preserved within river channel sandstone bodies or within overbank mudrocks representing ancient flood deposits. In the second case they are often partially or completely enveloped in pedogenic calcrete nodules associated with ancient soil horizons. Most recorded fossil vertebrate finds from the Beaufort Group occur within a broad arc stretching from Merweville, through Three Sisters to Graaff-Reinet (Nicolas, 2007; Figure 15.16). Fossil vertebrate sites are especially dense in the western Karoo, perhaps because of the more arid climates currently prevailing there and facilitating preservation as well as the finding of specimens exposed at the surface, while rich fossil plant sites are more concentrated in the east. It is important to note that previously-buried fossils are continually being exposed by surface weathering. If not collected, they will ultimately be destroyed by natural weathering processes and erosion. Most well-preserved, scientifically important fossils are collected at or near the surface where they are often already partially exposed by weathering. Articulated or semi-articulated vertebrate remains are especially significant. Fossils require skilled excavation by professional palaeontologists, taking care to record contextual geological data reflecting when and how the animal died and became preserved.

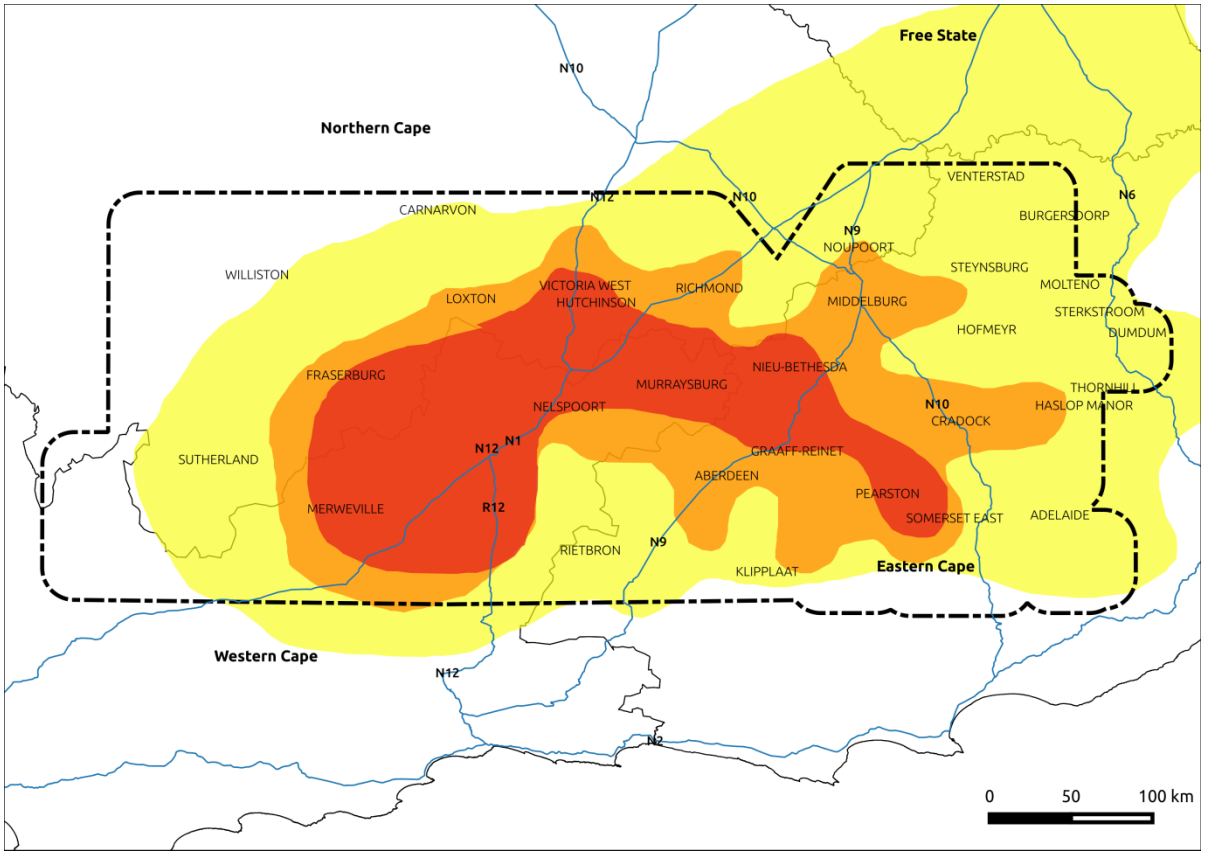

Figure 15.16: Map of the study area indicating the density of previously-recorded fossil vertebrate sites within the Permo-Triassic Beaufort Group (red: high; orange: medium; yellow: low). Note that this is not a palaeosensitivity map since it does not show key fossil groups such as plants or trace fossils (e.g. vertebrate trackways) (Redrawn from Nicolas, 2007).

Meteorites are rocky or metallic fragments of extra-terrestrial bodies (e.g. the Moon, planets, asteroids, comets), weighing anything from a few grams to many tons, that have fallen to Earth individually or as part of a swarm. These very rare natural objects provide unique data on the origins, early history and evolution of the Solar System, including planet Earth (Reimold and Gibson, 2005; McKenzie, 2014). They include some of the oldest objects to be found on Earth - up to 4.6 billion years old. The majority of meteorites have been collected in arid areas like the Karoo where rates of natural weathering are low, soils are thin and vegetation cover is sparse. Rocky meteorites ('stones') are much more common than metallic ones ('irons'). Historical sightings ('falls') are very rare and most specimens found must have landed on earth during earlier millennia. Iron-rich meteorites, such as those found in the Gibeon district of south-central Namibia, have occasionally been exploited by local peoples to make weapons and tools. Only about 50 meteorites are recorded for South Africa on scientific databases (e.g. The Meteoritical Society, 2016). However, due to fragmentation before and on impact, some may comprise hundreds or thousands of fragments within a strewn field that may be tens to hundreds of kilometres (km) across. Several major meteorite impact structures are known in southern Africa. They include the approximately 250 000 year old Kalkkop, a 640 m wide crater infill

between Jansenville and Graaff-Reinet within the study area. Meteorites have been reported from South Africa since the 1790s, with famous Karoo examples including Hofmeyr (fall, 1914) and several from the Beaufort West area such as Jakkalsfontein (fall, 1903), Merweville (find, 1977) and Wittekrans (fall, 1880).

The Great Karoo landscape records more than 100 million years of geological history related to the southern supercontinent Gondwana, and spanning the Late Carboniferous to Early Jurassic Periods with no major breaks. The iconic flat-topped *koppies* and endless undulating *vlakte* are sculpted from a pile of sedimentary and igneous rocks more than 12 km thick that is known as the Karoo Supergroup (Rubidge and Hancox, 1999; McCarthy and Rubidge, 2005; Johnson et al., 2006). Many features of the Karoo Supergroup succession in the Main Karoo Basin contribute to its international fame among geologists including:

- 300 million year old glacial deposits and ice-scoured rocky pavements of the Dwyka Group;
- Early to Middle Permian submarine fan and deltaic deposits of the Ecca Group with their economically valuable cool-climate coals and untapped oil and gas potential;
- Varied river and lake deposits of the Beaufort Group, globally one of the best-known rock successions for documenting the evolution of continental environments and their rich plant and animal biotas during the Permian and Triassic Periods;
- Arid climate fluvial and sandy desert deposits of the Elliot and Clarens Formations (Stormberg Group) recording environmental changes associated with major faunal turnover across the critical Triassic/Jurassic boundary; and
- Early Jurassic (*c*. 180 million years old) igneous intrusions of the Karoo Dolerite Suite. These dykes and sills represent huge volumes of hot magma that were forced upwards through the overlying sediments along lines of crustal weakness before solidifying into tough igneous rock below the Earth's surface or erupting at the surface as basaltic lavas (Drakensberg Group). Evidence of small-scale, more recent igneous activity in Late Cretaceous times (*c*. 70 million years ago) is seen at the Salpeterkop volcano near Sutherland (Verwoerd, 1990).

These ancient Karoo bedrocks are locally mantled by thick alluvial deposits (river sands, silts, gravels) and arid-climate pedocretes (e.g. lime-cemented deposits of ancient soils) that record the complex, ever-changing history of aridification, crustal uplift and drainage development in the South African interior over the past several tens of millions of years. Excellent sections through these younger deposits are seen in deep erosion gullies, especially in the eastern Karoo.

The spectacular natural scenery and exceptionally good exposures of fresh (i.e. unweathered) bedrocks available in the Great Karoo – along river and stream banks, on hillslopes, in erosion gullies,

around farm dams and in quarries as well as road and railway cuttings – have attracted geologists and other naturalists over the past 200 years or more. Locations such as the Nuweveld Escarpment in the Karoo National Park near Beaufort West and the Valley of Desolation in the Camdeboo National Park near Graaff-Reinet are now being increasingly exploited for ecotourism (Norman, 2013; Norman and Whitfield, 2006). Numerous scientifically significant geosites in the Karoo region exhibit important geological features and are worthy of protection from future development but, unfortunately, no national database of these sites and materials is currently available. Good examples of international significance are the key geological sections (termed stratotype sections) for all the constituent sedimentary formations of the Karoo Supergroup that have been, or are in the process of being, designated by the South African Committee for Stratigraphy (e.g. Abrahamskraal Formation exposures along the Gamka River south of Leeu-Gamka and Burgersdorp Formation sections near Burgersdorp).

15.1.1.6 Living heritage (National Estate)

Living (or intangible) heritage encompasses all those ideas, traditions, customs, associations and memories that are passed from generation to generation. It includes things such as language, folklore, traditional medicine, music, songs, dances and recipes. Knowledge, skills and practices related to the local economy, such as shepherding, animal husbandry and seasonal movement between summer and winter grazing areas, are also important because without them the Khoekhoe herders, early colonial settlers after them, and even modern farmers and their workers would never have survived. Many places in the study area are associated with living heritage or with works of literature or art and bear cultural value for this reason. These are all things that contribute to the identity of a group. The Department of Arts and Culture (DAC; 2009:5) defines living heritage as "cultural expressions and practices that form a body of knowledge and provide for continuity, dynamism, and meaning of social life to generations of people as individuals, social groups, and communities." Part of the importance of living heritage is that it helps to create a new national identity and promotes heritage that was repressed by missionaries, colonists and the apartheid regime (DAC, 2009).

One of the most well-known aspects of living heritage in South Africa is the Bleek and Lloyd archive recorded during the 1860s and 1870s (Bleek and Lloyd, 1911). It records much of the folklore of the Bushmen people and has, through analogy, been used extensively in the interpretation of southern African precolonial rock art (Lewis-Williams and Dowson, 1999), some of which occurs within the study area. Because it was collected during the 19th century, it is also directly informs the interpretation of 19th century Karoo rock engravings. An aspect of indigenous mythology that deserves special mention because of its widespread importance relates to water. Among a number of groups certain permanent water sources (pools, rivers or springs) are inhabited by the 'River People'

or water spirits. These can be in the form of snakes, mermaids ('*watermeide*') or other creatures. These places are regarded as sacred and are particularly important to traditional healers (Bernard, 2003). Rock art sites are often located in proximity to such water sources thus creating an associational link between the art and riparian landscapes (Rust and Van der Poll, 2011). Furthermore, the Water Snake is often depicted in rock art and still plays a prominent role in people's lives today (Hoff, 1997).

Recent research has aimed to collect contemporary narratives that continue some of the themes, structures and moral codes set out in the Bleek and Lloyd archive (De Prada-Samper, 2014). These narratives are important because the range of subject matter recorded by De Prada-Samper (2014:106) emphasises the continuities into the 21st century and therefore links contemporary Karoo dwellers with both their immediate and painful colonial past and their deeper precolonial past. Living heritage is constantly recreated in response to environmental and historical factors as reflected across the Karoo, for example, in the variability evident among stories that were clearly about the same character. In general, the Karoo region is the heartland of what remains of Bushman and Khoekhoe culture in South Africa.

While the majority of the study area affects typically Karoo – and frequently Afrikaans – heritage, a small section includes a traditionally Xhosa area – the former Ciskei. This introduces a wide body of living heritage related to initiation, marriage and other social and religious customs. Another more recent and often painful aspect of living heritage is the legacy of inequitable spatial planning left by apartheid. The memory of the Liberation Struggle and its activists is an important component of living heritage nationally and parts of the study area were key in the formation and history of the Liberation Movement.

Of course living heritage is constantly being created and inherited, with perhaps the most famous example in the context of modern South Africa being Karoo Lamb (protected under Notice 1074 of 2013 annexed to the Merchandise Marks Act 17 of 1941 (1941)), which now has a formal certification process (Karoo Development Foundation, 2016). This brand and others, like Mohair South Africa, encompass products that have become deeply entrenched in local heritage and are critical to the livelihood of many in the Karoo. Adaptations of traditional dances for tourism purposes and the publication of Karoo recipe and music books, for example, are preserving some of this heritage in ways that become tangible to outsiders. But the fortunes are mixed: the 'Rieldans' is a traditional Bushman dance form that has recently been revived and received world-wide attention (Johns, 2015), while the 'Karretjie Mense' (small family units migrating across the land in donkey carts in search of sheep shearing work) are rapidly disappearing because of modern transport and farming practices (De

Jongh, 2012). Much great South African literature (especially Afrikaans literature) has emanated from the Karoo with a number of prominent authors (e.g. Olive Schreiner; J.M. Coetzee; and Pauline Smith), and poets (e.g. N.P. van Wyk Louw; D.C. Esterhuyse; and Guy Buttler) having been brought up or spent time there (Schoeman, 2013). The Karoo has also produced visual artists (e.g. Walter Battiss; Helen Martin; and Johannes Meintjies). Many of these people have drawn inspiration from specific Karoo places and some have museums dedicated to their memory within the study area (e.g. Owl House in Nieu-Bethesda (Helen Martin), and the Walter Battiss Museum in Somerset East). The Afrikaans language is thus also an integral part of the living heritage of the study area. It can be very difficult to capture those aspects of living heritage that have not been publicised and interviews with local residents of all backgrounds are important in this regard.

Place names are also an aspect of living heritage that are, in a way, more tangible. They are a rich source of reference to various aspects of the local environment or culture, such as the climate (Karoo), animals (Leeu-Gamka), and places where food can be obtained (Hantam). Famous or respected people are commonly represented in street names throughout the area. Some street names indicate the original centre of town (Church Street in cases where towns developed around their first church) or the edge of town (Buitenkant Street, Burgersdorp), while others point to geographical places or sites (Carnarvon Street, Loxton; Location Street, Murraysburg). Street names also recall the broader history of South Africa (Constitution Street, Adelaide; Voortrekker and DF Malan Streets, Cradock).

15.1.1.7 Cultural landscapes (National Estate)

The cultural landscapes of the study area (some may argue for one large regional cultural landscape) are richly layered in history and give spatial and temporal expression to the many processes and products resulting from the interaction of people and the environment through the ages. As such, the cultural landscape may be seen as a particular configuration of topography, vegetation cover, land use and settlement pattern that establishes some coherence – or legibility – of natural and cultural processes (Müller and Gibbs, 2011). Cultural landscapes weave together all the aspects of heritage already described and, although they occur throughout the study area, the density of individual contributing elements will vary greatly from place to place.

Defining and understanding cultural landscape

The cultural landscape is an aspect of heritage not defined in the NHRA but nevertheless listed as part of the National Estate. A cultural landscape is "a set of ideas and practices embedded in a place" (Julian Smith and Associates Contentworks Inc., 2004) and serves to "map our relationship with the land over time" (The Cultural Landscape Foundation, 2015). While the cultural landscape is itself a heritage resource, it also unites the physical cultural resources of an area (tangible heritage) and its associated memories, perceptions, stories, practices and experiences (living heritage) in order to give a particular place or region its meaning. Because heritage sites are embedded in, and interwoven with, their landscape settings, the cultural landscape also gives these resources their sense of place and belonging through the provision of physical and metaphysical context (Müller and Gibbs, 2011). The concept of cultural landscape is thus very broad. Like the warp threads of a tapestry, the cultural landscape is the setting which holds together all the other aspects of heritage discussed in this Chapter.

After the palaeontological landscapes of the deep past, the first human-related cultural landscapes to form were precolonial ones (Orton, in press). Stone Age people had intimate physical and spiritual relationships with the landscape because their livelihoods depended on it. The multitudes of stone artefacts, rock engravings and paintings bear testimony to and provide tangible reminders of this relationship. The landscape of engravings at Nelspoort has been recognised as potentially of national significance (Winter and Oberholzer, 2013). The area has both fine-line and geometric tradition engravings and represents the greatest concentration of engravings in the central Karoo region.

One of the most prominent features of the Karoo landscape is the patterns of land use that developed during the long history of colonial pastoralist settlement. Wire-fenced, and occasionally stone-walled, grazing camps and jeep tracks stretch to the horizon, while farmsteads are often noticeable from a distance by their prolific exotic tree (*Eucalyptus* sp. and *Populus* sp.) growth in an otherwise sparsely vegetated landscape (Figure 15.17). Stands of *Agave americana*, for fencing or fibre, avenues of Pepper Trees (*Schinus molle*) and the ubiquitous wind pumps and associated concrete reservoirs are important features, often acting as landmarks. Likewise, the tall spires of Dutch Reformed Churches herald the existence of small, widely-spaced towns. Aspects of these patterns are direct responses to ecological systems and landscape features: farmsteads, agricultural fields and towns, for example, are often placed in relation to existing water sources or hills. Houses were built from local materials and designed for the climate. The long, straight roads and railways respond to the open plains, particularly to the south of the Great Escarpment, while the limited traffic on minor roads means that many retain the character imparted by their original gravel surfaces.

Figure 15.17: Aerial view of a south-western Karoo farmstead comprised of houses, outbuildings, stone kraals and walls, arable lands, wind pumps, tree plantings and a graveyard (Source: Google earth).

Also important cultural landscape features are the natural beauty systems of the Karoo (Winter and Oberholzer, 2013). These include the expansive views, hills and mountains, vast open spaces (Figure 15.18), clear horizons and, at night, the starry skies. Geological features such as the dolerite sill hills (e.g. the Three Sisters in the centre of the study area) and the Great Escarpment form termini to many viewscapes, while mountain passes and other scenic routes showcase these features and the achievements of South Africa's early road engineers, like Thomas Bain. Many mountain passes occur in the study area; some are wagon routes dating back more than 200 years and are long disused (Neville et al., 1994). Whether built features or cultural landscapes is debatable, but all are important heritage features in their own right. A number of scenic routes cross the study area, although only those in Western Cape are formally mapped (Winter and Oberholzer, 2013).

Figure 15.18: An expansive view from a back road between Nelspoort and Murraysburg.

The natural beauty of the Karoo lies in the patterns of muted greens, browns and sandy colours that combine with the coarse textures and forms derived from the vegetation and unique geology (Figure 15.19). The harshness of the Karoo landscape, which even informed its name, was often remarked upon by early adventurers, explorers, hunters and travellers who passed through it. A landscape of contrasts, it was at times extremely hot or cold, intensely dry and drought-stricken or subject to frosts and floods. The negative associations evoked by its natural attributes are reinforced by the sparse human settlements, but those who live or actively participate in the landscape have developed deeper meanings associated with its richness. Much of this meaning finds expression within the realms of living heritage. In contrast, the somewhat greener Border Kei region has a cultural landscape characterised by different features: rivers are more prominent features and traditional Xhosa settlement still occurs in places. Although rectangular dwellings have largely replaced rondavels, stock enclosures are still common outside homes in rural villages.

Figure 15.19: Typical Karoo koppie scenery in the Nuweveld Mountains, Karoo National Park near Beaufort West.

Karoo climates also inform the cultural landscape positively. Perhaps most important, in the context of the semi-arid Karoo, is the traditional spiritual association with rain and water as reflected in the Bushman mythology recorded both in the Bleek and Lloyd archive and in rock art. The stories give special meaning to places and impart spirituality to the landscape (Rust and Van der Poll, 2011). Rain is considered sacred and is personified in the rain animal and its legs which are represented by the columns of rain watering certain parts of the landscape (Parkington et al., 2008). As described above, water sources are also relevant to other aspects of oral tradition and form important aspects of the cultural landscape. Throughout time, humans and nature alike have responded exuberantly in the event of a rainstorm. When it is not raining, the vast, clear skies also contribute to the sense of place of the Karoo and attract people seeking the peaceful solitude it offers. These skies, along with the high altitude, tectonically stable geology and absence of artificial lights, are also the reason for the landscape of astronomy that has existed in the Karoo since the opening of the South African Astronomical Observatory near Sutherland in 1973 (Laney, 2013). The SKA is further testimony to the scientific value of the Karoo landscape.

15.1.1.8 Summary

A notable trend in the above review is that as one progresses through time the various categories of heritage become more strongly linked and the richness of the layering manifested in the cultural landscape increases dramatically. The earliest heritage – fossils – relates to the development of the earth, southern Africa and the Karoo. ESA and MSA archaeology allows us to understand hominin and modern human development as well as how the Karoo landscape was first populated and used. The LSA preserves a more diverse set of resources that elucidate precolonial life. Through the contact period we find a diversity of European and African residues, including locally developed architectural styles, being added to the LSA package, all of which is tied together by the living heritage developed and transferred inter-generationally by past and present communities. The relatively recent past then developed from this cultural fusion to give us the Karoo of today with its distinctive landscapes, architecture and rural character.

15.1.1.9 Why is our heritage important?

The importance of heritage in South Africa revolves around its significance as described in Section 2(vi) of the NHRA (see digital Addendum 15A). Cultural significance is "embodied in the place itself, its fabric, setting, use, associations, meanings, records, related places and related objects" (Australia International Council for Monuments and Sites (Australia ICOMOS), 1999:2). We identify here and discuss the types of cultural significance applicable to each heritage resource category today. Of course significance can be fluid with change through time occurring as a result of actions, legal or otherwise, natural or human, that can increase or decrease the cultural value of specific resources or categories.

- Built heritage can have aesthetic, architectural, social, spiritual and/or technological value for the contributions it makes to society and the cultural landscape. This echoes internationally accepted norms that state that "built vernacular heritage is important; it is the fundamental expression of the culture of a community, of its relationship with its territory and, at the same time, the expression of the world's cultural diversity" (ICOMOS, 1999:1).
- Archaeology (Stone Age and/or historical) can have historical, scientific, social, spiritual and technological significance for its contribution to the shared history of South Africa and our understanding of past societies.
- Graves, monuments and memorials can have historical, social and spiritual significance because they commemorate people and events that have shaped who we are as individuals and who we are as a country.

- Palaeontology, meteorites and geological heritage have scientific significance for their contributions to our understanding of changing prehistoric environments and life on Earth as well as the evolution of our planet.
- Living heritage has historical, social, spiritual and linguistic significance as it represents all those intangible things that make our multi-cultural society what it is today. In the context of apartheid South Africa, living heritage, including popular memory, was often all that people could cling to as their tangible heritage was removed from them and it is thus important to celebrate it today.
- Cultural landscapes can be significant for all the reasons cited above because they describe a complex and diverse history of association between generations of South Africans and their homeland. By imparting special meaning to places they create feelings of belonging and harmony with the land.

Aside from the formal attributes of cultural significance and what it can tell us about our past and present, all the above aspects of heritage have considerable importance for tourism and hence provide sustainable economic benefits to local communities. An unspoilt natural and cultural environment presents a far more sustainable economic opportunity when used for tourism purposes than the short-term benefits of mineral resource exploitation. It is important that the fragile heritage of South Africa is treasured in the present so that we may pass it on to future generations of South Africans.

Furthermore, Section 3(3) of the NHRA lists criteria that should be met for a place or object to form part of the National Estate. Table 15.1 shows how each criterion is met within the study area. Each achieves a high degree of significance in at least some parts of it.

Table 15.1: Criteria for inclusion in the National Estate.

NHRA qualities	Heritage aspects	Motivation
Importance in the community, or pattern of South Africa's history	• Cultural landscapes and all their constituent features	• Critical in understanding the history of South Africa, e.g. settlement patterns, townscapes, oral traditions, natural landscapes
Possession of uncommon, rare or endangered aspects of South Africa's natural or cultural heritage	• Built heritage • Archaeology • Geological and palaeontological sites	• Corbelled structures, British forts, Martello Tower, Karoo farmsteads, mills, wind pumps • Precolonial herder settlement • Certain aspects poorly understood
Potential to yield information that will contribute to an understanding of South Africa's natural or cultural heritage	• All heritage types • Geology and palaeontology	• High degree of intactness offers high research potential • Data expected from fresh excavations, road cuttings, borrow pits, borehole cores
Importance in demonstrating the principal characteristics of a particular class of South Africa's natural or cultural places or objects	• Built heritage • Archaeology • Geology and palaeontology	• 'Karoostyle' architecture, corbelled structures, British military fortifications - Martello Tower, block houses • Khoekhoe livestock enclosures, geometric tradition engravings and paintings • Continental rocks and fossils from the Permian and Triassic Periods
Importance in exhibiting particular aesthetic characteristics valued by a community or cultural group	• Built heritage • Archaeology • Cultural and natural landscapes.	• Karoo architecture • Engravings and paintings • Karoo sense of place
Importance in demonstrating a high degree of creative or technical achievement at a particular period	• Built heritage • Living heritage • Astronomical developments	• Architecture adapted to climate, British Military installations and forts • Strategies for arid environment agriculture, pastoralism and animal husbandry • Scientific developments of international importance
Strong or special association with a particular community or cultural group for social, cultural or spiritual reasons	• Built heritage • Archaeology • Geology and palaeontology • Astronomy	• e.g. Vernacular Architecture Society of South Africa, local interest groups • Rock art valued by descendant communities, and by locals as tourism resources • Geologists and palaeontologists, and locals as tourism resources • Scientific community
Strong or special association with the life or work of a person, group or organisation of importance in the history of South Africa	• Living heritage	• e.g. Chris Barnard (heart surgeon); Olive Schreiner, J.M. Coetzee (authors); Guy Buttler, N.P. van Wyk Louw (poets); Matthew Goniwe, Robert Sobukwe (struggle heroes); James Kitching, Sidney Rubidge, Robert Broom (palaeontologists)
Sites of significance relating to the history of slavery in South Africa (Note that although not listed in the NHRA, sites associated with indentured and unfree labour are also considered here)	• Built heritage • Various farms and missions throughout the study area	• Williston (Peerboom), Fort Beaufort • Slave and unfree labour

15.1.1.10 Links to other topics

There is a two-way relationship between heritage and various other scientific assessment Chapters because of the contributions they make to each other's meaning. The study area would not be what it is without its cultural attributes, and these attributes, in turn, are strongly defined by the local environment that gave them birth. Table 15.2 summarises these links.

Sense of place

Sense of place is a recognised heritage concept but, because of its broad scope extending beyond the realms of heritage, has been allocated its own Chapter in this scientific assessment. From the heritage perspective then, it refers to the meaning, identity, setting and intrinsic character of a place, as provided by its natural and cultural features and one's experience thereof.

Table 15.2: Aspects of heritage that link to other topics.

Topic	Heritage aspects	Links
Earthquakes (Durrheim et al., 2016)	• Built heritage • Archaeology (especially rock art)	Induced seismic activity could have a detrimental effect on heritage structures and possibly rock art sites and an understanding of expected induced seismic activity will help plan heritage buffers. Findings from Durrheim et al. (2016) have informed the conclusions of this Chapter.
Water Resources (Hobbs et al., 2016)	• Archaeology • Built heritage • Living heritage • Cultural landscapes	Surface water resources in the dry interior of South Africa were critical in allowing settlement across the region prior to the advent of the wind pump. As such, many archaeological sites, built heritage resources and smaller-scale cultural landscapes have developed around water sources. Water is also an important aspect of indigenous mythology.
Biodiversity and ecology (Holness et al., 2016)	• Built heritage • Living heritage • Cultural landscape	The natural features of the study area, especially its vegetation and geological features, contribute strongly to the cultural landscape because of their influence on both precolonial and historical settlement patterns and land use. They also form part of the natural heritage of South Africa. There is a large body of knowledge relating to the traditional use of plants and animals for medicinal, construction, ritual and other purposes.
Agriculture (Oettle et al., 2016)	• Built heritage • Living heritage • Cultural landscape	To be successful, agriculture and pastoralism require traditional knowledge of climates and land management practices. Many of the best places for cultivation will have long-since been developed and form part of the cultural landscape. Farming and its related built structures in turn comprise an important component of the cultural landscape.
Tourism (Toerien et al., 2016)	• Built heritage • Archaeology (especially rock art, military history) • Palaeontology • Geological heritage • Living heritage • Cultural landscape	While many Karoo tourists choose a destination for the overall cultural landscape character, specific heritage resources also function as tourist attractions. Obvious examples include rock art sites, battlefield tours, significant geological and palaeontological sites and festivals celebrating living heritage. Tourism has value for heritage in that it offers the opportunity to develop heritage sites in sustainable, income-generating ways that enhance and celebrate their cultural value. Tourist routes are of value in this regard.

Topic	Heritage aspects	Links
Social fabric (Atkinson et al., 2016)	• Built heritage • Living heritage	Built heritage aids the continuation of living heritage as communities associate with churches, schools, memorials and other structures that embody memory. Social fabric is partly defined by living heritage (memory and tradition).
Sense of place (Seeliger et al., 2016)	• Built heritage • Archaeology (especially rock art) • Palaeontology • Living heritage • Cultural landscape	Sense of place is determined by the natural and cultural landscape, setting, and its embedded heritage, which includes, among other things, the built environment, rock art, the aura around fossil dinosaurs and other long extinct creatures, local customs and culinary traditions.
Visual aesthetics (Oberholzer et al., 2016)	• Built heritage • Archaeology (mainly rock art) • Living heritage • Cultural landscape	Appreciation of urban and rural cultural landscapes and rock art is largely dependent on their settings which combine sights, sounds and smells. Visual, air and sound pollution can affect setting, sense of place and cultural landscape quality. Many aspects of living heritage are tied to places in the landscape that could be visually impacted by SGD.
Noise (Wade et al., 2016)	• Built heritage • Cultural landscape	The liveability of built heritage is strongly tied to the qualities of its environment. A negative change in the environmental qualities will, over time, erode the vitality of the resource. Appreciation of the cultural landscape depends partly on the sounds that come with it. Noise pollution can affect the sense of place and hence the cultural landscape quality.
Integrated spatial and infrastructure planning (Van Huyssteen et al., 2016)	• Built heritage • Cultural landscape	Many infrastructural elements, such as roads, bridges and railways, are heritage resources. Historical spatial planning (including under apartheid) has created the townscapes of today. Potential SGD-related changes to the urban landscapes and streetscapes of Karoo towns as well as wider landscape interventions could dramatically impact on built heritage resources, their settings, and cultural landscapes.

15.1.1.11 Assumptions and limitations

Scenario 1 (Exploration Only), Scenario 2 (Small Gas) and Secnario 3 (Big Gas) as provided in Burns et al. (2016) are assumed to be realistic. Any substantial changes to the scope of these scenarios may affect the conclusions of this Chapter and the requirements of later Heritage Impact Assessment (HIA) studies. We assume that seismic surveys, access roads and wellpads could be sited almost anywhere in the study area with only steep or inaccessible terrain and certain prescribed no-go areas (e.g. conservation or urban areas) being exempt. We assume that exploration and related impacts would be widespread, while SGD under the Small and Big Gas scenarios and any related impacts would occur within limited footprints. Although our heritage knowledge is necessarily limited by the low level of survey coverage, we assume that there are on record sufficient examples of all the general types of heritage that might occur in the study area to allow reasonably accurate predictions of potential impacts.

In the absence of fieldwork, previous research and our working knowledge of the area form the basis of this assessment. Academic and commercial research has been patchy and of variable quality, frequently focusing on a limited set of heritage resources. As such, fine-grained mapping of heritage resources across the entire study area is impossible. Although the NHRA requires preparation and maintenance of heritage inventories by local authorities, this has not occurred.

15.1.2 Overview of international experience

Literature relating to the impacts of hydraulic fracturing ("fracking") on heritage resources is rare and it is notable that in countries where SGD has been banned environmental and human health reasons are the driving force behind the actions; heritage sites are rarely mentioned. Nevertheless, various sources have allowed an estimation of the kinds of problems that might arise.

A primary concern stemming from the experiences of fracking in the United States of America (USA) is the economic boom and rapid population increases that can occur in conjunction with the discovery of a good resource, as has recently been the case in North Dakota (Brown, 2014). With population inflow heritage sites can be at direct risk from the increased development, while rapid urbanisation has been recognised by UNESCO (2011) as causing degeneration in the quality of both historic urban environments and their surrounding rural areas. Ancillary infrastructure related to the industry, like pipelines, also increases impacts. In the context of the present study, such a boom might only happen under the Big Gas scenario. In Utah, USA, the Navajo people were expecting employment when fracking commenced on their land. However, outsiders were brought in to do the work and according to a Navajo representative, this resulted in physical, financial and cultural suffering for the local population (Peacock, 2011).

Another key risk is that of increased seismicity. The underground disposal of waste water in deep wells, a practice banned in the Karoo (Mineral and Petroleum Resources Development Act (MPRDA), No 28 of 2002, Regulation 2015), has been blamed for most induced earthquakes in the USA (Rubinstein and Mahani, 2015), but in Alberta, Canada, the situation is different with the timing of fracking operations and induced earthquakes found to be very strongly correlated (Schultz et al., 2015). Given the fragility of vernacular Karoo architecture, there is a real risk of damage to buildings (particularly elements such as gables, domes and chimneys) and monuments should earth tremors occur. This has already been illustrated when a tremor in 2010 caused the collapse of at least three corbelled buildings and may have resulted in cracks in many more (Kramer, 2012). Although the literature lacks assessments of the impacts of induced earthquakes on heritage buildings, impacts have been recorded in the Netherlands where conventional gas extraction has resulted in earthquake-related property damage (Van der Voort and Vanclay, 2015).

Given the widespread occurrence of archaeological sites, this is also a resource type that can experience considerable impacts. Swaminathan (2011) reports from Pennsylvania, USA, that the natural gas industry has been considered a risk to archaeology since the 1980s. Although the South African study area does not contain precolonial built heritage on the scale of the American Southwest, the case of the Chaco Culture National Historical Park in New Mexico, a declared World Heritage Site, sounds a strong warning regarding impacts to a heritage landscape that is far greater than the sum of its associated sites (Dronkers, 2014). While some of the heritage resource is protected within the park, a large proportion of it lies outside the park and is seen as vulnerable to the effects of SGD.

Legislation covering environmental assessment and SGD is highly variable. While the United Kingdom (UK) has fairly stringent controls in place (Department of Energy and Climate Change (DECC), n.d.; The Town and Country Planning (Environmental Impact Assessment) Regulations No. 1824 of 2011: schedule 2, 2011), those in some USA states are weak. For example, the Antiquities Code of Texas applies only to developments undertaken by federal agencies and whose surface disturbance will exceed five acres (20 234 m^2) unless a known heritage resource will be affected (Texas Historical Commission, 2016). Furthermore, with respect to water and waste, Texas has not imposed any testing regulations specific to SGD (ALS, n.d.) and have recently enacted legislation preventing the banning of fracking by local authorities anywhere in the state (Texas House Bill, No 40 of 2015, 2015). The State authorities in Pennsylvania have actively promoted natural gas over heritage (Swaminathan, 2011). A law was passed stating that any gas project covering 10 acres (4.04 ha) or less does not have to be reviewed by the Pennsylvania Historical & Museum Commission (PHMC), and they do not even need to be notified of the application. Thanks to a 1995 legislative amendment, for projects larger than 10 acres the PHMC is notified but are required to conduct archaeological mitigation at their own expense. With shrinking staff and budget, they can do nothing but watch as sites of proven research value are destroyed. At least some authorities in the USA thus favour SGD over environmental, health and heritage concerns.

Heritage resources authorities (status quo)

Due to a lack of capacity, the heritage management system anticipated by the NHRA is not fully operational. As things stand at present, the following applies in each province under the NEMA process:

- Western Cape: Heritage Western Cape (HWC) is fully functional and applications within Western Cape would be commented on by them;
- Eastern Cape: Although the Eastern Cape Provincial Heritage Resources Authority (ECPHRA) is formally functional, it is poorly resourced and has limited capacity to respond to applications; and
- Northern Cape: The Northern Cape PHRA, Ngwao-Boswa Ya Kapa Bokoni (NBKB), is functional but also poorly resourced. Powers in terms of the NHRA for built environment and landscape matters have been devolved to the PHRA, but not those relating to archaeology and palaeontology (South African Heritage Resources Agency (SAHRA) handles those aspects on its behalf).

Although difficult to prove, this could relate to the corruption reported in the media and in documentaries.

Although the literature seems to deal almost exclusively with the extraction phase of SGD, it seems logical to conclude from the above that pressure on the authorities is likely to mount should a good resource be discovered and that the risks to heritage resources would grow in tandem.

15.1.3 Relevant legislation, regulation and practice

The NHRA (Act No. 25 of 1999, 1999) defines the heritage resources of South Africa in Section 2 and Section 3 (relevant definitions are reproduced in Digital Addendum 15A). Chapter II governs the protection and management of heritage resources. Important in this context is Section 38 which prescribes the manner in which an impact assessment should be carried out. It provides triggers for various activities that would require an impact assessment, however, under Section 4(b)(iii) of the National Environmental Management Act (NEMA) No. 107 of 1998, 1998) one is required to include an assessment of the impacts to the National Estate into any impact assessment triggered by the provisions of that act. Under the NHRA, Section 34 protects structures older than 60 years; Section 35 protects archaeology, palaeontology and meteorites; Section 36 protects burial grounds and graves; and Section 37 protects public monuments and memorials. The definitions mentioned above provide specific details of what is included within each of these categories. The study area contains two NHSs and more than 350 PHSs, declared as such under Section 27 of the NHRA. Under Section 28 heritage resources authorities may provide a measure of protection to certain areas over and above the basic provisions of Sections 34-37, while Section 29 allows the authorities to provisionally protect a heritage resource in order to allow for the consideration of further protection as may be required, often when the resource is under threat.

The World Heritage Convention Act (No. 49 of 1999, 1999) governs World Heritage Sites. Although the study area does not currently host such sites, it does include part of the previously described 'Human Rights, Liberation Struggle and Reconciliation: Nelson Mandela Legacy Sites' serial nomination as well as the Succulent Karoo Protected Areas (UNESCO, 2016c). There are also various national and provincial regulations and guideline documents as well as international guides (largely from ICOMOS and UNESCO) and charters that exist to guide development and mitigate change. There is a Western Cape Government guideline document for involving heritage specialists in Environmental Impact Assessment (EIA) processes (Winter and Baumann, 2005), while both SAHRA (2007) and HWC (2016b) have issued guidelines and standards for conducting specialist assessments of archaeology and palaeontology. International guidelines for heritage studies also exist (e.g. Australia ICOMOS, 1999; ICOMOS, 1999). Regulations concerning the exhumation and relocation of

graves have been published by SAHRA (National Heritage Resources Act 25 of 1999, Regulations R.548 of 2000, 2000).

In the context of SGD in which the Department of Mineral Resources (DMR) would be the decision-making body, heritage impact assessments produced under NEMA (No. 107 of 1998, 1998) and according to the guidelines of Section 38(3) should be submitted to the relevant heritage authorities (see text box) for comment. In the event of free-standing HIAs being conducted (if a development application fails to trigger NEMA), then the heritage resources authorities would be the decision-making authority.

15.2 Key potential impacts and their mitigation

The various heritage resource types are likely to be affected to greatly differing degrees by the many activities that might occur during SGD. This is both because of their variable distribution across the study area and because of the varying degrees to which avoidance or other mitigation measures are likely to be attainable. The activities that could cause direct, negative impacts include driving seismic exploration vehicles across the landscape, the preparation of wellpads and the construction of roads, pipelines, water storage reservoirs, gas processing and storage facilities, Combined Cycle Gas Turbine (CCGT) power stations, transmission lines, substations, and staff accommodation. Indirect impacts may occur through earth tremors, vandalism and a general lack of maintenance of heritage resources. There is currently a lack of proper heritage management throughout much of the study area and this should be redressed in areas where SGD takes place. While a degree of organisation will be required amongst the authorities, formal mitigation measures that require implementation must, in terms of South African legislation, be commissioned at the expense of the developer.

15.2.1 Built heritage

The built heritage resources located in the study area are diverse and only patchily recorded. Assessment for SGD thus has the potential to reveal many as yet unknown sites. Built heritage is generally visible and can be avoided but, without assessment, there is the chance of direct, negative impacts that might occur through any of the activities listed above. Direct impacts would generally occur in rural areas where most structures are likely to be of Grade IIIB or IIIC significance. Clearing of land in preparation for development could result in direct destruction of built heritage, while indirect impacts could also result if activities are situated too close to fragile resources – this applies equally to new development (e.g. roads and wellpads) and upgrades of existing infrastructure. Even if built heritage resources are successfully avoided, they would remain vulnerable to vandalism and the risk becomes greater when more people are on site. Vandalism can result in low intensity impacts

through, for example, breaking windows, but deliberate collapsing of fragile drystone structures, often to reuse the stone, presents a high intensity impact. Although relocation of people is not envisaged; indirect impacts can be exacerbated if people move away from their homes in order to avoid SGD. This would result in buildings not being maintained. Direct, negative impacts could be of medium to high intensity, but predicting the intensity of indirect impacts is very difficult, since human nature cannot be predicted and it is unknown to what degree earth tremors might occur if SGD is implemented. Should increased seismicity become a feature of the study area, then high intensity impacts could become widespread. All built heritage, including monuments and memorials, could be affected with impacts including cracking and partial or total collapse. Tall historical structures are especially vulnerable and damage may be irreparable. If seismic activity potentially great enough to result in widespread damage to fragile structures is expected; then this should be considered a fatal flaw.

Although it is expected that staff would be accommodated in purpose-built housing, the possibility of secondary industrial growth could well lead to impacts to towns. Population influx could have a positive impact on the built heritage (including townscapes) of both the study area and other settlements that lie along provisioning routes. The increased investment, if well managed, could reinforce economic and social structures that support built heritage and lead to appropriate restoration and maintenance practices. The potential economic injections could also be used to redress the legacies of apartheid planning still evident, and being perpetuated, in the townscapes of the study area. Poor management of investment, on the other hand, may result in uncontrolled development (from inappropriate planning approval or lack of heritage skills) that could negatively impact individual heritage structures and townscapes. An influx of new inhabitants unfamiliar with the maintenance of vernacular structures could bring about irreparable damage.

All impacts are permanent but some may be repaired to a degree. It should be noted that repairable damage is not insignificant: although it results in a smaller overall impact, it is not a preferred mitigation strategy. The degree to which impacts may be repaired, however, cannot be predicted during an impact assessment. Cumulative impacts are expected to increase dramatically as development progresses from Scenario 0 (Reference Case) to the Big Gas scenario. Should the study area remain in the Reference Case state, then many undiscovered heritage resources would continue to suffer from poor management and natural degradation. They would also be vulnerable to damage resulting from livestock, agricultural, ecotourism, mining and renewable energy development, inappropriate alteration and adaptive reuse, and the expansion of towns and related infrastructure. Also of concern, especially in rural areas, is the ongoing deliberate demolition of heritage structures to recover building materials that are either sold to the second hand market or used in new farm

buildings or guest houses. Built heritage is the only aspect under consideration here that has direct financial value: although the heritage belongs to the state, people can still sell properties that have heritage buildings on them. Under the Reference Case, the already marginal economic feasibility of many built heritage resources could be further reduced to the extent that they could be lost.

Should development proceed, it is envisaged that the first stage of assessment would be the identification, mapping, and photographic recording of all exteriors of built heritage structures within and close to the relevant study areas by a suitably qualified consultant, commissioned by the developer. This would apply to all aspects of Exploration only to the Big Gas scenario and would likely occur initially during archaeological surveys. Recommendations could then be put forward for the detailed recording and assessment of all built heritage where it is deemed that a risk of impact exists. This latter assessment, also commissioned by the developer, should be carried out by a suitably qualified heritage practitioner familiar with the built heritage of the Karoo region and, where appropriate, should include those less prominent elements (like dry-stone walls, furrows and the built aspects of historic roads) scattered across the landscape and which form an integral part of the regional cultural landscape. Recording would include, among other things, photography, digital three dimensional scanning (African Conservation Trust, 2016), measured drawings, plaster sampling and possibly archaeological excavation. If built heritage is known and serviced appropriately during SGD, the potential exists for positive impacts (benefits) to occur. The option also exists, depending on the willingness of the developers, to commission a large-scale built heritage survey of broad areas due to be prospected. This would be costly (incorporating student researchers could mitigate cost) but could introduce several benefits: heritage knowledge would benefit substantially, the confidence levels of built heritage impact assessments would increase, and a standardised record of potentially vulnerable structures would be put in place that could serve as a benchmark for the evaluation of any insurance claims that may arise in the event of structural damage. In addition, it is likely to be the only viable partial mitigation measure (even though not entirely acceptable) should widespread damage occur as a result of tremors.

15.2.2 Archaeology and Graves

Because archaeological resources are so widespread across the study area, it is likely that many sites and artefact scatters will be directly and negatively impacted by surface activities related to SGD. Graves are less common, but are as much at risk, especially the many unmarked or minimally marked graves of precolonial people, farm workers, early colonists and victims of conflict that could be less easy to locate. Assessment of any development activities would very likely result in the recording of large numbers of previously unknown archaeological sites and occurrences. The various development activities listed above would require clearing of the land surface which would damage or destroy any

archaeological material or graves occurring within the development footprint. It should be noted, however, that the majority of this material is likely to have limited scientific value and hence heritage significance (mostly Grade IIIC or Not Conservation Worthy (NCW)) but can still meaningfully inform the interpretation of larger scale patterns. Impacts to rock art could also occur. A minor consideration is the potential impact of quantities of dust (from drilling) settling on their surfaces, while the worst-case scenario could see rock art sites spalling or even collapsing as a result of seismic activity. Visual impacts to the setting of rock art sites are also a concern.

Impact intensity would generally be low-medium for the seismic exploration activities because of the relatively limited ground disturbance, but all other activities that physically break the land surface would result in high intensity impacts. All impacts are permanent. Indirect impacts could involve illegal collection of heritage objects and/or vandalism of archaeological sites. Ruined structures, rock art and graves are likely to be most at risk in this regard. These secondary impacts are likely to be of medium to high intensity and are generally permanent. All of the above impacts could occur in conjunction with any of the four scenarios and, because every archaeological site is unique, the intensity of impacts could vary more according to the discovered heritage resources than to the scenarios. However, as the sequence of potential development advances from the Reference Case through to the Big Gas scenario, the cumulative impacts will increase in intensity and extent. Other developments, such as renewable energy and mining, will also continue to impact on archaeology and graves, although micro-siting of infrastructure tends to avoid some impacts.

In the event of development proceeding, archaeological field studies would be required for all aspects of development because surface archaeological sites are very fragile and easily disturbed. It is expected that the surveys could generally recommend small locational adjustments of the relevant activities so as to avoid direct impacts to significant sites. Sites graded Grade IIIA or higher should be protected from harm, but if avoidance is not possible for Grade IIIB and IIIC sites, then mitigation involving excavation and collection by a suitably qualified and experienced archaeologist would be required at the expense of the developer. Insignificant sites (graded NCW) could be sufficiently recorded during the surveys with no further actions required before development. There is a chance that archaeological monitoring of construction work in certain areas may be required in order to identify any sites not visible at the surface. Graves should preferably be avoided and access to historic graveyards should never be blocked. Because unmarked graves are not easily located at the surface, it is possible that they may be uncovered during development. Should this happen, the remains would need to be protected, reported to the relevant authorities and then exhumed by a professional archaeologist before development continues. This should follow the process outlined in Chapter IX of the NHRA Regulations (National Heritage Resources Act 25 of 1999, Regulations R.548 of 2000,

2000). Archaeological impacts should not result in any fatal flaws, although there may be rare occasions where no-go areas need to be delineated to protect a particularly special resource for which mitigation is either not feasible or perhaps not the desired outcome from a heritage point of view.

15.2.3 Palaeontology, Meteorites and Geological heritage

While meteorites and designated geological heritage sites are generally rare (records for the latter are held by the CGS but are not published on SAHRIS), palaeontological resources are widespread both at and below the ground surface throughout the study area, with most of it considered highly sensitive on the SAHRIS palaeonsensitivity map (Figure 15.14). Since most scientifically useful fossils, rock exposures and meteorites are situated close to or at the surface, direct, negative impacts to fossils, geological sites and meteorites could occur through all of the same mechanisms outlined for archaeology above. Fossils may also be impacted by drilling through deeply-buried fossiliferous rocks (especially the carbon-rich mudrocks of the Whitehill Formation) during Exploration Only, and the Small and Big Gas scenarios. However, since such rocks and fossils are unlikely to ever be available for palaeontological study (with the exception of microfossils that can be extracted from drill cores), the impacts on them are not of concern in the present context.

Positive impacts can also result from SGD. For example, fresh road cuttings, borrow pits and borehole cores that are made available for scientific study promote geological and palaeontological knowledge. In the same way, any mitigation work carried out would enhance our understanding of Karoo geology and palaeontology. Because palaeontological material can be widely distributed within a particular rock unit (e.g. formation), which may have an outcrop area of tens to hundreds of square kilometres, impacts would likely be of low-medium intensity. They would, however, be permanent. Disturbance or destruction of key fossils – such as rare species or well-preserved, articulated specimens in their original geological context – or the designated type localities of fossil assemblage zones would represent localised, high-intensity impacts. Such localities are best avoided. Although just outside the study area, the extraordinary number of fossils discovered in a road cutting near Grahamstown (Van Rooyen, 2016) provides a dramatic example of a situation in which substantial palaeontological mitigation work may become necessary. Secondary negative impacts can also occur due to the influx of people who might illegally collect or disturb fossils. Like many archaeological artefacts, the value of a fossil often lies as much in its provenance (geographic, stratigraphic and sedimentological setting) as in the object itself. Because fossils are often difficult to recognise, these secondary impacts are likely to be of low intensity but are permanent. Meteorites and geological heritage sites are rarely identified, so impacts to them are difficult to assess and address. Relevant sites would need to be identified during EIA studies. Meteorites could be collected, while geological sites would need to be mapped and avoided. All of the above impacts could occur in conjunction with any of the three

development scenarios, although it is likely that the intensity of impacts will be greater as the level of SGD increases. The cumulative impacts would also increase as development progresses from Exploration Only to the Big Gas scenario.

Should development proceed, palaeontological field studies would be required during EIA studies for all aspects of development. For Exploration Only, a desktop study may be sufficient, however, unless extensive surface clearance, building of roads or substantial bedrock excavation is expected. Avoiding all sensitive palaeontology is generally not feasible and it is expected that recording and judicious sampling of representative surface or near-surface fossil material within the development footprint will sometimes be required before construction for Grade IIIB and IIIC material. Monitoring of excavations may still be recommended in certain sensitive areas to record subsurface geological and palaeontological data. Should the monitoring palaeontologist discover highly significant fossil material then it is likely that work would need to stop in order to allow for appropriate recording and collection by a suitably qualified and experienced palaeontologist. All such work is commissioned at the expense of the developer. Largely because of the positive impacts expected from such mitigation, palaeontological issues should not result in any fatal flaws.

15.2.4 Living heritage

Living heritage occurs throughout the study area but, because of its generally intangible nature, it is unlikely to be heavily impacted by SGD. Certain places will have very strong links to living heritage, especially where it informs land use and settlement patterns. Water sources associated with indigenous mythology are also important. In such instances direct negative impacts to the physical manifestations of living heritage could occur, but the majority of traditions, memories and customs are not tied to specific places and should not be unduly impacted. Two exceptions are noted: traditional knowledge related to the pastoral way of life is poorly recorded and can be easily lost when left unpractised, and the *Karretjie Mense*, with their fragile economic base could easily be forced to abandon their traditional practices. The conversion of sheep farms to game farms, for example, is already eroding traditional knowledge and taking people off the land. Should people choose to leave the SGD area then this will also remove the knowledge and cultural continuity that has been accumulated over many generations of Karoo family history. An influx of large numbers of non-local people, particularly speakers of ‘non-Karoo’ languages, might result in secondary impacts to local traditions and customs because of new equivalents being introduced. Generally, impacts to living heritage are likely to be unimportant, but some impacts may be of great concern to certain groups or in specific places. While Exploration Only should not result in many impacts, cumulative impacts are likely to worsen with the Small and Big Gas scenarios because of the larger areas of land being

transformed, the potential greater influx of non-local people and the changes to the economic base of the developed areas. The Reference Case has minimal impact.

Mitigation of impacts to most living heritage could not be meaningfully attained, although during any EIA work it would be necessary to ascertain if there are specific places that have social significance and then determine practical measures to avoid erosion of that significance. This can be achieved through interviews with local inhabitants. Interviews could also be conducted if farms are sold so that any links to living heritage that are known to the inhabitants can be recorded prior to them leaving the land. A readily implementable mitigation measure is to use local names, or names derived directly from local culture (in its broadest sense) to name components of the developments like production areas or housing schemes. The introduction of non-local names should be avoided.

15.2.5 Cultural landscapes

Cultural landscapes are ubiquitous across the study area. The rural Karoo landscape contrasts strongly with the overtly industrial nature of SGD such that it could be easily disrupted by the occurrence of incompatible activities, especially from the longer-term Small and Big Gas scenarios. With the exception of the renewable energy facilities located in certain parts of the Karoo, the prevailing local activities are overwhelmingly related to farming, especially pastoralism. Extensive tracts of land also have wilderness qualities. Physical features of the cultural landscapes, such as fence lines, tree rows, livestock drovers' routes, old wagon routes and agricultural lands can also be physically disturbed. Some of these features are very ephemeral and thus vulnerable to inadvertent damage. Another impact of concern is the potential for the uncontrolled expansion of towns if many new workers need to be accommodated or if secondary industry develops to service SGD. Erosion of the integrity of the historical layouts and inappropriate adaptive reuse of historical structures are potential concerns that can impact townscapes. Although it is noted that the workforce would most likely be accommodated in purpose-built villages close to the development blocks, it may well become feasible to rather expand town areas if, after exploration, a development block was placed close to a town. The impacts could be direct and negative, although there is the potential for a positive impact if good planning is employed. Streetscapes could be enhanced and new life brought to towns that are struggling economically. Because of the short duration of the visual intrusions related to the Exploration Only scenario and the relatively light footprint of the associated activities, the impact intensity for exploration is likely to be low. However, a progression to Small and Big Gas would likely result in high intensity impacts within the 30 x 30 km development blocks, especially in river valleys, and medium intensity impacts to areas within several kilometres around them. The latter distance would vary depending on topography and would be informed by the visual studies. If development occurs in areas visible from great distances, then impacts of medium to low intensity could be experienced still

further away. Although drilling rigs are incompatible with the agricultural landscape and highly visible due to their height, a relatively small number would be employed within the development block with each well taking about one month to drill. Impacts would thus be of short duration. The longer term impacts of concern are the alteration of the landscape through clearing and levelling of the many wellpads and access roads that would be required.

Should development proceed, then it is likely that studies investigating the visual impacts to the cultural landscape would be required in order to inform the potential delineation of no-go areas. This is because impacts to the cultural landscape tend to relate more to visual intrusion with the physical impacts to components of the landscape being less concerning. Mitigation measures could include shifting the locations of wellpads and access roads away from sensitive parts of the landscape, and avoiding road alignments that cut across contours and are visible from greater distances. Minimising the length of access roads will be important, although reducing cut and fill operations should be a priority. Wellpads should preferably be located in slight depressions in the landscape or areas that will be easy to rehabilitate. Impacts to the cultural landscape could be seen in a serious light by the heritage authorities but, with every attempt made to reduce visual impacts and good rehabilitation plans in place, it should not be a fatal flaw.

15.3 Risk assessment

15.3.1 How the risks are measured

15.3.1.1 Built heritage

The potential number and cultural significance of built heritage sites that could be impacted is important, although hard to predict. An intact but unused corbelled or stone-walled house in a remote location could have just as much cultural significance as a well-maintained historic hotel in Beaufort West or Graaff-Reinet. Also, significant heritage sites are distributed in varying concentrations throughout the study area. Because of the low level of survey coverage of the region, we are forced to extrapolate the potential density of built sites from better-known areas which makes it unfeasible to distinguish low and high risk parts of the study area. A consideration of the landscape to be impacted assists in this regard because in undulating terrain historic structures tend to be located in valley bottoms close to patches of alluvial soil, while in open areas far from topographic relief such sites are less predictable, especially because boreholes allowed settlement to occur on the plains away from rivers after the mid-19th century. The degree to which the likely locations of rural built heritage features, and the risk to them, can be predicted is thus variable. More reliable are towns and the

structures related to road and rail transport. It is thus necessary to make some broad assumptions regarding the potential density of built heritage when measuring the risk.

There are very few areas that have not seen historical settlement and we thus do not expect any parts of the study area to be particularly exempt from risk – these would require consideration during HIA reporting. Significance of individual heritage resources and ensembles such as towns and farmsteads, is not based solely on typological and architectural aspects, but includes consideration of authenticity, historical layering, rarity, representivity, associations and relationship with setting. The latter is surprisingly vulnerable and demands careful consideration. The significance of heritage resources can be compromised or even destroyed by changes to their setting, whether these relate to sights, sounds or even smells. There is also a management risk stemming from both poor quality HIA reporting (many assessments focus on archaeology) and the likelihood that formal comments on built heritage and cultural landscapes in the Northern and Eastern Cape Provinces may not be forthcoming from the respective Provincial Heritage Resources Agencies (PHRAs) because of lack of capacity – this lack of capacity poses a direct threat to heritage resources. Proper mitigation and management measures pertaining to built heritage may therefore never be carried through into Environmental Authorisations (EAs).

Therefore, in general, three factors inform the measurement of risk in relation to built heritage:

- Undulating landscapes – particularly those containing river valleys and alluvial floodplains – are likely to pose a somewhat higher risk. Although open areas also pose risks, these are less predictable and can occur anywhere in the study area;
- The more vehicles, people and activity occurring within the landscape, the higher the risk to built heritage resources is likely to be; and
- Parts of the study area are potentially susceptible to less rigorous assessment, mitigation and management of built heritage because of the limited capacity of some heritage resources authorities.

15.3.1.2 Archaeology

In the case of archaeology, the potential number and cultural significance of sites that may be affected is important. Because of the low level of survey coverage of the region, an assessment of the landscape to be impacted and thus the potential density of archaeological sites present is the most reliable way to determine these risks. This is because throughout the drier parts of South Africa a greater number of sites with higher significance is expected to occur in the vicinity of landscape features like river valleys, pans, dolerite outcrops and cliffs than would be the case in open, less protected situations far from water and shelter. More than half of the study area has undulating terrain

(including dolerite outcrops) in which a greater density of archaeological sites might be expected. It is this aspect that is used to map higher and lower sensitivity areas for the risk assessment. Graves could occur anywhere and, while precolonial graves are more likely to occur close to habitation sites, historical graves, if not located alongside farmsteads, may be in far more open contexts. The risks posed by graves are thus less easily assessed, although graves are likely to be very sparsely distributed on the landscape. It is assumed that the risk mapping for archaeology will approximate the risk for graves.

Therefore, in general, two factors inform the measurement of risk in relation to archaeology and graves:

- Rocky areas and more undulating landscapes – particularly those containing river valleys and alluvial floodplains – are likely to pose a far higher risk than flat, open plains that lack landscape features; and
- The more vehicles, people and activity occurring within the landscape, the higher the risk to archaeology and graves is likely to be.

15.3.1.3 Palaeontology, Meteorites and Geological heritage

Palaeontological resources of high sensitivity occur throughout most of the study area which means that risk will be virtually unavoidable. Many important palaeontological and geological type localities exist and such areas should be seen as very highly sensitive because of their established scientific value. Because of the low level of survey coverage of the region, the surface distribution of fossil heritage is not well known in detail. All the formations within the Beaufort Group as well as the Whitehilll Formation of the Ecca Group (the principal target of SGD) are rated as highly sensitive, for example. The Beaufort Group underlies the majority of the study area, approximately one third of which has yielded a high density of vertebrate fossil sites (Figure 15.16). It should be noted that palaeosensitivity maps are a very useful scoping tool but tend to exaggerate the palaeosensitivity of some rock formations in parts of their outcrop area by not taking into account factors such as levels of tectonic deformation, weathering, metamorphism and level of surface exposure. Furthermore, small-scale sedimentary units such as ancient alluvial deposits, *vlei* and pan sediments that locally may be highly fossiliferous are not usually represented on available palaeosensitivity maps. Nevertheless, to map risk we have taken all areas of high and very high sensitivity on the SAHRIS PalaeoSensitivity Map as higher risk and the remainder (rated as zero to moderate sensitivity) as lower risk. Intrusive works, like cut and fill operations for road construction or borrow pits, are likely to have the greatest impact, but negative risks are moderated by the degree of potential positive impact that might result from these works. Because of the relative scarcity of meteorites and geological heritage sites (i.e.

extremely low density and spatial coverage within the study area), these aspects of heritage are not expected to pose much risk.

Therefore, in general, two factors inform the measurement of risk in relation to palaeontology:

- The inferred palaeosensitivity of the bedrocks within the study area will indicate areas of higher and lower risk; and
- The more surface clearance or earthmoving that is required in the construction of, for example, access roads, the higher the risk to palaeontology is likely to be. Note that scientific study of cuttings and clearings may also result in positive impacts (benefits) to palaeontological and geological heritage.

15.3.1.4 Living heritage

Quantifying the amount of living heritage that exists in the study area, and hence the risk to it, is impossible. However, significant impacts are relatively unlikely with the result that risk is likely to remain low. This study reveals three possible sources of risk related to the loss or contamination of places associated with living heritage (especially water sources), large-scale influx of non-local populations and the possible loss of local family history should people choose to leave the area rather than live with SGD happening around them.

Three factors inform the measurement of risk in relation to living heritage:

- Risk will increase if contamination of or loss of access to water sources occurs;
- Risk will increase in the event of large-scale population influx; and
- Risk will increase should long-standing local residents choose to leave the Karoo.

15.3.1.5 Cultural landscapes

Because cultural landscapes occur throughout the study area, risk will be experienced in all parts of it. However, certain landforms and areas are more susceptible. Areas more conducive to farming, especially agriculture, generally contain the more developed rural landscapes – such areas are invariably close to reliable water sources. River valleys containing alluvial soils are particularly susceptible because of their contained nature and predisposition for historic and prehistoric settlement. Areas visible from a distance, especially steeper or undulating terrain, will present higher risk because of the greater possibility for perception of impact due to visible landscape scarring from, among other things, cut and fill operations that might be required to create access roads and wellpads. Town contexts are less likely to be impacted visually by fracking because of the buffers that would be imposed but could still be affected by poor planning if they expand. Risk will be higher in proximity

to landscapes possessing high cultural significance (as per Section 2(vi) of the NHRA) but this will vary based on the degree of intactness, representativity and layering and the presence of screening topography. Such factors must be incorporated into HIA assessments.

Therefore, in general, four factors inform the measurement of risk to cultural landscapes:

- Undulating landscapes – particularly those containing river valleys and alluvial floodplains – are likely to pose a high risk;
- Steep terrain where landscape scarring could be visible from a distance will pose high risk;
- Areas that were the focus of historical occupation pose high risk; and
- Intact rural and wilderness landscapes with minimal modern/industrial disturbance pose high risk.

15.3.2 Limits of acceptable change

Although every heritage resource and ensemble is considered unique and, in most cases, negative change to either their fabric or setting are undesirable, it is recognised that change must happen in order to allow for development. Although unauthorised alteration, disturbance, destruction or removal of any heritage resource is a criminal offence and entirely unacceptable when unmitigated, the impact assessment process is there to guide the degree of change that might be acceptable for any given heritage resource and to establish under what circumstances such change would be permitted. Because of the uniqueness and greatly variable heritage significance of individual heritage resources, and the uniqueness of their settings and the important vistas towards and from them, it is not possible to make sweeping statements as to the degree of change that is acceptable. Likewise, mapping of areas of higher or lower risk is difficult because significant resources can occur anywhere in the study area and, should seismic activity be a consequence of SGD, the location and timing of impacts cannot easily be assessed. Furthermore, in recognising the occasional need for change, the NHRA, under Section 38(3)(d), requires an evaluation of impact relative to the sustainable social and economic benefits to be derived from the development in order to allow for the fact that human needs take preference over those of heritage. This means that any limit discussed here would need to be reviewed in context during an impact assessment. The limits discussed below are based on a combination of experience, precedent and established regulations, and should be authorised and implemented under an EA.

15.3.2.1 Built heritage

For direct impacts to built heritage, very little change can be deemed acceptable because this aspect is one of the most tangible and accessible aspects of heritage and adequate mitigation of high

significance resources is generally impossible. Of course there are many built heritage resources that are in very poor condition due to neglect, inappropriate renovation and/or adaptive reuse, and their alteration or demolition may be acceptable. During field assessment decisions would need to be taken based on condition, rarity, representivity and setting as to which resources and their constituent attributes could be altered or destroyed if necessary, and the degree of prior investigation and recording that might be required. Change would only be allowed in exceptional circumstances if it is impossible to avoid the resource. At a broader level, any long-term infrastructural development that disrupts the setting, character and sense of unity of a built heritage resource or precinct would be unacceptable. Particularly important in this regard is the potential for insensitive industrial development in support of SGD that could occur in or on the peripheries of intact historic towns with a strong sense of place. Any widespread damage to built heritage resources that might occur through induced seismic activity or any other SGD related activity would be considered entirely unacceptable in heritage terms and, should the possibility of such widespread damage be expected then this may be considered a fatal flaw.

15.3.2.2 Archaeology and graves

Field experience has shown that the majority of recorded archaeological heritage resources (>90%) are of low heritage significance and can be destroyed without undue negative impact to the National Estate. A small proportion of these would require mitigation, while the remainder could be suitably recorded during the EIA Phase. Because of the unique nature of archaeological resources, degrees of change are not an appropriate measure – they should either be conserved or else destroyed, either with or without mitigation depending on their significance. Unacceptable change would therefore be if those sites set aside for *in situ* preservation (the other <10%) are disturbed or if sites requiring mitigation are disturbed prior to that mitigation being effected. By necessity, archaeological heritage resources that do not have formal protections (declaration or grading) in place or have not been identified during earlier assessments can only be identified at the EIA Phase. Only then could the number of sites requiring further attention be delineated for any particular area.

15.3.2.3 Palaeontology

Field experience has shown that the majority of identified palaeontological heritage resources (> 90%) are of comparatively low heritage significance and can be destroyed without undue negative impact to the National Estate. A small proportion of identified fossil sites would require mitigation (*i.e.* collection or protection *in situ*), while the remainder could be suitably recorded during the EIA Phase. The nature of palaeontological resources – the majority essentially hosted by large-scale geological units that can vary spatially in palaeontological sensitivity – means that degrees of change cannot be

meaningfully suggested. Unacceptable change would apply if those exposed geological sections / palaeontological sites set aside for *in situ* preservation (the other <10%) are damaged or disturbed, or if sites that require mitigation are disturbed prior to that mitigation being effected. Of necessity, palaeontological heritage resources that do not have formal protections (declaration or grading) in place, or that have not been identified during earlier assessments, can only be identified at the EIA Phase. Only then could the number of sites requiring further attention be delineated for any particular area. Formally recognised geological heritage sites and meteorites are very rare in comparison to other types of heritage. While meteorites can be recorded, collected and housed in a museum, geological sites and palaeontological type localities derive their meaning from their location and can therefore not be adequately mitigated; their destruction would be unacceptable unless equally good equivalents can be designated.

15.3.2.4 Living heritage

Because of its intangible nature, most living heritage should survive in the face of development. However, with large-scale population influx, new cultural traditions could arrive and possibly influence the degree to which local traditions continue to be practised. Marginalised communities like the Karretjie People are already struggling and with the addition of a new economic driver these communities would be particularly vulnerable. Unacceptable change would occur should local traditions, practices and customs be abandoned or forced out in favour of non-local ones. The addition of a new living heritage layer would not be unacceptable though. The irreparable damage to a place that has strong associations with living heritage, such as a water hole, would also be regarded as unacceptable change.

15.3.2.5 Cultural landscapes

Cultural landscapes cannot be destroyed but their integrity is eroded and their character changed through inappropriate development. The degree of erosion is impossible to quantify and universal limits cannot be set. This is partly due to the very personal nature of one's perception of the landscape and the amount of inter-observer variability that would result. Given the degree of variation in topography, vegetation cover, land use, settlement patterns and other cultural factors involved in the creation of cultural landscapes, it is likely that, given a consistent observer, the limits of acceptable change would also be strongly variable across space. In general, however, the wellpads and access roads should be sited in such a way as to not become the focus of attention when viewed from the middle to long distance. Because impacts to the cultural landscape are largely visual in nature and very variable across space, the limits of acceptable change would need to be set through the

application of viewshed analysis with appropriate visual buffers established on a case-by-case basis during EIA studies.

It is also necessary to consider that the merino sheep and the wind pump massively changed the cultural and economic landscape of the Karoo at the time of their introductions and are now revered as heritage. The landscape has also been changed by the ongoing addition of an astronomical layer which also has cultural significance. The introduction of SGD would introduce yet another new layer to the cultural landscape. However, this new layer would need to be carefully managed in order to maintain the complexity of the historical layering.

15.3.2.6 No-go areas

The no-go areas and buffers identified in this scientific assessment pertain to surface disturbance and risk to tangible heritage fabric only and are a guideline. Larger or smaller buffers may be determined during EIA studies depending on the specific resource, its setting, any shielding topography that may occur, and the nature of any possible threats to the resource. The buffers suggested are based on previously established precedents (see for example CNdV Africa, 2006; Fourie et al., 2014) but modified at times because of the greater amount of activity expected (for example around wellpads) over longer periods of time (Table 15.3). Built heritage buffers are informed by Durrheim et al. (2016). The categories include known sites and areas as well as those that may be identified during EIA studies. Note that many archaeological heritage resources in this arid environment will likely be protected by the already gazetted buffers from riparian areas (500 m) and wetlands (1 km) (MPRDA, No 28 of 2002, Regulation 2015).

Table 15.3: No-go areas.

Category	Applicable buffer
All sites/areas formally protected under the NHRA (see Digital Addendum 15B). • National and Provincial Heritage Sites; • Grade I, Grade II and Grade IIIA sites; • All heritage register sites (in Northern Cape and Eastern Cape). (Note that declarations can be of individual sites, land areas or groups of sites and in the latter case could fall within multiple administrative areas). Buffers should extend from the edge of the declared area.	> 10 km minimum for wellpads. > 1 km for other activities. Impact on setting to be evaluated on an individual basis.
All urban areas for their individual resources and townscapes (note that additional buffering should be determined in consultation with a seismologist during EIA/HIA phase)	> 10 km minimum for wellpads. Impact on setting to be evaluated on an individual basis.
Other built heritage resources requiring *in situ* conservation (note that additional buffering should be determined in consultation with a seismologist during EIA/HIA phase)	> 10 km minimum km for wellpads. > 500 m for all other related infrastructure. Impact on setting to be evaluated on an individual

Category	Applicable buffer
	basis.
Other archaeological sites, graves and graveyards requiring *in situ* conservation (note that additional buffering of fragile rock art sites should be determined in consultation with a seismologist during EIA/HIA phase)	> 50 m from all activities.
Other palaeontologically sensitive areas. Extensive buffering of very high sensitivity areas (e.g. Fourie et al., 2014) is unlikely because of the potential benefits that might occur through SGD, but limited areas (especially areas of unconsolidated sediment like pans and alluvial terraces) may be delineated in the field for exclusion.	> 50 m from all activities.
Cultural landscapes cannot easily be defined from the desktop. The visual sensitivity of the landscape (see Oberholzer et al., 2016) serves as the best proxy but would require moderation at EIA phase. They do not always require buffering and development within certain cultural landscapes may be permissible on a case-by-case basis depending on topographic shielding. The same applies to scenic routes and passes.	Variable but suggest > 5 km from wellpads and other visually intrusive components for highly sensitive landscapes. Impact on setting to be evaluated on an individual basis.
Living heritage is not conducive to the establishment of buffers. No-go areas may be suggested by EIA studies.	Impact to be evaluated on an individual basis.

15.3.2.7 Risk assessment table

Table 15.4 indicates the assessed risks in terms of the impacts to various categories of heritage resources. The majority of assessments are indicated as of low or very low risk after mitigation. Those with higher levels of risk are generally those for which mitigation will still result in a residual impact, often because mitigation is difficult to implement. The cultural landscape is the most problematic but it should be borne in mind that the study area is large and the indicated assessment would only pertain to the eventual area(s) chosen for development if highly significant landscapes were impacted. This aspect is probably the only one for which a greater risk could be expected with development greater than the Big Gas scenario. For the rest the risk would be similar but occurring over a greater extent. The assessment is based on the expected consequence of impacts (explained in Table 15.5) and the likelihood of them occurring. The areas listed under Location are mapped in Figure 15.20 to Figure 15.24.

A number of notes are provided to assist with the interpretation of the risk assessment:

- All impacts are seen as accumulative. That is, even though the impacts of the specific activities related to Exploration Only may, in some instances, be of less consequence than those relating to the Reference Case, the level of risk cannot be lower in the Exploration Only scenario. This is particularly relevant to the built environment and palaeontology where the impacts from illegal demolition of rural buildings and the construction of renewable energy facilities respectively (Reference Case) are likely to be worse than those from shale gas exploration (Exploration Only).

- Because the consequences of impacts could vary greatly within each category of heritage, the consequence levels assigned in Table 15.4 reflect an expected 'average' consequence.
- It is assumed that mitigation of direct impacts would be relatively successful, usually through micro-siting, but that indirect impacts, predominantly vandalism, would be difficult to control.
- For the Reference Case it is assumed that the present pace of urban growth, livestock and game farming, and ecotourism, mining and renewable energy development would continue into the foreseeable future and that most impacts would be as a result of these types of development. In addition, the continuing impact of ignorance results in the loss of many heritage resources that have little or no perceived value to the owner but yet which form part of the National Estate. These impacts occur, for example, through demolition, renovation or unregulated land use changes.
- In the case of palaeontology and geological heritage, negative impacts are, to a large degree, offset by positive impacts – provided that appropriate mitigation measures are fully implemented – which helps keep the risk lower. Other areas, like wetlands and alluvial terraces, are too small to be mapped on 1:250 000 geological maps. Their partial protection is anticipated through the already gazetted water resource buffers but this would not apply to ancient defunct drainage systems.
- With regards to the mapping of different levels of sensitivity across the study area for the risk assessment, the following observations are made:
    - For built heritage we consider all areas within 10 km of towns and settlements as high sensitivity although it is likely that this area could be reduced substantially on a case-by-case basis during EIA Phase studies. The remaining areas are considered as being of medium sensitivity. It has been necessary to separate the impacts to built heritage that might occur through earth tremors from all other impact sources because the risk from tremors is impossible to compare with other sources of risk. This is because of the unpredictability of earth tremors and the fact that they could have widespread, extreme impacts that are difficult or impossible to mitigate. Durrheim et al. (2016) have considered the occurrence of a seismic event due to a fracking within 10 km of a town to have potentially severe consequences, and state that fracking is very unlikely to induce such an event. Only one risk assessment is provided in relation to earthquakes for the entire study area (with no specific sensitivity) because the potential risk is very difficult to accurately quantify.
    - For archaeology (including and graves) the plains and low foothills present an environment that is generally of low to medium sensitivity, while the uplands with their variable topography, rock outcrops and more prominent river valleys present far

more opportunity for precolonial and historical occupation and are considered highly sensitive.

- For palaeontology, we have used the SAHRIS PalaeoSensitivity Map with all areas denoted high and very high sensitivity being mapped and assessed as highly sensitive for the purposes of this assessment and the remainder as low sensitivity. Geological heritage and meteorites are neither mapped nor assessed because they are too rare to merit meaningful assessment.
- Living heritage occurs throughout the study area and, because significant impacts are unlikely, we have assessed the entire study area as low sensitivity.
- For cultural landscapes we have provided a single sensitivity class with the entire study area considered to be highly sensitive because the identification and interpretation of this aspect will vary greatly among specialists and authorities alike. This is therefore a cautious approach. We recommend that the visual sensitivity synthesis be consulted as a proxy for where cultural landscapes are more likely to be found but note that all parts of the study area could still be seen as sensitive.

- Because every heritage resource is unique, the potential exists for impacts of varying consequence. The levels indicated reflect the probable 'average' consequence in each case.

Table 15.4: Risk assessment.

Impact	Scenario	Location	*Without mitigation*			*With mitigation*		
			Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
Impacts on built heritage, monuments & memorials (all impacts except earth tremors)	Reference Case	High sensitivity areas (land less than 10 km from towns and settlements)	Moderate	Likely	Low	Moderate	Unlikely	Low
	Exploration Only		Moderate	Likely	Low	Moderate	Unlikely	Low
	Small Gas		Substantial	Very Likely	Moderate	Substantial	Likely	Moderate
	Big Gas		Severe	Very likely	High	Substantial	Likely	Moderate
	Reference Case	Medium sensitivity areas (land more than 10 km from towns and settlements)	Moderate	Likely	Low	Moderate	Unlikely	Low
	Exploration Only		Moderate	Likely	Low	Moderate	Unlikely	Low
	Small Gas		Moderate	Likely	Low	Moderate	Unlikely	Low
	Big Gas		Substantial	Likely	Moderate	Moderate	Unlikely	Low
Impacts on built heritage, monuments & memorials (earth tremors only)	Reference Case	All areas	Extreme	Extremely unlikely	Very low	Extreme	Extremely unlikely	Very low
	Exploration Only		Extreme	Very unlikely	Low	Extreme	Unlikely	Low
	Small Gas		Extreme	Unlikely	Moderate	Extreme	Likely	Moderate
	Big Gas		Extreme	Likely	High	Extreme	Likely	High
Impacts on archaeology & graves	Reference Case	High sensitivity areas (uplands	Substantial	Unlikely	Moderate	Moderate	Extremely unlikely	Very low
	Exploration Only		Severe	Likely	High	Substantial	Very unlikely	Low

Impact	Scenario	Location	*Without mitigation*			*With mitigation*		
			Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
	Small Gas	and areas with highly variable topography)	Severe	Likely	High	Substantial	Very unlikely	Low
	Big Gas		Severe	Very likely	High	Substantial	Very unlikely	Low
	Reference Case	Medium and low sensitivity areas (foothills and areas with undulating topography)	Moderate	Likely	Low	Slight	Extremely unlikely	Very low
	Exploration Only		Substantial	Likely	Moderate	Slight	Unlikely	Low
	Small Gas		Substantial	Likely	Moderate	Substantial	Very unlikely	Low
	Big Gas		Severe	Likely	High	Substantial	Very unlikely	Low
	Reference Case	Low sensitivity areas (lowlands and plains)	Moderate	Unlikely	Low	Slight	Very unlikely	Very low
	Exploration Only		Substantial	Very unlikely	Low	Slight	Very unlikely	Very low
	Small Gas		Substantial	Very unlikely	Low	Slight	Very unlikely	Very low
	Big Gas		Severe	Very unlikely	Low	Slight	Unlikely	Very low
Impacts on palaeontology, meteorites & geological heritage	Reference Case	High sensitivity areas	Moderate	Likely	Low	Slight	Unlikely	Very low
	Exploration Only		Moderate	Likely	Low	Slight	Unlikely	Very low
	Small Gas		Substantial	Likely	Moderate	Slight	Unlikely	Very low
	Big Gas		Substantial	Likely	Moderate	Moderate	Likely	Low
Impacts on palaeontology, meteorites & geological heritage	Reference Case	Low sensitivity areas	Slight	Likely	Very low	Slight	Unlikely	Very low
	Exploration Only		Slight	Likely	Very low	Slight	Unlikely	Very low
	Small Gas		Slight	Likely	Very low	Slight	Unlikely	Very low
	Big Gas		Substantial	Likely	Moderate	Moderate	Unlikely	Low
Impacts on living heritage	Reference Case	All areas	Slight	Extremely unlikely	Very low	Slight	Extremely unlikely	Very low
	Exploration Only		Slight	Very unlikely	Very low	Slight	Extremely unlikely	Very low
	Small Gas		Slight	Very unlikely	Low	Slight	Extremely unlikely	Very low
	Big Gas		Moderate	Very unlikely	Moderate	Slight	Extremely unlikely	Very low
Impacts on cultural landscapes	Reference Case	All areas	Substantial	Likely	Moderate	Moderate	Likely	Low
	Exploration Only		Substantial	Likely	Moderate	Moderate	Likely	Low
	Small Gas		Severe	Likely	High	Substantial	Likely	Moderate
	Big Gas		Extreme	Very likely	Very high	Severe	Very likely	High

Table 15.5: Definitions of consequence levels. They combine significance (here measured through grading) and degree of impact. Note that Phases 1 and 2 refer to the impact assessment and mitigation phases respectively and that grades refer to formal and proposed grades (see text box in Section 15.1.1.2).

Consequence	Definition
Built heritage	
Slight	A NCW site is demolished without basic recording at Phase 1.
Moderate	A Grade IIIC site altered without detailed recording at Phase 2.

Consequence	Definition
Substantial	A Grade IIIC site is demolished without detailed recording at Phase 2. A Grade IIIB site is altered without detailed recording at Phase 2. Medium significance negative impacts to the setting of one of the above or a conservation-worthy town or protected area.
Severe	A Grade IIIB site is demolished without detailed recording at Phase 2. A Grade IIIA site is altered without detailed recording at Phase 2. A Grade I, II or IIIA site set aside for *in situ* conservation is damaged. High significance negative impacts to the setting of one of the above or a conservation-worthy town or protected area.
Extreme	A Grade I, II or IIIA site set aside for *in situ* conservation is destroyed. The setting of one of the above or a conservation- worthy town or protected area is changed to such an extent that the value of such is irrevocably destroyed.
Archaeology & Palaeontology	
Slight	A NCW site is destroyed without basic recording at Phase 1.
Moderate	A Grade IIIC site damaged without recording/sampling/excavation at Phase 2.
Substantial	A Grade IIIC site is destroyed without recording/sampling/excavation at Phase 2. A Grade IIIB site is damaged without recording/sampling/excavation at Phase 2.
Severe	A Grade IIIB site is destroyed without recording/sampling/excavation at Phase 2. A Grade IIIA site is damaged without recording/sampling/excavation at Phase 2. A Grade I, II or IIIA site set aside for *in situ* conservation is damaged.
Extreme	A Grade I, II or IIIA site set aside for *in situ* conservation is destroyed.
Living heritage	
Slight	An element of living heritage or an associated place is slightly affected.
Moderate	Multiple elements of living heritage or associated places are slightly affected.
Substantial	One or more elements of living heritage or associated places are significantly affected.
Severe	An element of living heritage or an associated place is completely eliminated or irreparably damaged.
Extreme	Multiple elements of living heritage or associated places are completely eliminated or irreparably damaged.
Cultural landscapes	
Slight	The cultural landscape is NCW. A Grade IIIC cultural landscape is compromised in limited areas such that development is barely noticeable or only visible from certain places. A Grade IIIB cultural landscape adequately screens or absorbs development.
Moderate	A Grade IIIC cultural landscape is compromised such that development becomes distinctly noticeable in the landscape. A Grade IIIB cultural landscape is compromised in limited areas such that development is barely noticeable or only visible from certain places. A Grade IIIA cultural landscape adequately screens or absorbs development.
Substantial	A Grade IIIC cultural landscape is heavily compromised such that development becomes a focus of attention. A Grade IIIB cultural landscape is compromised such that development becomes distinctly noticeable in the landscape. A Grade IIIA cultural landscape is compromised in limited areas such that development is barely noticeable or only visible from certain places.
Severe	A Grade IIIB cultural landscape is heavily compromised such that development becomes a focus of attention. A Grade IIIA cultural landscape is compromised such that development becomes distinctly noticeable in the landscape.
Extreme	A Grade IIIA cultural landscape is heavily compromised such that development becomes a focus of attention.

Consequence	Definition
	A Grade I or II cultural landscape is compromised in any way by development.

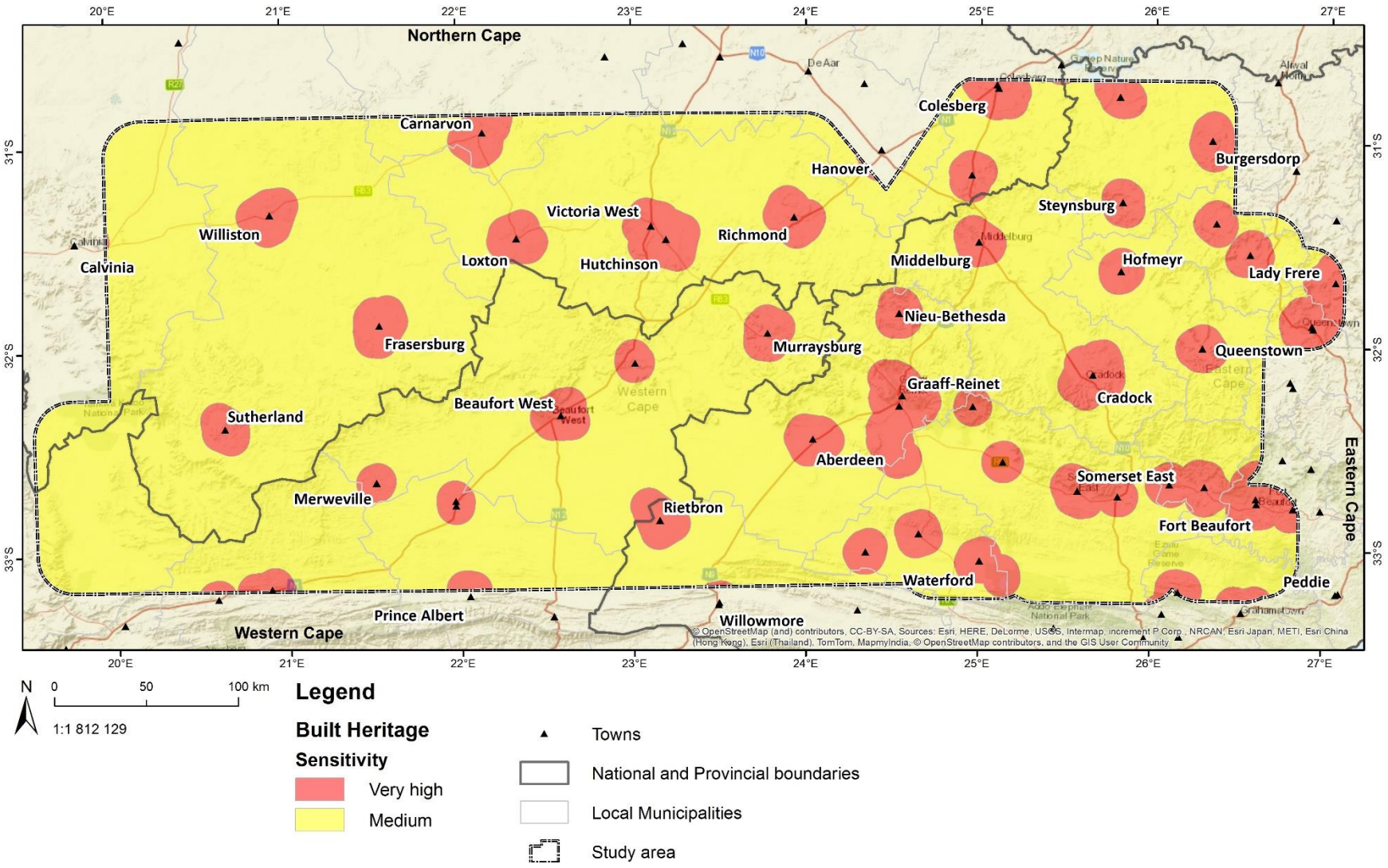

Figure 15.20: Sensitivity mapping for built heritage resources.

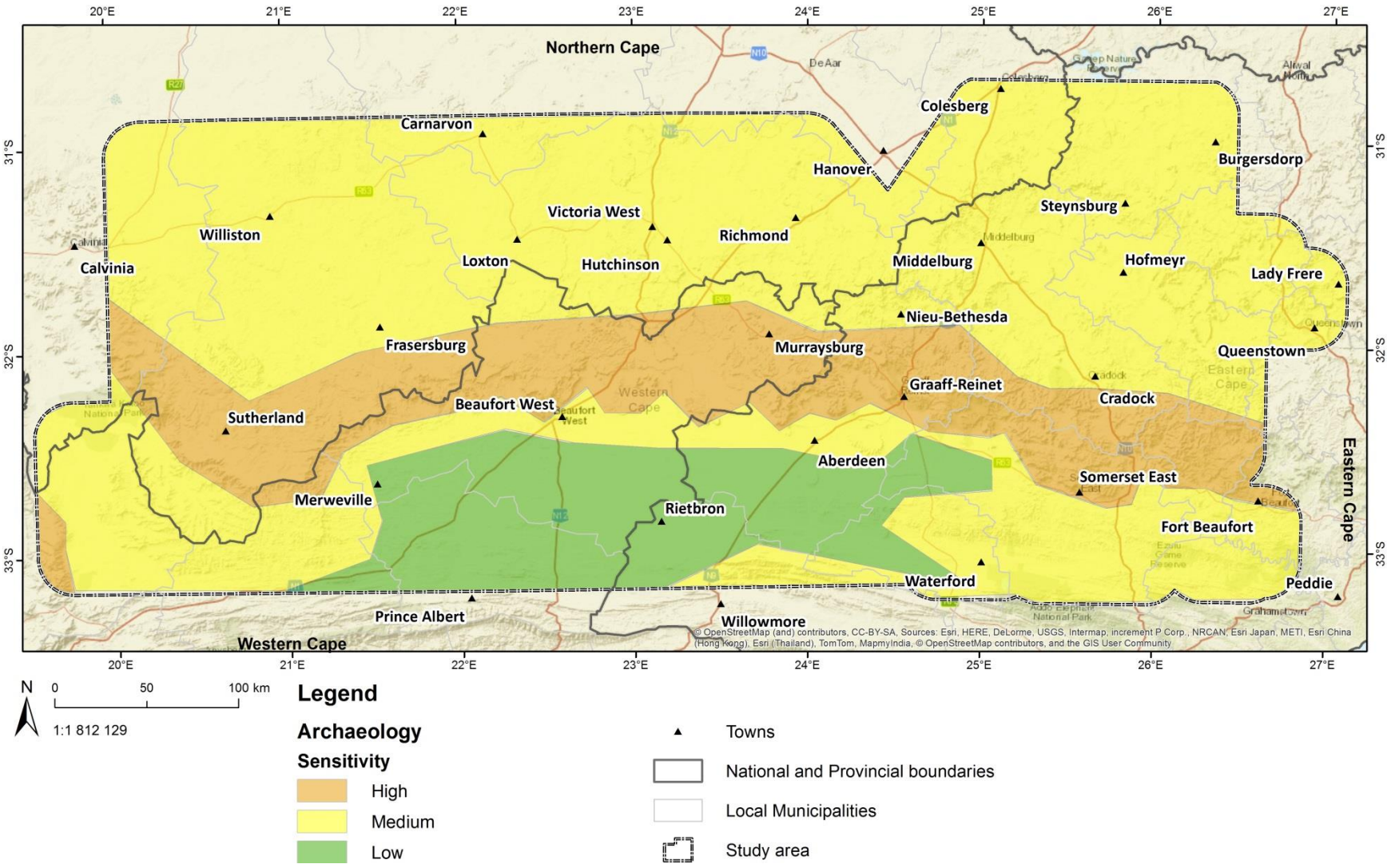

Figure 15.21: Sensitivity mapping for archaeological resources.

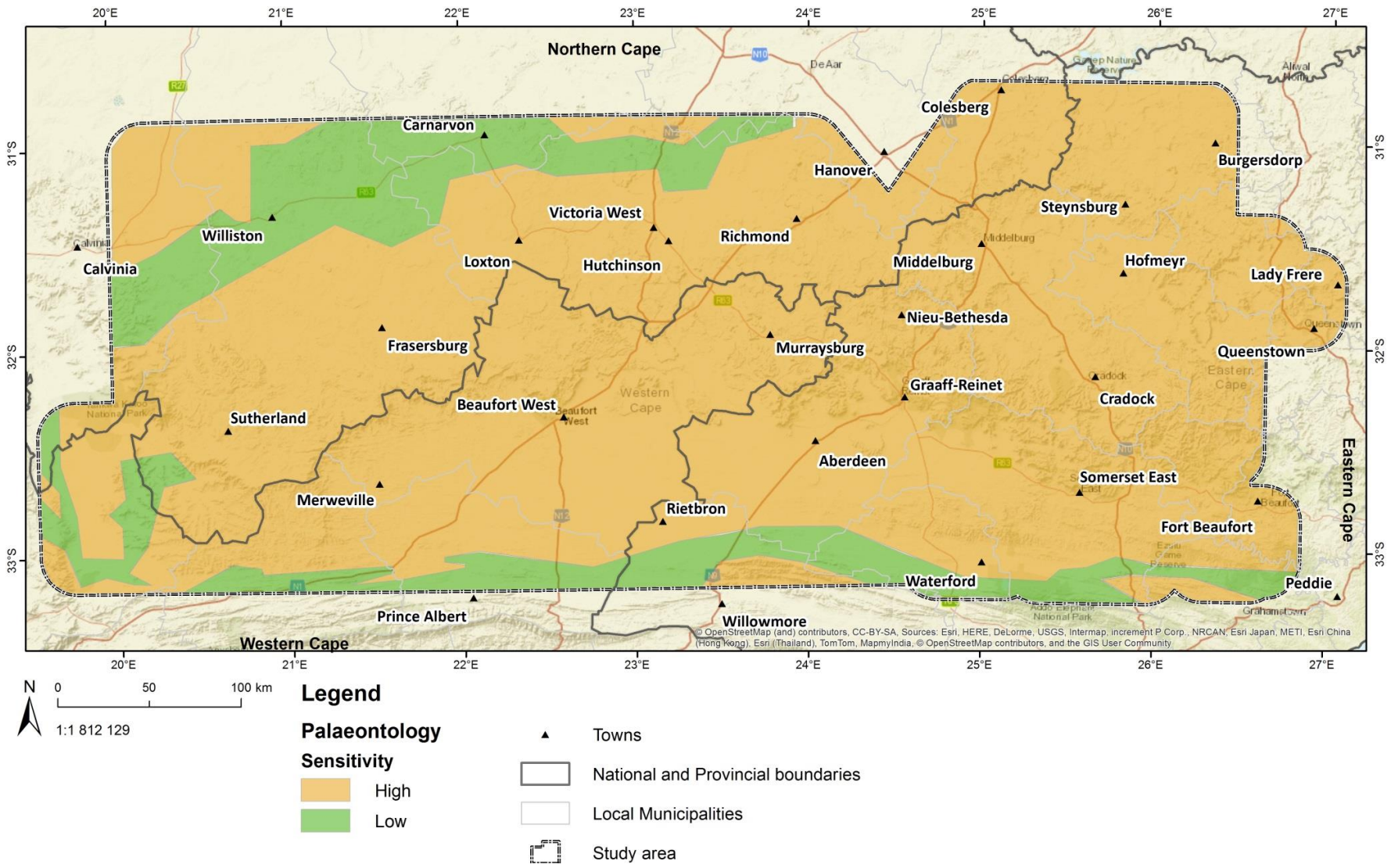

Figure 15.22: Sensitivity mapping for palaeontological resources.

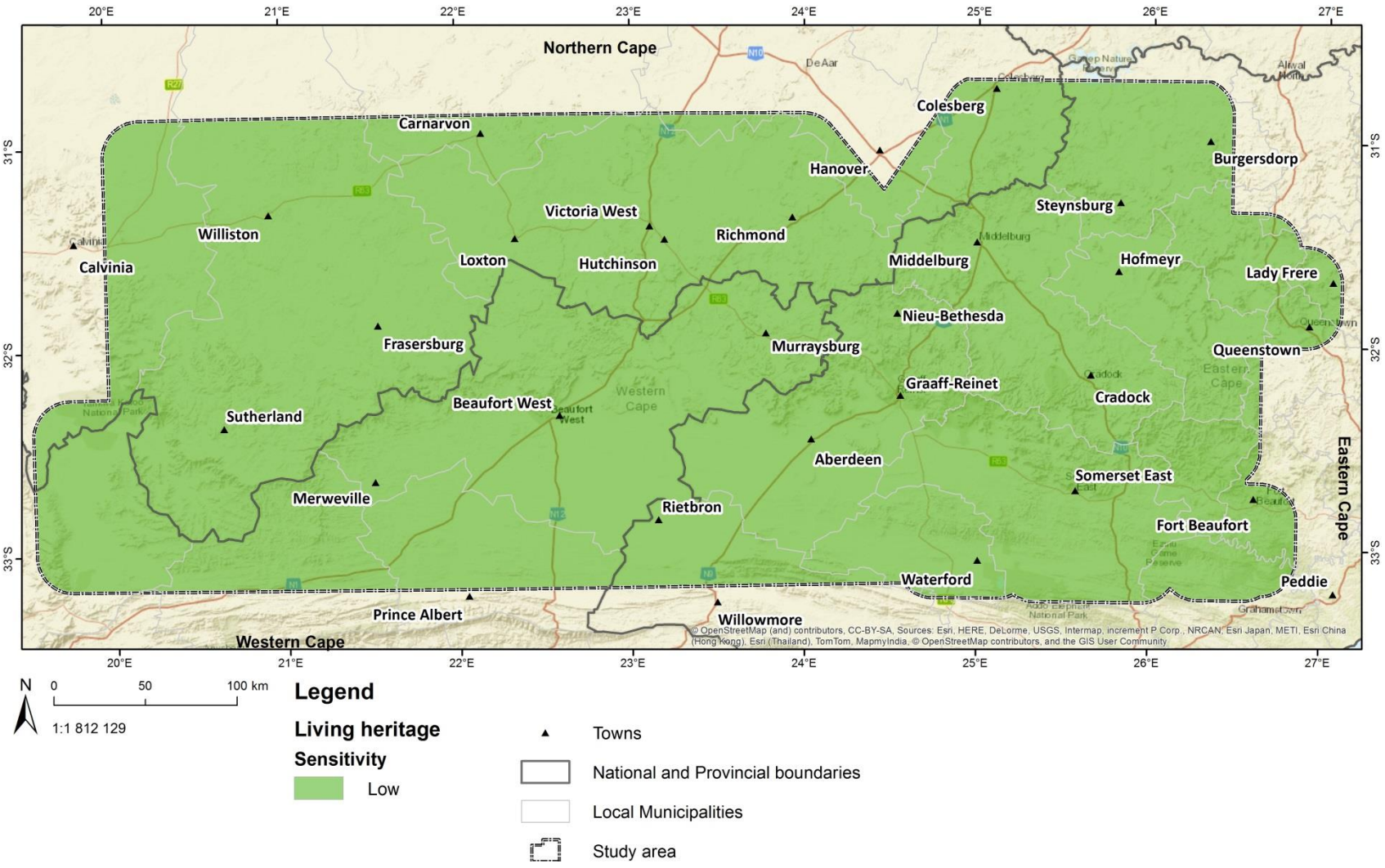

Figure 15.23: Sensitivity mapping for living heritage resources.

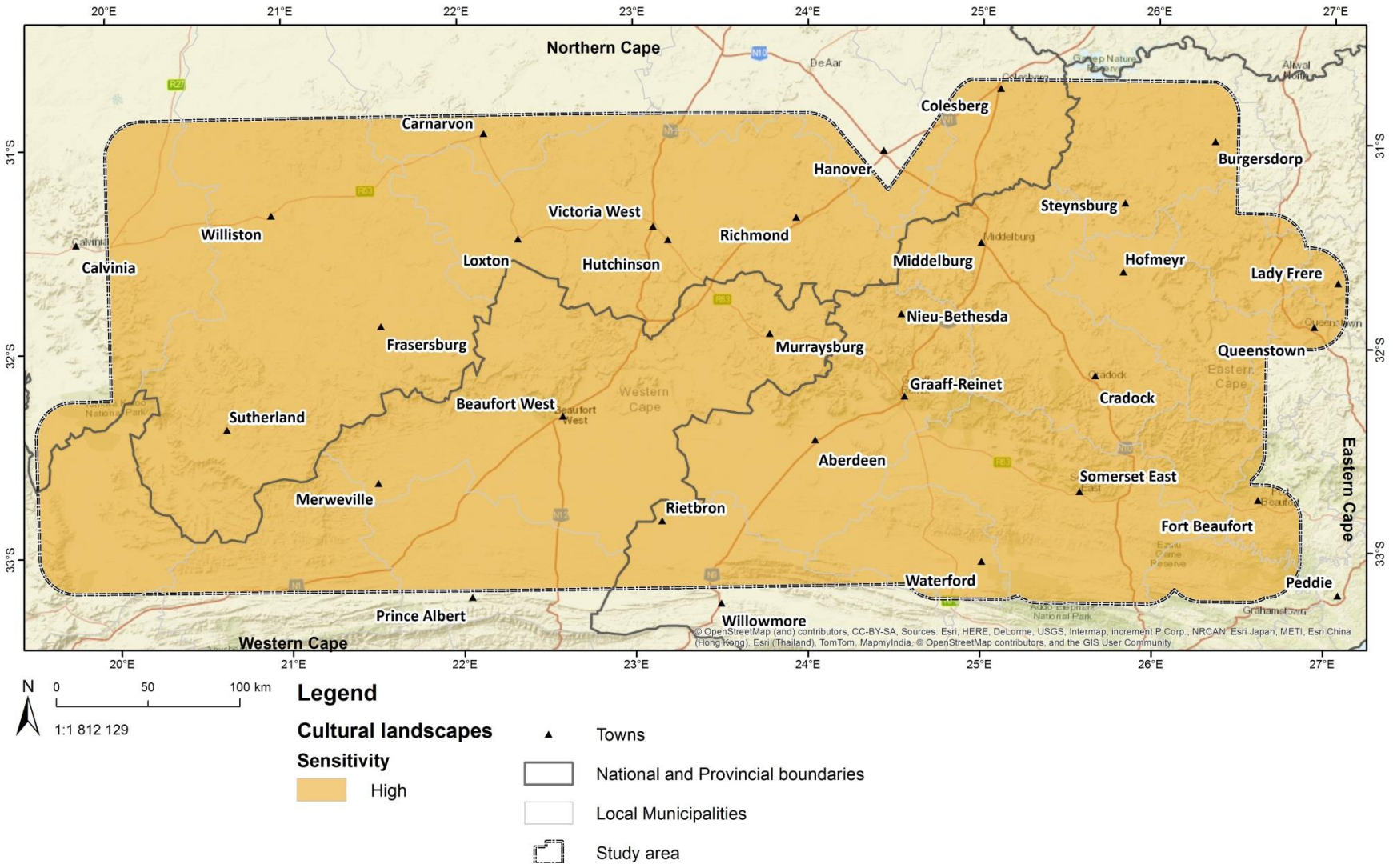

Figure 15.24: Sensitivity mapping for cultural landscapes.

Figure 15.25 to Figure 15.27 present risk maps of impacts on built heritage, palaeontology and archaeology across four SGD scenarios, with- and without mitigation. Note: maps of regional risks to living heritage and cultural landscapes have not been produced.

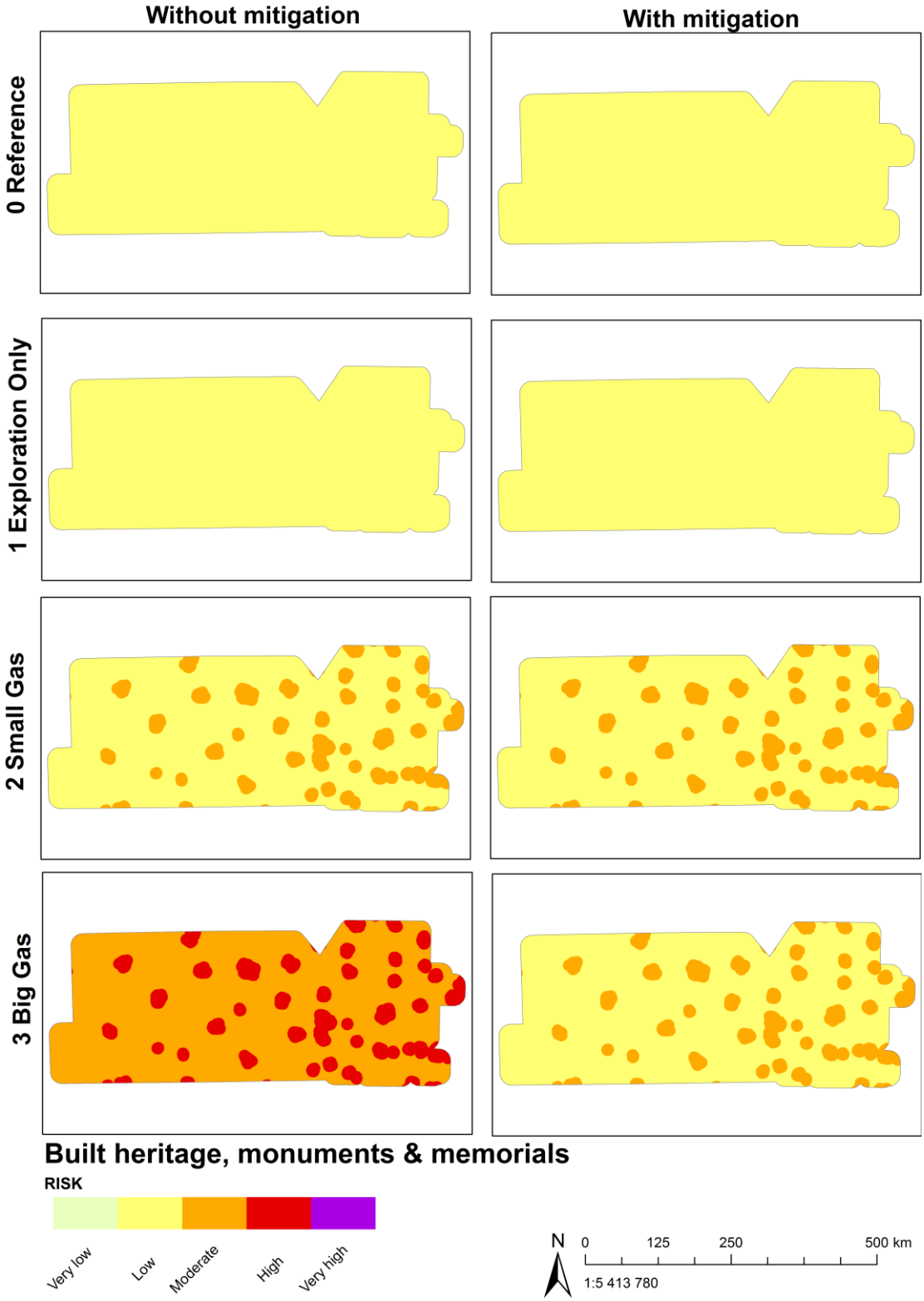

Figure 15.25: Map indicating the risk to built heritage, monuments and memorials across four SGD scenarios, with- and without mitigation.

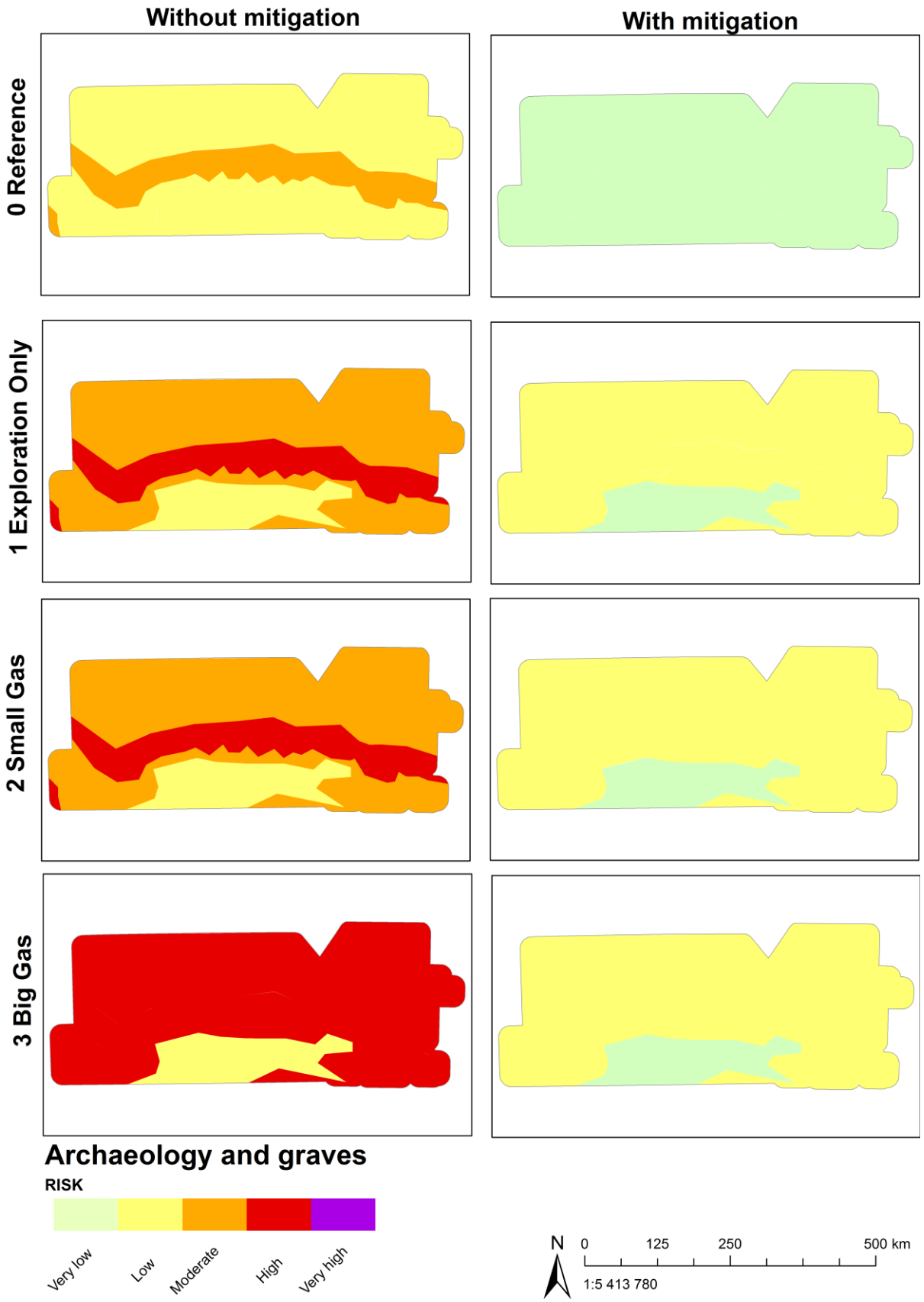

Figure 15.26: Map indicating the risk to archaeology and graves across four SGD scenarios, with- and without mitigation.

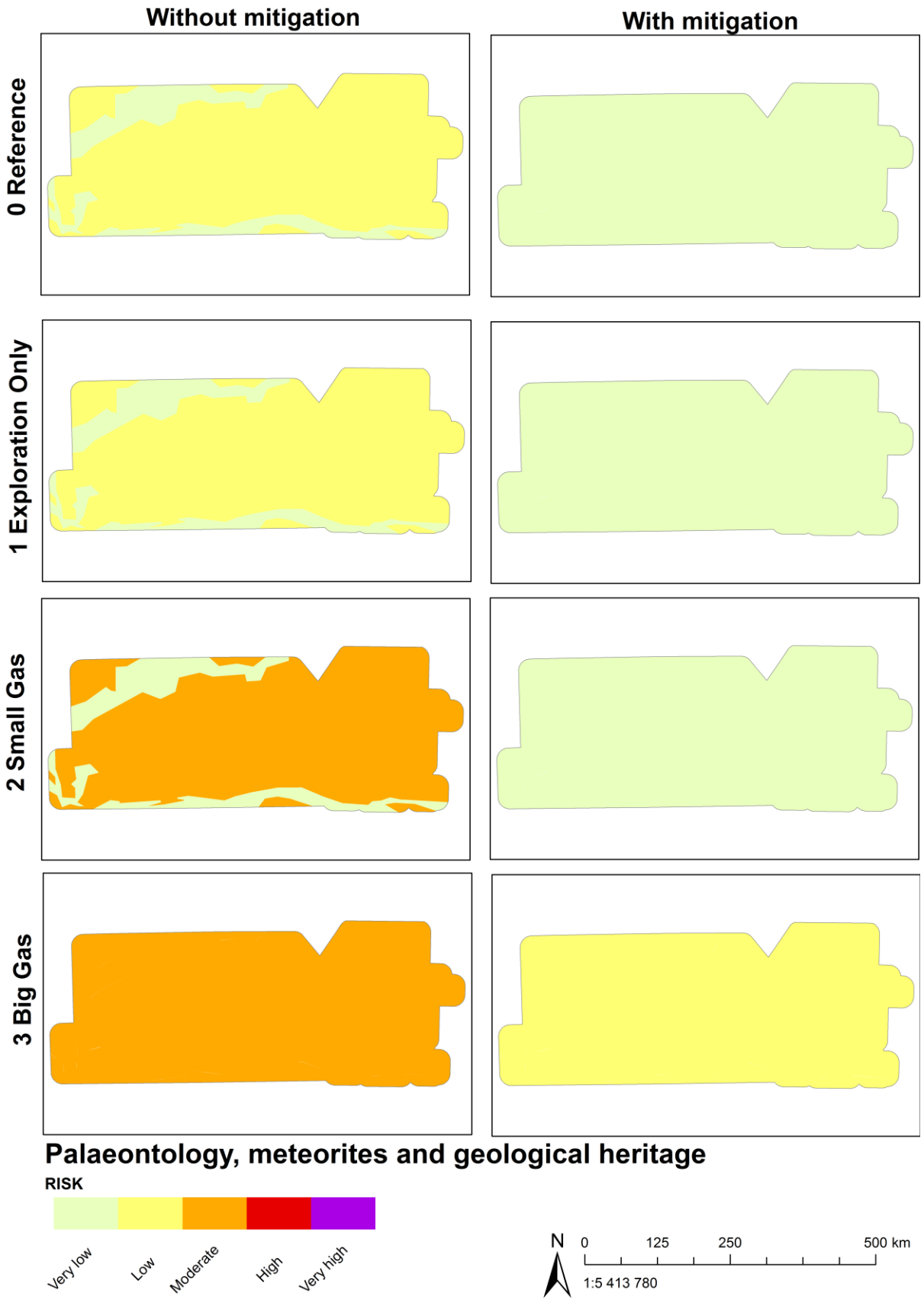

Figure 15.27: Map indicating the risk to palaeontology, meteorites and geological heritage across four SGD scenarios, with- and without mitigation.

15.4 Best practice guidelines and monitoring requirements

15.4.1 Planning phase

In many respects, the Planning Phase is the most critical phase of any development. It is at this stage in the process that the most significant potential impacts can be avoided by an awareness of all known important heritage resources. Responsibilities lie both with the heritage and planning authorities and with any potential developers and, as such, we discuss them separately.

15.4.1.1 Authority responsibilities

- Because SGD and related activities have the potential to span provincial boundaries, it is recommended that SAHRA, under Section 38(1)(e) and with input from provincial and local authorities, draft a set of guidelines for the implementation of shale gas exploration and development which will serve to guide the assessment and monitoring of all activities.
- For the same reason, where necessary, SAHRA, with input from provincial and local authorities, should be responsible for comments and decisions related to SGD. This should occur under a Memorandum of Understanding between SAHRA and each PHRA as appropriate.
- Heritage monitoring is generally only requested during excavations that may reveal buried heritage resources. It is recommended, however, that more extensive monitoring (similar to that carried out by an Environmental Control Officer (ECO) in the EIA context) be encouraged by Heritage Resources Authorities in order to monitor Development Phase impacts, especially those associated with built heritage. International guidelines should be taken into consideration.
- In terms of Section 30 of the NHRA, all PHRAs should have an updated heritage register. Local planning authorities are required, under certain circumstances, to submit to the PHRA a list of heritage resources under their jurisdiction. The PHRA is then responsible for adding to the Provincial heritage register those sites that it considers to be conservation-worthy and that meet the requirements for listing on the register. This is an existing legal requirement that has not yet been complied with throughout the study area but is considered important to action should SGD be permitted. Such heritage registers should include urban and rural areas and should be updated so as to adhere to the 60 year provision of Section 34 of the NHRA.
- Heritage Resources Authorities are also required to have an up-to-date register of communities who have expressed interest in heritage. Such registers should be in place before exploration commences. To date, of the three provinces included in the study area, only Western Cape is reasonably functional in this regard.

- Section 31 of the NHRA requires that all new Spatial Development Frameworks (SDFs) include the investigation of heritage areas for protection. All towns where population growth is to be expected as a result of SGD should preferably have SDFs in place and, if required, should therefore have heritage areas identified and formally promulgated. Although capacity may constrain this process, it should ideally take place before any exploration is carried out and for all towns within 50 km of an exploration area. Additionally the principles of the UNESCO (2011) "Recommendation on the Historic Urban Landscape" should be applied to all such towns.

15.4.1.2 Developer responsibilities

- The commissioning of a screening study is recommended for each prospecting, exploration or production project in order to identify as many sensitive heritage resources as possible (especially those for which adequate mitigation is difficult or impossible). This will enable developers to plan to avoid such heritage resources with appropriate buffers at the earliest possible stage.
- A key aspect once the result of the screening study are known will be the baseline documentation of the current physical condition of all potentially affected heritage structures, both for the purposes of protection against legal claims because of the risks posed by earth tremors and to create a built heritage database from which to commence future studies. A standardised format that briefly describes each resource and complies with relevant guidelines as issued by the various heritage authorities should be used throughout the study area and detailed photographic and or three dimensional records should be created. All structures within 10 km of wellpads and 250 m of any related infrastructure and transport corridors should be included. For tall structures such as church steeples or obelisk-type monuments and infrastructure such as dam walls, the study should include engineering assessments of their structural soundness. The records should be lodged on the SAHRIS database.
- It is recommended that all EIA and HIA studies explore potential impacts from possible seismic activity and establish no-go buffer-zones.
- It is recommended that a trust fund be established for the repair of damage to built heritage resultant from SGD. This fund should be managed by an independent body, representing a broad range of stakeholders. Financial input to the fund will be required on a long-term basis, extending far beyond the end of the closure phase, as it is unknown when/if seismic activity might cease.
- Monitoring of seismic activity in the study area should be intensified in order to assist with predictions of induced activity and to plan appropriate buffers from important historic structures.

- A continuous monitoring system should be established to monitor all built heritage resources at regular intervals as well as after seismic events. The frequency of such monitoring could be reduced during later years once the degree of impact from tremors and vibrations has been better established, but such frequency should not be less than once per year.
- A geologist should be commissioned to compile a full database of conservation-worthy geological heritage sites located within the study area.
- Because of the institutional and professional capacity constraints within the heritage industry, it is suggested that developers and their appointed environmental assessment practitioners ensure that sufficient time is allowed in which to complete the necessary heritage studies. This may require commissioning such studies well before the start of an EIA, given the 300-350 day timeframe allowed for during an EIA process.

15.4.2 Exploration Phase

- EIAs in advance of exploration must always include specialist heritage assessments that consider *all* potentially vulnerable heritage resources and hence satisfy Section 38(3) of the NHRA. It will generally be the case that such assessments are carried out by more than one individual to ensure that the necessary range of skills are present to address those aspects of heritage that are seldom considered in assessments (e.g. living heritage, geological heritage, meteorites). An archaeological field study is mandatory since such studies are generally the point at which isolated examples of heritage in remote locations (e.g. ruined structures or graves) are found and recorded. Because of the potential for widespread impacts, both from SGD and ancillary development, cumulative impacts must also be considered.
- Adhering to mitigation requirements (including micro-siting to avoid heritage sites and reduce landscape scarring) and footprint restrictions as stipulated in an EA will greatly reduce impacts (the EA should specify the heritage mitigation requirements resulting from the HIA process).
- If the baseline documentation suggested above is not in place, then mitigation should include such documentation of all built heritage resources following the same guidelines.
- Any EA amendment applications for disturbance of areas not originally assessed must include heritage assessments.
- Monitoring as suggested above will serve to identify damage and, where feasible, such damage should be repaired from the fund established for the purpose. Appropriate heritage techniques and materials should be used.

15.4.3 Development Phase

- All stipulations under Exploration Phase above apply equally to the Development Phase.
- Additionally, because of the longer term presence of people and activity, the appointed ECO or an appropriate heritage practitioner should conduct regular inspections of heritage resources that are protected *in situ* to ensure that indirect impacts are not occurring.

15.4.4 Closure Phase

- Adhere to footprint restrictions as stipulated in an EA.
- Any new disturbance not included in original application needs to be assessed. This might, for example, include areas from which topsoil is sourced to be used in rehabilitation.
- Adhere to all rehabilitation as stipulated in an EA.
- Assess the residue of the industrial landscape resulting from SGD as an important historical phase of the development of not only the Karoo Basin but of the country as a whole. Identify structures and sites of historical importance, stabilise these and ensure protection and interpretation of these new heritage resources.

15.4.5 Monitoring guidelines

Any monitoring will be strongly linked to the limits of acceptable change established above. Monitoring will serve largely to ensure that EA conditions are respected and implemented such that change can be kept within the established acceptable limits. Table 15.6 proposes monitoring guidelines that could be implemented from both the heritage and environmental points of view. The frequencies indicated are a guideline only and may need revision on a case-by-case basis. Some monitoring could be dealt with by the ECO, but other aspects might require specialist input. Some aspects, however, could be handled by a 'heritage monitor' who could be trained specifically to fulfil the role. Reports describing the monitoring activities and any finds made will need to be submitted to the relevant heritage authorities.

Table 15.6: Heritage monitoring guidelines for SGD.

Objectives	Methodology	Frequency	Responsibility
Exploration and Development Phases			
Avoid premature direct or indirect damage to any heritage resources that are to be mitigated prior to development and in order to allow their destruction.	Ensure that any required mitigation measures have been carried out prior to commencement of SGD activities and that mitigation reports have been submitted to relevant heritage authorities.	Once-off prior to commencement of any activities.	ECO
	Ensure that positive comments have been received from heritage authorities prior to commencement of activities.	Once-off prior to commencement of any activities.	ECO
Avoid direct or indirect damage to any heritage resources that are to be protected *in situ*.	Establish no-go areas and ensure that these are appropriately marked (on plans or on the ground).	Once-off prior to commencement of any activities.	ECO/heritage monitor
	Monitoring will aim to check that such areas remain undisturbed.	Weekly during site establishment and construction periods, 6-monthly during production.	ECO/heritage monitor
Avoid direct or indirect damage to any heritage resources not discovered during the EIA Phase	Such monitoring is only likely to be required if development is to occur on alluvial plains or in close proximity to pans. Monitoring will aim to locate and protect any buried heritage resources (generally archaeological) until such time as they can be assessed by an archaeologist and, if required, be mitigated.	Daily or as and when required during excavation works in alluvial plains or close to pans.	Archaeologist
Early detection of damage to built heritage in order to minimise overall impacts.	Monitoring will aim to detect any damage to the fabric of built heritage resources so that repairs can be affected quickly and the source of the impact identified and prevented.	At least every three months at first but reduced to at least once per year when the degree of impact has been properly established; and immediately after any seismic events deemed of high enough magnitude to have caused damaged.	Heritage architect/ Heritage monitor
Identification, protection and rescue of buried palaeontological resources.	Monitoring will aim to identify any palaeontological material that might be revealed during earthmoving activities in areas where palaeontological monitoring has been requested.	Daily in areas of high sensitivity and/or areas of intense activity.	Palaeontologist
		Weekly/bi-weekly as determined during impact assessment for areas of lesser sensitivity and less intense impact.	Palaeontologist/ ECO with training by palaeontologist
Closure Phase			
Avoid direct or indirect damage to any heritage resources that have been protected *in situ*.	Establish no-go areas and ensure that these are appropriately marked (on plans or on the ground).	Once-off prior to commencement of any activities.	ECO/Heritage monitor
	Monitoring will aim to check that such areas remain undisturbed.	Weekly during site rehabilitation.	ECO/Heritage monitor

15.5 Gaps in knowledge

Built heritage resources are perhaps most at risk and, because of a lack of understanding on how the area might be affected by seismic activity, it is impossible to present a full picture of this risk. The gathering of seismic data would help build models to predict this risk. The vulnerability of built heritage in general is difficult to assess in the absence of completed heritage registers (as required by the NHRA) and large-scale built heritage surveys, particularly in rural areas. Improvements in the capacity of heritage and municipal authorities should allow for compilation of these databases, but completion times are likely to be lengthy. Despite the limited survey coverage of the study area and the fact that the locations of any SGD remain unknown, our confidence in the assessment of the remaining risks is relatively high.

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15.7 Digital Addenda 15A – 15B

SEPARATE DIGITAL DOCUMENT

Digital Addendum 15A: Extracts from Sections 2 and 3 of the National Heritage Resources Act (No. 25 of 1999)

Digital Addendum 15B: Spatial distribution of formally protected heritage sites within the study area.

DIGITAL ADDENDA 15A – 15B

Digital Addendum 15A: Extracts from Sections 2 and 3 of the National Heritage Resources Act (No. 25 of 1999)

Definitions[1]

2. In this Act, unless the context requires otherwise—

(ii) "archaeological" means—

(a) material remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures;

(b) rock art, being any form of painting, engraving or other graphic representation on a fixed rock surface or loose rock or stone, which was executed by human agency and which is older than 100 years, including any area within 10 m of such representation;

(c) wrecks, being any vessel or aircraft, or any part thereof, which was wrecked in South Africa, whether on land, in the internal waters, the territorial waters or in the maritime culture zone of the Republic, as defined respectively in Sections 3, 4 and 6 of the Maritime Zones Act, 1994 (Act No. 15 of 1994), and any cargo, debris or artefacts found or associated therewith, which is older than 60 years or which SAHRA considers to be worthy of conservation; and

(d) features, structures and artefacts associated with military history which are older than 75 years and the sites on which they are found;

(vi) "cultural significance" means aesthetic, architectural, historical, scientific, social, spiritual, linguistic or technological value or significance;

(viii) "development" means any physical intervention, excavation, or action, other than those caused by natural forces, which may in the opinion of a heritage authority in any way result in a change to the nature, appearance or physical nature of a place, or influence its stability and future well-being, including—

(a) construction, alteration, demolition, removal or change of use of a place or a structure at a place;

(b) carrying out any works on or over or under a place;

(c) subdivision or consolidation of land comprising, a place, including the structures or airspace of a place;

(d) constructing or putting up for display signs or hoardings;

[1] Only definitions relevant to the present Chapter are listed.

(e) any change to the natural or existing condition or topography of land; and

(f) any removal or destruction of trees, or removal of vegetation or topsoil;

(xiii) "grave" means a place of interment and includes the contents, headstone or other marker of such a place, and any other structure on or associated with such place;

(xvi) "heritage resource" means any place or object of cultural significance;

(xvii) "heritage resources authority" means the South African Heritage Resources Agency, established in terms of Section 11, or, insofar as this Act is applicable in or in respect of a province, a provincial heritage resources authority;

(xviii) "heritage site" means a place declared to be a national heritage site by SAHRA or a place declared to be a provincial heritage site by a provincial heritage resources authority;

(xxi) "living heritage" means the intangible aspects of inherited culture, and may include—

(a) cultural tradition;

(b) oral history;

(c) performance;

(d) ritual;

(e) popular memory;

(f) skills and techniques;

(g) indigenous knowledge systems; and

(h) the holistic approach to nature, society and social relationships;

(xxv) "meteorite" means any naturally-occurring object of extraterrestrial origin;

(xxvii) "national estate" means the national estate as defined in Section 3;

(xxxi) "palaeontological" means any fossilised remains or fossil trace of animals or plants which lived in the geological past, other than fossil fuels or fossiliferous rock intended for industrial use, and any site which contains such fossilised remains or trace;

(xxxii) "place" includes—

(a) a site, area or region;

(b) a building or other structure which may include equipment, furniture, fittings and articles associated with or connected with such building or other structure;

(c) a group of buildings or other structures which may include equipment, furniture, fittings and articles associated with or connected with such group of buildings or other structures;

(d) an open space, including a public square, street or park; and

(e) in relation to the management of a place, includes the immediate surroundings of a place;

(xxxvii) "provincial heritage resources authority", insofar as this Act is applicable in a province, means an authority established by the MEC under Section 23;

(xxxviii) "public monuments and memorials" means all monuments and memorials—

(a) erected on land belonging to any branch of central, provincial or local government, or on land belonging to any organisation funded by or established in terms of the legislation of such a branch of government; or

(b) which were paid for by public subscription, government funds, or a public-spirited or military organisation, and are on land belonging to any private individual;

(xiii) "site" means any area of land, including land covered by water, and including any structures or objects thereon;

(xivl) "structure" means any building, works, device or other facility made by people and which is fixed to land, and includes any fixtures, fittings and equipment associated therewith;

National estate

3. (1) For the purposes of this Act, those heritage resources of South Africa which are of cultural significance or other special value for the present community and for future generations must be considered part of the national estate and fall within the sphere of operations of heritage resources authorities.

3. (2) Without limiting the generality of Subsection (1), the national estate may include—

(a) places, buildings, structures and equipment of cultural significance;

(b) places to which oral traditions are attached or which are associated with living heritage;

(c) historical settlements and townscapes;

(d) landscapes and natural features of cultural significance;

(e) geological sites of scientific or cultural importance;

(f) archaeological and palaeontological sites;

(g) graves and burial grounds, including—

(i) ancestral graves;

(ii) royal graves and graves of traditional leaders;

(iii) graves of victims of conflict;

(iv) graves of individuals designated by the Minister by notice in the *Gazette*;

(v) historical graves and cemeteries; and

(vi) other human remains which are not covered in terms of the Human Tissue Act, 1983 (Act No. 65 of 1983);

(h) sites of significance relating to the history of slavery in South Africa;

(i) movable objects, including—

(i) objects recovered from the soil or waters of South Africa, including archaeological and palaeontological objects and material, meteorites and rare geological specimens;

(ii) objects to which oral traditions are attached or which are associated with living heritage;
(iii) ethnographic art and objects;
(iv) military objects;
(v) objects of decorative or fine art;
(vi) objects of scientific or technological interest; and
(vii) books, records, documents, photographic positives and negatives, graphic, film or video material or sound recordings, excluding those that are public records as defined in Section 1(xiv) of the National Archives of South Africa Act, 1996 (Act No. 43 of 1996).

3. (3)Without limiting the generality of Subsections (1) and (2), a place or object is to be considered part of the national estate if it has cultural significance or other special value because of—

(a) its importance in the community, or pattern of South Africa's history;

(b) its possession of uncommon, rare or endangered aspects of South Africa's natural or cultural heritage;

(c) its potential to yield information that will contribute to an understanding of South Africa's natural or cultural heritage;

(d) its importance in demonstrating the principal characteristics of a particular class of South Africa's natural or cultural places or objects;

(e) its importance in exhibiting particular aesthetic characteristics valued by a community or cultural group;

(f) its importance in demonstrating a high degree of creative or technical achievement at a particular period;

(g) its strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;

(h) its strong or special association with the life or work of a person, group or organisation of importance in the history of South Africa; and

(i) sites of significance relating to the history of slavery in South Africa.

Digital Addendum 15B: Spatial distribution of formally protected heritage sites within the study area.

The following maps indicate the spatial distribution of all heritage sites that have been formally graded and/or declared as NHSs or PHSs or placed on the heritage register. Because a grading must precede a declaration, the listed grade serves to indicate the following:

- Grade I: The site is formally graded I and/or has been declared a NHS;
- Grade II: The site is formally graded II and/or has been declared a PHS;
- Grade IIIA: The site is formally graded IIIA (in Western Cape only) and/or has been listed on the provincial heritage register.

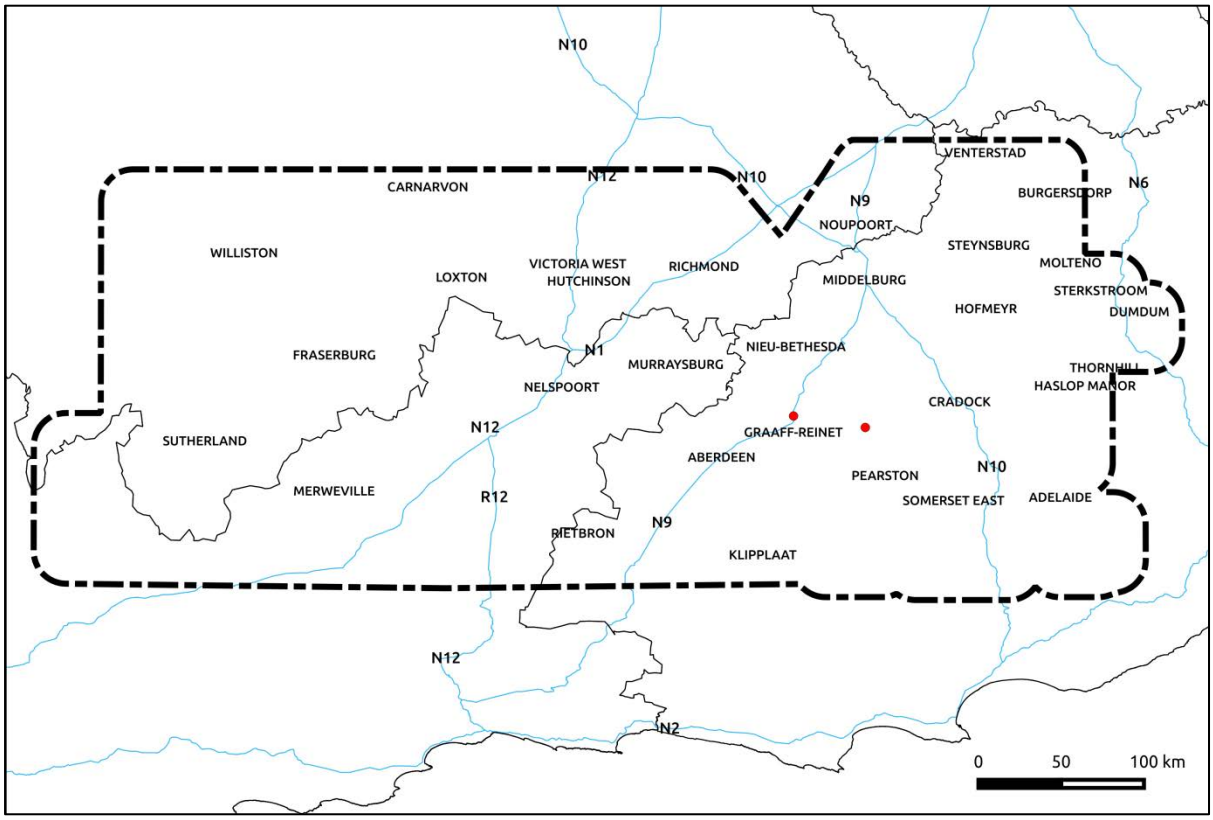

Figure B1: Spatial distribution of Grade I resources in the study area.

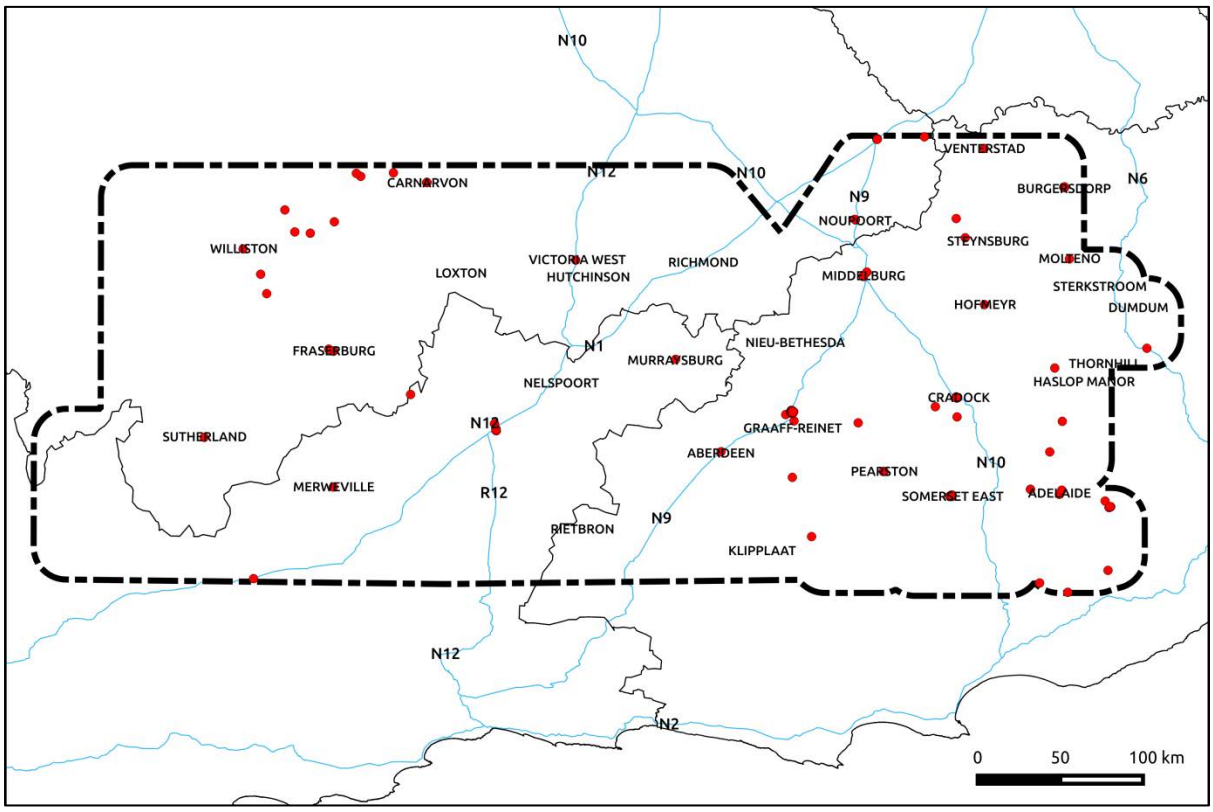

Figure B2: Spatial distribution of Grade II resources in the study area.

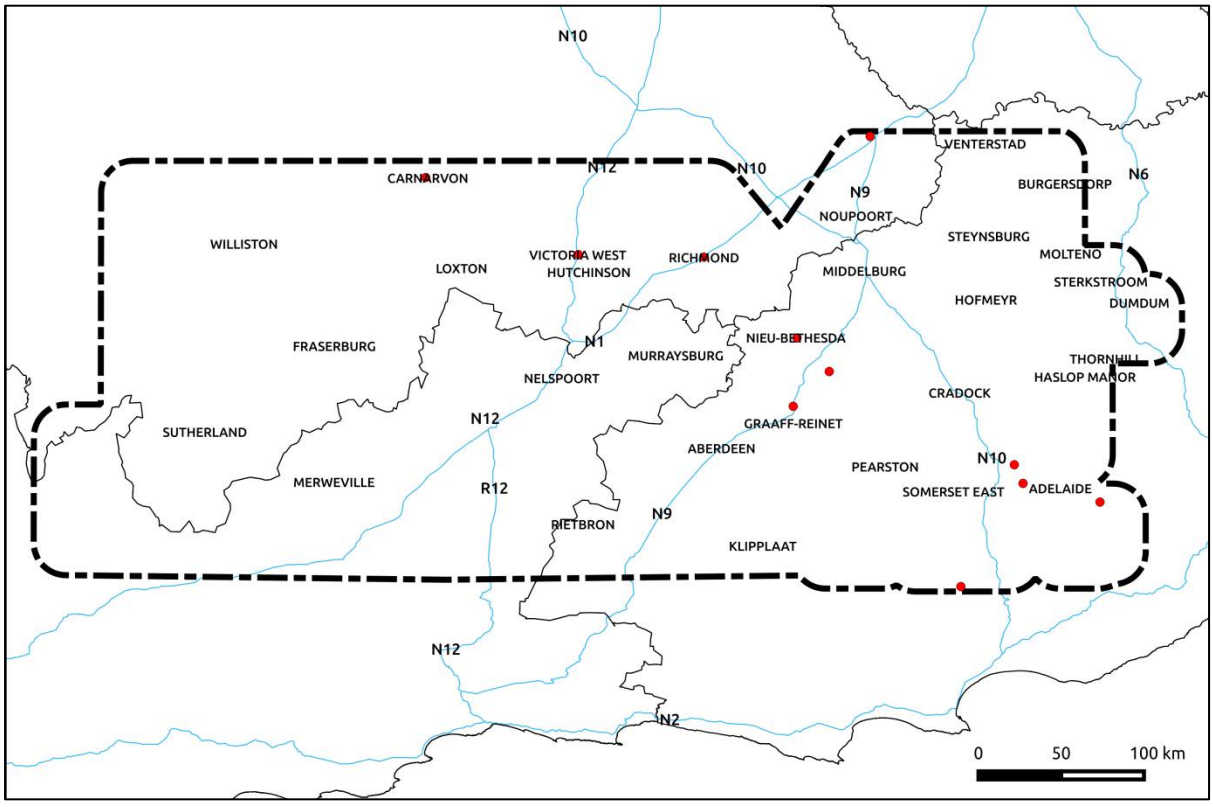

Figure B3: Spatial distribution of Grade IIIA resources in the study area.

APPENDIX 3

Integrating and Contributing Author Biosketches

Preface	
Authors	
Robert Scholes	Robert (Bob Scholes is a systems ecologist at the University of the Witwatersrand. He has led many assessments over the past 25 years, including parts of the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment, the South african Assessment on Elephant Management, and the global Land Degradation and Restoration Assessments. Bob has co-led the shale gas development scientific assessment.
Paul Lochner	Paul Lochner is an environmental assessment practitioner at the CSIR in Stellenbosch, with over 25 years of experience in a wide range of environmental assessment and management studies. His particular experience is in the renewable energy, oil and gas, and industrial and port development sectors. He has been closely involved in the application of Strategic Environmental Assessment in South Africa. Paul has co-led the shale gas development scientific assessment.
Greg Schreiner	Greg Schreiner has worked at the CSIR for the past five years. He is interested in novel approaches to environmental assessment and social processes. He has a Masters Degree in Environment and Development from the University of Cambridge. He has for the past two years managed the day to day processes of the shale gas development scientific assessment.
Luanita Snyman-Van der Walt	Luanita Snyman-Van der Walt has worked at the CSIR for the past 3 years as an environmental assessment practitioner focussing on environmental assessment and Geographic Information System analyses. She has a Masters Degree in Environmental Science from North West University and assisted in managing the shale gas development scientific assessment.
Megan de Jager	Megan de Jager holds an MSc degree in Environmental Geography from the Nelson Mandela Metropolitan University. She is employed at the CSIR as an intern on the shale gas development scientific assessment and is currently undertaking a PhD on baseline monitoring of the Central Karoo.

Chapter 1: Scenarios and Activities	
Integrating Author	
Mike Burns	Mike Burns, who is a Harvard University Research Fellow, is qualified in both ecology and environmental ethics. He understands human valuation of the environment and the often conflicting sustainability implications thereof. A capacity to understand the functioning of coupled social-ecological systems is the hallmark of his contribution to sustainability science. Mike has 20 years of consulting experience in Africa's oil and gas sector.
Contributing Authors	
Doreen Atkinson	Doreen Atkinson is a Research Associate at the University of the Free State, Bloemfontein. Her areas of research expertise include local government, community development, intergovernmental relations, policy analysis, governance, local economic development, small towns and rural development, land reform, sustainable livelihoods, project and programme evaluation, and regional development. Doreen has extensive research on Karoo tourism, and has organised five Karoo conferences since 2009.
Oliver Barker	Oliver Barker has an MSc from the University of the Witwatersrand, and is a registered natural scientist and member of numerous organisations, including AEG, SAIEG and the Ground Water Division of the GSSA. Oliver has consulted for large corporations and assessed geological risk in mining prospects. He has authored and co-authored numerous technical reports and published papers.
Claire Davis	Claire Davis is climate change impacts and adaptation specialist with a particular research interest in the field of biodiversity and conservation. She currently holds the position of Researcher in the Natural Resources and the Environment Unit (NRE) at CSIR. A key area of expertise is her skills in conducting vulnerability and adaptation assessments and producing tailor-made climate change projections for specific sectors.

Elizabeth (Liz) Day	Liz Day has over 20 years' experience in the field of freshwater ecosystems, mainly in the Western, Northern and Eastern Capes. Her particular interests include wetland and river water quality management, pollution abatement and protection strategies and understanding surface-groundwater interactions in wetlands. She has also been involved in wetland mapping and prioritisation projects for the CAPE fine-scale biodiversity planning project and for various local municipalities.
Surina Esterhuyse	Surina Esterhuyse is a researcher at the Centre for Environmental Management, University of the Free State. Recently, she has been extensively involved in work related to unconventional oil and gas extraction and led the project on the unconventional oil and gas interactive vulnerability map and monitoring framework development for the South African Water Research Commission.
Philip Hobbs	Philip Hobbs is a registered Professional Natural Scientist employed as a Senior Research Hydrogeologist in the NRE business unit. His ~35 years' experience includes the exploration and development of groundwater resources for water supply at all scales, the evaluation and assessment of land use activities (e.g. mining, industry and waste disposal) on groundwater, and the mapping of groundwater resource quantity and quality.
Ian McLachlan †	Ian McLachlan has a BSc Honours degree in Economic Geology from the University of the Witwatersrand, and is a Life Fellow of the GSSA. He worked for Soekor and Petroleum Agency SA where he gained wide experience in exploration operations in the Karoo and elsewhere. He also contributed to the compilation of the Minerals and Petroleum Resources Development Act of 2002 and associated Regulations.
Nigel Rossouw	Nigel Rossouw has more than 20 years' experience, working in different industry sectors and in a variety of roles, ranging from research, training, consulting, project implementation and corporate environmental planning. Nigel is the Environmental Planner for Shell South Africa Integrated Gas and is currently completing a PhD at UCT focusing on environmental governance of large engineering projects.
Simon Todd	Simon Todd has 18 years' experience as a terrestrial ecologist in arid systems. His primary focus includes examining the impacts of land use on biodiversity with the arid ecosystems of South Africa. Recent notable projects include specialist input for the Wind and Solar- and Eskom Grid Infrastructure Strategic Environmental Assessments, as well as on-going work related to the SKA.
Luanita Snyman-Van der Walt	Luanita Snyman-Van der Walt has worked at the CSIR for the past 3 years as an environmental assessment practitioner focussing on environmental assessment and Geographic Information System analyses. She has a Masters Degree in Environmental Science from North West University and assisted in managing the shale gas development scientific assessment.
Elsona van Huyssteen	Elsona van Huyssteen is a Principle Urban and Regional Planner at the CSIR and has over 20 years' experience in research, and policy development. She has lead collaborative multi-disciplinary initiatives in the urban and regional development planning field. Her interest focusses on innovative ways to engage collective futures through profiling spatial growth dynamics impacting cities, settlements and regions; transdisciplinary and multi-stakeholder initiatives, and action-orientated leadership.

Chapter 2: Energy

Integrating Author	
Jarrad Wright	Jarrad Wright is a Principal Engineer at the CSIR Energy Centre, with an MScEng (Elec), working predominantly in energy system operations and planning. He has extensive power sector operations and planning experience in eleven African countries. Jarrad was appointed by the President of South Africa to the NPC in 2015 as a Commissioner for the period 2015-2020 to assist in the implementation of the NDP.
Contributing Authors	
Tobias Bischoff-Niemz	Tobias Bischof-Niemz is the Energy Centre Manager at the Council for Scientific and Industrial Research, prior to which, he was with the Energy Planning Unit at Eskom, as part of the team that developed the long-term power-capacity expansion plan (Integrated Resource Plan) for South Africa. Tobias is also a member of the

	Ministerial Advisory Council on Energy.
Clinton Carter-Brown	Clinton Carter-Brown has a PhD in Electrical Engineering from the University of Cape Town, and spent 18 years in Eskom, the later portion of which as a specialist in the Technology Division. He is lead author of over 15 conference and journal papers and has co-authored a number of contributions. Carter-Brown joined Aurecon's Tshwane Energy Unity as a Technical Director in 2014.
Owen Zinaman	Owen Zinaman is the Technical Lead for the 21st Century Power Partnership South Africa Programme, operated out of the United States National Renewable Energy Laboratory. He holds a dual appointment as a Research Analyst at the Joint Institute for Strategic Energy Analysis, where he leads and supports various research activities and technical writing efforts for the U.S. natural gas sector.

Chapter 3: Air Quality and Greenhouse Gas Emissions

Integrating Author	
Harald Winkler	Harald Winkler is Director of the Energy Research Centre, University of Cape Town. His research interests focus on energy, environment and climate change mitigation. Harald has co-authored a journal publication on GHG emissions from coal compared to shale gas for electricity in South Africa. Harald has been a lead author on the Intergovernmental Panel on Climate Change and serves on editorial boards of six journals.
Contributing Authors	
Katye Altieri	Katye Altieri is a senior researcher at the Energy Research Centre, University of Cape Town. She has extensive experience in atmospheric chemistry and air pollution, including building shale gas emissions inventories. Katye completed a PhD focused on atmospheric chemistry at Rutgers University, and a Masters in Public Policy focused on development and energy at Princeton University.
Simon Clarke	Simon Clarke has an MSc in Environment and Development and is founding Director of IBIS Consulting, where he is a sustainability and climate change specialist with 15 years' experience. His experience covers greenhouse gas reporting, energy and carbon reduction and physical climate change risk. He has led the development and verification of over 100 greenhouse gas inventories for corporate clients and governments across multiple sectors.
Rebecca Garland	Rebecca Garland holds a PhD from the University of Colorado and has been an atmospheric chemist at the CSIR since 2011. She has worked in the field of atmospheric science for 16 years. Her expertise is in atmospheric science, with a research focus on modeling atmospheric composition, the resultant impacts from poor air quality and a changing climate.
Gerrit Kornelius	Gerrit Kornelius is a chemical engineer specialising in air quality management and greenhouse gas policy for the past 30 years. He has worked in the hydrocarbon industry, academia and consulting practice. He was involved in drafting regulations under the Air Quality Act and was a participant in drafting of Long-term Mitigation Strategy that advised government on greenhouse gas reduction pathways.
Matthew Meas	Matthew Meas is currently undertaking a Masters in Sustainable Energy Engineering at the University of Cape Town. Matthew received a bronze medal for research involving sympathetic vibrations of musical instruments with strings at the Eskom Expo for Young Scientists National Competition in 2009. His interests include thermodynamics, sustainable energy technologies, mechanical engineering research and development, and energy policy.

Chapter 4: Earthquakes

Integrating Author	
Raymond Durrheim	Raymond Durrheim is the South African Research Chair of Exploration, Earthquake and Mining Seismology and holds joint appointments at the University of the Witwatersrand and CSIR. He is co-director of the AfricaArray research and capacity-building programme and was co-leader of the Japanese-South African collaborative

	project "Observational studies in South African mines to mitigate seismic risks" (2010-2015).
Contributing Authors	
Moctar Doucouré	C. Moctar Doucouré is an Associate-Professor of geophysics, Managing Director of AEON-Earth Stewardship Science Research Institute, and Manager of the Karoo Shale Gas Baseline Research Programme at the Nelson Mandela Metropolitan University, where he is responsible for geophysical research including airborne geophysics, deep subsurface geophysics, and micro-earthquakes. The programme involves 30 post-graduate students of which four are dedicated to geophysical operations and research in the Eastern Cape Karoo.
Vunganai Midzi	Vunganai Midzi has a PhD in Seismology from the University of Bergen, Norway. He is employed by the Council for Geoscience in Pretoria, South Africa, where he is mainly responsible for a team that carries out seismic hazard assessments for critical structures in South Africa and beyond. Vunganai also has experience in seismic monitoring and is well published.
Chapter 5: Water Resources	
Integrating Authors	
Philip Hobbs	Philip Hobbs is a registered Professional Natural Scientist employed as a Senior Research Hydrogeologist in the NRE business unit. His ~35 years' experience includes the exploration and development of groundwater resources for water supply at all scales, the evaluation and assessment of land use activities (e.g. mining, industry and waste disposal) on groundwater, and the mapping of groundwater resource quantity and quality.
Elizabeth (Liz) Day	Liz Day has over 20 years' experience in the field of freshwater ecosystems, mainly in the Western, Northern and Eastern Capes. Her particular interests include wetland and river water quality management, pollution abatement and protection strategies and understanding surface-groundwater interactions in wetlands. She has also been involved in wetland mapping and prioritisation projects for the CAPE fine-scale biodiversity planning project and for various local municipalities.
Contributing Authors	
Peter Rosewarne	Peter's 40 years of experience includes geological mapping in the Merwerville/Fraserberg area, groundwater supply for municipalities, e.g. Beaufort West, hydrogeological studies for the proposed Ryst Kuil uranium mine near Beaufort West and assisting Shell with assessment of groundwater occurrence/risks related to shale gas. He has/currently sits on the Reference Groups of three groundwater projects related to Karoo shale gas for the Water Research Commission.
Surina Esterhuyse	Surina Esterhuyse is a researcher at the Centre for Environmental Management, University of the Free State. Recently, she has been extensively involved in work related to unconventional oil and gas extraction and led the project on the unconventional oil and gas interactive vulnerability map and monitoring framework development for the South African Water Research Commission.
Roland Schulze	Roland Schulze is Emeritus Professor, Fellow of the Royal Society of South Africa (FRSSAf), Member of the Academy of Science of South Africa, and is retired Professor of Hydrology at the University of KwaZulu-Natal. His research focus is currently on agro-hydrological modelling and mapping; impacts assessments of land use; and climate change impacts on the water and agricultural sectors.
Jenny Day	Jenny Day is an Emeritus Associate Professor Director of the Freshwater Research Unit at the University of Cape Town and is currently Honorary Professor at the Institute for Water Studies at the University of the Western Cape. Her particular interests include wetlands and their associated biotas; the effects of water chemistry on living organism, and the conservation and management of aquatic ecosystems.
Justine Ewart-Smith	Justine Ewart-Smith has 16 years of experience in the field of freshwater ecology, ranging from specialist input into biomonitoring, strategic environmental assessments and situation assessment surveys, to environmental flow studies both locally and abroad. Justine studied algal dynamics in Cape Rivers at the University of Cape Town and completed her PhD in Freshwater Ecology in 2012.

Marthie Kemp	Marthie Kemp is a plant ecologist at the Centre for Environmental Management, University of the Free State. Marthie has been involved in the development of an interactive vulnerability and monitoring framework to assess the potential environmental impact of unconventional oil and gas extraction and the development of a methodology to determine environmental water requirements for non-perennial rivers.
Nick Rivers-Moore	Nick Rivers-Moore is an aquatic ecologist with 15 years' professional experience. After completing a PhD in Hydrology at the University of Natal in 2003, he went on to a post-doctorate at the Institute for Water Research (Rhodes University). Nick is also a published regional expert on freshwater conservation planning, and successfully developed the first provincial freshwater conservation plan for KwaZulu-Natal, South Africa.
Henk Coetzee	Henk Coetzee has over 24 years' experience in Geophysics, and currently works at Council for Geoscience as a Specialist Scientist; Sustainable Resources and Environment Competency unit. His scientific experience includes radiometric surveying; remote sensing of mining environments; and research experience, specialising in the investigation, characterisation and rehabilitation of mining environments and abandoned mines and mine water, with a strong focus on acid mine.
Danita Hohne	Danita Hohne is a Scientific Technician with the Department of Water and Sanitation (Northern Cape), with 7 years' experience in groundwater management. Projects she has worked on include MeerKAT (SKA); renewable energy and thermal springs in Augrabies. With regards to hydraulic fracturing; Danita has been formulising baseline and monitoring concepts and assisting in writing the regulations for oil and gas exploration.
Ashton Maherry	Ashton Maherry has a BSc Honours degree from the University of the Free State, and is currently a full time Masters GISc student at UNIGIS International. Ashton has ~12 years' experience as a Geohydrologist at the Council for Scientific and Industrial Research, where he serves as a Senior Knowledge Applicator, GIS- and Groundwater specialist, and Project Manager.
Chapter 6: Impacts on Waste Planning and Management	
Integrating Author	
Suzan Oelofse	Suzan Oelofse is a Principal Researcher and Research Group Leader at the CSIR, an Extra-ordinary Associate Professor in Environmental Sciences and Management at the North-West University and the President of the Institute of Waste Management of Southern Africa. Her expertise involves integrated waste management and water resource management; waste information and data; and reducing the environmental impacts of waste.
Contributing Author	
Johan Schoonraad	Johan Schoonraad is a professional chemist with EnviroServ Waste Management, where he interacts with a small dedicated team of professional scientists and engineers to find appropriate solutions to complex hazardous waste and chemical pollution problems. He is involved in on-going operational issues as well as providing input to the development of solutions to meet the strategic goals of the company.
Chapter 7: Biodiversity & Ecological Impacts: Landscape Processes, Ecosystems and Species	
Integrating Authors	
Stephen Holness	Stephen Holness has 17 years' experience as a conservation planner, landscape ecologist and environmental GIS specialist. He is also an independent scientist associated with the Centre for African Conservation Ecology and the Coastal and Marine Research Institute at Nelson Mandela Metropolitan University. He specialises in systematic conservation planning in support of land use planning, marine spatial planning, protected area expansion and reserve management.

Amanda Driver	Amanda Driver is the Senior Biodiversity Policy Advisor at the South African National Biodiversity Institute (SANBI). Her work focuses on translating South Africa's biodiversity science into policy, legislation and practice. She led the National Biodiversity Assessment (2011), and has extensive experience in the application of spatial biodiversity information in a range of contexts at national and sub-national level.
Contributing Authors	
Simon Todd	Simon Todd has 18 years' experience as a terrestrial ecologist in arid systems. His primary focus includes examining the impacts of land use on biodiversity with the arid ecosystems of South Africa. Recent notable projects include specialist input for the Wind and Solar- and Eskom Grid Infrastructure Strategic Environmental Assessments, as well as on-going work related to the SKA.
Kate Snaddon	Kate Snaddon has 20 years of experience in the field of freshwater ecology (both as a researcher and consultant) and general environmental consulting. Her skills are in environmental impact assessment of infrastructure and development projects that impact on surface freshwater ecosystems. Recently, Kate has been lead consultant on two national strategic environmental assessments for wind and solar, and electricity transmission infrastructure.
Michelle Hamer	Michelle Hamer has a PhD from the University of KwaZulu-Natal. She has worked as a museum curator and academic, and is currently the Director for animal taxonomy at SANBI. She has led several large scale invertebrate surveys and participated in red listing and other conservation initiatives. She has published 70 scientific papers and contributed to six book chapters.
Domitilla Raimondo	Domitilla Raimondo is the Threatened Plant Programme Manager at the South African National Biodiversity Institute. Domitilla is the lead author of the "Red List of South African Plants" (2009), inter alia, and co-authored "Taxonomic research priorities for the conservation of the South African flora" (2013). She is also involved in the Custodians of Rare and Endangered Wildflowers (CREW) programme.
Fahiema Daniels	Fahiema Daniels plays a key role in supporting biodiversity planning in South Africa by leading spatial analyses for National-scale projects, such as the Electricity Grid Infrastructure Strategic Environmental Assessment. Additional projects include listing of threatened ecosystems; the terrestrial component of the National Biodiversity Assessment; and developing the spatial layers that feed into Department of Environmental Affairs Natural Resource Management Land User Incentive tool.
Chapter 8: Agriculture	
Integrating Author	
Noel Oettlé	Noel Oettlé holds a Post Graduate Diploma in Agricultural Development from the University of London. He was founding Director of the Farmer Support Group at the University of KwaZulu-Natal, and is the Rural Programme Manager for the Environmental Monitoring Group. His work focuses on enabling small-scale farmers to adapt to climate change and enhance their livelihoods through the sustainable use of natural resources and improved market access.
Contributing Authors	
Lehman Lindeque	Lehman Lindeque is a Professional Natural Scientist in Agricultural Science with a Masters degree in Environmental Studies from the University of Newcastle, Australia. Lehman's field of expertise is the assessment and mapping of land degradation and sustainable land management. His knowledge and skills are also internationally recognised, as demonstrated by his involvement in training and consultation abroad.
Justin du Toit	Justin Du Toit is as an agricultural researcher in Middelburg, Eastern Cape. His research interests include long-term vegetation changes as influenced by fire, grazing and rainfall in the central to eastern Karoo; dealing with invasive plants in semi-arid areas, notably slangbos and satansbos; and rainfall patterns in semi-arid South Africa. He also teaches courses on planted pastures, environmental management, and rehabilitation/ restoration.

Igshaan Samuels	Igshaan Samuels is a research scientist working for the Agricultural Research Council. His current research focus involves assessing indigenous knowledge systems and its application in climate change adaptation in Namaqualand; assessing diet selection and resource use amongst different livestock species in semi-arid rangelands; and investigating and mapping livestock mobility patterns under variable socio-ecological conditions on the commons of Namaqualand.

Chapter 9: Impacts on Tourism in the Karoo

Integrating Author	
Daan Toerien	Daan Toerien had an early career as researcher/academic, specialising in ecological and water research, involvement in science management. A period at the Sloan Business School of M.I.T. prompted research and scientific publications on the similarities between natural ecosystems and enterprise development in South African towns. This enabled the development of predictive capabilities that extend to shale gas and the Karoo's tourism industry.
Contributing Authors	
Gerrie du Rand	Gerrie Du Rand is a Senior Lecturer and Head of the Foods and Nutrition Section at Department of Consumer Science, University of Pretoria. Her area of interest is Food Tourism and the use of Local foods in culinary mapping. She has received academic recognition nationally and internationally as a researcher and expert in the field of Food and Hospitality related consumer behaviour.
Caroline Gelderblom	Caroline Gelderblom has over 20 years' of experience in the environmental sector working with National and Provincial Agencies and at a municipal scale to strengthen institutions. She has a particular interest in public works programmes and sustainable land use planning, including the promotion of conservation, sustainable tourism and agriculture, which extend across South Africa into the Southern African Development Community.
Melville Saayman	Melville Saayman is the director of the Tourism Research in Economic Environs and Society (TREES) at the Potchefstroom Campus of the North-West University in South Africa. His field of research is tourism economics and management and he has published more than 160 scientific articles, 20 tourism books and more than 330 technical reports.

Chapter 10: Impacts on the Economics

Integrating Author	
Hugo van Zyl	Hugo van Zyl is the director of Independent Economic Researchers, focusing on economics impact assessment, project appraisal and applied environmental resource economics. He has 18 years' experience in providing specialist inputs to environmental authorisation and policy processes, including projects in the mining, oil and gas sectors. He was lead author of a 2012 WWF sponsored discussion document on financial provisions for mine closure in South African.
Contributing Authors	
Saliem Fakir	Saliem Fakir is the Head of the Policy and Futures Unit at the WWF-SA. His areas of focus include the economy, energy, climate and the food-water nexus. He has written on the economics of shale gas based on a study on framing the economics of shale gas. He is a regular columnist for Engineering News and other media outlets.
Anthony Leiman	Anthony Leiman is an associate professor at the School of Economics at the University of Cape Town. His expertise includes mining, fisheries, and project appraisal, particularly cost benefit analysis. Leiman co-authored a report on the sustainable management of natural resources focussing on Tanzania's new gas deposits in 2014 and helped formulate the WWF sponsored discussion document on financial provisions for mine closure in South Africa in 2012.

Barry Standish	Barry Standish is visiting Professor of Economics at the Rotterdam School of Management, Erasmus University in Rotterdam. He specialises in applied macroeconomics, and has written and consulted extensively on the analysis of energy and electricity. Barry is director and consultant at Stratecon, and while he has consulted in various capacities in the past; economic and financial modelling is his key specialisation.

Chapter 11: Impacts on Social Fabric

Integrating Author	
Doreen Atkinson	Doreen Atkinson is a Research Associate at the University of the Free State, Bloemfontein. Her areas of research expertise include local government, community development, intergovernmental relations, policy analysis, governance, local economic development, small towns and rural development, land reform, sustainable livelihoods, project and programme evaluation, and regional development. Doreen has extensive research on Karoo tourism, and has organised five Karoo conferences since 2009.
Contributing Authors	
Catherine Schenk	Catherine Schenk has 34 years of teaching experience and 40 years of work experience, which includes rural social work in South Africa, involving the evaluation of the recruitment; and retention strategy of the Department of Social Development, which was commissioned by Chiastolite Professional Services (CPS). In 2015 the University of the Western Cape and University of Johannesburg provided funding for her research on the waste pickers in the Karoo.
Sethulego Matebesi	Sethulego Matebesi is a Senior Lecturer and Acting Academic Head of the Department of Sociology at the University of the Free State. Sethulego's research focuses on community protests in South Africa, specifically the differential social organisation of communities and civic organisations in predominantly black and white neighbourhoods, as well as the effect of community trusts on protests in mining towns.
Karin Badenhorst	Karin Badenhorst founded the Footsteps Foundation and has over 25 years of research, consulting, business development and executive management experience in the large institutional environment. Her current research focuses on socio-economic and ecological entrepreneurship, sustainability, the renovation of selected economic, agricultural, natural, cultural and technological value chains for the benefit of small, distant, vulnerable, rural communities, with a particular focus on the Karoo.

Chapter 12: Impacts on Human Health

Integrating Author	
Bettina Genthe	Bettina Genthe has over 30 years' experience in the field of environmental health aspects and water quality. She has been a temporary advisor to the World Health Organisation and United States Environmental Protection Agency on Exposure Assessment. She has extensive experience in water-related human health risk assessments, water quality monitoring, risk communication, health interventions, and health and hygiene awareness creation and education.
Contributing Authors	
Ashton Maherry	Ashton Maherry has a BSc Honours degree from the University of the Free State, and is currently a full time Masters GISc student at UNIGIS International. Ashton has ~12 years' experience as a Geohydrologist at the Council for Scientific and Industrial Research, where he serves as a Senior Knowledge Applicator, GIS- and Groundwater specialist, and Project Manager.
Maronel Steyn	Maronel Steyn has an M.Tech degree in Environmental Health from the Central University of Technology, and is a researcher within the CSIR's Water Resources competency area. Her key competencies lie in environmental epidemiology, human health risk and burden of disease. Maronel's areas of interest include drinking water treatment, wastewater treatment and reuse, water pollution microbiology, health

	economics and diseases.
Hanna- Andrea Rother	Hanna-Andrea Rother, PhD, is Associate Professor and Head of the Environmental Health Division in the School of Public Health and Family Medicine at the University of Cape Town. She has over 25 years' experience in research, policy analysis, capacity building and teaching related to chemical exposure risks, risk management and mitigation, as well as risk perceptions and risk communication.
Leslie London	Leslie London is a public health specialist and Professor at the School of Public Health and Family Medicine, University of Cape Town. He is actively involved in the Centre for Occupational and Environmental Health Research, and has served on many committees dealing with ethics and human rights. He has published over 150 articles and 15 books or book chapters.
Mieke Willems	Mieke Willems is employed as evaluator in a technical position as Assistant Director in the Western Cape Government Health's Impact Assessment Unit. She has a Master's in Public Heath from the University of Cape Town where her thesis related to risk perceptions surrounding fracking, specifically from a health perspective. Other research interests include environmental health, non-communicable diseases and diseases of lifestyle.
Chapter 13: Impacts on Sense of Place Values	
Integrating Author	
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Contributing Authors	
Michael de Jongh	Michael de Jongh is Professor Emeritus, Anthropology, at Unisa. He has published widely and presented scientific papers internationally. For some 25 years his research focus has been on the Karoo in particular. He has published over 20 articles and several books and research reports in the fields of prehistory, history and anthropology reflect his engagement with the region and its people.
David Morris	David Morris heads Archaeology at the McGregor Museum and is Extraordinary Professor at Sol Plaatje University in Kimberley. His main research interest in rock art was the focus of his PhD at the University of the Western Cape. He is involved in a wide cross-section of projects and publications in Northern Cape archaeology, including development of public archaeology sites.
Chapter 14: Visual, Aesthetic and Scenic Resources	
Integrating Author	
Bernard Oberholzer	Bernard Oberholzer is a landscape architect and environmental planner with over 20 years' experience in visual assessments, particularly for wind and solar energy, as well as gas pipelines and powerlines. He authored the *Guideline for Involving Visual and Aesthetic Specialists in EIA Processes*, and co-authored a heritage and scenic resources study for the Provincial Government, Western Cape.
Contributing Authors	
Quinton Lawson	Quinton Lawson is a professional architect, with 15 years' experience in visual assessments. He is visiting lecturer for the University of Cape Town and serves on the Impact Assessment Committee of Heritage Western Cape for the Provincial Government Western Cape. Has been involved in numerous visual assessments, usually in association with BOLA, for solar and wind energy facilities, as well as gas pipelines and powerlines.

Menno Klapwijk	Menno Klapwijk has 33 years' experience as a SACLAP registered professional landscape architect, and is a founding and principal member of Bapela Cave Klapwijk, landscape architects and environmental planners. He has over 100 publications and reports dealing mostly with environmental planning, environmental rehabilitations and control specification, and environmental- and visual impact assessment. He also assisted in drafting 'A Guideline for Involving Visual and Aesthetic Specialists in EIA Processes'.
Graham Young	Graham Young is a registered landscape architect and visual impact assessment specialist. He was awarded an ILASA Merit Award for his work and helped develop the *Guideline for Involving Visual and Aesthetic Specialists in EIA Processes.* He authored a research document for Eskom, *The Visual Impacts of Power Lines,* and produced '*Guidelines for involving visual and aesthetic specialists'* for a World Heritage Site in Mauritius.
Chapter 15: Impacts on Heritage	
Integrating Author	
Jayson Orton	Jayson Orton has conducted numerous heritage impact assessments for a wide range of project types throughout the western half of South Africa since 2004, often collaborating with other specialists. His research interest is in the Later Stone Age archaeology and rock art of South Africa's arid environments, especially Namaqualand; on which he has published widely.
Contributing Authors	
John Almond	John Almond is a Cape Town-based palaeontologist with almost 30 years' experience working on the geology and fossils of southern Africa. He worked for the Council for Geoscience for eight years, and has carried out numerous palaeontological impact assessments for developments and conservation areas in the Karoo, including strategic Impact Assessments for the SKA project and alternative energy developments.
Nicholas Clarke	Nicholas Clarke, a heritage architect, obtained his professional degree from the University of Pretoria, followed by a Masters Degree from Cambridge University. He has practiced as an architect and heritage advisor and lectured in built heritage studies at the University of Pretoria and Delft University of Technology. He is active in World Heritage, having undertaken numerous ICOMOS/UNESCO Missions.
Roger Fisher	Roger Fisher is Professor Emeritus, at the Department of Architecture, University of Pretoria. His research focuses on the South African built heritage, particularly as it serves sustainable communities. His expertise serves the public as advisor and committee member of various heritage bodies and committees and as practitioner acting as a heritage consultant.
Chapter 16: Noise generated by Shale Gas- related activities	
Integrating Author	
Andrew Wade	Andrew Wade is the Managing Director of Sound Research Laboratories South Africa (SRL SA). He is a registered Chartered Engineer with the Engineering Council (UK), and is a member of the Institute of Acoustics (UK). He has significant experience in environmental noise and vibrations, building acoustics, industrial acoustics, acoustic modelling and Noise and Vibration Harshness (NVH).
Contributing Author	
Adrian Jongens	Adrian Jongens (M.Sc. Electrical Engineering) has trained undergraduate and postgraduate engineering students on the application of fundamental physical acoustical principles to noise and vibration control for 40 years. In parallel, he has provided a consulting service in all aspects relating to noise and vibration control, building and architectural acoustics, noise management policy formulation and environmental noise impact assessment and mitigation.

Chapter 17: Electromagnetic Interference	
Integrating Author	
Adrian Tiplady	Adrian Tiplady has worked at SKA South Africa since 2005, and currently sits on the SKA Executive Committee as Head of Strategy. He has experience across a number of technical, scientific and strategic areas. Adrian was a member of the Working Group of the Task Team on Hydraulic Fracturing, and is involved in the environmental impact assessments of renewable energy projects in the Northern Cape Province.
Contributing Authors	
Paul van der Merwe	Paul van der Merwe, in his role as managing director of MESA Solutions, deals mainly with impact assessments of extensive engineering systems. MESA is involved in assessments of proposed large renewable energy developments in close proximity to the SKA project in the Northern Cape. MESA has assisted at least seven manufactures during various stages of their project proposal, including theoretical desktop investigation and field measurements of installed systems.
Braam Otto	Braam Otto has a Ph.D. in Electrical Engineering from the University of Stellenbosch. He works as a radio frequency engineer in the field of electromagnetic compatibility and radio frequency interference mitigation. He is actively involved in the South African Square Kilometre Array Project as EMC consultant, and has contributed to various environmental impact assessments in the renewable energy sector.

Chapter 18: Impacts on Integrated Spatial and Infrastructure Planning	
Integrating Authors	
Elsona van Huyssteen	Elsona van Huyssteen is a Principle Urban and Regional Planner at the CSIR and has over 20 years' experience in research, and policy development. She has lead collaborative multi-disciplinary initiatives in the urban and regional development planning field. Her interest focusses on innovative ways to engage collective futures through profiling spatial growth dynamics impacting cities, settlements and regions; transdisciplinary and multi-stakeholder initiatives, and action-orientated leadership.
Cheri Green	Cheri Green has over 30 years' research experience in fields of accessibility, transportation planning, land use development, facility location planning (in urban and rural context), and social facility provision norms. She is a Registered Town & Regional Planner and Senior Researcher at the CSIR. She has been involved in several studies in the Karoo region since 2002, including the development of Integrated Transport Plans.
Contributing Authors	
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Mark Oranje	Mark Oranje is Professor and Head of the Department of Town and Regional Planning at the University of Pretoria. His key areas of interest are planning policy, regional development, intergovernmental development planning and the interface between mining and settlement development. Mark has authored and co-authored numerous publications and consulted on a wide range of issue related to his above areas of interest.
Stephen Berrisford	Stephen Berrisford is an independent consultant working at the intersection between law and urban planning in Sub-Saharan Africa. Stephen is an Honorary Adjunct Associate Professor at the University of Cape Town's African Centre for Cities. His work focuses on legal and policy dimensions of land use and urban development. He holds degrees from the University of Cape Town and Cambridge University.