Strategic Environmental Assessment of Shale Gas Development in the Central Karoo

Phase 3:
Decision Support Tools Report

June 2017

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List of acronyms, abbreviations and units

°	Degrees
°C	Degrees Celsius
2-D	2-dimensional
3-D	3-dimensional
AEL	Air Emissions License
AGAA	Astronomy Geographic Advantage Act of 2007
ASSAf	Academy of Science of South Africa
bbl	barrel
BS	British Standard
CARA	Conservation of Agricultural Resources Act of 1983
CBA	Critical Biodiversity Area
CFB	Cape Fold Belt
CGS	Council for Geoscience
CO_2	Carbon dioxide
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
dB	Decibel
dBA	A-weighted decibel
DEA	Department of Environmental Affairs
DEA&DP	Western Cape Government Environmental Affairs And Development Planning
DMF	Decision-Making Framework
DMR	Department of Mineral Resources
DoE	Department of Energy
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EDD	Economic Development Department
EIA	Environmental Impact Assessment
EMF	Environmental Management Framework
EMI	Electromagnetic interference
EMP	Environmental Management Plan
EMPR	Environmental Management Plan Report
EMPr	Environmental Management Programme
ER	Exploration Rights
EU	European Union
FEPA	Freshwater Ecosystem Priority Area
FOD	First Order Draft
GHG	Greenhouse Gas
GIS	Geographic Information System
GJ	Gigajoule
GN	Government Notice
GUMP	Gas Utilisation Master Plan
GVA	Gross Value Added
ha	Hectare

Ha/ LSU	hectares per livestock unit
HIA	Heritage Impact Assessment
IEP	Integrated Energy Plan
IFC	International Finance Corporation
IRP	Integrated Resources Plan
ITU-R	International Telecommunications Union Recommendation
KCAAA	Karoo Central Astronomy Advantage Area
kg	kilogram
km	kilometre
km^2	square kilometre
kWh	kilowatt hour
LNG	Liquefied Natural Gas
LUPA	Western Cape Land Use Planning Act of 2015
M	Magnitude
m	metre
m^3	cubic metre
MC	Management Class
MIRs	Minimum Information Requirements
mm	millimetre
MPa	MegaPascal
MPRDA	Mineral and Petroleum Resources Development Act of 2002
MW	MegaWatt
NAAQS	National Ambient Air Quality Standard
NBA	National Biodiversity Assessment
NBSAP	National Biodiversity Strategy and Action Plan
NCPDA	Northern Cape Planning and Development Act of 1998
NCR	Noise Control Regulations
NDP	National Development Plan
NEM:AQA	National Environmental Management: Air Quality Act of 2004
NEM:WA	National Environmental Management: Waste Act of 2008
NEMA	National Environmental Management Act of 1998
NEMBA	National Environmental Management: Biodiversity Act of 2004
NHRA	National Heritage Resources Act
NORM	Naturally Occurring Radioactive Material
NPAES	National Protected Area Expansion Strategy
NWA	National Water Act of 1998
OES	One Environmental System
PASA	Petroleum Agency South Africa
PCG	Process Custodians Group
PEC	Project Executive Committee
PHRA	Provincial Heritage Resources Agencies
PV	Photovoltaic
SAHRA	South African Heritage Resources Agency
SAHRIS	South African Heritage Resources Information System
SALT	Southern African Large Telescope
SANBI	Southern African National Biodiversity Institute
SANS	South African National Standard
SARAS	South African Radio Astronomy Service

SAWIS	South African Waste Information System
SDF	Spatial Development Framework
SEA	Strategic Environmental Assessment
SEMA	NEMA Specific Environmental Management Act
SGMC	Shale Gas Monitoring Committee
SKA	Square Kilometre Array
SOD	Second Order Draft
SOEKOR	Southern Oil Exploration Corporation
SPLUMA	Spatial Planning and Land Use Management Act of 2013
t	Ton
Tcf	trillion cubic feet
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	Unites States of America
WHO	World Health Organization
WUL	Water Use Licence

1. BACKGROUND TO THE SEA

In 2010 the Department of Mineral Resources (DMR) received five Exploration Rights (ER) applications in terms of the Minerals and Petroleum Resources Development Act, 28 of 2002 (MPRDA) to explore for shale gas in the Central Karoo. One application was submitted by Falcon Oil & Gas Limited ("Falcon"), three by Shell Exploration Company B.V. ("Shell") and one by Bundu Gas and Oil Exploration (Pty) Ltd ("Bundu").

The potential economic and energy security benefits of a large shale gas resource in the Karoo Basin could be substantial; as are both the positive and negative social and environmental issues associated with a domestic gas industry. Shale gas exploration and production has already become a highly divisive topic, but one which is poorly informed by publically-available evidence.

To address this lack of critically-evaluated information, a Strategic Environmental Assessment (SEA) for shale gas exploration and production was commissioned in February 2015 by the Department of Environmental Affairs (DEA) of the Republic of South Africa, with the support of the National Departments of Energy (DoE), Mineral Resources (DMR), Water and Sanitation (DWS), Science and Technology (DST), and Agriculture, Forestry and Fisheries (DAFF); and the Provincial Departments of the Eastern, Western and Northern Cape Governments. The Council for Scientific and Industrial Research (CSIR) coordinated the SEA, in partnership with the South African National Biodiversity Institute (SANBI) and the Council for Geoscience (CGS).

The point of departure for the SEA is that South African Government, through Cabinet and various other decision-making institutions, has made high-level public commitments to shale gas exploration. If the exploration phase reveals economically-viable hydrocarbon deposits and gas-flow regimes, the Government will seriously consider permitting the development of those resources at significant scale. South African society, collectively comprising all levels of government, the private sector and civil society, needs to be in a position to make the decisions relevant to that choice in a timely and responsible manner.

Drawing from the National Development Plan (NDP), 2012, and the Constitution of South Africa (Act 108 of 1996), the overarching *Mission Statement* for exploration and production in South Africa was developed at the first Project Executive Committee (PEC) meeting held in February 2015. Guided by the principles of saliency, legitimacy and credibility[1], the mission is *to provide an integrated assessment and decision-making framework to enable South Africa to establish effective policy, legislation and sustainability conditions under which development of shale gas could occur.*

Note that the mission statement, developed in collaboration with government at the first PEC meeting, is phrased in the conditional - it does not presume that development will occur, since no modern exploration has been undertaken.

1.1 A Phased Approach

The SEA was undertaken as three distinct but overlapping Phases (Figure 1–1). Phase 1, beginning in February 2015 and extending to around October 2015, was the ‘Preparation Phase’. The Preparation Phase included the necessary arrangements involving contracts and procurement arrangements, recruitment, convening project governance structures, collating literature, Geographic Information Systems (GIS) data libraries, identifying the multi-author expert teams, undertaking project team training (e.g. in managing and responding to conflict situations), arranging logistics and compiling the first draft of the Scenarios and Activities – which later came to form Chapter 1 of the Phase 2 Scientific Assessment and provide the material basis of the Phase 2 assessment.

Phase 2 of the SEA was the ‘Scientific Assessment Phase’, where data and information was organised and assessed by the multi-author expert teams. The Phase 2 process included two peer review rounds, initially by independent review experts appointed by CSIR, and then (following revision to produce the second draft) by stakeholders plus the experts who reviewed the first draft. Phase 2 commenced with the first multi-author expert workshop on 28 September 2015, and ended with the completed final Scientific Assessment, published on 15 November 2016 and available at http://seasgd.csir.co.za/scientific-assessment-chapters/

[1] ***Legitimacy*** refers to running an unbiased process which considers appropriate values, the concerns and perspectives of different actors, and corresponds with political and procedural fairness. ***Saliency*** is established by ensuring that the outcomes of the assessment are of relevance to the public and decision-makers and seeks to address quite specific questions. ***Credibility*** means meeting the standards of scientific rigor and technical adequacy. The sources of knowledge in an assessment must be considered trustworthy along with the facts, theories, and causal explanations invoked by these sources. Local and traditional knowledge should be included in the assessment where appropriate and possible. Involving eminent and numerous scientists as authors and ensuring that all reports undergo expert peer review are essential.

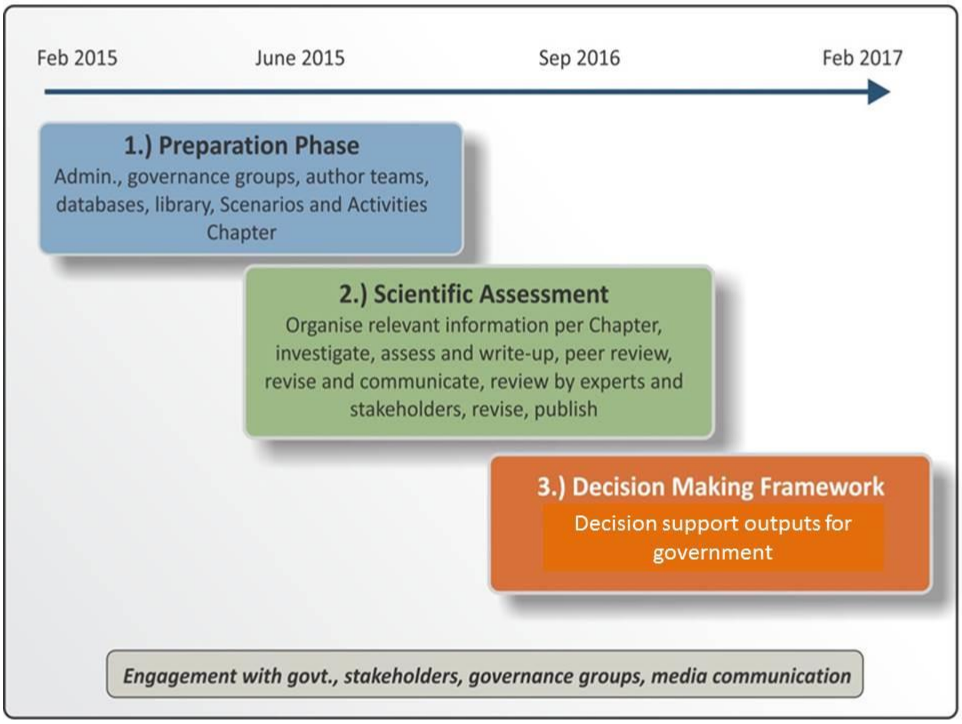


Figure 1–1: Shows the 3 overlapping phases of the SEA process and how the Scientific Assessment is used as the evidence base from which to develop an appropriate Decision Making Framework.

Phase 3 of the SEA, i.e. the contents of this report, translates the peer- and stakeholder reviewed Scientific Assessment into an operational Decision-Making Framework (DMF) for Government. This final phase of the SEA will conclude end May 2017 and will provide the framework for how site and activity specific assessment processes should be undertaken and provide Government with the necessary tools it needs to enable responsible decision-making into the future. This includes guidance on regulations, decision-making protocols, monitoring requirements and institutional arrangements. The separation between Phase 2 and Phase 3 is to honour the Scientific Assessment 'mantra' of being "policy relevant, but not policy prescriptive". The experts involved in Phase 2 were not asked to make decisions about the development of shale gas – this is a responsibility mandated to Government – but were asked to give an informed, evidence-based, scientifically-sound and balanced opinion on the consequences and opportunities of different scenarios and development options into the future and the best processes for future site specific assessments and mitigation actions. The ultimate decisions regarding authorisation processes for shale gas, whether at a national, provincial or local level, will be made by the authorities mandated to do so. In making these decisions they will be guided by the scientific evidence and decision support tools developed through the SEA process, and any other relevant and trusted sources of information that may have become available between the completion of the SEA and the time at which government needs to make decisions or implement policy - which may be years or decades into the future[2].

[2] Other such publications which were released at similar times as the Phase 2 Scientific Assessment include the Academy of Science South Africa (ASSAf) in collaboration with the South African Academy of Engineering who in October 2016 published a ret entitled '*South Africa's Readiness to Support the Shale Gas Industry'* (ASSAf, 2016) and 'Hydraulic Fracturing in the Karoo: Critical Legal and Environmental Perspectives' published by a large team of academics based out of South African research institutions (Glazewski & Esterhuyse, 2016).

1.2 Scope of the SEA

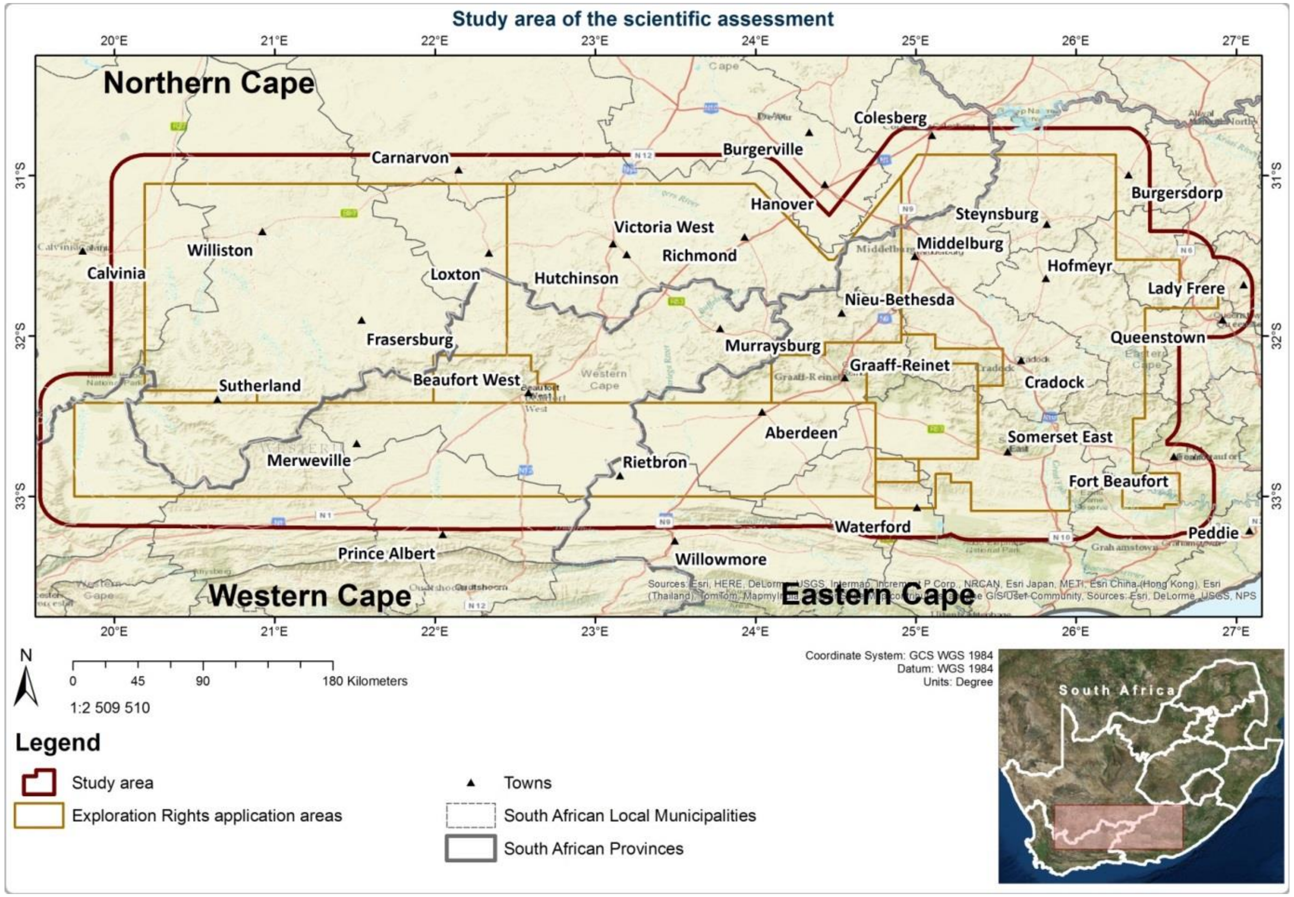


Figure 1–2: The SEA considered activities origination in the 171 811 km^2 region of the study area delimited by the applications for ER lodged by Shell, Falcon and Bundu, plus a 20 km extremity buffer. The assessment follows the consequences of shale gas exploration and production activities in this region to the point of material impact, even if that is outside the study area – as may be the case of impacts on vectors such as air or water which are not spatially static.

The geographic scope of the assessment was restricted to the potential impacts originating from shale gas exploration and production within the Central Karoo (Figure 1–3). This is not only the most promising gas prospect, but also the only region at the date of commencement of the SEA, for which ER applications (specifically for shale gas) had been accepted by the Petroleum Agency South Africa ("PASA" – the regulatory body representing DMR). While the ER applications were lodged with PASA in 2011, they are still currently under consideration with no decision yet made on the applications. Other types of unconventional gas reserves may exist in regions of the South African onshore and offshore territory, and would need separate consideration if their development was considered.

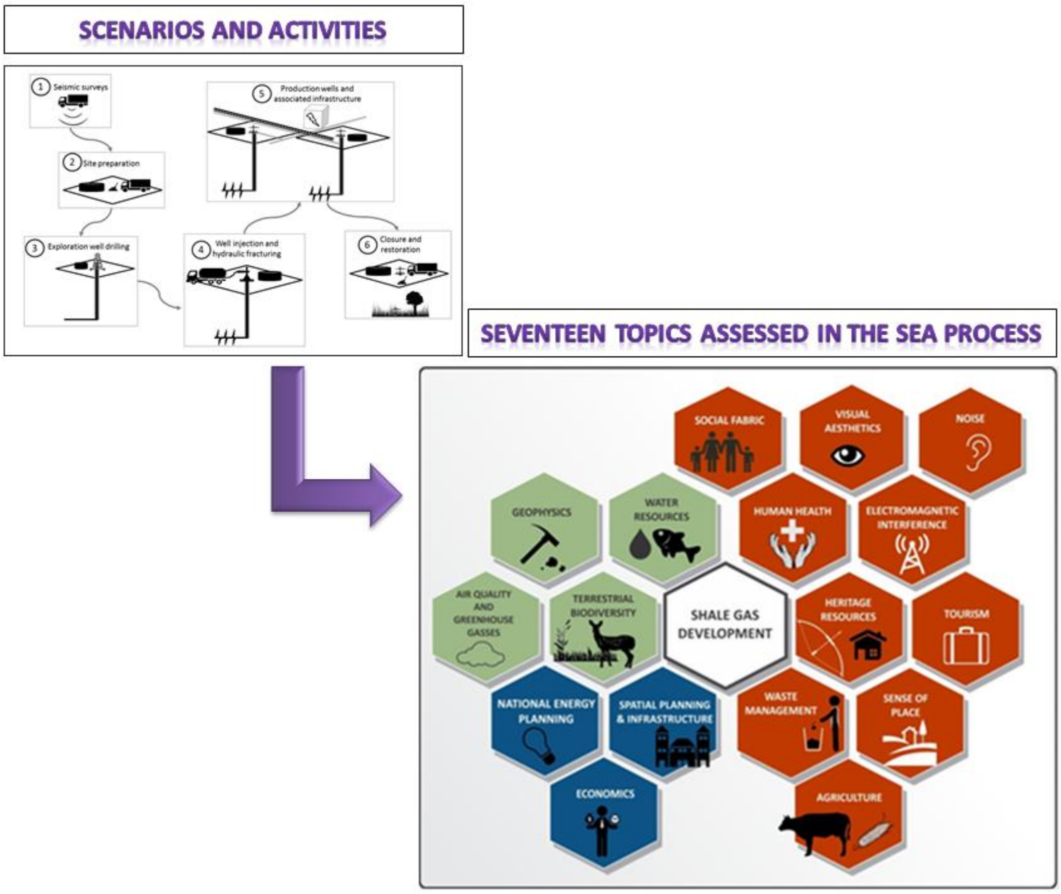


Figure 1–3: All seventeen topics where assessed within a common methodological framework and common point of departure as presented in the Scenarios and Activities document.

The scope of this SEA considered shale gas exploration, production and downstream related activities, up to and including eventual closure of facilities and restoration of their sites, and included a risk assessment of all the material social, economic and biophysical opportunities and consequences associated with the shale gas industry across its entire lifecycle, as described in detail in the Scenarios and Activities. This temporal scope extends, in some instances up to 40 years into the future. The scope of issues addressed in the SEA (Figure 1-4) was informed by an in-depth review of similar international assessments undertaken around the world; the development of a casual-loop model to aid in describing the Central Karoo as a dynamic system and trace relationships between social and ecological variables and proposed shale gas development; and by engagement with stakeholders (see Appendices 1 and 1a) and governance groups (see Section 1.3). Furthermore, the scope of the SEA was vetted by the governance groups and the stakeholders participating in the process.

1.3 Governance of the Process

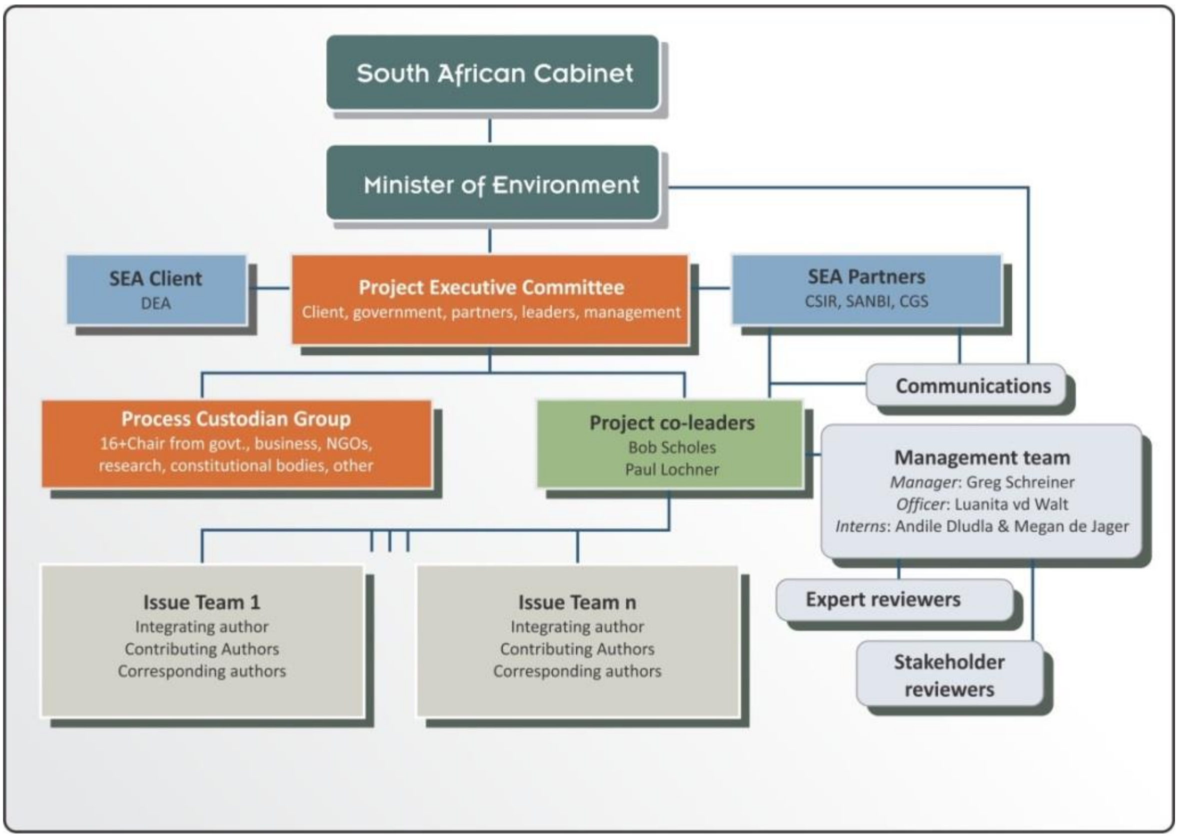


Figure 1–4: The project governance structure of the entire SEA process showing the interaction between the two governance groups, the SEA partners, the co-leaders and management team, the multi-authors teams, the peer review experts and stakeholders.

1.3.1 Project Executive Committee

The PEC comprised representatives of government who have been involved in all 3 phases of the SEA since its inception and up to its completion in 2017. The composition of the PEC is provided in Table 1-1 indicating organisational representation and delegate names.

Table 1–1: PEC members who participated in the shale gas SEA process.

Representing	Member name	Other members
DEA (Chair)	Dee Fisher	Simon Moganetsi, Surprise Zwane, Marlanie Sargonum Moodley, Sabelo Malaza, Wilma Lutsch, Patience Sehlapelo
DWS	Mkhevu Mnisi	Bayanda Zenzile, Alice Mabasa
DMR	Mosa Mabuza	Nonthanthla Jali
DoE	Muzi Mkhize	Mmarena Mphahlele, Stella Mamogale
DST	Somila Xosa	Mere Kgampe, Mmboneni Muofhe, Nametshego Gumbi
DAFF	Lydia Bosoga	Mary-Jean Gabriel, Edwin Mametja, Mpume Ntlokwana
Eastern Cape Department of Economic Development, Environmental Affairs and Tourism	Alistair McMaster	Gerrie Pienaar
Western Cape Department of Environmental Affairs and Development Planning (DEA&DP)	Paul Hardcastle	Henri Fortuin
Northern Cape Department of Environment and Nature Conservation	Bryan Fischer	Natalie Uys
Agricultural Research Council	Garry Paterson	
SANBI	Jeffrey Manuel	Kristal Maze
CGS	Henk Coetzee	V.R.K. Vadapalli, Muvhuso Musethsho, Thato Kgari
CSIR	Bob Scholes and Paul Lochner (SEA co-leaders)	
Secretariat	Greg Schreiner (Project Manager), Luanita Snyman-Van der Walt (Project Officer), Megan de Jager and Andile Dludla (Project Interns)	

The key responsibilities of the PEC included the coordination and communication of information through the SEA process, both within government and in stakeholder engagement; ensuring that the project remained on scope, within timelines and budget; and that strategic and policy questions were adequately incorporated into the SEA process. Any feedback and questions raised by the PCG was referred to the PEC for deliberation and are reflected in detailed project notes as contained in Appendix 1a.

Table 1–2: The PEC met at the following key junctures and for the following purposes

Date	Meeting	Venue	Purpose of the meeting
12-13 Feb 2015	1	Main auditorium DEA, Environment House, Corner Steve Biko & Soutpansberg, Arcadia, Pretoria	Welcome and introductions; SEA approach; vision and objectives; governance; presentation on the report: *Opportunities and risks of Shale Gas Extraction in the Western Cape* (2012) (Paul Hardcastle); Presentation on the report: *Technical Evaluation and Socio-Economic Analysis of Shale Gas in the Eastern Cape* (Alistair McMaster); SEA strategic issues or 'topics'; approach to SANBI Bioblitz (Jeff Manual); project management and timelines; approach to media liaison and public engagement; process to launch the project in Parliament; agreement on scope; approach and timelines.
22 July 2015	2	Executive Boardroom (A222), Building 3, CSIR Campus, Pretoria	Confirm scope of the study; provide background to the SEA process, summary of outcomes from the Inception Workshop (12-13 February 2015); confirm governance mandates; provide an update on the SEA management and process, and on the SANBI Bioblitz; and discuss the shale gas regulatory environment with regards to changes and new developments.
22 October 2015	3	Ulwazi Room, CSIR Knowledge Commons, Pretoria Campus	Provide an update on SEA progress; provide and confirm SEA scope of work in terms of the Zero Order Draft; provide overview of planned public outreach (9-13 November 2015) and confirm roles and responsibilities for PEC members; convey key points from the 2nd PCG Meeting; and clarify other issues raised including PEC mandate; commissioning of SEA Process document, engagement between PEC and PCG.
04 May 2016	4	Demo Room, Building 22, CSIR Pretoria Campus	Provide an update on SEA progress with regards to public outreach programme; present the draft scenarios and activities report; Present peer review process to be followed; convey key findings on the identified topics in the First Order Drafts (FODs).
13 June 2016	5	Ulwazi Room, CSIR Knowledge Commons, Pretoria Campus	Discuss the key issues of concern in the Second Order Draft (SOD) Chapters of the Scientific Assessment prior to the release of the SOD; engagement with the Summary for Policy-Makers; and provide feedback and plans for public outreach.
26 September 2016	6	Executive Boardroom (A222), Building 3, CSIR Campus, Pretoria	Provide an update on SEA progress with regards to the Scientific Assessment process and its key findings, and the public outreach programme; discuss the DMF for Phase 3 of the SEA.
23 March 2017	7	ECD Boardroom, Building 23, CSIR Campus, Pretoria	Provide an overview of the key Scientific Assessment findings; discuss the approach to strategic mitigation, limits of acceptable change and the Minimum Information Requirements, specifically the splitting of "Exploration" and "Appraisal" into two regulatory processes. This approach was discussed with and approved by PASA.
17 May 2017	8	Ulwazi Room, CSIR Knowledge Commons, Pretoria Campus	Present draft Decision Support Tools Report to the PEC for comment. Final PEC meeting. Project closure.

1.3.2 Process Custodians Group

A key innovation, used specifically for the Scientific Assessment Phase, was the PCG. The PCG was designed to ensure that the Scientific Assessment was undertaken in an independent, thorough and balanced manner.

The PCG comprised eminent people, drawn approximately equally from government, non-governmental organisations, the private sector and the research community. The PCG met at key junctures during the Scientific Assessment to ensure that the process has been fair and rigorous. The PCG had no influence on the content of the Scientific Assessment, but acted as referees to ensure that the Phase 2 process had been undertaken in a legitimate, transparent and credible manner.

The organisations from which the PCG members were sourced were identified by the PEC as having credibility in their ‘sectors’ through having a mandate of some distinction, broad representation and a demonstrated interest in the topic of shale gas development. Members of the PCG were not appointed as ‘representatives’ of their organisation in a narrow sense, but were expected to reflect the breadth of opinion in their sectors.

The PCG was neither ‘approving’ nor ‘disapproving’ of shale gas development, nor did it have a say on the detail of the content of the Scientific Assessment. It was a trustworthy collective, tasked with ensuring that the process of evidence collection, evaluation and presentation was comprehensive and unbiased. This distinction remained critical especially for the non-governmental members of the PCG, as they and their respective organisations did not necessarily agree with every outcome of the Scientific Assessment.

The PCG provided feedback to the PEC, ensuring that the Scientific Assessment was followed within the prescribed process as approved in the SEA Process Document[3]. Their specific mandate was to evaluate the following five topics of the Scientific Assessment process:

1) Has the assessment process followed within the guidelines of the SEA Process Document?
2) Do the Chapter teams have the necessary expertise and show balance?
3) Does the assessment cover the material issues?
4) Are the identified expert reviewers independent, qualified and balanced?
5) Have the review comments received from expert and stakeholders been adequately addressed and have the responses been adequately documented?

[3] The SEA Process Document available at http://seasgd.csir.co.za/library/

Table 1–3: PGC members who participated in the shale gas SEA process

Sector	Organisational home of member	Member name	Other members
Chair	International Association for Impacts Assessment South Africa	Sean O'Bierne	-
Government	Department of Performance Monitoring and Evaluation	Rudi Dicks	Nkhensani Golele, Mukondi Masithi
Government	South African Local Government Agency	Intelligent Chauke	-
Government	Economic Development Department (EDD)	Andrew Matjeke	Khathutshelo Sikhitha
Government	DEA	Dee Fischer	Surprise Zwane, Marlanie Sargonum Moodley, Patience Sehlapelo
Government / Business	PetroSA	Jessica Courtoreille (withdrew from PCG)	Portia Manuel, Bongani Sayidini
Business	AgriSA	Wayman Kritzinger	Nic Opperman
Business	Onshore Petroleum Agency South Africa	Peter Price	Lizel Oberholzer/ Jane Blomkamp
Business	Business Unity South Africa	Marius Diemont	Laurel Shipalana
NGO	Treasure the Karoo Action Group	Jeanie le Roux	Jonathan Deal, Julius Kleynhans
NGO	World Wide Fund For Nature –South Africa	Morné du Plessis	-
NGO	South African Faith Communities Environment Institute	Stefan Cramer	-
NGO	Project 90 by 2030	David Fig	-
Research	Water Research Commission	Shafick Adams	Jo Burgess
Research	Human Sciences Research Council	Demetre Labadarios	Temba Masilela, Selma Karuaihe
Research	Square Kilometre Array (SKA)	Selaelo Matlhane	Adrian Tiplady (withdrew from PCG to become assessment author)
Research	Nelson Mandela Metropolitan University	Barry Morkel	Moctar Doucouŕe, Maarten de Wit (withdrew from PCG)
Constitutional Body	South African Human Rights Commission	Janet Love	Chantal Kisoon, Angela Kariuki, Nada Kakaza
Project team	SANBI	Jeff Manuel	Kristal Maze
Project team	CGS	Henk Coetzee	V.R.K. Vadapalli, Muvhuso Musethsho, Thato Kgari
Project team	CSIR	Bob Scholes and Paul Lochner (SEA co-leaders)	-
Project team	Secretariat	Greg Schreiner (Project Manager), Luanita Snyman-Van der Walt (Project Officer), Megan de Jager and Andile Dludla (Project	-

Sector	Organisational home of member	Member name	Other members
		Interns)	

Table 1–4: The PCG met at the following key junctures and for the following purposes

Date	Meeting no.	Venue	Purpose of the meeting
22 July 2015	1	Executive Boardroom (A222), Building 3, CSIR Campus, Pretoria	Introduction to the process and the process governance and mandates; project principles and principles for engagement; confirmed project approach and scope; mandate for the PCG; approach to the multi-author teams.
22 October 2015	2	Ulwazi Room, CSIR Knowledge Commons, Pretoria Campus	Provide an outline of the SEA in terms of objectives, study area and governance; Provide update on Status of SEA project and progress; Discuss comments and responses on Specialist/ Author Team composition and balance; Provide SEA Scope of Work in terms of the Zero Order Draft and Risk Assessment approach; Provide Public Outreach programme for November 2015; Discuss issues such as duration allocated for comment and review, feedback to PEC, and circulation of PCG comments prior to submission to Project Team.
3 May 2016	3	Demo Room, Building 22, CSIR Pretoria Campus	Provide an update on SEA progress with regards to Public Outreach feedback and programme, the SOD of the Scenarios and Activities Chapter, and the Peer Review Process to be followed for the FOD; Provide preliminary feedback on FODs.
26 September 2016	4	Executive Boardroom (A222), Building 3, CSIR Campus, Pretoria	Provide an update on SEA progress with regards to the Scientific Assessment process and its key findings, and the Public Outreach programme; Address questions on the process and other matters arising.

The final PCG meeting was undertaken on 26 September 2016. No objections to the Phase 2 process, as outlined in the mandate of the PCG, were registered before final publication of the Scientific Assessment on 15 November 2016. This was confirmed in formal correspondence from the PCG Chair (Sean O'Beirne) to the Project Manager (Greg Schreiner) on 10 November 2016. Since final publication, there have been no objections registered from any stakeholders regarding the integrity of the stakeholder review process and engagement undertaken.

2. SHALE GAS EXPLORATION AND PRODUCTION

2.1 International Context

Around 2010, when international enthusiasm for shale gas peaked, oil prices were in the region of $100 per barrel and horizontal drilling and gas extraction technologies were improving rapidly. The shale gas revolution in the United States of America (USA) sparked worldwide interest in the domestic development of shale gas to enhance economic beneficiation and sovereign energy security (Zuckerman, 2013). The United States Energy Information Administration issued a series of reports providing initial assessments of world shale gas resources which prompted local consideration of shale gas resources in numerous countries with potentially viable shale gas reserves (US EIA, 2013)

Experience elsewhere in the world with shale gas exploration and production has revealed some of the potential negative environmental impacts. For instance, there is credible evidence of leakage of gas from deep sources into surface aquifers following hydraulic fracturing (Brantley et al., 2014; Jackson et al., 2013; Kargbo et al., 2010; Myers, 2012; Osborn et al., 2011), generally attributed to inadequate sealing of the borehole in its upper sections; accidental and operational leakage of methane to the atmosphere during the extraction and transport; and that use of natural gas significantly reduces the climate change benefits of using gas as an energy source rather than coal (Allen et al.,2013; Howarth et al., 2011; Klausmann et al., 2011; Tollefson, 2012).

The surface disturbance from wellfield development such roads, traffic, drill pads, waste fluid holding lagoons and treatment works, gas storage and other transport infrastructure (such as pipelines) associated with a production-scale gasfield is not negligible (Drohan et al., 2012); neither are the sensory impacts in what are often previously non-industrial environments and the unintended social impacts of attracting non-local workers into formerly rural communities (U.S Department of Energy, 2009) – the ‘Boomtown’ phenomenon. As a result, internationally, countries have generally taken a risk averse and cautious approach to shale gas development with a number of countries undertaking large assessment processes and continuing to advance the research baseline prior to significant production of shale gas.

The USA has largely led the shale gas energy revolution. As a case study, it offers policy-makers in countries thinking about shale gas exploration, or production at significant scale, an insight into the consequences and opportunities associated with the impacts typical of the development life-cycle. In the USA, policy and regulation of shale gas extraction occurs at a federal, state and local level of government. Historic allocations of authority and the number of large exemptions made by federal government to states have prompted the latter to assume the role of active regulators of shale gas development, and thereby hold majority of the responsibility for shale gas governance risks. The regulation of oil and gas operations by local governments is prohibited in some states.

The state-specific regulation of shale gas exploration and production has resulted in disparities between the different states in the regulatory requirements for hydraulic fracturing operators (Boersma and Johnson, 2012). For instance, North Dakota is seemingly unconcerned about the environmental consequences of hydraulic fracturing which is evident from the environmental concessions granted in favour of the oil and gas industry with the purpose of promoting resource recovery, while states such as New York, Colorado and Pennsylvania have heightened regulatory requirements in place, such as the provision of site specific environmental information and full disclosure of hydraulic fracturing fluid composition prior to application approval (Ash, 2011).

In states such as Texas, a fragmented administrative structure exists whereby multiple commissions and authorities hold jurisdiction over resource regulation for minerals, water, land and air. In some cases a single resource is governed by a number of authorities. Despite overlapping jurisdiction over certain resources by a number of authorities, other important resources such as groundwater for drilling operations are devoid of a regulatory authority (Rahm, 2011). Similarly, the state regulation of shale gas extraction seems to be conducted in an isolated manner, as regulatory islands, which counteracts the protective intention of the three tiered government structure of regulatory requirements (Centner and Kostandini, 2014).

The general consensus is that shale gas development in the USA has outpaced both research and legislation (Souther et al. 2014; Robbins, 2013), leaving industry to spearhead the process of shale gas extraction and market developments (Boersma and Johnson, 2012, Wiseman, 2014). Despite no state in the USA having collected baseline data at each stage of the shale gas extraction process, theUSA Environmental Protection Agency (EPA), the most active governance institution at a federal level, have conducted a number of studies, after the fact; typically being initiated in response to public concerns regarding water- and air quality and contamination thereof (Rahm, 2011; Wiseman, 2009, 2014). Such public concern has also prompted policy-makers across the USA to adopt or update their regulation policies for the shale gas industry (Blohm et al. 2012).

The importance of baseline data, with particular reference to water quality, lies in the identification of pre-existing contamination, as well as that of the responsible party (or parties) should contamination occur; and avoids lengthy litigation procedures which may arise as a result (Adair et al. 2012; Stephens, 2015). Gathering scientific knowledge in areas earmarked for shale gas extraction prior to any development is preferential, as experience in the USAhas shown this task to become complicated by private landowner rights once development activities are underway, where private landowners own the mineral rights and therefore stand to benefit financially from utilisation of their land (Adair et al. 2012).

As more states begin to realise the necessity for baseline data, mandatory pre-drilling well testing programs are being implemented, as well as voluntary programs upon landowner's requests, and presumptive liability is being enforced on drilling operators to provide an incentive to conduct water quality tests within the area of presumptive liability prior to commencing drilling activities (Adair et al. 2012). An overarching lesson that can be learnt from the regulation of shale gas development practises in the USA, is that proactive regulations are required, which utilise the aphorism "do it right the first time"; as opposed to reactive regulations which are typically enforced in response to unacceptable and costly events such as spills (Ash, 2011).

Table 2–1: A summary of shale gas exploration and production progress in countries around the world other than the USAand South Africa (after ASSAf, 2016)

Country	Summary of shale gas exploration and production activities and policy regulations in selected countries
European Union (EU)	ERs should be the same across Europe, however the application of the directives established by the EU remains the responsibility of the Member States. The directives include aspects related to water (drinking and groundwater, and dangerous substances in water); air quality and noise pollution; ecological habitats and wild birds, all of which form part of the planning and regulation of shale gas development. The debate on shale gas in the EU is influenced by environmental issues and differs between the Member States, depending on each State's own political agenda, energy policies and energy security requirements.
United Kingdom (UK)	Natural gas already occupies a third of the UK energy mix, with the technically recoverable resources for shale gas estimated to be 26 tcf. Shale gas exploration and production are supported by the UK government due to its contribution to greater energy security, increased employment opportunities, tax revenue and overall economic growth. The relatively long standing practise of hydraulic fracturing in the UK has been absent of any negative environmental impact, and is reported to be effectively managed through the implementation of operational best practices and strict regulatory enforcement thereof. This is achieved by means of baseline monitoring and the public awareness of scientific knowledge, which is supported by national agencies and industry. The UK government provide financial benefits to all stakeholders through incentives offered to communities hosting energy sites.
Poland	The estimated technically recoverable resource for shale gas in Poland is uncertain with resource assessments varying between 1.3 tcf – 148 tcf. Due to Poland's' heavy reliance on indigenous coal and gas imports from Russia; the diversification of Poland's energy mix by means of shale gas production is a high political priority. In spite of the governments favourable stance on shale gas exploration and production, its active

Country	Summary of shale gas exploration and production activities and policy regulations in selected countries
	support for scientific research, and the strong public support for shale gas development, which involves regular dialogue and debates with stakeholders; the shale gas industry appears to have reached a stalemate. This is due to a lack of appropriate regulations, laws and framework required for the development of shale gas; coupled with bureaucratic indecision and unattractive investment opportunities. In 2015 Poland planned to introduce another regulation for shale gas designed to attract and accelerate investments.
Germany	Despite the longstanding and successful development of oil and gas in Germany 70% of the country's energy resources are imported, and only a quarter of its energy supply is produced domestically, mainly as coal. Germany plans to shut down all nuclear power plants by 2022, which will leave an energy gap to which natural gas could contribute. There are, however, several citizen initiatives and environmental organisations in opposition to shale gas, as well as other forms of energy production including geothermal and wind energy, despite the government supporting the use of renewable energy. The federal government has no clear policy on shale gas, and is prepared to continue to rely on imported oil and gas to supplement its current energy mix. A report by the German Federal Institute for Geosciences and Natural Resources stated that the extraction of shale gas is safe provided that best practices are implemented. A monitoring programme for a shale gas test well is envisaged which will investigate the impacts on the environment.
France	France has extensive shale gas resources, particularly shale oil in-place, with estimated technical recoverable resources around 137 tcf. However, the extractability of the resources is unknown. The future for shale gas exploration and production in France is uncertain. Following civil interest a ban of exploration and production of hydrocarbons by hydraulic fracturing in 2011 by means of political lobbying; while numerous pro-shale reports have been issued and debates continue as to the benefits of shale gas. Coincident with the ban on shale gas activity, which resulted due to environmental concerns, was the cancellation of already granted exploration permits.
Canada	Canada has an estimated 4 995 tcf total shale gas resources, of which 343-819 tcf is economically recoverable under current conditions. Consequently, Canada is the second major producer of commercially viable natural gas from shale formations in the world, with shale gas accounting for 15% of the country's total natural gas production in 2012. The public have expressed considerable concern regarding the negative impacts of hydraulic fracturing on the environment, human health and seismicity. The economic viability of projects has also come into question, particularly if the environmental costs are outweighed by the economic benefits. The development and application of regulations are informed by science-based environmental monitoring programmes, the transparency and credibility of which are essential for building public confidence, trust and social acceptance with regards to shale gas.
Australia	Despite the 396 tcf recoverable shale gas resources in Australia, commercial production is currently limited, mainly due to the limited economic viability of the resources. The relatively high costs of the exploitation techniques required and the absence of infrastructure and limited water availability at remotely located production sites are contributing factors. The transformation of Australia's energy market by the production of coal-seam gas coupled with the migration of mining activities closer to more densely populated areas over recent years had already triggered public scepticism over the risks of hydraulic fracturing, particularly the contamination of groundwater and the drawdown of aquifers. In Australia, shale gas production could be effectively managed and the impacts minimised provided that research of the Australian receiving environment be conducted in terms of the geological setting and related landscapes, water resources and ecosystems, and how they can be monitored. An important consideration in the

Country	Summary of shale gas exploration and production activities and policy regulations in selected countries
	Australian context is that sustainability principles are applicable to both largely unpopulated and highly populated areas.
China	China has the largest known shale gas resources in the world, estimated at 1 115 tcf. Despite this vast shale gas potential, the development of these resources has proven difficult due to the more complex geology and deeper shale targets compared to traditional USA shale plays. Furthermore, these more challenging geological conditions are not yet fully conducive to effective well spacing existing stimulation strategies. The Chinese government have produced a five year shale gas exploration and production plan which provides incentives for shale gas production, such as subsidies, financial control waivers and defined standards for the shale gas industry. Regulation states an Environmental Impact Assessment (EIA) is mandatory and must be filed with national and local regulators, and approval must be granted prior to application. In order to advance and improve China's shale gas technology, China is keen to acquire overseas assets and technology; however technological difficulties remain even after the introduction of a dedicated Shale Gas Industrial Policy in 2013. Resultantly, the cost of producing shale gas is double that of the USA's biggest projects. The lack of adequate infrastructure and water and competition for the latter has further constrained progress, while substantial effort will also be required to overcome regulatory hurdles including a flawed policy regime and divided administrative responsibility for the shale gas industry.

According to ASSAf (2016), South Africa has the following key learning experiences to draw from the international context:

- South Africa must learn from and build upon the shale gas experiences in the USA, Europe, Asia and Australia, fully utilising the wealth of published evidence made available by eminent scientific bodies and advance its own scientific research;
- An adaptive management approach should be adopted with the understanding that shale gas potential is not realised overnight and in South Africa a significantly long lead in period can be expected before production at any scale commences;
- There will be an element of 'learning-by-doing' during exploration, which if sufficiently planned and managed, should not result in disproportionally high risks to the Central Karoo environments and people; and
- Learning from both Poland and China demonstrates that managing public expectations is critical to developing a rational and robust national discourse on shale gas exploration and production and that in other countries in the EU, negative and alarmist media coverage has stalled exploration for a protracted period.

2.2 Energy Planning in South Africa

The South African energy system is currently based mainly on domestic coal complemented by imported oil and petroleum fuels. Smaller contributions from biomass/waste, natural gas, nuclear and imported hydro-power make up the remainder of South Africa's primary energy supply. In recent years, renewable energy mostly from solar and wind has been introduced. The largest energy supply sub-sector in South Africa is electrical power, about 90% of which is generated by burning coal.

Including more natural gas in South Africa's energy mix would make the energy system more resilient, efficient, cheaper and reliable. Natural gas, regardless of its source, has a desirable set of qualities that coal and oil do not possess. Natural gas can be used in almost all subsectors (power generation, heat, transport, chemicals manufacturing); is easily transported once professionally operated gas infrastructure is in place; is supported by a growing international market; is a more homogenous fuel than coal (thus more flexible and easier to handle); is less CO_2 intensive when burnt than coal (if leakage during production and transport is minimised); can be more efficiently used for power generation (more kWh per GJ); has high operational flexibility; and has an end-use cost structure that is capital- light and fuel-intensive, making it economically flexible.

Because of its high operational flexibility, shale gas could enable the integration of more renewables into the energy mix and reduce the portfolio costs of power generation. The use of relatively low-cost shale gas would enable the creation of a network of gas-fired power stations located in the Central Karoo These power stations have attributes complementary to solar photovoltaic (PV) and wind generation plants which are inherently variable. Thus a portfolio containing all three is cheaper to build and operate than any one alone, for now and into the foreseeable future. As such, shale gas finds would not change the selected planning scenario for the electricity sector, which already calls for more natural gas and renewables, but would likely make this mix cheaper and cleaner.

This is recognised in the NDP 2030, which was compiled by the National Planning Commission who was appointed by the President in 2010. The NDP does not reflect the views of any one department or office - it is a plan for South Africa that provides a broad strategic framework to guide key choices and actions. The plan, published in 2012, is composed of 15 chapters with 119 implementable actions to promote sustainable growth and development in South Africa. Specifically, related to shale gas Chapter 4, actions 16 and 17 state:

16. *Enable exploratory drilling to identify economically recoverable coal seam and shale gas reserves, while environmental investigations will continue to ascertain whether sustainable exploitation of these resources is possible. If gas reserves are proven and environmental concerns alleviated, then development of these resources and gas-to-power projects should be fast-tracked.*

17. *Incorporate a greater share of gas in the energy mix, both through importing Liquefied Natural Gas (LNG) and if reserves prove commercial, using shale gas. Develop infrastructure for the import of LNG, mainly for power production, over the short to medium term.*

From the high-level NDP, the Integrated Energy Plan (IEP) is the plan that links the different energy sectors and plans for the entire South African energy system in an integrated strategic planning framework. The Integrated Resource Plan (IRP) is the electricity plan for the country. The Gas Utilisation Master Plan (GUMP) is a strategic plan which provides a long term roadmap for the strategic development of natural gas demand and supply into South Africa's diversified future energy mix. Additional energy planning policy and legislation as it relates to shale gas development is discussed in Section 2.6.5.

DoE is at present finalising a GUMP for South Africa, which will analyse potential and opportunity for the development of South Africa's gas economy and sets out a plan of how this could be achieved. Currently, natural gas plays a very small part of South Africa's current energy mix and the GUMP will form a critical part of diversifying the energy mix by outlining the possible future paths for natural gas market development, including the potential to utilise shale gas.

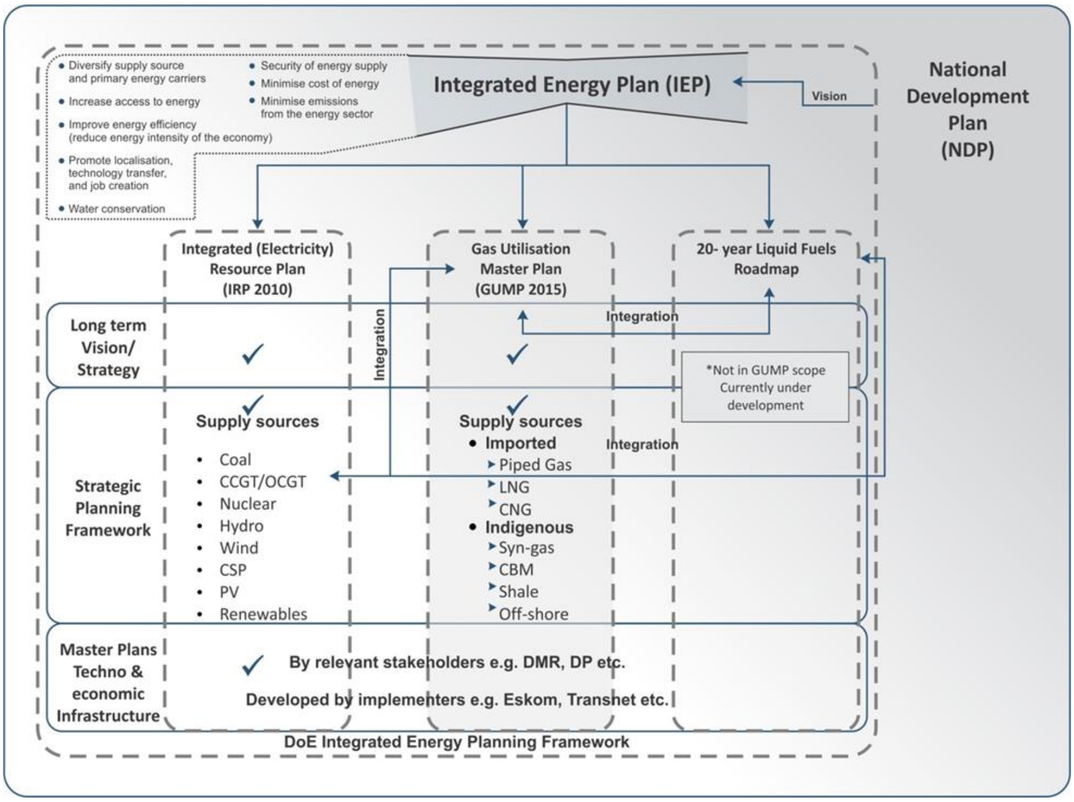


Figure 2–1: An extract from the draft IEP indicating the DoE Integrated Energy Planning Framework. The framework shows the envisioned integration between the principal energy plans of South Africa and the NDP 2030.

2.3 Petroleum Geology in the Karoo Basin

2.3.1 Geological features

The main Karoo Basin is filled with sedimentary formations of the Karoo Supergroup, and covers an area of approximately 700 000 km^2, representing more than half the surface of South Africa. Within the study area, ~87% of the surface area comprises intercalated arenaceous and argillaceous strata of the Beaufort Group (Figure 2-3 and Figure 2-4). From a flat-lying morphology in its northern part, the basin deepens and the sedimentary succession thickens towards the south-west, up to its interface with the northern margin of the mountains of the Cape Fold Belt (CFB) Mountains.

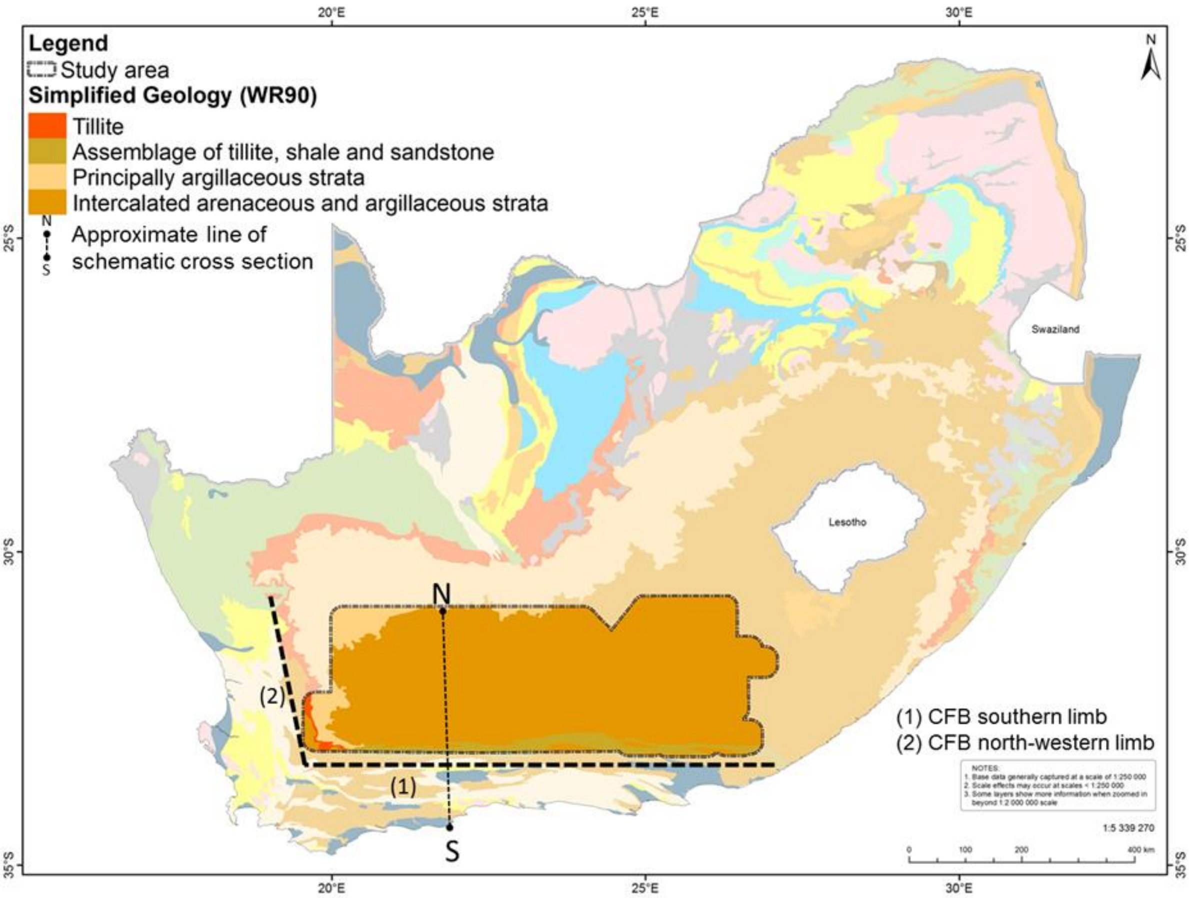


Figure 2–2: Simplified geology of South Africa showing the substantial extent of the main Karoo Basin (light brown areas) deepening from the north-eastern interior to the south-central interior where it abuts against the southern limb of the CFB; section line S-N through the study area marks the schematic profile in Figure 2-3.

The sedimentary formations are subdivided into groups that reflect variations in depositional environment, rock type, position in the geological record and age. At the base of the succession, and therefore the oldest, is the glacial deposit of the Dwyka Group. This is overlain in turn by mainly finegrained sediments of the Ecca Group and, with the inclusion of subordinate sandstone, the Beaufort Group (see Figure 2-2). The Ecca and Beaufort groups are themselves subdivided into formations on similar grounds that define the groups. Of direct relevance to this study area are the carbon-rich shales of the Prince Albert, Whitehill and Collingham formations at the base of the Ecca Group. The Whitehill Formation is black in colour, relatively rich in organic carbon and is around 40 m thick through the extent of the study area. The Whitehill Formation represents an attractive shale gas exploration target. For various technical reasons, the Prince Albert and Collingham Formations are considered less favourable targets for shale gas.

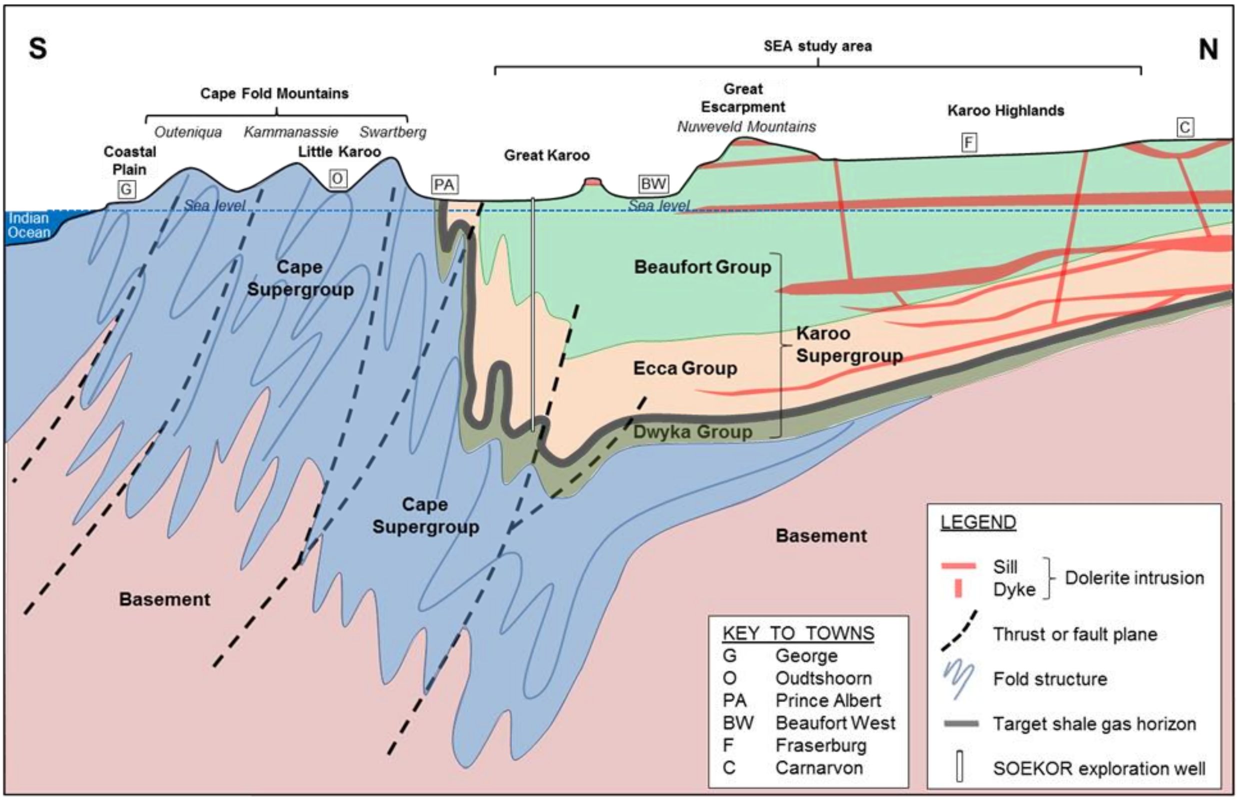


Figure 2–3: Schematic geological profile across the study area along the S-N section line in Figure 2-3, illustrating the basin-like stratigraphic succession of Karoo Supergroup sedimentary strata in the main Karoo Basin north of the Swartberg Mountains, the Great Escarpment formed by the Nuweveld Mountains, and the underlying Cape Supergroup rocks that pinch out northwards against basement rocks. The Prince Albert, Collingham and Whitehill formations of the Ecca Group include carbon-rich shales ranging in depth below surface from about 300 m to over 3 000 m.

The Prince Albert, Collingham and Whitehill Formation shales have been severely affected by intense thermal maturation associated with deep burial, the CFB folding processes and, in a large portion of the northern part of the study area, by intrusion of igneous dolerite as shown in Figure 2-4 as red sills and dykes penetrating the Beaufort and Ecca Groups. The dolerite structures represent the main targets for groundwater exploration. Dykes in particular are the feature most commonly targeted by landowners for successful water borehole siting, whereas more prominent sill complexes are typically targeted for larger-scale municipal water supply to towns such as at Victoria West.

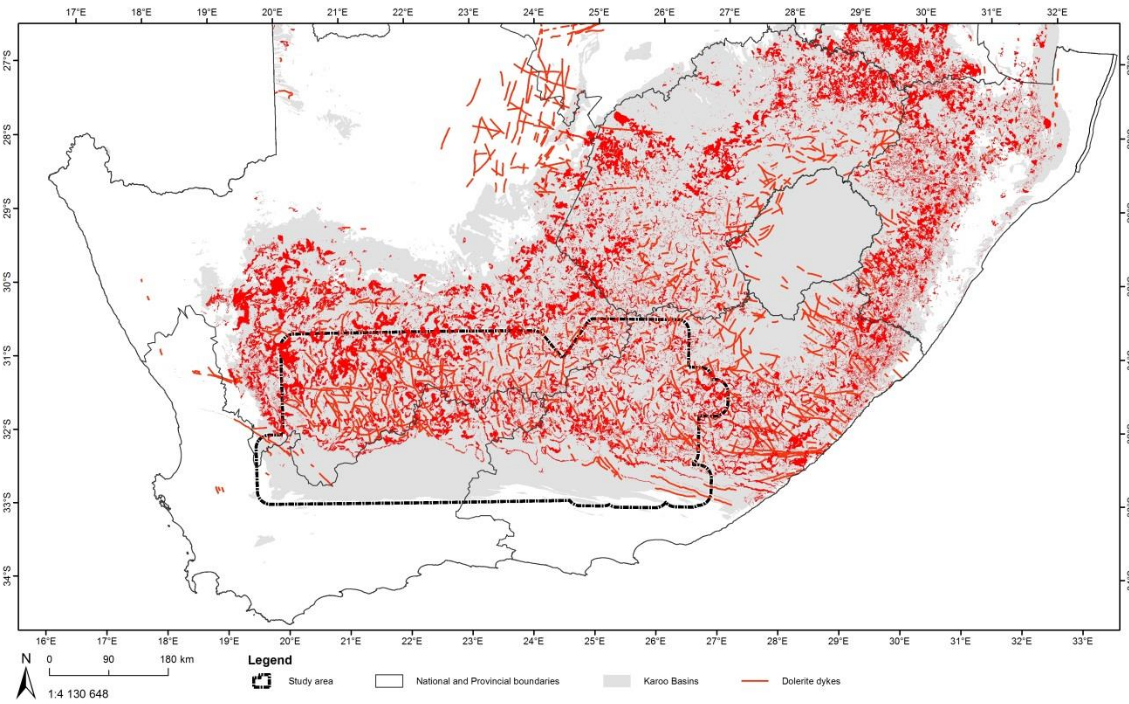


Figure 2–4: Distribution of dolerite dykes and sills in the main Karoo Basin

One of the overriding factors used in defining the potential reserves the shale gas has been the perceived negative effect on gas retention of dolerite sills and dykes, especially in the Whitehill Formation. These effects are additional to the loss of shale gas that will have occurred along faults during periods of rebound and decompression associated with the CFB structures. An effect of these factors has been to severely reduce the capacity of the shales to generate gas.

2.3.1.1 A History of Petroleum Exploration

The Southern Oil Exploration Corporation (SOEKOR) was established in 1965 with the mandate to prove or disprove the existence of economic amounts of oil and gas in South Africa. Seismic surveys were initiated in the southern part of the Main Karoo Basin, and between 1965 and 1972 a total of some 13 000 km of data was acquired. Exploration drilling that was undertaken in the same period demonstrated the presence of gas within the Ecca shales, with minor high pressure, low volume gas shows having been encountered in most of the 12 wells drilled in the southern part of the Karoo Basin.

In 1976 a comprehensive study was initiated by the Council for Geoscience to investigate the oil-shale potential of the Whitehill Formation on the western flank of the Karoo Basin. Sixteen cored boreholes were drilled in the area between Strydenburg and Hertzogville. The study was subsequently extended to include all available borehole logs and cores over the whole extent of the Whitehill Formation, with the logs of 48 borehole and petroleum exploration wells that intersected the Whitehill Formation having been considered. It is these data that form the basis of the majority of shale gas resource estimates for the Karoo Basin that have been made to date. In 2006, the PASA focused on locating and assembling the geological and geophysical data relating to the southern part of the main Karoo Basin.

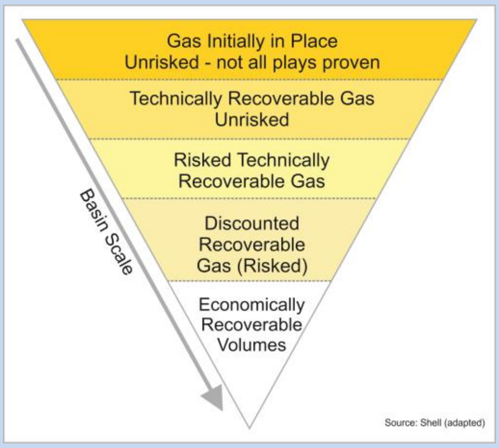
2.3.2 Shale gas reserve models

The shale gas reserve model developed the Scientific Assessment was based on a consolidated review of previous resource assessments undertaken by:

1) Kuustraa et al. (2011);
2) Kuustraa et al. (2013);
3) Decker and Marot (2012);
4) Cole (2014b);
5) Geel et al. (2015); and
6) Mowzer and Adams 2015).

The different approaches adopted for the respective reserve assessments made direct comparison of the results difficult. However, to the extent that this is possible, there is reasonable agreement between the results, in that much the same range of shale 'Gas in-Place' and 'Technically Recoverable' reserve quantities are presented. Accounting for the study area, where the depth to the top of the Whitehill Formation is at least

Box 1 Technically Recoverable Resources Versus Economically Recoverable Resources



Gas in Place Unrisked *is the total volume of hydrocarbon stored in a reservoir prior to production excluding factors determining extraction such as existing technology.*

(Unrisked and Risked) Technically Recoverable Gas *resources represent the volumes of oil and natural gas that could be produced with current technology, regardless of oil and natural gas prices and production costs. A large number of direct sub-surface measurements (depth, mineralogy, total organic content, thermal maturity, etc.) gathered by current drilling technology need to be undertaken to quantitatively calculate technically recoverable gas reserves.*

Economically Recoverable Gas *resources are those that can be profitably produced under current market conditions. The economic recoverability of oil and gas resources depends on three factors: the costs of drilling and completing wells, the amount of oil or natural gas produced from an average well over its lifetime, and the prices received for oil and gas production.*

1 500 m, a reserve estimate can be made for this formation, ranging between 17 tcf and 81 tcf of Technically Recoverable gas. To this volume of gas can be added what might be contained within the underlying Prince Albert Formation for the same area, which could range between 54 tcf and 72 tcf of Technically Recoverable gas. Thus, for both formations within the study area, where the depth to the top of the Whitehill Formation exceeds 1 500 m, the total Technically Recoverable shale gas reserve could range between 71 and 153 tcf. Applying roughly a 10% recovery factor to estimate Economically Recoverable volumes of shale gas in the study means that the Small Gas and Big Gas scenarios considered for the SEA were 5 and 20 tcf, respectively[4]. The area most likely to be targeted, certainly initially for exploration, might include the central and eastern/north-eastern parts of the study area within areas of high (red) and medium (beige) prospectivity. The reserve models used to develop Figure 2-5 are based on historical data collected through the SOEKOR historical exploration campaigns. As such, they are merely indicative of how shale gas may be distributed through the Central Karoo. Modern exploration practices are the only ways of determining to any greater detail the magnitude and distribution of the gas reserves.

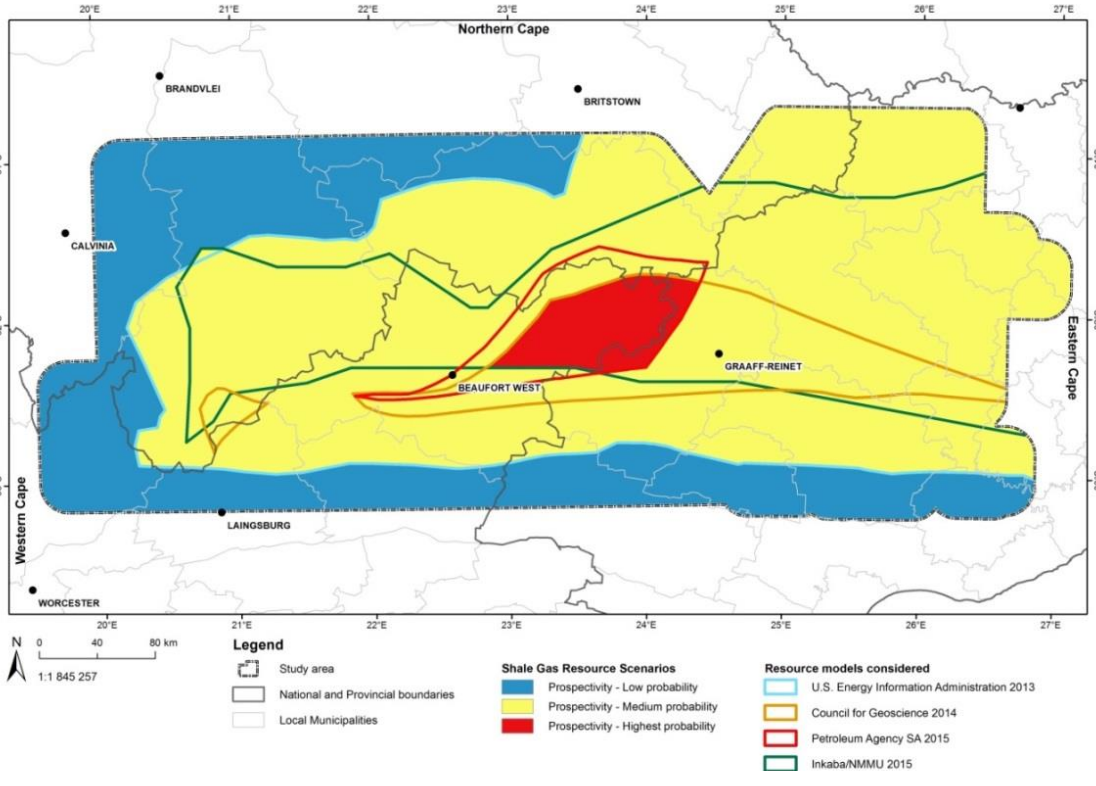


Figure 2–5: Shale gas prospectivity map for the study area generated by overlaying four existing reserve models. Based on this overlay approach, the solid red polygon, followed by the yellow/beige-shaded area, is considered most likely to yield technically recoverable shale gas (Burns et al., 2016).

[4] South Africa's draft unpublished GUMP suggests a conservative estimate for Economically Recoverable reserves of shale gas of 9 tcf. The range assumed for the SEA (5-20 tcf) spans the GUMP estimate and demonstrates policy alignment with the scenarios.

To put into context the significance of Economically Recoverable shale gas assumed for the scenarios, reference can be made to recent discoveries of conventional gas in Mozambique and Tanzania. Mozambique holds over 100 tcf of proved natural gas reserves, up from 4.5 tcf a few years ago. This positions the country as the third-largest proved natural gas reserve holder in Africa, after Nigeria and Algeria. There have been several major natural gas discoveries made in offshore southern Tanzania since 2010. The country has proven reserves totalling about 50 tcf of gas. The volumes of Economically Recoverable shale gas assumed are considerably lower than that of the proven reserves of conventional gas in Mozambique and Tanzania.

2.4 SEA Scenarios

Based on the Economically Recoverable reserve estimates, four scenarios were developed. Scenarios provide plausible and relevant stories about how the future could unfold. They originate on the assumption that the future is fundamentally unpredictable, but acknowledge that complexity and uncertainty can be reduced to within logical parameters. Scenarios provide the qualitative and quantitative information from which assessments can be made about future activities which cross spatial and temporal range (see Burns et al., 2016 for full description of the scenarios and activities).

The scenarios developed in the shale gas assessment followed an incremental approach which had two main stages: 1.) Identifying the major concerns; and 2.) Determining the major uncertainties. The major concerns related to the nominal risk associated with increasing shale gas development activities in the sensitive receiving environment of the Central Karoo and the major uncertainty related to the volumes of Economically Recoverable gas reserves (Figure 2-6).

Three ‘development’ scenarios (“Exploration”, “Small Gas” and “Big Gas”) were generated with a Reference Case where no shale gas development occurs but regional trends in the region continue on observed trajectories (Table 2-2). A reference scenario is usually a plausible and relatively nonthreatening scenario, featuring no surprising changes to the current environment and continued stable growth. All the development scenarios are cumulative in the sense that they would hypothetically occur with, and in addition, to the preceding scenarios (Figure 2-6).

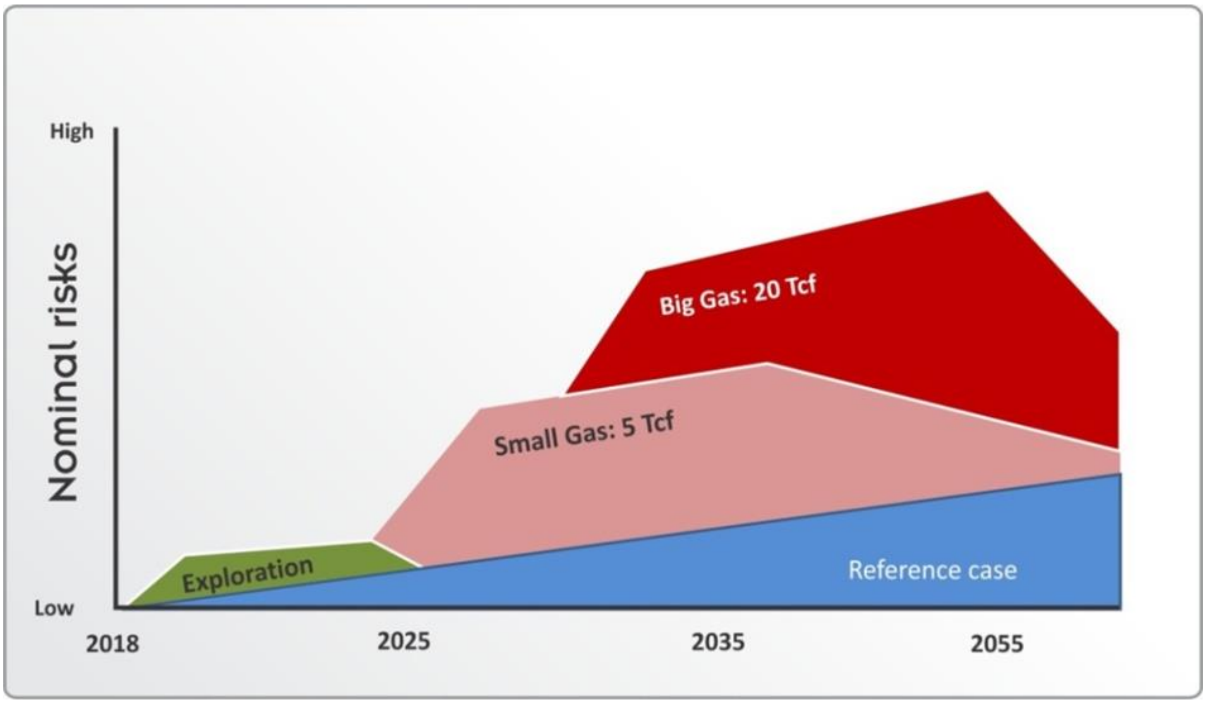


Figure 2–6: The four incremental scenarios. Note that the scenarios are cumulative: Exploration Only includes the Reference Case; Small Gas includes Exploration Only and the Reference Case; and Big Gas includes all three of the preceding scenarios. Thus they extend from 2018 to beyond 2055.

The scenarios were ‘co-designed’ - while the scenario team led the process, multiple content generation points were sourced. This was undertaken through a collaborative process of expert engagement workshops consisting of more than 60 experts from the oil and gas industry, petroleum geologists, engineers, energy planners; and natural and social scientists. Qualitative information was presented as narrative descriptions of future developments in the form of storylines and images. Quantitative information expanded on numerical estimates of future developments and was presented as tables, graphs and maps (see Table 2-2).

Table 2–2: A summary of the activity metrics described in the three shale gas exploration and production scenarios.

Unit	Exploration Only	Small Gas	Big Gas
Trillion cubic feet (Tcf)	-	5	20
Production block/s [30 x 30 km well field]	-	1	4
Combined cycle gas turbine [1 000 MW]	-	1	-
Combined cycle gas turbine [2 000 MW]	-	-	2
Gas-to-liquid plant [65 000 bbl]	-	-	1
Number of wellpads [2 ha each]	30	55	410
New roads (km) [unpaved, 5 m wide]	30	58	235
Total area of wellpads and new roads (ha)	75	199	998
Percentage spatial coverage of study area	< 0.0001	0.0002	0.0009

Unit	Exploration Only	Small Gas	Big Gas
Total number of truck visits	45 000	365 000	2 177 000
Industry water needs (m^3) [assuming no re-use of fluids]	*488 250	**9 212 625	***65 524 500
Industry water needs (m^3) [assuming re-use of 50% drill fluid + 30% frack fluid]	*319 110	**6 056 160	***43 087 235
Flowback waste (m^3) [sludge + brine + water]	*101 400	**5 573 900	***40 356 400
Other hazardous waste (t) e.g. oil, grease	*85	**635	***4 185
* For five exploration drilling campaigns, each with six exploration wells = total 30 wells over lifetime of Exploration Only ** For 55 wellpads, each with 10 wells, total 550 wells over lifetime of a Small Gas *** For 410 wellpads, each with 10 wells, total 4 100 wells over lifetime of a Big Gas Note: gas production pipelines assumed to be located within the road reserves			

The purpose of the scenarios and activity metrics was to describe the scale and type of activities assumed for the three shale gas exploration and production scenarios of increasing magnitude. The scenarios served as a common point of departure for the topics comprising the assessment which estimate, for the issues on which they focus, the levels of risk associated with each of the scenarios and their main defining activities.

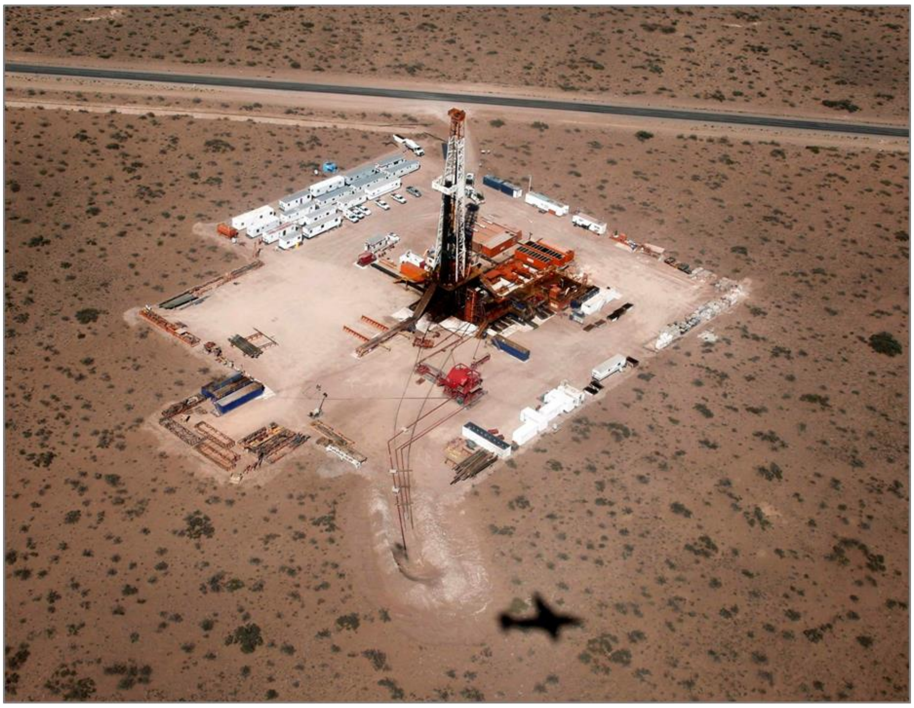


Figure 2–7: A typical wellpad layout with drilling and supporting infrastructure in place within an arid environment in Argentina, similar to what may be encountered in the Central Karoo. Each wellpad in 1-2 ha in size and during production is supported by a range of infrastructure such as roads, pipelines, water treatment facilities, gas compressors stations. For the Small Gas scenario, 55 of these wellpads are considered. For the Big Gas scenario 410 wellpads are required to extract 20 tcf over the lifespan of wellfield production.

2.5 South African Exploration in Context

2.5.1 Background

In 2010 the DMR received five ER applications. One application was submitted by Falcon, three by Shell and one by Bundu (Figure 2-8). Collectively, the scope of the ER applications include exploration campaigns involving seismic surveys, the drilling of vertical boreholes to depths of 1 – 5 km, and horizontal drilling to around 2 km in length with test hydraulic fracturing (Golder Associates, 2011, 2015; SRK, 2015).

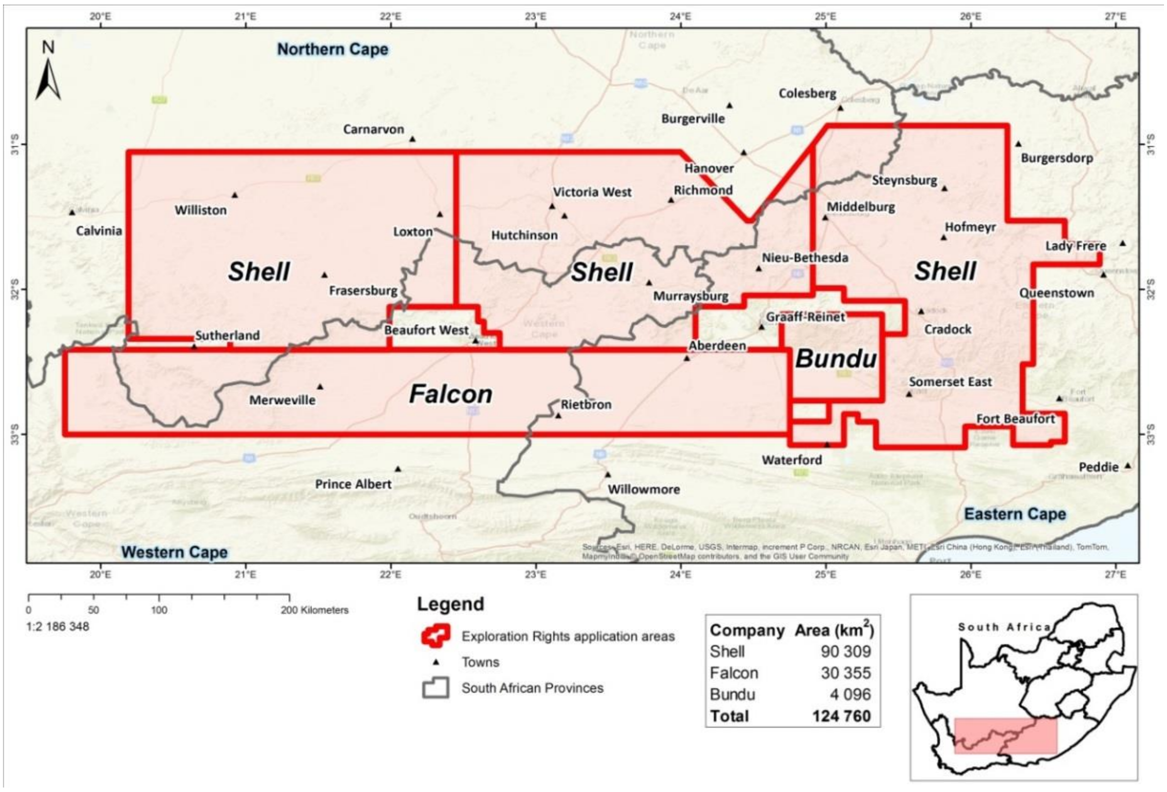


Figure 2–8: The location and extent of the ER applications made by Shell, Bundu and Falcon in the Central Karoo. The Exploration Rights application areas cover 124 760 km^2 and affect 26 local municipalities in the Western, Northern and Eastern Cape Provinces of South Africa.

Bundu submitted the first application for an ER in May 2010, with Falcon Oil and Gas following suit a few months later in August. Shell decided to submit three applications for ERs in December of 2010, after poor progression in terms of their Technical Coordination Permits. The Environmental Management Plan Reports (EMPR) required in terms of section 39 of the Mineral and Petroleum Resources Act were compiled shortly thereafter, with Bundu Gas' EMPR (compiled by Golder and Associates) submitted in October of 2010, Falcon's EMPR (compiled by SRK) submitted in January 2011, and Shell's EMPRs (compiled by Golder and Associates) submitted in April of 2011.

In April 2011, the South African Cabinet imposed a moratorium on all decisions related to the ER applications to provide an opportunity to establish the necessary regulatory framework, as well as conduct a preliminary assessment. Following the publication of the preliminary assessment undertaken by an inter-governmental task team led by DMR, the moratorium was lifted in November 2013, with the recommendation to "authorise hydraulic fracturing....under an augmented regulatory framework" (DMR, 2012: 8).

In 2014, restrictions promulgated by the Minister of Mineral Resources resulted in a two year hiatus on the granting of new applications. The inclusion of a requirement for existing applications to consider regulations that had not yet been promulgated (a version of which had been published for comment in October of 2013) effectively suspended the five applications accepted prior to the 1st of February 2011.

The technical regulations for petroleum exploration and exploitation were subsequently promulgated on the 3rd of June 2015 ("the technical regulations"), enabling the three existing applicants to continue with the requisite process. These regulations have since been legally contested by the Treasure the Karoo Action Group, who submitted the related documentation to the North Gauteng High Court in November of 2015.

After the ensuing hiatus caused by the 2011 moratorium, the DMR requested applicants to update their EMPRs in November of 2014 in preparation of recommencing the processing of existing applications. Both Bundu Gas and Falcon Gas and Oil reviewed their EMPRs and submitted the updated EMPR at the end of February 2015. Shell engaged in an information sharing process in terms of Section 39(5) of the MPRDA. The DMR has not yet decided on any of the existing ER applications, and no applications for Environmental Authorisation (EA) in terms of the National Environmental Management Act (NEMA) (Act 107 of 1998) have been submitted to date.

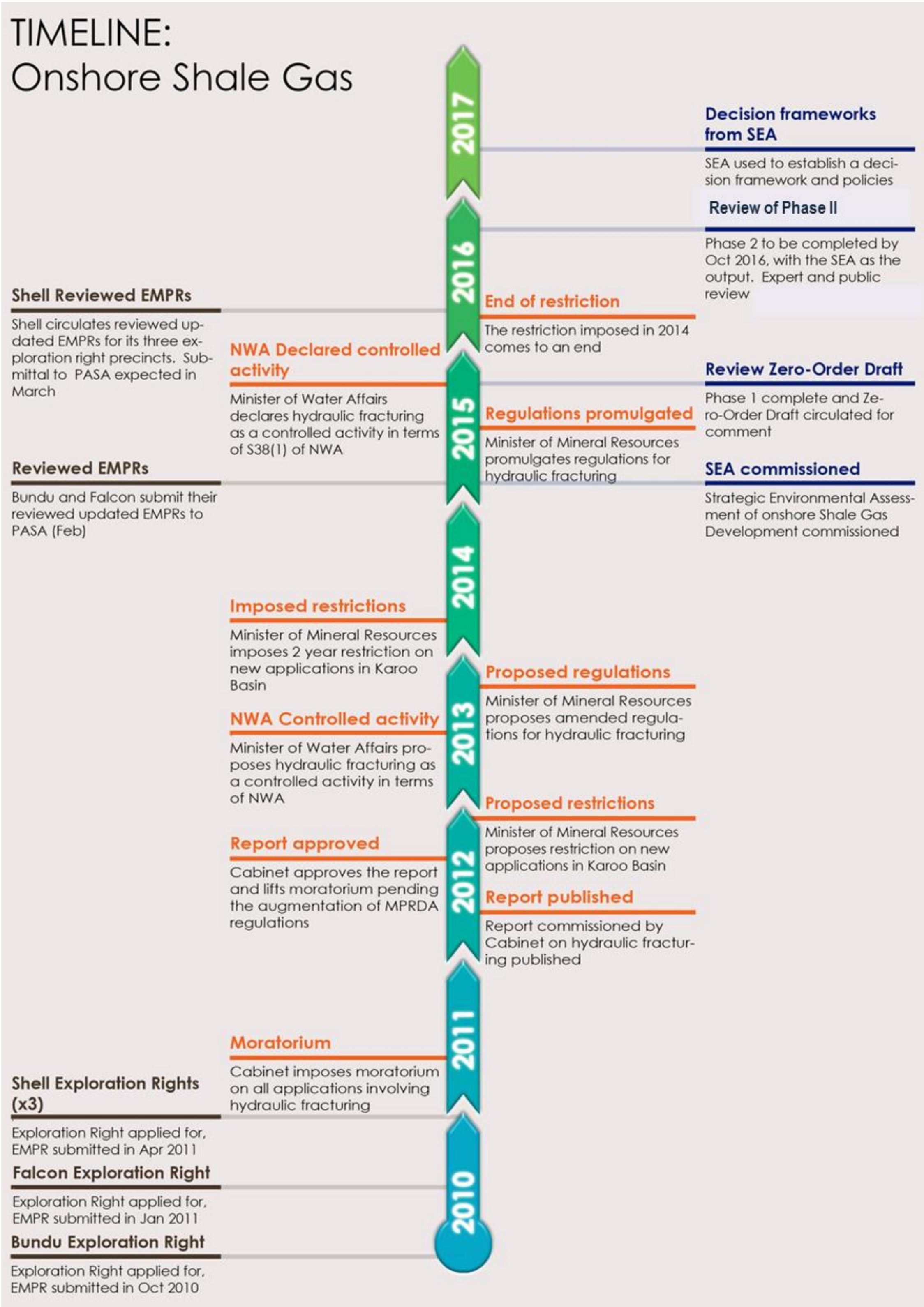


Figure 2–9: Exploration Rights application process, key policy and regulatory decisions intersection with SEA process steps (image courtesy of John Wilson from DEA&DP)

2.5.2 Shell's Exploration Programme

Shell's exploration program would entail three broad steps (Golder, 2011; Golder, 2013):

1. Gathering geophysical data. This data acquisition process is largely non-intrusive and does not involve drilling or significant excavation. The process will take place largely on existing roads.
2. Drilling of vertical exploration wells of between 1 000 m and 5 000 m deep to identify the shale layer. Horizontal boreholes may be drilled from the base of a vertical hole extending up to 2 km in length into the shale layer. During this stage of exploration, geological samples from the target shale formations would be subject to a variety of tests to confirm whether unconventional gas exists within the shale formation. If the shale layer cannot be found or no hydrocarbons are detected, fewer wells may be drilled.
3. Gas stimulation (hydraulic fracturing and testing) which would only take place should exploration drilling, logging and coring, indicate that intercepted shale layers contain gas and/or liquid hydrocarbon.

Based on these tests, if the exploration proves unsuccessful, the gas exploration wells will be decommissioned. Figure 2-10 below show "potential Areas of Interest" where Shell might concentrate their initial exploration drilling efforts. These areas were selected considering resource prospectivity and also overlaying a range of surface and subsurface GIS layers such as landscape features, proximity to existing infrastructure and people, water resources and other social and ecological sensitivity considerations (Golder Associates, 2013). The potential Areas of Interest are not the areas where Shell will exclusively locate their exploration activities - these areas merely indicate the locations that companies will target their initial activities, based on current information. As new information as gathered, these Areas of Interest will be revised.

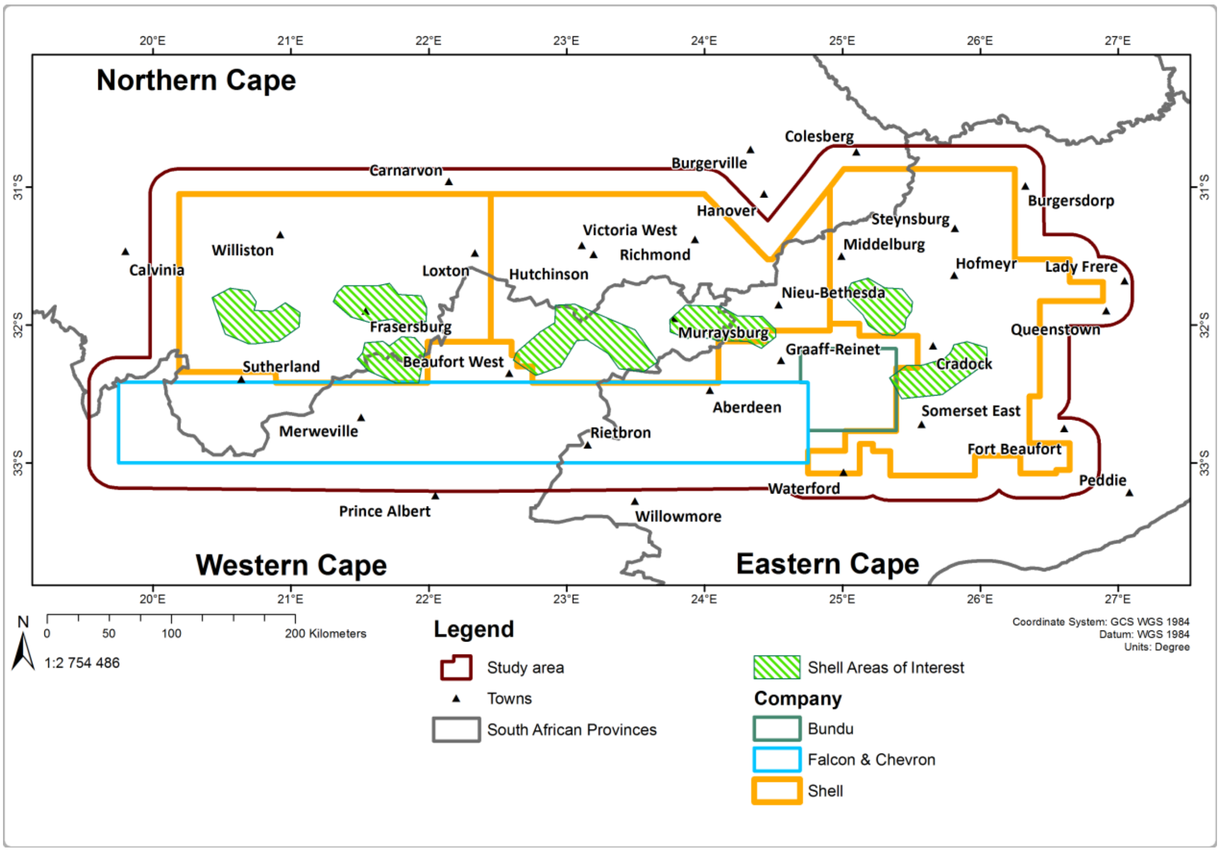


Figure 2–10: Shell "potential Areas of Interest" for exploration activities in the study area. Note that these areas merely indicate the locations that companies will target their initial activities, based on current information. As new information as gathered, these Areas of Interest will be revised.

2.5.3 Bundu's Exploration Programme

Bundu will focus their exploration activities specifically on seismic data analysis, geological investigations, hydrocensus and core drilling activities. The Bundu exploration programme includes drilling of up to 3 exploration boreholes with a drill pad of approximately half a hectare in size, including lay down areas for casing. The location of the possible core holes is not yet known (Golder, 2015).

2.5.4 Falcon's Exploration Programme

Falcon's exploration campaign will focus on seismic exploration and will rely on analysis of existing (historical) seismic and well information and from studying published field data. Falcon has identified preliminary corridors for the seismic surveys. The preliminary seismic survey lines were compiled to follow, as far as possible, existing roads, railway lines and other linear routes identified through a desktop assessment of aerial photographs and topocadastral maps (Figure 2-11) (SRK, 2015).

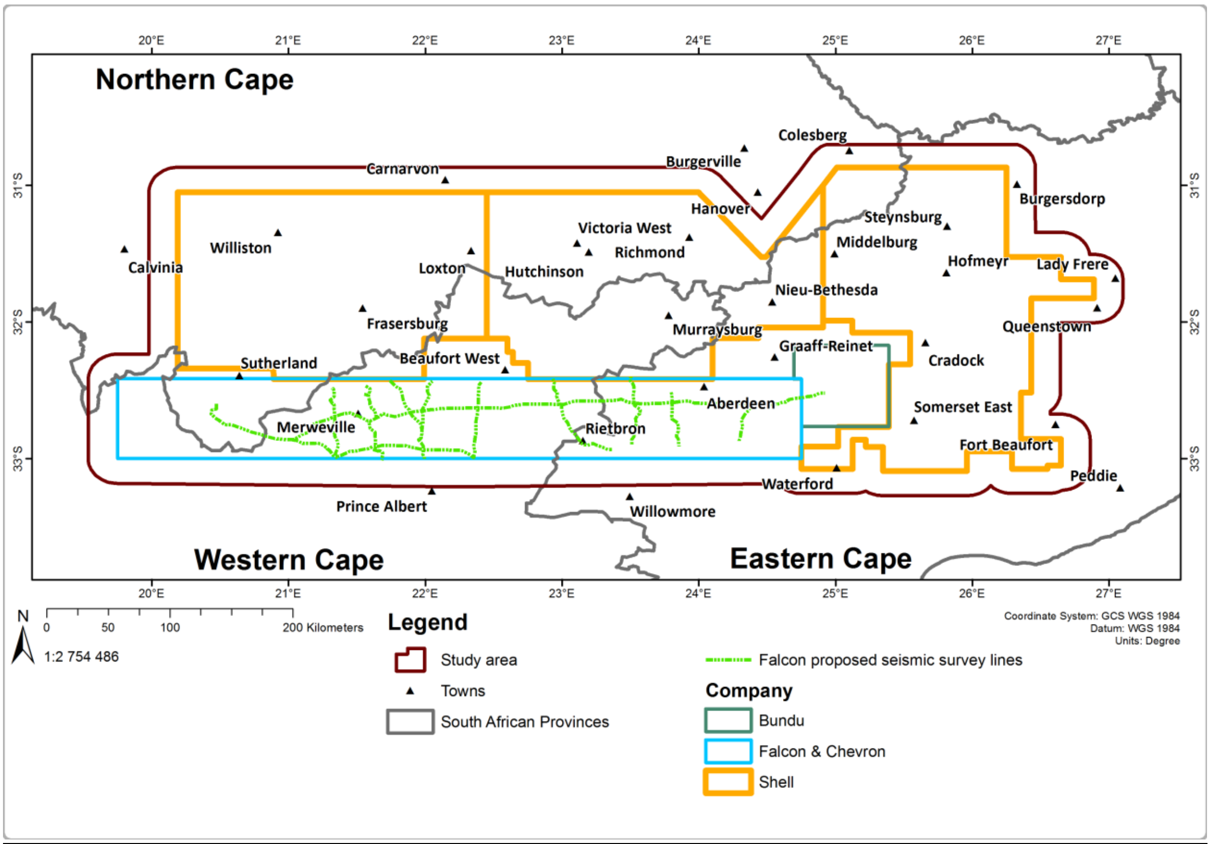


Figure 2–11: Proposed corridor locations for Falcon's seismic surveys

2.6 Overarching Regulatory Framework

2.6.1 The Constitution and Integrated Governance

In Section 24 (b) (iii), the Constitution provides that everyone has the right to an environment that is not harmful to their health or well-being; and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

Chapter 3 of the NEMA requires co-operative governance, which would be important if shale gas exploration and production is to be managed effectively between different spheres of government. In this regard: "All spheres of government and all organs of state within each sphere must" –
(g) Exercise their powers and perform their functions in a manner which does not encroach on the geographical, functional or institutional integrity of government in another sphere.

There is case law precedence to illustrate that the national government's competence to regulate mining does not supersede local government's functional competence of municipal planning (ASSAf, 2016).

2.6.2 The MPRDA and Technical Regulations

The MPRDA is the primary legislative enactment regulating minerals and petroleum resources and their exploitation. The Act grants custodianship of all such resources to the State, whose obligations, among others, are to ensure equitable access to these resources and to expand opportunities for the historically disadvantaged people to enter the sectors and to benefit from resource exploitation. The Act is required to give effect to the environmental right, as contained within Section 24 of the Constitution (Esterhuyse et al., 2014)

Shale gas exploration and production activities are regulated by Chapter 6 of the MPRDA. Thus, any person wishing to engage in such activities will need to obtain an ER, followed by a Production Right, in order to extract shale gas. In addition, an EA and Environmental Management Programme (EMPr) are required before any such activities can commence (Esterhuyse et al., 2014).

The technical regulations drafted under the MPRDA are the central legislation governing the extraction and development of shale gas resources. They were published for comment in October 2013 and subsequently promulgated on the 3rd of June 2015, enabling the three existing shale gas ER applicants to continue with the requisite process. The regulations have since been legally contested by the Treasure the Karoo Action Group, who submitted the related documentation to the North Gauteng High Court in November of 2015.

The technical regulations indicate that the central institution to oversee the regulations is the so-called 'designated agency', which is currently the PASA. The technical regulations are broad-ranging and cover aspects relating to monitoring and best-practice mitigation of risk associated with water contamination and other environmental or geophysical concerns (ASSAf, 2016).

While the exploration and production of petroleum resources is legislated for in MPRDA, all environmental management aspects are dealt with in terms of the "One Environmental System" (OES) which became effective on 14 December 2014.

2.6.3 The NEMA and One Environmental System

The DEA administers the NEMA as well as a suite of related laws dealing with waste management, air quality, biodiversity and protected areas. The notion of sustainable development underpins the NEMA, supported by the NEMA principles as contained in Section 2 of the Act. In this regard, NEMA promotes that "development must be socially, environmentally and economically sustainable and that sustainable development requires the consideration of all relevant factors, including the following":

- *i.* *That the disturbance of ecosystems and loss of biological diversity are avoided; or, where they cannot be altogether avoided, are minimised and remedied;*
- *ii.* *that pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;*
- *iii.* *that the disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimised and remedied;*
- *iv.* *that waste is avoided, or where it cannot be altogether avoided, is minimised and re-used or recycled where possible and otherwise disposed of in a responsible manner;*
- *v.* *that the use and exploitation of non-renewable natural resources is responsible and equitable, and takes into account the consequences of the depletion of the resource;*
- *vi.* *(vi) that the development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;*
- vii. *that a risk-averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and that negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimised and remedied.*

The principles in Section 2 of the NEMA also apply to the MPRDA. In this regard, an important principle is the precautionary approach, specifying that a risk-averse cautious approach is applied to development ("the precautionary principle"), which takes into account the limits of current knowledge about the consequences of decisions and actions. Another important principle is that the costs for remedying pollution, environmental degradation and consequent adverse health effects must be paid for by those responsible for harming the environment (the "polluter pays principle") (Hobbs et al., 2016).

To meet many of the requirements of the NEMA principles as they relate to mining and to accelerate progress toward reducing poverty, inequality and joblessness as required in the NDP. The National

Planning Commission called for a more coherent and predictable regulatory framework which reduced red tape and the cost of compliance. Specifically it identified the need for integration in decision making between the departments responsible for mining, water and environmental issues (DEA, 2015).

Applicable legislation to shale gas exploration and production in South Africa has been promulgated by the DMR, the DWS and the DEA. The DMR is responsible for the sustainable development of South Africa's mineral and petroleum resources within the framework of national environmental policy, norms and standards; while promoting economic and social development. The DEA is the lead agent for the protection of the environment and waste management while the DWS is the public trustee of the nation's water sources (Oelofse et al., 2016).

The OES was introduced as a synchronised system for environmental authorisation between the National Water Act (NWA) of 1998, the MPRDA, the NEMA, and the NEMA Specific Environmental Management Acts (SEMAs which include the NEM: Air Quality Act (NEM:AQA) and NEM: Waste Act (NEM:WA)). It is envisages that the OES regulatory system runs in parallel and that decisions regarding mining, water and environment are issued simultaneously within the prescribed 197 days fast track / 247 days slower track (in the case of a Basic Assessment); or 300 days fast track / 350 days slower track (in the case of a full-scoping EIA) as contemplated in the 2014 EIA Regulations (DEA, 2015).

The OES is designed to streamline environmental authorisation processes so that companies can simultaneously apply for EAs, Mining Rights and Water Use Licences (WULs) (van Zyl et al., 2016). Prior to the establishment of the OES, the environmental provisions of the MPRDA and the NEMA would be invoked to assess and manage environmental impacts of petroleum resource extraction (Glazewski & Esterhuyse, 2016). Under the OES, the environmental management function will remain with the DMR, but will be governed under NEMA. The DMR will assess applications based on NEMA and associated regulations with the Minister of Environmental Affairs becoming the competent authority if there is an appeal lodged by a stakeholder during the EA process (van Zyl et al., 2016).

In accordance with the OES, the Minister of Environmental Affairs has the power to determine the regulatory framework to be applied to environmental management aspects of any proposed exploration and production programme. The Minister of Environmental Affairs may make regulations on the consultation with landowners/lawful occupiers, financial provisioning and assessment and monitoring requirements, amongst others (Glazewski & Esterhuyse, 2016).

For example, the technical regulations for petroleum production and exploitation stipulate in 86(3) that when submitting an application in terms of the NEMA 2014 EIA Regulations for EA related to shale gas exploration or production, an applicant must comply with the "NEMA Minimum Information Requirements" (MIRs). At present, MIRs refer back to 2014 EIA Regulations, simply meaning that any EA application for shale gas exploration and production is subject to the 2014 EIA Regulations. One of the purposes of this report is to expand on the MIRs and outline and clear and structured process for environmental monitoring, assessment and decision-making related to shale gas exploration (see Appendix 3).

To this end, the Minister of Environmental Affairs May: 1.) Identify activities which may proceed subject to compliance with norms and standards and 2.) Prohibit or restrict the granting of an environmental authorisation by a competent authority for a specific listed activity in a specified area if this is necessary to ensure the protection of the environment, the conservation or resources or sustainable development (Glazewski & Esterhuyse, 2016).

Table 2–3: Decision-making mandates and permit requirements under the Constitution and OES for exploration and production related activities

Decision	Competent Authority	Legislation	Regulatory process
Exploration and Production Rights	DMR and PASA	MPRDA	EMPr initial submissions made to PASA in 2010 and 2011. DMR requested EMPrs to be updated in November 2014. DMR has not yet decided on any of the existing ER applications.
Environmental Authorisation	DMR and PASA[5]	NEMA	No applications for EA in terms of the NEMA have been submitted to date. Applications would be guided by the NEMA Minimum Information Requirements (MIRs) amongst other legislation. DMR is the competent authority with DEA providing decision on appeals.
Atmospheric Emission Licence	DEA	NEM:AQA	Integrated into the EA process with the establishment of the OES. DEA remain the competent authority.
Waste License	DMR	NEM:WA	Integrated into the EA process with the establishment

[5] In terms of the OES the Minister of Mineral Resources is the competent authority to grant environmental authorisations for shale gas development. The Minister must however delegate the task of evaluating environmental reports submitted by the project proponents. Presently, there is uncertainty regarding the particular state agency to which such task would be delegated. In the case of environmental applications for petroleum-related activities, the MPRDA indicates that the task would be undertaken by a 'designated agency' namely the PASA, however, the MPRDA Bill shifts this responsibility to the regional offices.

<table>
<tr><th>Decision</th><th>Competent Authority</th><th>Legislation</th><th>Regulatory process</th></tr>
<tr><td></td><td></td><td></td><td>of the OES. DMR are the competent authority.</td></tr>
<tr><td>Water Use License</td><td>DWS</td><td>NWA</td><td>Integrated into the EA process with the establishment of the OES. DWS are the competent authority. The Catchment Management Agencies will process all applications but the final authority to issue the license will be National Office – currently the Director General possibly later the Deputy-Director General of Water Sector Regulation.</td></tr>
<tr><td>Municipal Planning Decision</td><td>Relevant local authority</td><td>Spatial Planning and Land Use Management Act (SPLUMA) of 2013, Western Cape Land Use Planning Act (LUPA) of 2015 and By-laws</td><td rowspan="2">For non-invasive 3-D seismic surveys, it is thought that rezoning will not be required. For the development of well pads, regional services, infrastructure servitudes, waste water treatment works, housing developments, camps, gravel pits, landfill sites, roads, the subdivision of farm land etc., these will require rezoning. These will require a Municipal Application to be submitted to the municipality or in some cases (if the general welfare of the inhabitants of the region are affected) the land development applications could require provincial approval and in other instances when the activity is considered a national interest, the national Minister responsible for SPLUMA then has decision-making oversight.</td></tr>
<tr><td>Provincial Planning Decision</td><td>Provincial competent authority</td><td>SPLUMA and LUPA</td></tr>
</table>

2.6.3.1 <u>Environmental Authorisation</u>

Section 32 of the Mineral and Petroleum Resources Amendment Act 2008 (Act No. 49 of 2008) inserted a new Section 38B into the MPRDA which reads:

"(1) An environmental management plan or environmental management programme approved in terms of this Act before and at the time of the coming into effect of the National Environmental Management Act, 1998, shall be deemed to have been approved and an environmental authorisation been issued in terms of the National Environmental Management Act, 1998.

(2) Notwithstanding subsection (1), the Minister may direct the holder of a right, permit or any old order right, if he or she is of the opinion that the prospecting, mining, exploration and production operations is likely to result in unacceptable pollution, ecological degradation or damage to the environment, to take any action to upgrade the environmental management plan or environmental management programme to address the deficiencies in the plan or programme.

(3) The Minister must issue an environmental authorisation if he or she is satisfied that the deficiencies in the environmental management plan or environmental management programme in

subsection (2) have been addressed and that the requirements in Chapter 5 of the National Environmental Management Act, 1998, have been met."

According to Proclamation No. 14 of 2013 issued on 31 May 2013, the Act 49 of 2008 would have come into operation on 7 June 2013, but in terms of Proclamation No. 17 of 2013 issued on 6 June 2013, Proclamation No. 14 of 2013 was amended so that certain sections of the Act would not come into operation on 7 June 2013. Section 38B was one of the sections which did not come into operation on 7 June 2013 (or since then)[6].

Section 12(7) of the National Environmental Management Amendment Act (Act No. 62 of 2008), which was amended by Section 26 of the National Environmental Management Laws Amendment Act (Act No. 25 of 2014), states that an application for a right or permit in relation to prospecting, exploration, mining or production in terms of the MPRDA that was pending on 8 December 2014, must be dispensed of in terms of the MPRDA as if the MPRDA had not been amended.

The current shale gas ER applications in terms of the MPRDA, which were pending on 8 December 2014 must accordingly be dispensed with in terms of the MPRDA as if the MPRDA was not amended.

Section 12(4) of the National Environmental Management Amendment Act (Act No. 62 of 2008), which was amended by Section 26 of the National Environmental Management Laws Amendment Act (Act No. 25 of 2014), states that an Environmental Management Plan (EMP) or EMPr approved in terms of the MPRDA before 8 December 2014 must be regarded as having been approved in terms of NEMA.

The applications for ERs in terms of the MPRDA by Falcon & Chevron, Bundu Gas and Shell, were still pending on 8 December 2016. Even if an EMPR associated with these applications is approved, this will happen after 8 December 2014. As such, approval of any of these EMPRs, even if regarded to have been approved in terms of NEMA, does not constitute an Environmental Authorisation in terms of NEMA.

[6] In Mineral Sands Resources, the court also held that "MSR's counsel did not argue that, in terms of the legislative regime prevailing prior to 8 December 2014 (which may have remained in force in respect of pending matters), the obtaining of approvals under the Mining Act made it unnecessary for MSR to obtain environmental authorisation in terms of NEMA for any listed activities which the mining company would be undertaking. That any such suggestion would be unsound is clear from the judgment of the Constitutional Court in Maccsand (Pty) Ltd v City of Cape Town & Others 2012 (4) SA 181 (CC)." In Mineral Sands Resources (Pty) Ltd v Magistrate for the District of Vredendal, Kroutz NO and Others ("Mineral Sands Resources") the Western Cape High Court held that section 38B was nonsensical for the following reasons "NEMA came into effect on 21 January 1999. The Mining Act came into force on 1 May 2004. Accordingly it would be impossible for there to have been any EMPs approved in terms of the Mining Act as at 21 January 1999. The lawmaker may have intended to refer to NEMA as amended with effect from 8 December 2014. If so, the new s 38B(1) would be a repetition of s 12(4) of Act 62 of 2008." (Par 37 of the judgment)

The above was confirmed in Mineral Sands Resources court case, where the court held that "The effect of s 12(4) is that a Mining EMP approved prior to 8 December 2014 is to be regarded as an EMP approved in terms of s 24N of NEMA." The court furthermore held that "the DMR's approval of the amended Mining EMP did not simultaneously constitute an environmental authorisation". "The process for obtaining an environmental authorisation is more rigorous than for an amendment of a Mining EMP."

Regulation 54 of the 2014 NEMA EIA Regulations states that an application submitted in terms of the previous MPRDA Regulations for a permit, right, approval of an EMPR or amendment to such permit, right, or EMPR which was pending on 8 December 2014, must despite the repeal of those Regulations be dispensed with in terms of the those previous MPRDA regulations, as if those previous MPRDA Regulations were not repealed. However, an application submitted after 8 December 2014 for an amendment of an EMPR approved in terms of the MPRDA must be dealt with in terms of the 2014 NEMA EIA Regulations.

The current shale gas ER applications in terms of the MPRDA Regulations were pending on 8 December 2014 and must accordingly be dispensed with in terms of the MPRDA Regulations, as if the MPRDA Regulations were not amended.

On 4 December 2014, the Minister of Environmental Affairs promulgated the 2014 NEMA EIA Regulations and Listing Notices in terms of Chapter 5 of the NEMA6. These Regulations came into effect on 8 December 2014 and repealed the 2010 EIA Regulations.

The gas exploration operations proposed in the ER applications in terms of the MPRDA, trigger one or more of the following listed activities in terms of the 2014 NEMA EIA Regulations:

- Activity 20 of Listing Notice 1: "Any activity including the operation of that activity which requires a prospecting right in terms of section 16 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002), including associated infrastructure, structures and earthworks, directly related to prospecting of a mineral resource, including activities for which an exemption has been issued in terms of section 106 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)."
- Activity 18 of Listing Notice 2: "Any activity including the operation of that activity which requires an exploration right as contemplated in section 79 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002), including associated infrastructure, structures and earthworks."
- Listed activities pertaining to watercourses, river crossings, vegetation removal and or construction of roads should also be considered.

Where the above activities apply, EA will be required from the relevant authority prior to the undertaking of the said activities.

It is also important to note that the proposed National Environmental Management Laws Amendment Bill, 2016, ("the Bill") contains the following provisions:

"Transitional provisions for mining applications submitted before 8 December 2014

75. (1) An environmental management plan or environmental management programme approved in terms of the Mineral and Petroleum Resources Development Act, 2002 on 8 December 2014, or before 8 December 2014, or after 8 December 2014 in the case of applications that were pending on that date, shall be deemed to have been approved and an environmental authorisation issued in terms of the National Environmental Management Act, 1998.

(2) Subsection (1) does not apply in the instances where an application for an environmental authorisation in relation to activities ancillary to exploration, prospecting, mining, or primary processing was not obtained, was refused or there was failure to obtain an environmental authorisation in terms of the Environment Conservation Act, 1989 (Act No. 73 of 1989) for activities that required such an environmental authorisation in terms of that Act, or for activities identified or specified under section 24(2) of National Environmental Management Act, 1998, or a waste management licence has not been obtained, was refused or not obtained for any activity listed in terms of section 19 of the National Environmental Management: Waste Act, 2008."

The above provision in the Bill confirms that, even if these proposed amendments are brought into effect, the requirement that Environmental Authorisation is required for the listed activities (contained in the 2014 NEMA EIA Regulations) shall remain in effect.

The transitional arrangement provided for in Regulation 53(3) of the 2014 NEMA EIA Regulations (GN No. R. 982 of 4 December 2014 refers) states that, where an application submitted in terms of the previous NEMA Regulations, was pending on 8 December 2014, in relation to an activity of which a component of the same activity was not identified under the previous NEMA notices, but is identified in terms of section 24(2) of the Act in terms of the 2014 NEMA Listing Notices, the competent authority must dispense of such application in terms of the previous NEMA Regulations, but may authorise the activity identified in terms of the 2014 NEMA Listing Notices as if it was applied for on condition that all impacts of the newly identified activity and requirements of the 2014 NEMA EIA Regulations have also been considered and adequately assessed. However, it must be noted that no application for EA has been submitted to date by any of the shale gas applicants. As such, the above-mentioned transitional provisions of the 2014 NEMA EIA Regulations are not applicable.

In summary, current legal interpretation suggests:

- No one may commence with an activity identified in terms of Section 24(2)(a) of NEMA unless EA in terms of NEMA has been obtained for the activity.
- An approval of an EMPR in terms of the MPRDA does not constitute an Environmental Authorisation in terms of NEMA. Furthermore, an EMPR, even if regarded to be approved (as an EMPR) in terms of NEMA, does not constitute an EA in terms of NEMA - Section 12(4) of the National Environmental Management Amendment Act (Act No. 62 of 2008).
- The applications submitted by Falcon & Chevron, Bundu Gas and Shell for ERss in terms of the MPRDA, prior to 8 December 2014, are pending and no application for EA in terms of NEMA has been submitted to date. As such, applications for EA are required prior to the commencement of any activities listed in the 2014 NEMA EIA Regulations (including Activity 20 of Listing Notice 1 and Activity 18 of Listing Notice 2).

2.6.4 Regulations Governing Mine Closure

The mining industry generally distinguishes between three distinct stages in a project lifecycle: The *exploration phase*, *the production phase* and the *closure phase*. In planning for the closure phase, Section 41 of the MPRDA states that applicants for prospecting rights, mining rights or mining permits must make financial provisions for the rehabilitation or management of negative environmental impacts.

The technical regulations developed under the MPRDA include provisions on well abandonment and closure which must be read in conjunction with Section 43 of NEMA which provides that: "the holder of a prospecting right, mining right, retention permit, mining permit, … or previous owner of works that has ceased to exist, remains responsible for any environmental liability, pollution, ecological degradation, the pumping or treatment of extraneous water, compliance to the conditions of the environmental authorisation and the management and sustainable closure thereof until the Minister [of Environmental Affairs] has issued a closure certificate in terms of this Act…". This conforms to the tenets of the pollute pays principle.

A number of further environmental provisions relevant to closure have been transferred from the MPRDA to the NEMA, including sections titled "Financial provision for remediation of environmental damage; Monitoring and performance assessment; Mine closure on environmental authorisation". The new financial provisioning regulations require companies to provide comprehensive itemisation of all the costs associated with annual and final rehabilitation, decommissioning and closure as well as the costs associated with remediating long-term latent or residual impacts i.e. impacts that may only become visible in the future with a particular emphasis on potential water related threats.

A permit or right holder or applicant must calculate and make provision for the availability of sufficient rehabilitation and closure funds, which the DMR Minister must approve. Importantly the regulations specify that, at any point, the funds available for latent and residual effects must be able to cover the actual costs of implementation for at least ten years after closure. Financial provisions can be made through a financial guarantee, a deposit to a specific account administered by the DMR Minister or a combination of both. A trust fund can only be used for the purposes of financial provisions for residual or latent impacts subject to conditions set out in the Act. This marks a change from previous regulation which allowed for a trust to be used for other impacts.

The regulations prohibit the deference of "provisioning liability to assets at the mine closure or the mine infrastructure salvage value" and require the verification of registration of a financial institution in the case of a guarantee. In the case of residual or latent impacts, provisions must be ceded to the DMR Minister once a closure certificate has been issued. Companies are further required to review, assess and adjust all financial provisions and the assessment must be audited by an independent auditor. EMPs are required to be publically accessible. Companies can be placed under care and maintenance subject to specific requirements and Ministerial approval but cannot operate under care and maintenance for more than five years.

2.6.5 Other Policy, Plans, Regulations and Standards

Table 2–4: A summary of the national policy, plans and legislation application to shale gas exploration and production activities. Note that there are numerous other policy, plans, regulations and standards that could apply to shale gas exploration and production, the list contained here is comprehensive but not exhaustive.

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
Energy Planning. Integrated Energy Plan, Integrated Resources Plan, Gas Utilisation Masterplan and National Development Plan discussed in reference to the DoE Integrated Energy Planning Framework in Section 2.2	Energy Policy White Paper of the Republic of South Africa of 1998, NEMA: EIA Regulations, 2014	Security of energy supply for South Africa through energy supply diversity. Natural gas identified as a viable source of complementary primary energy supply to the existing mix.
	National Energy Act of 2008, Electricity Regulation Act of 2006, NEMA: EIA Regulations, 2014	Prescribes that energy planning in South Africa must be conducted in an integrated manner and that the Energy Minister has the mandate and the obligation to conduct such planning. The Act is very explicit in that it prescribes an IRP to precede any implementation of new power generation capacity.
	Gas Act of 2001, NEMA: EIA Regulations, 2014	Promulgated with the broad objective to stimulate the natural gas industry and explicitly introduces a number of new gas technologies e.g. gas liquefaction and regasification. Seeks to promote the orderly development of the piped gas industry and to establish a national regulatory framework.
	Eskom Transmission Development Plan, Strategic Grid Plan of 2015, NEMA: EIA Regulations, 2014	Outlines how the electric transmission system needs to be developed over the next 10 years. Indicates financial commitments required by Eskom in the short to medium term. This is inclusive of grid infrastructure required to integrate new gas-fired power plants. The Eskom Strategic Grid Plan outlines where new transmission grid development is needed.
	Transnet Long-term Strategic Framework of 2015, NEMA: EIA Regulations, 2014	Provides a long-term and broader view of transportation networks required, including expansions of existing transportation infrastructure. Specifically, natural gas infrastructure planning and pipeline developments include the possibility of domestic onshore gas finds.
Air Quality and Greenhouse Gas (GHG) Emissions	United Nations Framework Convention on Climate Change (UNFCCC) of 1992, the National Development Plan of 2012, the National Climate Change Response White Paper	In 2015, all countries signed an agreement under the UNFCCC, for the first time committing each one to reduce their GHG emissions. South Africa's contribution to the collective climate challenge is framed by our National Development Plan and the National Climate Change Response White Paper.

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
	of 2011, NEMA: EIA Regulations, 2014	
	National Environmental Management: Air Quality Act of 2004 (NEM:AQA), NEMA: EIA Regulations, 2014	Air quality is governed by the NEM:AQA. Municipalities are responsible for generating and maintaining air quality management plans. Emission limits have been set for the petroleum industry, but no subcategory yet exists for shale gas. Any legal person undertaking shale gas exploration or production will require an Air Emissions License (AEL), if they have an incinerator capacity of 10 kg or more of waste processed per hour. Six GHG are being declared 'priority pollutants' under the NEMAQA; companies which directly emit over 100 000 tonnes of GHG (expressed as a CO_2 equivalent) annually must produce a regular 'pollution prevention plan'. The regulatory institutions and mechanisms available under NEM:AQA should be assessed and the most relevant options applied to shale gas exploration and production.
	National ambient air quality standards of 2009 (NAAQS), NEMA: EIA Regulations, 2014	The NAAQS are community exposure standards which are implicitly health-based, being largely based on the World Health Organisation (WHO) guidelines for the ambient limit values of the major pollutants, with some local adaptations.
	Hazardous Chemical Substances regulations of the Occupational Health and Safety Act of 1993, NEMA: EIA Regulations, 2014	Occupational exposure standards will apply on both the well drilling sites and downstream processing facilities. The regulations specify the allowed exposure limit over eight hour shifts. These are based on the guidelines produced by the American Conference of Governmental Industrial Hygienists. Because the South African regulations have not been updated for some time, it would be prudent to consider a revision of the regulations, taking into account good practice internationally.
	Regulations for Petroleum Exploration and Production of the MPRDA of 2015, NEMA: EIA Regulations, 2014	The technical regulations include a section on "management of air quality". Specifically paragraph 127 requiring license holders to minimise fugitive emissions, including natural gas during hydraulic fracturing operations by various means, or if those are not feasible, to flare the gas. These regulations seek to avoid venting methane to the atmosphere and to minimise flaring.
Seismicity	Regulations for Petroleum Exploration and Production of the MPRDA of 2015, NEMA: EIA Regulations, 2014	The regulations include requirements on how to conduct assessments of related seismicity (regulation 89) which must be undertaken by PASA, mechanical integrity tests and monitoring processes (regulation 112), the contents of a post-hydraulic fracturing report (regulation 120), a 'general' section prohibiting deep well injection of waste fluids (regulation 124), well decommissioning and closure procedures (regulation 132). Provide a sound basis for discussions between regulators and developers of shale gas wells. Several of the clauses might require clarification, be too stringent or unnecessarily prescriptive. For example, the meaning of the phrase "fracture behaviour of targeted formations" (sub-regulation 89 (1) (b)) should be explained; while the stipulation that an array of accelerometers must be installed in a monitoring well (sub-regulation 112 (8) (b))

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		should be reviewed, as it is possible that satisfactory measurements could be obtained from a far cheaper surface array using modern location algorithms. Other regulations relevant to seismicity, are contained in Chapter 8 titled "Well design and construction", specifically regulations 94 (Well risk identification and assessment), 95 (well design) and 96 (well construction standards) and 97 – 100 (on different types of casing to be used during well construction). Due to the high levels of technical specification, these regulations should be amended as exploration progresses, more geological and seismic information is gathered and hydraulic fracturing technologies develop further.
Water Resources, including surface and groundwater	National Water Act 36 of 1998, NEMA: EIA Regulations, 2014	Ensures that the nation's water resources are protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner. DWS has invoked Section 38 of the NWA to declare hydraulic fracturing a controlled activity, thus exploration and/or production will require a WUL. The NWA provides for the determination of a Reserve and related matters (Section 16 to 18), before the issuing of a license on groundwater and surface water. Sections 19 and 20 of the NWA require shale gas operators to prevent pollution incidents and emergency incidents and outlines how operators should act in the case of an emergency incident. Chapter 14 of the NWA (Section 137 to 145) requires monitoring, recording, assessing and disseminating information on water resources. In this regard, the Minister of Water and Sanitation must establish national monitoring systems and national information systems, each covering a different aspect of water resources, such as a national register of water use authorisations, or an information system on the quantity and quality of water resources. Key regulations important for hydraulic fracturing under the NWA, includes Government Notice (GN) 704 (GN 704/1999 in Government Gazette of 4 June 1999) where the following is relevant: • Regulation 4: No person in control of a mine or activity may locate or place any residue deposit, dam, reservoir together with any associated structure or any other facility within the 1:100 year floodline or within a horizontal distance of 100 m from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on water-logged ground, or on ground likely to become water-logged, undermined, unstable or cracked. • Regulation 5: No person in control of a mine or activity may use any residue or substance which causes or is likely to cause pollution of a water resource for the construction of any dam or other impoundment or any embankment, road or railway, or for any other purpose which is likely to cause pollution of a water resource. • Regulation 6: Capacity requirements for clean and dirty water systems; and • Regulation 7: Specific requirements for the protection of water resources.

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		Other relevant regulations are GN 1199 (18 December 2009), which specifies conditions for impeding or diverting flow or altering the bed, banks, course or characteristics of a watercourse to persons using water under Sections 21 (c) and (i) of the NWA. In these regulations, no water use is allowed within a 500 m radius from the boundary of a wetland. Also, altering the bed, banks, course or characteristics of a watercourse is not allowed within the 1:100 floodline or within the riparian habitat, whichever is the greatest.
	The Water Services Act of 1997, NEMA: EIA Regulations, 2014	Governs the provision of water services and promotes effective water resource management and conservation. Municipalities must ensure that water of a specific quality is provided (see quality standards below), must ensure assurance of supply and must ensure sanitation. If shale gas development occurs in a specific area, there may be an additional strain on the infrastructure. Treatment of waste water will not be possible at existing Waste Water Treat Works as the waste streams are significantly different from what is currently treated there.
	The South African Water Quality Guidelines (DWAF, 1996), NEMA: EIA Regulations, 2014	Serve as the primary source of information for determining the water quality requirements of different water uses and for the protection and maintenance of the health of aquatic ecosystems. Recognising that suitable quality may differ for different water users, separate guidelines are provided for domestic, recreational, industrial and agricultural (irrigation and livestock watering) use, as well as for maintenance of aquatic ecosystems. As the name implies, these are guidelines for best practice and are not legally binding.
	South African National Standards (SANS) for drinking water and waste streams, NEMA: EIA Regulations, 2014	In contrast, standards for drinking water and purification of waste waters are legislated. The SANS specifies the minimal quality of drinking water, defined in terms of microbiological, physical, chemical, and taste-and odour parameters at the point of delivery to the consumer. The Water Services Act of 1997, updated as SANS (2015a: 2015b), requires that water provided by water services authorities meets the specified standards. It should be noted that these standards apply only to water to be delivered to the consumer, and not to water in rivers or aquifers, where only the relevant guidelines apply. Standards are drawn from: • SANS. 2015a. SANS 241-1. Drinking water. Part 1: Microbiological, physical, aesthetic and chemical determinands. Edition 2. Standards South Africa. • SANS. 2015b. SANS 241-2. Drinking water. Part 2: Application of SANS 241-1. Edition 2. Standards South Africa. Standards were also set in the 1956 Water Act for some 23 constituents in effluents and waste waters entering a stream. While the updated version modifies the legal limits of some constituents, no additional constituents are considered. The values set for most or all of the constituents listed in the current list are derived from the South African Guidelines for Aquatic Ecosystems.
Waste	Regulations for Petroleum	Makes specifications for site underlay systems (regulation 91); material safety datasheets for drilling fluids (

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
	Exploration and Production of the MPRDA of 2015, NEMA: EIA Regulations, 2014	regulation 109); tagging of proppants with radioactive isotopes and addition of tracers in fracture fluids (regulation 112); fracturing fluid disclosure including prohibition of substances listed in Schedule 1; a risk management plan for fracturing fluids (regulation 115); management of flowback through an approved waste management plan (regulation 116); the requirement of a fluid transportation plan (regulation 117); requirements for storage of fluids and re-use at the well pad (regulation 118 &123); waste disposal in accordance with applicable legislation (sub-regulation 124(1)); radioactive materials management in accordance with National Radioactive Waste Disposal Institute Act of 2008 (sub-regulation 124(2)); liquid waste must be disposed of at an approved waste treatment facility in accordance with relevant legislation and disposal of liquid waste at domestic waste water treatment facilities must only take place after prior consultation with the department responsible for water affairs (sub-regulation 124(3)); deep well injection and annular disposal of drill cuttings or fluids is not permitted (sub-regulation 124(4&6)); discharge of fracking fluids, fracking flowback, and produced water into surface water courses is prohibited (sub-regulation 124(5)); drill cuttings and waste mud must be temporarily stored in above-ground tanks (sub-regulation 127(7)); solid waste generated during operations must be categorised and disposed of accordingly at a licensed landfill site or treatment facility (sub-regulation 124(8)); a waste management plan must be prepared and approved as part of the application for Environmental Authorisation (regulation 125). The existing legislated waste management provisions in the technical regulations are largely adequate to reduce the waste-related risks of shale gas development to low, if rigorously enforced. NEMA Section 30 and 30A establish the framework for dealing with emergency situations. Waste management activities that are likely to have a detrimental effect on the environment as listed in Regulation 921 of 29 November 2013 are subject to the EIA Regulations made under Section 24(5) of NEMA as part of a Waste Management Licence application under the NEM:WA.
	National Environmental Management Act of 1998 (NEMA), NEMA: EIA Regulations, 2014	NEMA Section 30 and 30A establish the framework for dealing with emergency situations. Waste management activities that are likely to have a detrimental effect on the environment as listed in Regulation 921 of 29 November 2013 are subject to the EIA Regulations made under Section 24(5) of NEMA as part of a Waste Management Licence application under the NEM:WA.
	National Environmental Management: Waste Act of 2008 (NEM:WA), NEMA: EIA Regulations, 2014	At present waste is pre-classified as hazardous waste in terms of Schedule 3 of the Waste Act. There is an amendment to the schedule in the pipeline as present "Category A: Residue deposits and residue stockpiles included) waste from drilling muds and other drilling operations" which will mean that drill cuttings are not pre-classified as hazardous waste. South Africa has an integrated pollution and waste management policy, driven by the vision of environmentally sustainable economic development by preventing and minimising, controlling and

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		remediating pollution and waste to protect the environment. Waste management in South Africa is informed by the waste management hierarchy which outlines waste management options covering the lifecycle of waste, in descending order of priority: waste avoidance (prevention and minimisation), re-use and recycling, recovery, waste treatment and disposal as last resort. Waste management activities that may require a licence in terms of NEM:WA are listed in Regulation 921 of 29 November 2013 and Regulation 633 of 24 July 2015. These activities include: storage of general waste, recycling of waste, treatment of waste, disposal of waste, construction, expansion or decommissioning of waste facilities and the establishment or reclamation of a residue stockpile or residue deposit. Depending on the size, handling capacity and the type of waste to be managed, a basic assessment or full EIA set out in the EIA will be required as part of the licence application process. All hazardous waste management facilities will require a full EIA. Applicable regulations under NEM:WA include: • Waste Information Regulations (Regulation 625 of 13 Aug 2012) – every person generating more than 20 kg of hazardous waste per day or disposing of any amount of hazardous waste to landfill must register on the South African Waste Information System (SAWIS) and submit actual quantities of waste into the SAWIS. • Waste Classification and Management Regulations (Regulation 634 of 23 Aug 2013) - All waste generators must ensure that the waste they generate is classified in accordance with SANS 10234 and a safety data sheet prepared for each waste stream as prescribed. • National Norms and Standards for the Assessment of Waste for Landfill Disposal (Regulation 635 of 23 Aug 2013). • National Norms and Standards for Disposal of Waste to Landfill (Regulation 636 of 23 Aug 2013). • List of Waste Management Activities that have or are likely to have a detrimental impact on the Environment (GN 921 of 29 Nov 2013). • National Norms and Standards for Storage of Waste (GN 926 of 29 Nov 2013). • National Norms and Standards for Remediation of Contaminated Land and Soil (GN 331 of 2 May 2014). • Regulations regarding the planning and management of residue stockpiles and residue deposits from a prospecting, mining, exploration or production operation (Regulation 632 of 24 July 2015). • Amendments to the list of waste management activities that have or are likely to have a detrimental effect on the environment (Regulation 633 of 24 July 2015). The Minister or MEC may identify investigation areas, direct site assessments to be done and issue remediation

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		orders for the remediation of contaminated land. All costs associated with the assessments and remediation will be for the account of the owner of the land or company responsible for shale gas exploration and production in line with the "polluter-pays-principle". Recovery of drilling muds and hydraulic fracturing fluids will require a waste management license in terms of the Waste Act of 2008. It is recommended that shale gas development wastes be added to the list of pre-classified hazardous waste streams in Annexure 1(2) of waste Regulation 634. The DEA have indicated their intention to amend schedule 3 of NEM:WA which currently pre-classify wastes resulting from exploration, mining, quarrying, and physical and chemical treatment of minerals as hazardous waste. If this pre-classification of waste from shale gas development changes, then it is possible that the waste may be classified as Type 1, 2 or 3. Most municipal landfill sites in the study area would at best be Class C or D sites and will not be able to receive Type 1, 2, or 3 wastes. Although norms and standards for waste classification and containment barrier system designs at landfill sites is prescribed; there is no requirement for operational and groundwater monitoring requirements. Possible contact between the waste from shale gas development and humans is also not regulated.
	National Water Act of 1998, NEMA: EIA Regulations, 2014	Provides regulatory and market based instruments to manage the impacts on water quality. These instruments include licensing of water uses, including disposal of waste, which may impact on water resources and waste discharge charges.
	National Nuclear Regulator Act of 1999, NEMA: EIA Regulations, 2014	Regulates Naturally Occurring Radioactive Material (NORM) waste. The National Nuclear Regulator document RD-004 'Requirements Document on the Management of Radioactive waste associated with waste products from facilities handling NORM (2007)' describes how NORM waste must be managed.
	National Road Traffic Act of 1996, NEMA: EIA Regulations, 2014	Vehicles transporting dangerous goods (including hazardous waste) must adhere to SANS 10228 in terms of identification and classification of goods. In terms of Section 76 the following standards are deemed to be regulations: • SANS 10228: Identifies and classifies each of the listed dangerous goods and substances and set out information including the United Nations Number, the correct shipping name, hazard class assigned and other information. • SANS 10229: Contains information on acceptable packaging for dangerous goods and substances and also include requirements for the testing of packaging and the correct marking and labelling of packages. • SANS 10230: Includes statutory vehicle inspection requirements for all vehicles conveying dangerous goods. This code stipulates the safety aspects of both the vehicle and the goods containment. Minimum inspection requirements by both in-house and outside agencies are listed.

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		• SANS 10231: This code of practice prescribes the operation rules and procedures for transporting Dangerous Goods and Hazardous Materials. It also includes the prescribed responsibilities of the owner/operator of the dangerous goods vehicle. It outlines the information required and who will have to supply information for the safe conveyance of dangerous goods. The requirements for the drafting and formulating of an operational agreement are also specified. This code also requires the owner/operator or vehicle to be registered as dangerous goods carrier. It is also prescribed that the owner operator has available adequate insurance cover for civil liability as well as pollution and environmental rehabilitation cover in the event of an incident. • SANS 10232-1: 2007: This code includes details of new placarding requirements for vehicles transporting dangerous goods and the individual or substance exempt quantities and the compatibility requirements of mixed loads. Part 3 of this code contains information on the Emergency Response Guides to be used in case of an incident or accident.
	Disaster Management Act, 2002 (Act 57 of 2002), NEMA: EIA Regulations, 2014	This act provides for an integrated and coordinated disaster management policy that focuses on preventing or reducing the risk of disasters (natural or human induced) mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post-disaster recovery.
Biodiversity	The National Environmental Management: Biodiversity Act (NEMBA) of 2004, as amended, NEMA: EIA Regulations, 2014	Provides for the management and conservation of biodiversity, the protection of species and ecosystems that warrant national protection, and the sustainable use of indigenous biological resources.
	The National Environmental Management: Protected Areas Act of 2003, NEMA: EIA Regulations, 2014	Provides for the protection and conservation of ecologically viable areas representative of natural landscapes. The Act provides for protected areas to be declared on private or communal land, with the landowner retaining title to the land.
	National Biodiversity Strategy and Action Plan (NBSAP), NEMA: EIA Regulations, 2014	South Africa is obliged to develop a National Biodiversity Strategy and Action Plan (NBSAP). Strategic objectives of the NBSAP include that the management of biodiversity assets and their contribution to the economy, rural development, job creation and social wellbeing is enhanced.
	National Biodiversity Assessment (NBA), the National Protected Area Expansion Strategy (NPAES),	All plans undertake spatial assessment and prioritisation of biodiversity regions based on the principles of systematic biodiversity planning. These principles include the need to conserve a viable representative sample of all ecosystems and species, as well as the ecological and evolutionary processes that allow biodiversity to persist over time. At the provincial level, provincial environmental affairs departments are often the authority

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
	Atlas of Freshwater Ecosystem Priority Areas of South Africa (FEPA), and provincial spatial biodiversity plans, NEMA: EIA Regulations, 2014	for permitting or authorising for a range of activities, and they provide comments on mining-related authorisations. Provincial spatial biodiversity plans identify Critical Biodiversity Areas (CBAs) and Ecological Support Areas which guide such authorisations and comments.
Agriculture	The Conservation of Agricultural Resources (Act 43 of 1983) (CARA), NEMA: EIA Regulations, 2014	Prevents the degradation of the agricultural potential of soil and requires the protection of land against waterlogging and salinisation of soils by means of the construction and maintenance of suitable soil conservation works. The sustainable utilisation of marshes, water sponges and watercourses on agricultural land is also regulated in terms of the Act. CARA was promulgated more than three decades ago, and did not anticipate all of the current potential impacts of new developments on agricultural resources. CARA could be augmented drawing from principles contained in international best practice documentation such as the International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability that became effective on 1 January, 2012.
	The National Water Act (Act 36 of 1998) (NWA), NEMA: EIA Regulations, 2014	Is concerned with the quality and quantity of water used, including for agriculture. Any impacts caused by shale gas activities on the volume and quality of water available for authorised agricultural water use, will be an infringement of this Act.
Tourism	National Development Plan (NDP) (2012), NEMA: EIA Regulations, 2014	The NDP identifies tourism as an essential part of our economy into the future.
	Medium Term Strategic Framework for 2014 – 2019, NEMA: EIA Regulations, 2014	Tourism is a key sector contributing to Outcome 2 regarding “decent employment through economic growth”.
	National tourism plans, NEMA: EIA Regulations, 2014	At the national level, guidance is provided by the Marketing Tourism Growth Strategy for South Africa (2010) and the National Tourism Sector Strategy (DoT, 2011). The Rural Tourism Strategy (DoT, 2012) highlights the importance of rural areas for tourism and emphasises the fact that rural areas contain important tourism attractions. These plans are implemented by different authorities and government agencies, a situation that is adding to management complexity.
	Provincial and regional tourism plans, NEMA: EIA Regulations, 2014	At provincial and regional level there are: an Integrated Tourism Development Framework (Western Cape Department of Economic Development and Tourism, 2006), an Eastern Cape Tourism Master Plan (Eastern Cape Department of Economic Development and Economic Affairs, 2009) and a Northern Cape Tourism

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		Master Plan Review (Grant Thornton, 2014). The Karoo Development Foundation (2012) produced a Karoo Tourism Strategy and Kyle Business Projects (2009) produced a Camdeboo Responsible Tourism Sector Plan. In essence the strategies of these communicated in the planes are to develop and market unique tourism products, grow domestic and international tourism arrivals and spend, create sustainable economic benefits and to protect the environment.
Micro and macroeconomics	The Industrial Policy Action Plan 2015/16 – 2017/18, NEMA: EIA Regulations, 2014	Proposes a Long Term Strategic Framework to leverage the opportunities presented by petroleum and gas resources. The Department of Trade and Industry has also recently announced that it will be establishing a unit to manage gas industrialisation that intends replicating the success of the Independent Power Producer programme unit of the DoE.
Social fabric	The Social Assistance Act of 2004, NEMA: EIA Regulations, 2014	Creates a broad social protection strategy. Several types of grants are available: Grants for Older people, Disability grants, War veterans' grants, Foster care grants, Child support grants and Grants in Aid. Poor people also have access to other developmental initiatives such as the National Schools Nutrition Programme, the Expanded Public Works Programme, the Municipality Infrastructure Grant , municipal services subsidies, and the Umsobomvu Youth Fund.
Human health	National Environmental Management Act of 1998 (NEMA), NEMA: EIA Regulations, 2014	Responsibility for the environmental health and safety consequences of a policy, programme, project, product, process, service or activity exists throughout its life cycle.
	National Water Act, Act 36 of 1998 (NWA), NEMA: EIA Regulations, 2014	Sustainability and equity identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to a thieve the purpose of the Act.
	Regulations for Petroleum Exploration and Production of the MPRDA of 2015, NEMA: EIA Regulations, 2014	"Well examination schemes" are required to by competent and independent persons to assess "risks to the health and safety of persons from the well or anything in it, or from strata, to which the well is connected, have been assessed and are within acceptable levels." During hydraulic fracturing, a permit holder must: • prevent well design risks to health and safety of persons from the well or anything in the well, or in strata to which the well is connected. • address hydraulic fracturing fluids management to ensure assessment of potential environmental and health risks of fluids and additives in both diluted and concentrated form.

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		• conduct operations in a manner that does not pose a risk to public health, life, property and the environment. The protection of human health, with particular reference to the Health Act of 2003, is missing from the MPRDA technical regulations.
	Health Act (Act No. 61 of 2003), NEMA: EIA Regulations, 2014	Supports the Constitution in terms of everyone having a right to an environment not harmful to health and well-being (Section 24). Water quality monitoring is referenced in terms of municipal health services provisions, there is no other mention of water.
Sense of Place	The National Environmental Management Act (NEMA) of 1998, NEMA: EIA Regulations, 2014	Sustainable development requires the consideration of all relevant factors including…"that decisions must take into account the interests, needs and values of all interested and affected parties, and this includes recognising all forms of knowledge, including traditional and ordinary knowledge".
	National Heritage Resources Act (NHRA) of 1999, NEMA: EIA Regulations, 2014	Describes the reasons a place or object may have cultural heritage values; some of these speak directly to the cultural landscapes. "Cultural significance" means aesthetic, architectural, historical, scientific, social, spiritual, linguistic or technological value or significance. The concept of 'sense of place' has been used to legally block developments locally and internationally. For example, the development of a shopping mall was blocked at Princess Vlei, in Cape Town in 2009, and the development of mining was blocked at St Lucia in KwaZulu-Natal in 2002.
Visual aesthetics	The National Environmental Management: Protected Areas Act of 2003, NEMA: EIA Regulations, 2014	The Minister/MEC may restrict or regulate development in a 'protected environment' that may be inappropriate for the area given the purpose for which the area was declared. Local authority zoning schemes can be used to protect natural and cultural heritage resources through 'Conservation Areas', 'Heritage Overlay Zones' and 'Scenic Overlay Zones' including scenic routes.
	National Heritage Resources Act of 1999, NEMA: EIA Regulations, 2014	Includes protection of national and provincial heritage sites, as well as areas of environmental or cultural value, and proclaimed scenic routes.
Heritage	National Heritage Resources Act (NHRA) of 1999, NEMA: EIA Regulations, 2014	Defines and governs heritage resources. Section 38 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

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
		37 protects public monuments and memorials. The definitions mentioned above provide specific details of what is included within each of these categories. 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. In the context of shale gas development, Heritage Impact Assessments (HIAs) produced under NEMA and according to the guidelines of Section 38(3) should be submitted to the relevant heritage authorities 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. 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 is fully functional and applications within Western Cape would be commented on by them; • Eastern Cape: Although the Provincial Heritage Resources Authority (PHRA) of the Eastern Cape 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, 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).
	World Heritage Convention Act (No. 49 of 1999, 1999), NEMA: EIA Regulations, 2014	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.
	National and provincial regulations and guideline documents	There is a Western Cape Government guideline document for involving heritage specialists in Environmental Impact Assessment (EIA) processes, while both SAHRA (2007) and HWC (2016) have issued guidelines and standards for conducting specialist assessments of archaeology and palaeontology.
Noise	Environmental Conservation Act of 1989, the Western Cape Noise Control Regulations (NCR) (2013) and national standards, NEMA: EIA	Both these regulations set the concepts of a “disturbing noise” and a “noise nuisance”. A disturbing noise can be objectively measured, while a noise nuisance is a subjective “annoyance” that cannot be reliably measured, such as a dog barking or other discrete events. Two standards, SANS 10328 and SANS 10103 further expand on these regulations. SANS 10328 specifies the standard procedure for conducting a noise impact assessment. SANS 10103 specifies procedures for assessing the noise under investigation. The Western Cape NCR

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
	Regulations, 2014	supersede the national NCR.
Electromagnetic interference	Astronomy Geographic Advantage Act (AGAA) of 2007, NEMA: EIA Regulations, 2014	Empowers the Minister of Science and Technology to declare Astronomy Advantage Areas, and protect these areas through regulations. Required protection threshold levels for the radio astronomy service are described in International Telecommunications Union Recommendation ITU-R RA.769-2. The basic principles upon which this recommendation is developed has been used in the derivation of the South African Radio Astronomy Service (SARAS) protection level. This protection level has been promulgated in terms of the AGAA and adopted in South Africa to provide a clear and objective decision making process in the assessment of radiofrequency interference on the SKA and other radio astronomy facilities.
Spatial planning	Municipal Systems Act of 2000, NEMA: EIA Regulations, 2014	Enable coordinated service delivery and development between the three spheres of government and other role players within a municipal area, to 1) improve quality of life, 2) support sustainable development and transformation, and 3) facilitate democratic and multi-sector planning processes. The municipal Integrated Development Plan (IDP) addresses current and future societal needs within the context social and ecological systems in which they exist. All project and activities related to infrastructure, land development, service delivery, as well as land and environmental management within any area needs to form part of the relevant IDP and associated sector plans and infrastructure investment frameworks.
	The Spatial Planning and Land Use Management Act of 2013 (SPLUMA), NEMA: EIA Regulations, 2014, Western Cape Land Use Planning Act, 2014 (LUPA)	Makes provision for the establishment of a planning instrument to enable focused temporal and spatial coordination of governance and investment actions in and between different spheres of government, within areas with unique, but interrelated, attributes or development challenges that span more than one municipality and/or province. Since the advent of the SPLUMA in 2013, and in line with a series of pronouncements by the Constitutional Court since 2010, the locus of land use change approvals is the municipality. The decisions of other national or provincial departments may not overturn that of the municipality.
	Land Use Planning Ordinance, 15 of 1985	In the Northern Cape, the Northern Cape Planning and Development Act (NCPDA) of 1998 was promulgated. The three affected provinces are, however, each at different stages in evolving from a legal position based on LUPO to one that is in line with SPLUMA. The Western Cape already has new legislation in place (LUPA and an accompanying set of Land Use Planning Regulations (2015)), while the Northern and Eastern Cape provinces have draft legislation that is being considered in each of the respective provinces. In the absence of new provincial legislation and until such time as the municipalities have municipal planning bylaws in place, the former LUPO-based (or NCPDA-based in the case of the Northern Cape) system stays in effect until repealed by provincial governments as set out in the Guideline on Transitional Measures (DRDLR, 2015)
	Development Facilitation Act of	These legislation have allowed for a range of plans and investment instruments to be put in place to guide

Issue	National policy, plans and legislation	Relevance to shale gas exploration and production and comments on the existing regulatory framework
	1996 and Intergovernmental Relations Framework Act of 2005, NEMA: EIA Regulations, 2014	development and bring about more effective intergovernmental and spatial alignment within the planning system
	Spatial and integrated development planning and governance instruments, NEMA: EIA Regulations, 2014	Integrated and strategic national, local and regional plans are developed for every local and district municipality in the study area, and the Provincial Growth and Development Strategies and equivalent plans within the Western Cape, Eastern Cape and Northern Cape Provinces. Integrated Spatial Development Frameworks (SDFs) guide spatial development within national, provincial, regional, local and precinct scales. While plans are in place for all three provinces as well as relevant district and local municipalities, most of the local and district plans require an update to ensure that they can fulfil the functions and purposes as set out by recent legal developments and regulations. Integrated provincial and municipal sector plans include integrated housing plans, integrated transportation plans and integrated disaster management plans. Integrated investment frameworks i.e. Integrated Infrastructure Investment Framework (provincial and municipal), Capital Investment Framework (municipal) and spatially targeted budgeting instruments were introduced by National Treasury. Land use management schemes which are largely in place for towns, and in most cases require support to develop for the full extent of the municipal area, need support to ensure alignment with SDFs and EMFs and support with the preparation of relevant by-laws to guide development. In the Western Cape, the Laingsburg, Prince Albert and Beaufort West Local Municipalities (amongst others) have all adopted municipal by-laws enabling LUPA.

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3. ACTIVITIES ASSOCIATED WITH EXPLORATION AND PRODUCTION

3.1 Typical Shale Gas Project Life Cycle

Mining projects are typically divided into three distinct stages: Exploration, production and decommissioning. The typical shale gas project assumes five stages: Exploration, appraisal, development, production and decommissioning. The first two stages of a shale gas project (i.e. exploration and appraisal) lead to a decision on “possible exit” by the applicant based on the economic feasibility, where investment choices are made about whether or not to proceed to the next stage or not. These decisions are informed by technical and economic criteria, among other factors.

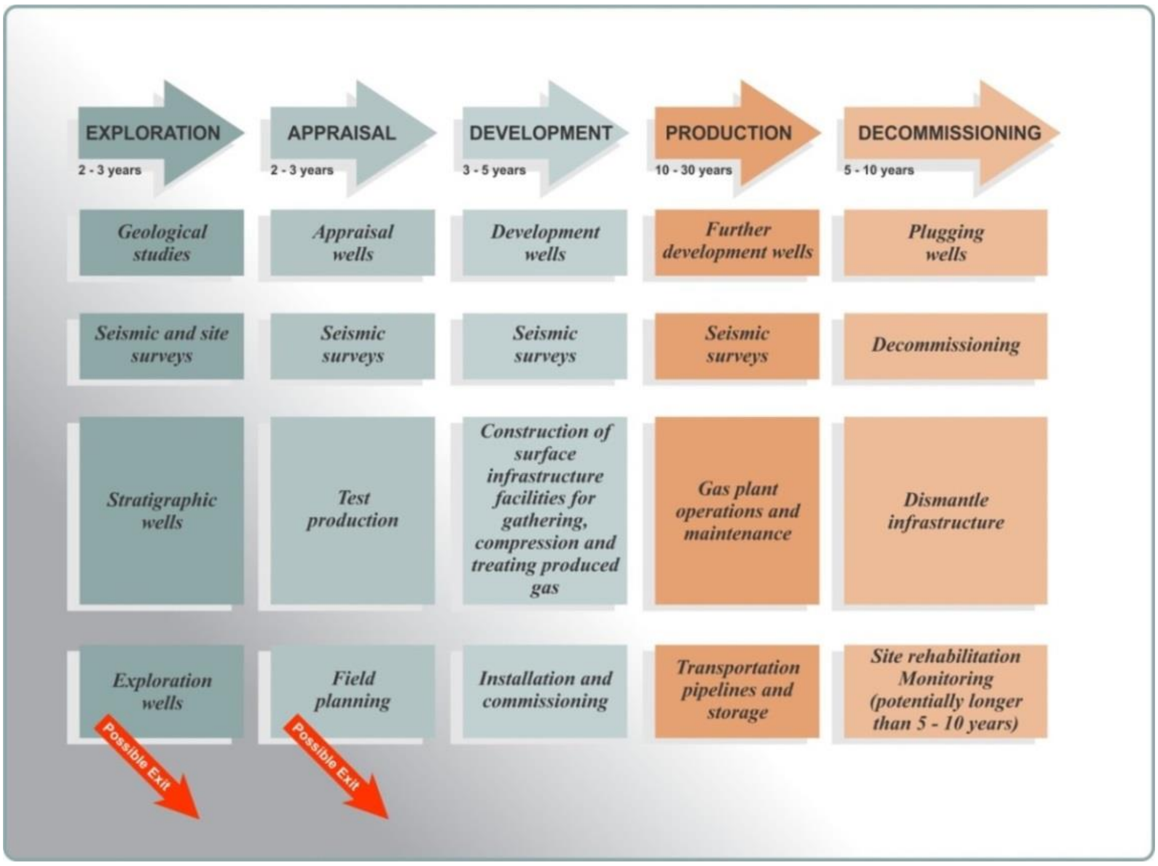

Figure 3–1: Typical life cycle of a shale gas project. The indicative timelines are associated with shale gas exploration and production activities characteristic of the USA and do not consider the geological complexity of the Karoo Basin nor the timing associated with the regulatory and baseline monitoring requirements that would be required in the South African context.

The foremost priority for South Africa is the accurate determination of the quantity of potentially recoverable shale gas and the protection of the resources which sustain the Central Karoo. The former can only be achieved through modern exploration. Based on the Scientific Assessment and in concurrence with ASSAf (2016), we recommend that the government assess the option of dividing exploration licencing into two distinct phases (Phase I "Exploration" and Phase II "Appraisal"), linked by continuous environmental monitoring and adaptive management. In this way, exploration is detached from production via continuous environmental impact assessments that can account for the environmental and operational baseline data obtained during Phase I. Considering this recommendation, the typical stages of traditional mining projects, relative to the typical shale gas development project lifecycle are provided in Table 3-1 which proposes two phases (Phase I "Exploration" and Phase II "Appraisal") prior to production, separated by different permitting procedures. Table 3-1 also provides the timing of the stages and the nature of activities associated with each of the stages.

Table 3–1: The typical stages of a mining project in comparison to a shale gas exploration and production project with suggested regulatory phasing, timing and the nature of activities. Note that the drilling of horizontal wells and hydraulic fracturing mark the beginning of "Appraisal".

Typical stages of a mining project	**Exploration**		**Production**		**Decommissioning**
Typical shale gas project	Exploration	Appraisal	Development	Production	Decommissioning
Suggested regulatory phasing	Phase I	Phase II	Small Gas 5 tcf	Big Gas 20 tcf	Decommissioning
Timeframe typical of projects in the U.S	3-5 years	3-5 years	10 Years	10 years	10 years (+ legacy monitoring)
Regulatory checks	EIA for Phase I and commencement of baseline monitoring for Phase II	Review of exploration data from Phase I, review and consolidation of baseline data for Phase II, EIA for Phase II, ongoing monitoring	EIA for limited production wellfield, baseline monitoring, ongoing monitoring	For > 50 wellpads, EIA for large-scale production wellfields (in the region of 400 wellpads), baseline monitoring, ongoing monitoring	EIA for decommissioning, continued monitoring according to closure EMPr requirements
Nature of activities	2-D seismics	3-D seismics	3-D seismics	3-D seismics	Gas flow suspension
	3-D seismics	Vertical wells	Vertical wells	Vertical wells	Well closure
	Vertical wells	Horizontal wells	Horizontal wells	Horizontal wells	Well plugging
	Roads	Hydraulic fracturing	Hydraulic fracturing	Hydraulic fracturing	Site clear up
	Trucks	Trucks	Roads	Roads	Production infrastructure removed
	Water management	Water management	Trucks	Trucks	Rehabilitation

<table>
<tr><th>Typical stages of a mining project</th><th colspan="2">Exploration</th><th colspan="2">Production</th><th>Decommissioning</th></tr>
<tr><td rowspan="8"></td><td rowspan="8">Waste management</td><td>Waste management</td><td>Water management</td><td>Water management</td><td rowspan="8"></td></tr>
<tr><td rowspan="7">Flaring</td><td>Waste management</td><td>Waste management</td></tr>
<tr><td>Flaring</td><td>Flaring</td></tr>
<tr><td rowspan="5">Gas compressors</td><td>Gas compressors</td></tr>
<tr><td>Gas2Power plants</td></tr>
<tr><td>Powerlines</td></tr>
<tr><td>Pipelines</td></tr>
<tr><td>Water treatment facilities</td></tr>
</table>

3.2 Exploration and Appraisal Activities

3.2.1 Phase I "Exploration"

During Phase I Exploration, the subsurface distribution of gas-shales and location of 'sweetspots' would be determined to establish with greater accuracy the total potential recoverable shale gas using seismic surveys and the drilling of stratigraphic wells. The sections which follow provide a summary of the key activities associated with Phase I Exploration.

3.2.1.1 Seismic Surveys

Seismic surveys involve mapping and imaging the sub-surface geological structures. They are typically conducted in a phased manner during exploration and also in stages during development of gas fields for production. Regional seismic surveys, usually comprising two-dimensional (2-D) seismic acquisitions, are normally conducted during initial exploration campaigns with the aim of furthering understanding of the sub-surface geological structure and identifying prospective zones for the next phases of exploration. More sophisticated three-dimensional (3-D) seismic surveys are typically commissioned during subsequent stages of exploration and/or production planning. The intensity of the surveys (e.g. density of seismic lines that are surveyed on a per km^2 basis) tends to increase for each subsequent stage of seismic exploration, especially as areas are prioritised for drilling.

A seismic survey is in effect an echo sounding technique. An acoustic pulse is initiated from a surface location, with reflection occurring at the boundaries of rock layers. This results in the seismic pulse traveling upwards as a reflected wave. The sub-surface response is recorded by an array of receivers placed on the land surface. Travel time to the reflectors and the velocity of propagation of the reflected pulse are analysed to develop a picture of the sub-surface geology.

The main approaches that would apply to gathering seismic data would include the shot-point method and the use of vibroseis trucks. The shot-point method of creating shock wave energy is used, amongst other reasons, in areas where the deployment of vibroseis trucks is not an option. The vehicles used for a shot-point seismic programme include a number of truck- or track-mounted drill rigs, a recording truck and several light pickups or stake-bed trucks for transporting crew and light equipment. The drilling rigs create small-diameter holes 3 to 8 m deep. Different shot hole depths are associated with different charge sizes that are used. Drilling water, when needed, is obtained from the nearest licenced source. To avoid contamination potentially attributable to the explosives that are used, water-bearing zones are sealed with gravel that is either poured directly down the hole or is placed down-hole in biodegradable cardboard tubes. A light helicopter is often used to move cabling, data boxes, geophones and other light equipment to workers on the ground.

An explosive charge is placed in the hole, which is back-filled with drill cuttings (the material excavated from the shot hole). Before the charge is detonated, the fill is tamped down to secure the charge. A ground crew is tasked to work through the area and set off the sources in sequence and retrieve equipment such as geophones, markers, etc. Detonations are often triggered (and/or effects measured) using a radio-controlled unit located in a nearby recording truck. Detonations are contained within the hole to force the generated energy downward through the rock strata. As a result, the only sound heard above ground is a dull thud.

Vibrator or 'vibroseis trucks' are mobile seismic sound sources (Figure 3-2) designed to do away with the need to drill shot holes and the complex process of detonating explosives, and to reduce safety and security risks relative to the shot-point method. These advantages are, however, offset by other impacts on the environment (e.g. vehicle passage width, which exceeds that of vehicles used for the shot-point method). The trucks can be equipped with special tyres or tracks for deployment in a range of environments; although terrain can impose limits to their operation.

During operations, the vehicle moves into position and lowers the baseplate to the ground. Seismic vibrators fitted to the trucks produce ground motion that propagates into the sub-surface. The vehicle operator can make the piston and baseplate assembly move up and down at specific frequencies thereby transmitting energy through the baseplate and into the ground. Vibroseis trucks can be employed individually or as a group, often with four or more trucks operating simultaneously. After the prescribed number of sweeps is completed, the baseplates are raised and the vehicles move to the next location, typically a distance of 10-50 m.

Figure 3–2: Seismic vibration (vibroseis) truck

The objective of an initial seismic acquisition programme in the study area would be to contribute to the understanding of the sub-surface geology of the Karoo Basin including its depositional environment, the tectonic activity that it has been subjected to and the presence of igneous intrusions including dykes, sills, breccia pipes and hydrothermal vents. The objective would also be to gauge the presence and distribution of potential shale gas plays. Subsequent seismic surveys would support, minimise or eliminate further exploration, including drilling programmes. Initial seismic operations would likely be completed in the first 3 years following the issuance of ERs. This could be followed by subsequent surveys conducted over a number of years, throughout the development and production cycle[7].

Only a fraction (< 0.0001) of the study area would be impinged upon directly through surveys conducted along quite widely spaced grids (e.g. 10 km spacing for a regional 2-D survey) of seismic lines (< 5 m wide, which is the width of the vehicles that traverse the lines). Exclusion areas would include municipal areas, conservation areas, wetlands and riparian zones, restricted activity zones and topographically complex landscapes, for example, where slopes exceed 10°[8]. There are likely to be other exclusion areas, discussed in Section 6.1.1.1. A closer grid spacing (e.g. 1 km or narrower) would be used for targeted areas, where 3-D surveys are commissioned.

[7] Companies generally complete the majority of spatially extensive seismic work relatively quickly so that drilling options can be determined early in the development process. They usually commission additional concentrated seismic work later when there is need to focus on a specific area/region.
[8] Slopes in excess of 10° would practically be extremely difficult to traverse in the course of seismic operations.

Various towns distributed across the study area would be used to support the seismic survey activities, including offices for project administration, accommodation of personnel, equipment storage and staging areas for equipment destined for deployment in the field and pre-processing and temporary archiving of seismic data. For a proportion of operations, in isolated areas, mobile camps in the immediate vicinity of operations might serve as operational bases for the seismic teams. The key sources of impacts associated with seismic surveys are:

1. Clearing of seismic lines (minimal if wireless technology is used optimally);
2. Vehicle and pedestrian traffic traversing the seismic grid; and
3. Noise emissions.

3.2.1.2 Stratigraphic Wells

Following seismic exploration, establishing the presence and potential yield of hydrocarbon reserves is achieved through drilling stratigraphic wells. The objectives of drilling a vertical stratigraphic well or set of wells ("X-wells" in Figure 3-3) are to:

- Correlate stratigraphic and structural records to seismic interpretations;
- Identify freshwater aquifers, drilling hazards and hydrocarbon-bearing zones;
- Confirm predicted organic-rich shale formation packages that might be anticipated, identify new potential target zones and identify existing fractures;
- If encountered, evaluate the thermal maturity, presence/absence of fractures, gas content, gas saturation (free and adsorbed), gas composition, mineralogy, porosity and permeability of the hydrocarbon-bearing shale unit/s (using cores, electric logs and other means).

Drilling is initiated by lowering a drill bit through a conductor pipe installed at the surface and by rotating the drill string to which the bit is attached. The rotating bit crushes the rock into small particles or 'cuttings'. Drilling fluid, often termed 'drilling mud', is used to perform a number of functions including providing hole stability, the entrainment and transport of drill cuttings to surface and circulating drill gas out of the hole. Drilling fluid is prepared through the addition of various compounds and chemicals to water that is supplied to site.

Cement is pumped down inside the casing and forced out of the bottom and up into the annular space between the casing and the borehole wall until there is a "show" at the surface. The cemented casing then undergoes a mechanical integrity pressure-test to ensure that there is adequate structural integrity at the bottom of the casing or casing shoe. The purpose of the casing is to provide structural support and integrity to the borehole, allow for deep drilling into high pore pressure formations and to isolate water- and hydrocarbon-bearing formations to prevent cross-contamination.

Petro-physical evaluation of the formations penetrated by the well is carried out during the course of drilling operations. Open hole wireline logging involves lowering diagnostic tools on an electric cable into the uncased hole. The ultimate goal is to determine the fluid/gas content in the rock along with the quality and quantity of a hydrocarbon reservoir. This data is key to determining if further well evaluation is necessary and to inform future exploration, development and production decisions and activities.

3.2.2 Phase II "Appraisal"

Hydraulic fracturing marks the start of Phase II, before and during which a new EIA should be conducted, inclusive of 3-D analyses based on continuous down the- hole data acquired during the drilling of vertical wells. No hydraulic fracturing should be permitted within 1 500 m of the surface until hydraulic fracturing and casing technologies improve to the point where it can be clearly demonstrated that such technologies are able to prevent groundwater pollution caused by rock and technology failure. Limited multi-directional hydraulic fracturing at selected wellpads will be needed during Phase II to evaluate the retrieval success of the shale gas and how efficiently the gas can be extracted to determine its economic return, and its status as gas reserve (ASSAf, 2016).

3.2.2.1 Appraisal Wells

If the results of tests from stratigraphic wells invite further investigation and following a new EIA permitting process for Phase II, additional appraisal wells will be drilled nearby. These wells are planned to yield increasingly detailed information on the properties of the target formation. An appraisal well ("Y-Well") is created in a similar way as a stratigraphic well with vertical ("X-well") and, typically, horizontal sections. In order to drill horizontally, directional drilling methods are used. In the region of 10 to 15 of horizontal laterals can be drilled from the same vertical wellbore.

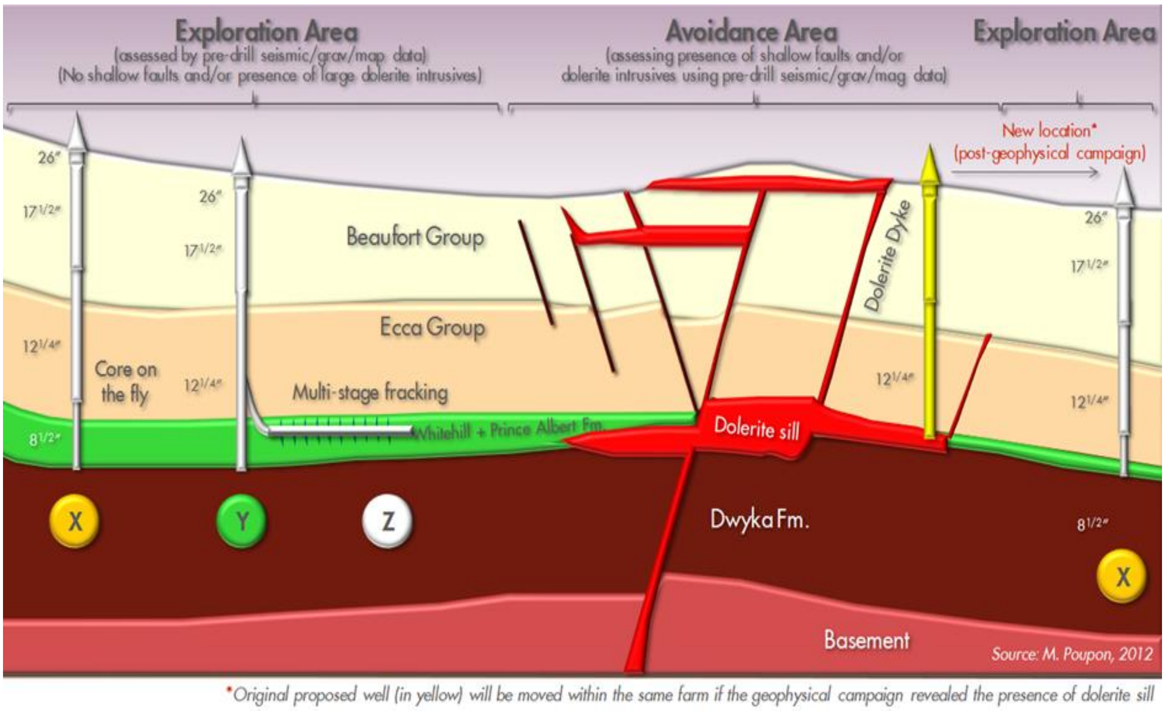

Figure 3–3: A stratigraphic well (indicated by "X-well") is a vertical well drilled to obtain geological core samples, ideally from the target formation. An appraisal well is a vertical well (indicated as "Y-well") that is drilled some distance away from the stratigraphic-well so that the characteristics of the formation can be further evaluated and delineated. If the evaluation is positive, a side track may be drilled through the wall of an appraisal well on a curved trajectory, ending with a horizontal section of well bore within the target formation. The horizontal well (indicated as "Z-well") is subjected to hydraulic fracturing.

3.2.2.1.1 Hydraulic Fracturing

On completion of drilling, the rig is removed and the site is prepared for hydraulic fracturing. Well perforating guns, employing directional explosive charges, are lowered into the cased wellbore by tubing or wireline. Once the guns reach the predetermined depths along the section(s) of the target formation they are discharged to perforate the casing (Figure 3-4).

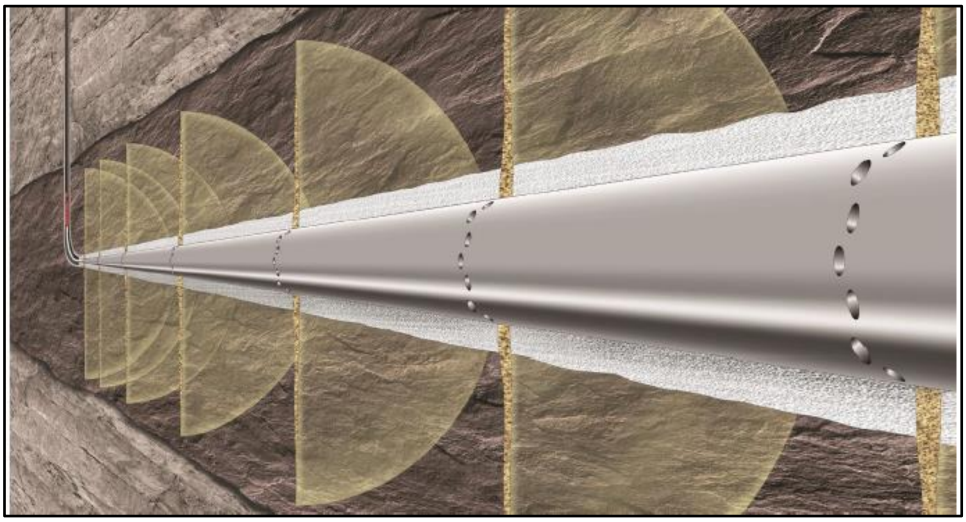

Figure 3–4: Schematic illustration of a horizontal wellbore with perforations through which fluid is transmitted into the surrounding shale (Burns et al., 2016).

Detonation of the charges punches holes through the well casing and surrounding cement layer into the reservoir rock in the sections of the well bore where gas is expected to be extracted. The perforating guns are then pulled out of the hole to surface where the pumping unit and other equipment are attached to the wellhead; pumping of hydraulic fracturing fluid to increase the hydraulic pressure then begins.

3.2.2.1.2 Hydraulic Fracturing Fluid

The hydraulic fracturing fluid is injected down the wellbore at a pressure of between 400 and 600 bar (40 – 60 MPa). The fluid migrates through the perforations in the well casing and cement into the reservoir rock to create fractures that are typically 2-7 mm in width, close to the wellbore. The fractures become narrower as they extend outwards for distances of up to about 300 m from the wellbore. The hydraulic fracturing fluid is made up of more than 90% water, with the balance comprising proppant (sized particles, either ceramic beads or high silica sand) and other additives. The proppant that is pumped into the fractures holds them open when the hydraulic pumping pressure is reduced. Gas that is released in the process flows out of the shale to the surface via the wellbore. In terms of the MPRDA technical regulations, an Exploration or Production Right holder required to disclose the fluids, chemicals and other additives used in hydraulic fracturing to the competent authority (MPRDA Regulations for Petroleum Exploration and Production, 2015: Chapter 9, Subsection 113). The use of Material Safety Data Sheets is a common means of communicating this information.

3.2.2.1.3 Proppant

Proppant is high specification aggregate, usually sand, which is treated and coated with a resin. It can also be produced as ceramic nodules. Sand in the southern Karoo is largely unsuitable for use as proppant because of the high clay content of the local soils, which are derived from shales and mudstones. For this reason, it unlikely that proppant would be sourced locally within the study area for shale gas extraction operations. For the scenario considered here, entailing exploration operations only, it can be assumed that proppant would be imported to South Africa and transported to the sites of hydraulic fracturing by road or rail. For the Small- and Big Gas scenarios outlined in, importation of proppant at the scales required would be uneconomical and it is likely that the product would be manufactured at a location where suitable aggregate can be sourced, for example where sandstones define the local geology, and transported to the study area.

3.2.2.1.4 Water Requirements

According to the industry, the volume of water used to effect hydraulic fracturing within the study area, for example, within a well comprising a 3 000 m vertical and 1 000 m horizontal section would amount to about 6 000 m^3. Water requirements for hydraulic fracturing can be much higher, with some reporting that the volumes used in wells drilled within the US Marcellus formation, with a 1 500 m vertical section and a 980 m horizontal section, ranging from 7 700 to 38 000 m^3. Vertical shale gas wells typically use approximately 2 000 m^3 of water, whereas horizontal wells typically use between 10 000 and 25 000 m^3 per well. Water requirements reported in the literature for hydraulic fracturing of individual wells range from 10 000 to 30 000 m^3. The volume of water used depends, amongst other factors, on well characteristics (depth, hole sizes and conditions, horizontal lateral length) and the number of fracturing stages within the well. Although oil and gas developers aim to reduce freshwater consumption through water re-use and use of waste water from other sources, in current practice freshwater still comprises 80-90% of the water used for hydraulic fracturing.

> Box 2: Water supply alternatives for shale gas exploration and production
>
> Supply options could include:
>
> - *Local non potable groundwater in the proximity of wellpads*
> - *Groundwater/surface water outside the shale gas licence areas.*
> - *Desalinated seawater from the coast, trucked, piped or transported via freight rail.*
> - *'Grey' water or waste water (e.g. treated Acid Mine Drainage) sourced either within or outside the shale gas licence areas.*

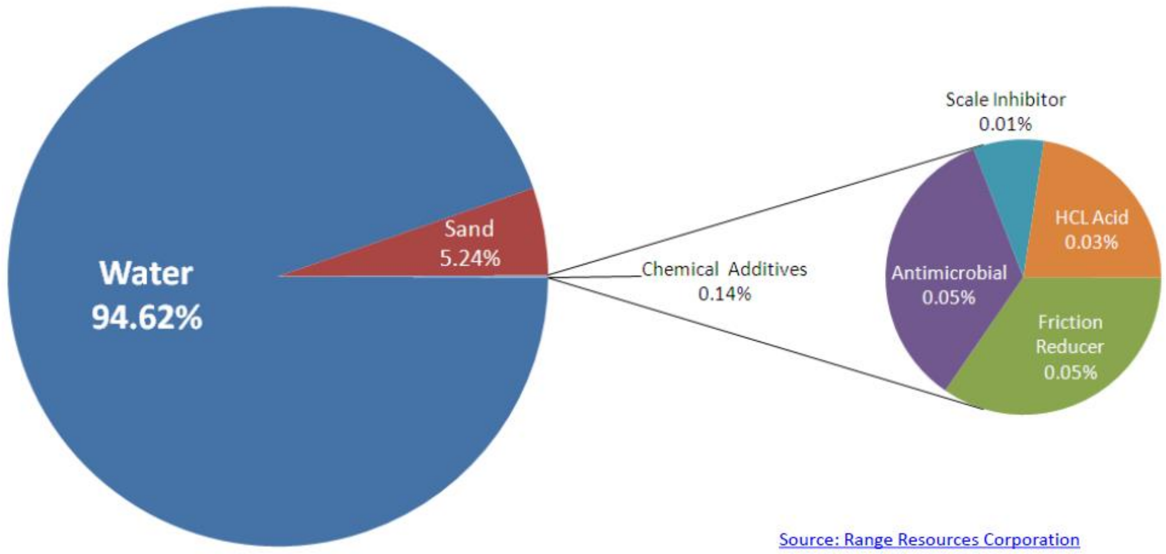

Figure 3–5: Example of the relative composition (% contribution to total volume) of compounds comprising a typical batch of hydraulic fracturing fluid (Burns et al., 2016)

Phase II includes planning, site preparation, drilling, hydraulic fracturing and flow-testing would proceed for each exploration and appraisal drilling campaign and involves the following key activities:

- Clearing of wellpad areas and the crew accommodation sites.
- Construction of new access roads to wellpads and temporary infrastructure.
- Road transport to the wellpad and ancillary equipment.
- Sourcing and supply of potable water for domestic use.
- Sourcing and supply of process water to prepare drilling mud and for hydraulic fracturing.
- Process water treatment for recovery (re-use as drilling and hydraulic fracturing fluid) and disposal of process waste (e.g. sludge recovered from flowback) and produced water.
- Drill cuttings disposal.
- Domestic and solid waste management.
- Hazardous waste management (additional to waste process water and solids).
- Flaring of gas during drilling and well-flow testing.
- Noise and light emissions.
- Decommissioning, including removal of equipment and infrastructure from site.
- Employment, personnel logistics, and labour negotiations.
- Management of safety, security and medical/health.

3.2.3 Development and Production

Following hydraulic fracturing, surface equipment is installed on the wellpad in order to allow it to be ‘produced’. In the course of initial well-testing, the produced gas may be flared. Well testing is normally conducted for 30 to 60 days, with flaring undertaken for 30 days or less. Development and production would proceed based on the results of the most successful of appraisal campaigns that are undertaken. Activities associated with development and production would be contained within production blocks measuring in the region of 30 x 30 km.

It is likely that a significant proportion of activities undertaken to support production would be initiated immediately following exploration and appraisal to accelerate monetisation of the gas to offset these costs. The construction of production infrastructure (e.g. the initial suite of production wells, the associated gathering pipeline network, gas processing stations) would be concluded in a period of around 10 years. Ongoing drilling, completion and testing of production wells and related infrastructure would continue for much of the duration of production, extending over several decades. New wellpads would be developed on a regular basis, whilst existing wellpads would remain operational for several years as additional horizontal wells and/or horizontal laterals are drilled and hydraulic fracturing is undertaken to maintain a supply of gas at the required level.

Production from shale gas wells typically declines rapidly after start-up. Calculations are made of the estimated recovery per well, which then determine the number and average spacing of the wells (i.e. number of wells per unit area) and the rate at which they are established. New wells are drilled constantly in order to maintain a particular level of gas production.

Development would continue with the commissioning of supplementary seismic surveys across the production block. In parallel with or immediately following this, access roads and new wellpads would be established to enable drilling of a series of wells aimed at both resource delineation and production. Importantly, a supply of process water would be sourced and, most likely, a central treatment facility designed and constructed to treat the water evacuated from the wells (flowback water, including produced water). Water would be recovered for re-use and the waste separated from the flowback for disposal. The activities associated with appraisal are replicated for the production phase, but at different volume and intensity scales depending on the scenario of production, ranging from 5 tcf to 20 tcf of Economically Recoverable shale gas.

3.2.4 Decommissioning

On completion of production, gas-flow is suspended, surface equipment is disconnected and demobilisation proceeds. The decision to either suspend or permanently decommission (plug and abandon) is based largely on test results. Well suspension is affected by closing the valves on the wellhead to prevent product flow to surface; gauges are installed to detect possible changes in pressure that could be indicative of a leak. For final decommissioning, cementing of the well bore is undertaken from the furthest point to surface. This aims to ensure that all hydrocarbon- and water-bearing zones are isolated to prevent cross contamination or communication with shallow aquifers or the surface. The issue of well closure/decommissioning is critical and is implemented in accordance with industry best practice as described, for example, by American Petroleum Institute (2009) (see http://www.api.org/~/media/Files/Policy/Exploration/API_RP_51R.pdf).

If there is full decommissioning, in addition to well plugging, the wellhead and testing and production facilities are removed. Wellpad areas and access roads are rehabilitated to achieve pre-disturbance landform states, with vegetation re-established in accordance with EMPr specifications and relevant prescribed regulations. Baseline environmental studies undertaken in advance of exploration and production provide reference standards to be achieved through rehabilitation. The decommissioned well, along with one or more monitoring wells, are routinely inspected in accordance with prescriptive rules and EMPr commitments to ensure there is no sub-surface communication and subsequent groundwater contamination. In this regard, the period of operator liability extends as long as might be necessary (potentially several decades) in order to achieve compliance.

4. THE CENTRAL KAROO

4.1 The Sensitivity of the Receiving Environment

The Central Karoo is a special and even ‘magical’ place which has captured the hearts and minds of many people from around the world. The region includes relatively high levels of biodiversity (Holness et al., 2016), unique heritage features (Orton et al., 2016) and scenic hotspots (Oberholzer et al., 2016) which make it an attractive region to a growing niche tourism market (Toerien et al., 2016). The peace and tranquillity (‘The Nothingness’ or ‘Die Niks’) of the Central Karoo are especially important to tourists and their experience of the region (Toerien et al., 2016; Seeliger et al., 2016).

On the other hand, economic growth and adaptability to economic change varies across the Central Karoo. The region has high levels of poverty, inequality and limited opportunity for local inhabitants. Poverty rates in the Central Karoo are in the region of 30 – 60%, with high levels of inequality. Most of the Human Development Indices range between 0.5 and 0.6, which is fairly consistent with the national average for rural areas in South Africa. Dependency ratios (in other words, the non-working age population dependent on working age population) ranges from around 45 – 82% (Atkinson et al., 2016).

The Central Karoo is a semi-desert environment, with a mean annual precipitation that ranges from 100 mm in the west to 400 mm in the east. This assigns a premium value to freshwater resources that are critical, for example, for sustaining local communities and their livelihoods. Water availability in the Central Karoo is severely constrained. With surface water availability generally low, Central Karoo landowners are mainly reliant on groundwater resources for domestic, stock water supplies and the sustenance of local economic activity like agriculture (Hobbs et al., 2016).

The majority of the land in the Central Karoo is occupied by relatively large commercial farms used for domestic livestock grazing, with smaller areas used for game farming, communal farming or biodiversity protection. Agriculture in the western areas focuses on small livestock for meat and wool production, with a shift evident toward agri-processing and the use of crop types more resistant to lower rainfall (Burns et al., 2016).

The region is not a static system - its social, economic and biophysical characteristics are changing. For example, there are notable trends in human migration into and across the region (Atkinson et al., 2016), there are novel economic developments materialising, such renewable energy farms (van Zyl et al., 2016) and the SKA (Tiplady et al. 2016), there are increased tourism initiatives and land-use changes from traditional agriculture to game farming and eco-tourism enterprises (Toerien et al, 2016). Global trends, such as climate change, will also have impact on the Central Karoo as temperatures are expected to increase, in the region of 1-2° C, with a significantly higher number of very hot days likely to be experienced (temperatures are exceeding 35° Celsius) (Burns et al., 2016).

Based on a number of the special features of the Central Karoo, spatial sensitivity maps were developed for:

1.) Local community exposure to diminished air quality mapped around existing towns and populated areas which does not account for isolated populations, farms, homesteads etc. which may be encountered in the region (see Figure 4-1)
2.) Local community exposure to increased seismic activity (M>5) mapped around existing towns and populated areas which does not account for isolated populations, farms, homesteads etc. which may be encountered in the region (see Figure 4-2)
3.) Groundwater and surface water resources based on water supply wells and boreholes, distance to shallow groundwater, springs, watercourses, recharges zones, dykes and other geological features (see Figure 4-3)
4.) Biodiversity and ecology based on the outcomes of the Bioblitz, see Appendix 2, considering habitat for rare and endemic species, features that perform critical ecological functions such as wetlands, springs, Critical Biodiversity Areas, Protected Areas etc. (see Figure 4-4)
5.) Agriculture based on metrics calculated at a quaternary catchment scale for land capability, grazing land, surface water, rivers, dams, irrigated land and cultivated fields (see Figure 4-5)
6.) Tourism based on the number of enterprises in important town and scenic routes (see Figure 4-6)
7.) Visual, aesthetic and scenic resources based on topographic features, surface water, cultural landscapes, Protected Areas, human settlements, major roads, sites of optical and radio astronomy (see Figure 4-7)
8.) Heritage features based on archaeology (including graves) and palaeontological resources (see Figure 4-8)
9.) Electromagnetic and optical interference with the development of the SKA and existing Sutherland Large Telescope (SALT) (see Figure 4-9)

4.2 Spatial Sensitivity Analysis

Table 4–1: Rational and sensitivity class criteria for spatial sensitivity per topic

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
AIR QUALITY: LOCAL COMMUNITY EXPOSURE	
Proximity to towns / highly populated areas Protect against exposure to harmful air pollutants.	
Within 5 km	Very high
Within 10 km	High
Within 15 km	Medium
Beyond 15 km	Low
EARTHQUAKES: LOCAL COMMUNITY EXPOSURE	
Proximity to towns / highly populated areas Protect against loss of life and structural damage to buildings in towns densely populated and built-up environments.	
Within 10 km	Very high
Within 20 km	High
Within 30 km	Medium
Beyond 30 km	Low
GROUND- AND SURFACE WATER RESOURCES	
Water supply wells Protect current known water supply wells against contamination and/or over-abstraction, especially in areas dependent on groundwater and in view of climate variability and associated droughts.	Very high
Groundwater < 10 m Very susceptible to contamination due to shorter distance to saturated zone / water table.	Very high
Thermal springs Thermal springs usually closely associated with deeper geological structures: faults, folds, dykes.	Very high
Cold springs Possible vertical / horizontal connectivity between surface water and groundwater resources. Preferential pathways for contamination via associated	Very high

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
geological structures.	
Watercourses, wetlands, dry river beds and high flood risk areas High sensitivity in arid environments with high climatic variability, important / sole water supply in some areas.	**Very high**
Fold axis Possible preferential pathway via associated fracture zones.	**High**
Artesian boreholes Possible connection between deep and shallow aquifers and preferential pathways for contamination, apply precautionary principle.	**High**
Fault / shear zone Possible preferential pathway via associated fracture zones.	**High**
Undifferentiated geophysical anomaly Possible preferential pathway. Real extent of features unknown, therefore apply precautionary principle.	**High**
Artificial recharge zone Protect for possible future storage, groundwater storage areas will become more important in future in South Africa.	**High**
Kimberlite pipe Possible preferential pathway for contamination movement.	**Medium**
Dolerite dyke Possible preferential pathway for contamination movement.	**Medium**
Dolerite sills Possible preferential pathway for contamination movement.	**Medium**
Diatreme Represent possible preferential pathway for contamination movement.	**Medium**
BIODIVERSITY AND ECOLOGY	
Ecological and Biodiversity Importance and Sensitivity Class 1 Areas that contain extremely sensitive features, such as key habitat for rare, endemic or threatened species, or features that perform critical ecological functions. These sites are irreplaceable (i.e. no ecologically equivalent sites exist and there is no exchangeability between sites). • Wetlands, springs (including intact buffers) • Specific sites important for Threatened species and for range-restricted endemic or near-endemic species (fauna and flora) • High priority habitat for Threatened species or for range-restricted endemic or near-endemic species	**Very high**
Ecological and Biodiversity Importance and Sensitivity Class 2 Areas that contain highly sensitive features and/or features which are important for achieving targets for representing biodiversity and/or maintaining ecological processes. These areas represent the optimal configuration for securing the species, ecosystems and ecological processes of the Karoo.	**High**

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
• Rivers and associated habitats (including intact buffers) • Special habitats e.g. rocky outcrops, escarpment areas, riparian vegetation • Sites selected through a systematic biodiversity planning process to meet targets for terrestrial or aquatic ecosystems in an efficient configuration that aligns with other biodiversity features and priority areas Incorporates all FEPAs, both rivers and wetlands • Includes CBA 1 from relevant provincial biodiversity plans • Buffers around protected areas (intact areas) • United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve	
Ecological and Biodiversity Importance and Sensitivity Class 3 Other natural or semi-natural areas that do not contain currently known sensitive or important features, and are not required for meeting targets for representing biodiversity or maintaining ecological processes. • Severely modified areas that retain some importance for supporting ecological processes (e.g. agricultural fields within buffers around rivers and wetlands) • Natural habitat which is not irreplaceable and has not been selected as part of the optimal sites	**Medium**
Ecological and Biodiversity Importance and Sensitivity Class 4 Areas in which there is no remaining natural habitat, e.g. urban areas, larger scale highly degraded areas, large arable intensively farmed lands • Areas that have been severely or irreversibly modified and that are not important for supporting provision of ecological processes	**Low**
AGRICULTURE (Features equally weighted to determine sensitivity at quaternary catchment scale)	
Soil, Climate and Terrain Protect areas with high land capability for possible agricultural production.	
Land capability evaluation classes 8 - 10	**Very high**
Land capability evaluation classes 6 - 7	**High**
Land capability evaluation classes 3 - 5	**Medium**
Land capability evaluation classes 1 - 2	**Low**
Grazing Land Protect areas with good grazing potential	
2.5 – 10 Ha/LSU	**Very High**
11 – 30 Ha/LSU	**High**
31 – 60 Ha/LSU	**Medium**

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
61 – 140 Ha/LSU	Low
Surface water (Rivers and dams) Protect water resources for agricultural use	
Rivers	
>201 km per quaternary catchment	Very High
101 – 200 km per quaternary catchment	High
51 – 100 km per quaternary catchment	Medium
0 – 50 km per quaternary catchment	Low
Dams	
14 – 29% per quaternary catchment	Very High
2 – 4% per quaternary catchment	High
1 - 1.9% per quaternary catchment	Medium
<1% per quaternary catchment	Low
Irrigated land Protect irrigated land	
803 – 4077 ha per quaternary catchment	Very High
154 – 802 ha per quaternary catchment	High
25 – 153 ha per quaternary catchment	Medium
0 – 24 ha per quaternary catchment	Low
Cultivated Fields Protect cultivated fields	
1075 – 4077 ha per quaternary catchment	Very High
1074 – 272 ha per quaternary catchment	High
271 – 58 ha per quaternary catchment	Medium

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
0 – 57 ha per quaternary catchment	Low
TOURISM	
Mountain passes and 'poorts' Protect integrity of tourism infrastructure and experiences	Very high
Tourism routes Protect integrity of tourism infrastructure and experiences	
N9	Very high
N1 and N10	High
Tourism Towns Protect integrity of tourism infrastructure and experiences	
Graaff-Reinet Nieu-Bethesda, Prince Albert, Sutherland	Very high
Beaufort-West, Carnarvon, Colesberg, Cradock, Jansenville, Laingsburg, Loxton, Merweville, Middelburg, Murraysburg, Pearston, Queenstown, Richmond, Somerset East, Victoria West, Williston,	High
Aberdeen, Burgersdorp, Fort Beaufort, Fraserburg, Hofmeyr, Klipplaat, Lady Frere, Noupoort, Steynsburg	Medium
VISUAL, AESTHETIC AND SCENIC RESOURCES	
Topographic features Relates to significant landscape features of scenic or natural heritage value.	
Actual feature / receptor	Very high
Within 500 m	High
Within 1 km	Medium
Beyond 1 km	Low
Major rivers, water bodies (vleis, wetlands, dams, pans) Scenic and recreational value.	
Actual feature / receptor	Very high
Within 500 m	High
Within 1 km	Medium

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
Beyond 1 km	Low
Cultural landscapes (incl. cultivated lands) Rural scenic value and possible historical or heritage value.	
Actual feature / receptor	Very high
Within 500 m	High
Within 1 km	Medium
Beyond 1 km	Low
National Parks High wilderness and scenic value, including dark skies at night. Sensitive tourist receptors.	
Actual feature / receptor	Very high
Within 5 km	High
Within 7.5 km or viewshed	Medium
Beyond 7.5 km	Low
Nature Reserves (Provincial and Municipal reserves) Wilderness and scenic value, including dark skies at night. Sensitive visitor receptors.	
Actual feature / receptor	Very high
Within 5 km	High
Within 7.5 km or viewshed	Medium
Beyond 7.5 km	Low
Private reserves (incl. game farms, tourist accommodation) Wilderness and scenic value. Sensitive visitor receptors. Important for local tourism industry.	
Actual feature / receptor	Very high
Within 2.5 km	High
Within 5 km or viewshed	Medium
Beyond 5 km	Low

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
Human settlements (towns and villages, excl. farmsteads, rural kraals) Visually sensitive residents and visitors. Relates to property values. Subject to Integrated Development Plans, zoning schemes and bylaws.	
Actual feature / receptor	**Very high**
Within 5 km	**High**
Within 7.5 km or viewshed	**Medium**
Beyond 7.5 km	**Low**
National and Provincial roads (major arterial routes) Visually sensitive commuters, residents and visitors within the view corridor.	
Actual feature / receptor	**Very high**
Within 1 km	**High**
Within 2.5 km	**Medium**
Beyond 2.5 km	**Low**
Scenic routes, mountain passes and 'poorts' Visually sensitive visitors and tourists within the view corridor. Possible historical or heritage value.	
Actual feature / receptor	**Very high**
Within 2.5 km	**High**
Within 5 km or viewshed	**Medium**
Beyond 5 km	**Low**
Passenger rail lines (commuter and tourist routes) Visually sensitive commuters and tourists within the view corridor.	
Actual feature / receptor	**Very high**
Within 1 km	**High**
Within 2.5 km	**Medium**
Beyond 2.5 km	**Low**
SALT	

TOPIC, RATIONALE AND CRITERIA	SENSITIVITY
The Sutherland Core Astronomy Advantage Area. All land in the Northern Cape within an annulus of inner radius 3 km and outer radius 75 km centered on the dome of the SALT	**Very high**
HERITAGE	
Archaeology (including graves) Protect archaeological heritage resources.	
Uplands: Variable topography, rock outcrops, river valleys, cliffs and high lying interior plateaus with dolerite dykes and pans	**High**
Low foothills: Base of the escarpment where it is not mountainous yet and it's also not flat plains	**Medium**
Plains: Very flat land that stretches with little interruption and no topography	**Low**
Palaeontology Protect palaeontological heritage resources.	
High likelihood of fossiliferous geological units based on the South African Heritage Resources Information System (SAHRIS)	**High**
Medium likelihood of fossiliferous geological units SAHRIS	**Medium**
Low likelihood of fossiliferous geological units SAHRIS	**Low**
ELECTROMAGNETIC INTERFERENCE	
Separation distances from SKA antennae Protect radio astronomy from interference	
22 km	**Very high**
29 km	**High**
33 km	**Medium**
38 km	**Low**

4.2.1 Sensitivity of inhabitants to diminished air quality

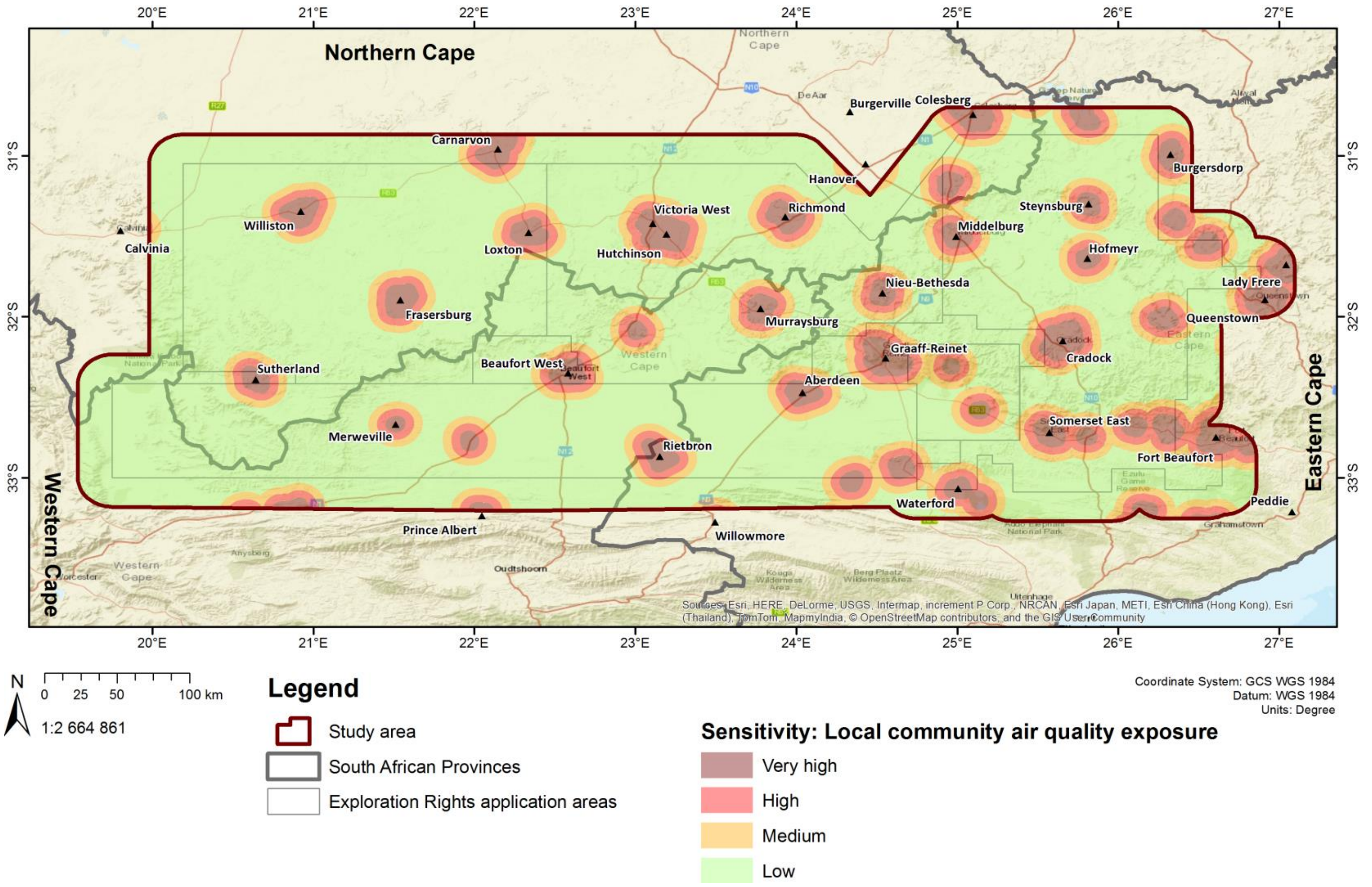

Figure 4–1: The sensitivity of local community exposure to diminished air quality mapped around existing towns and populated areas know at this GIS scale. The map does not account for isolated and rural populations on farms, homesteads which will be encountered in the Central Karoo and will have to be assessed on a case by case basis.

4.2.2 *Sensitivity of inhabitants to earthquakes*

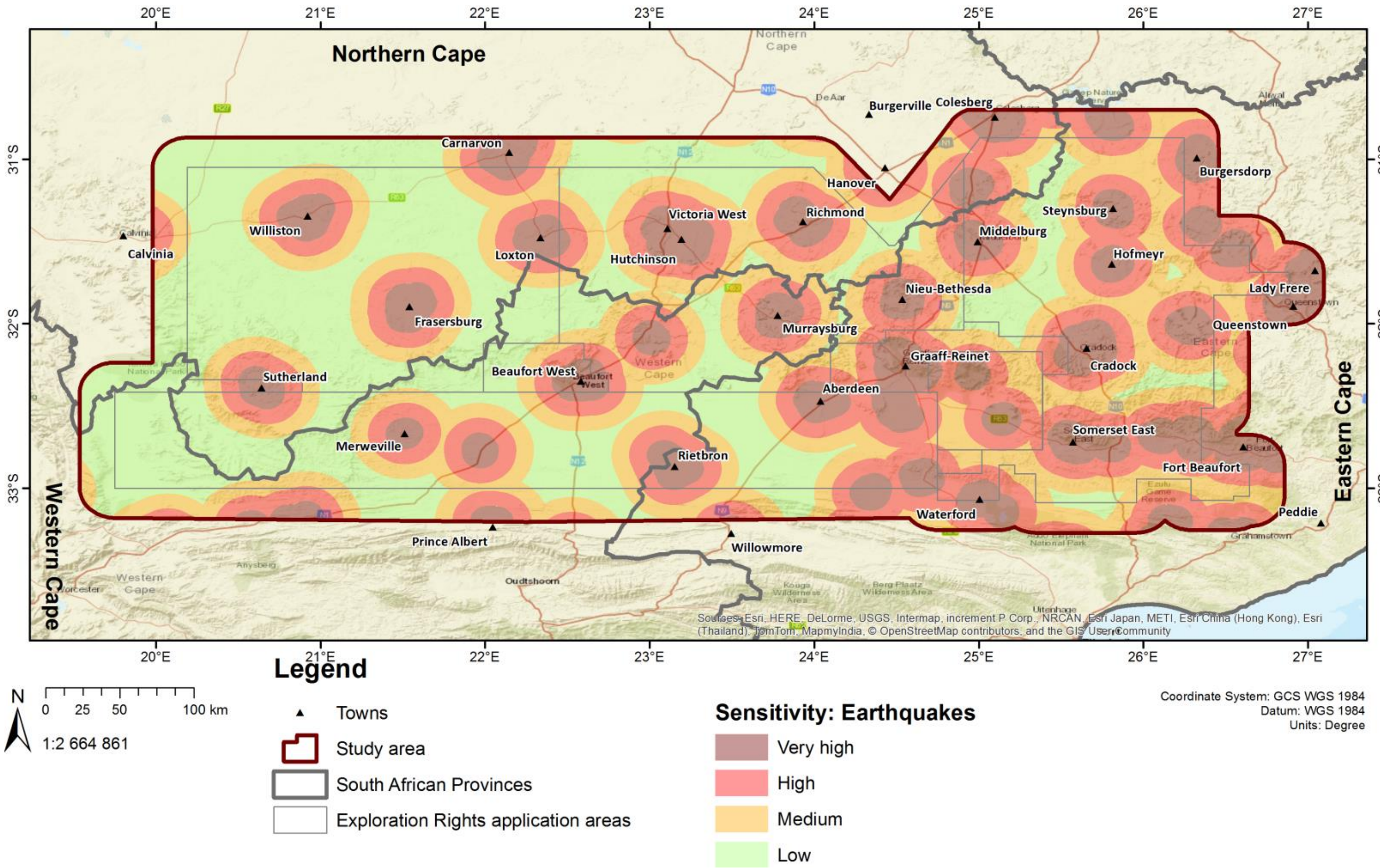

Figure 4–2: Local community exposure to increased seismic activity (M>5) mapped around existing towns and populated areas known at this scale. The map does not account for isolated and rural populations on farms, homesteads which will be encountered in the Central Karoo and will have to be assessed on a case by case basis.

4.2.3 Groundwater and Surface Water

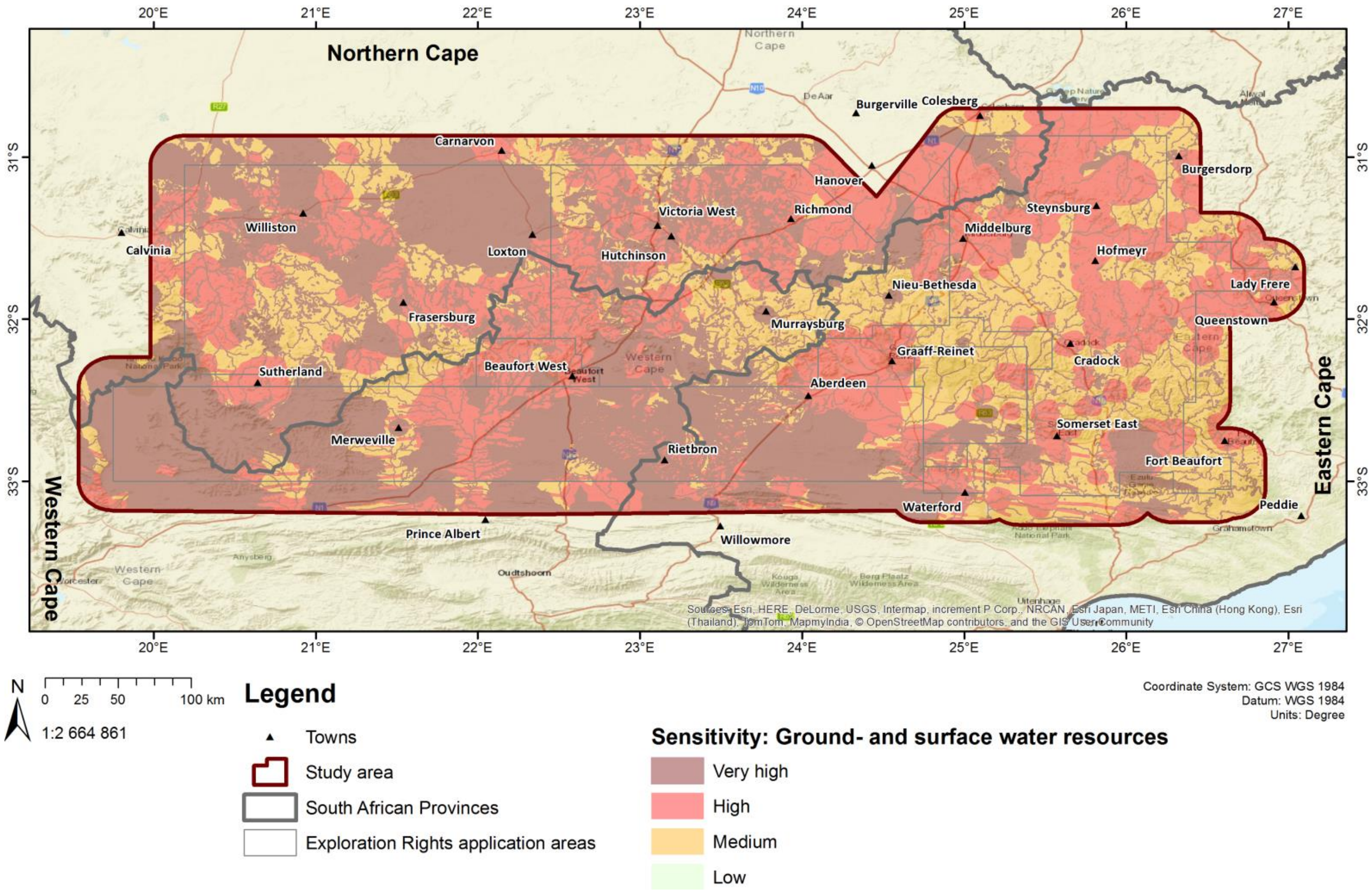

Figure 4–3: Groundwater and surface water resources based on water supply wells and boreholes, distance to shallow groundwater, springs, watercourses, recharges zones, dykes and other geological features.

4.2.4 *Biodiversity and ecology*

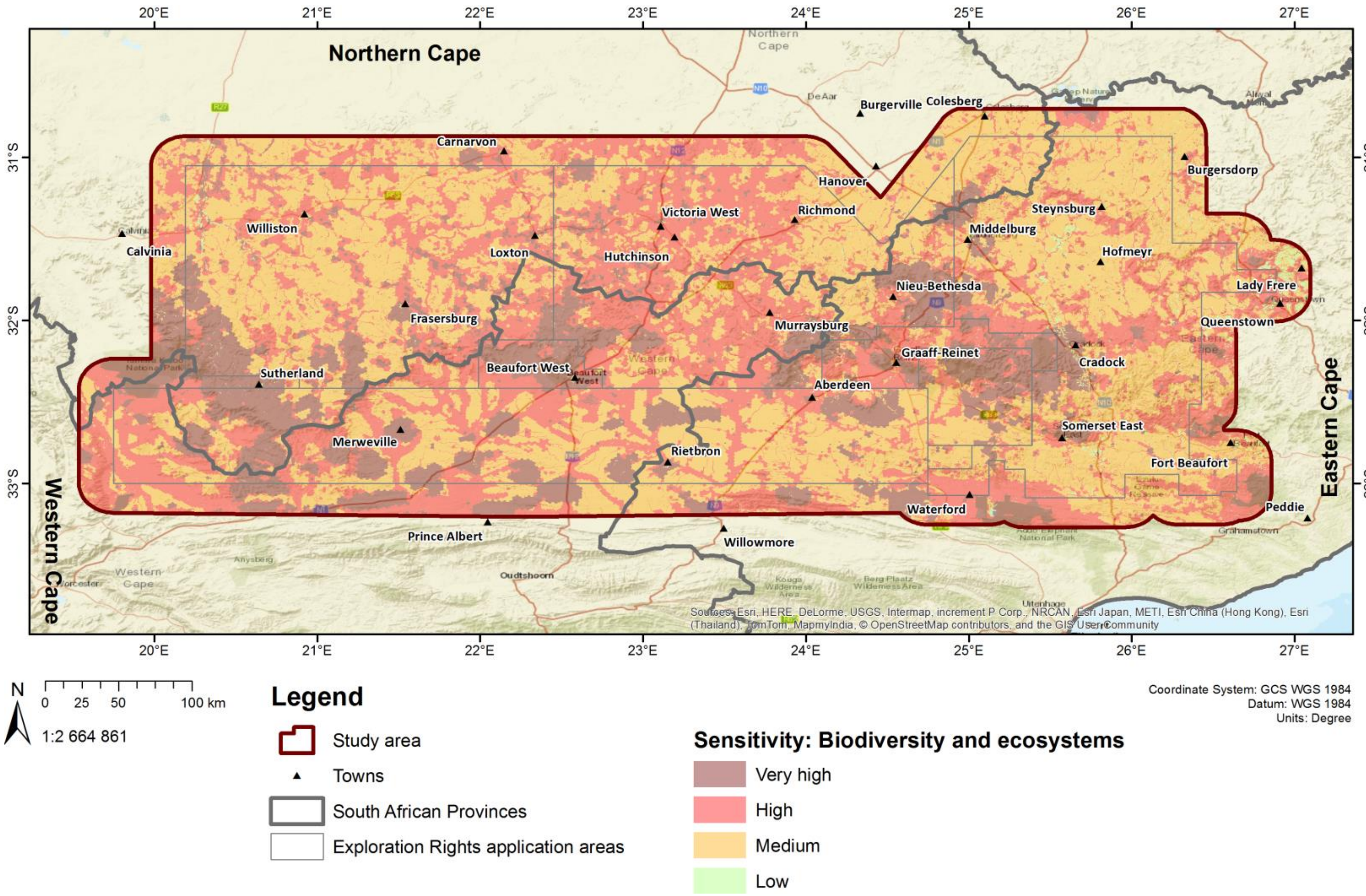

Figure 4–4: Biodiversity and ecology based on the outcomes of the Bioblitz, see Appendix 2, considering habitat for rare and endemic species, features that perform critical ecological functions such as wetlands, springs, Critical Biodiversity Areas and Protected Areas.

4.2.5 *Agriculture*

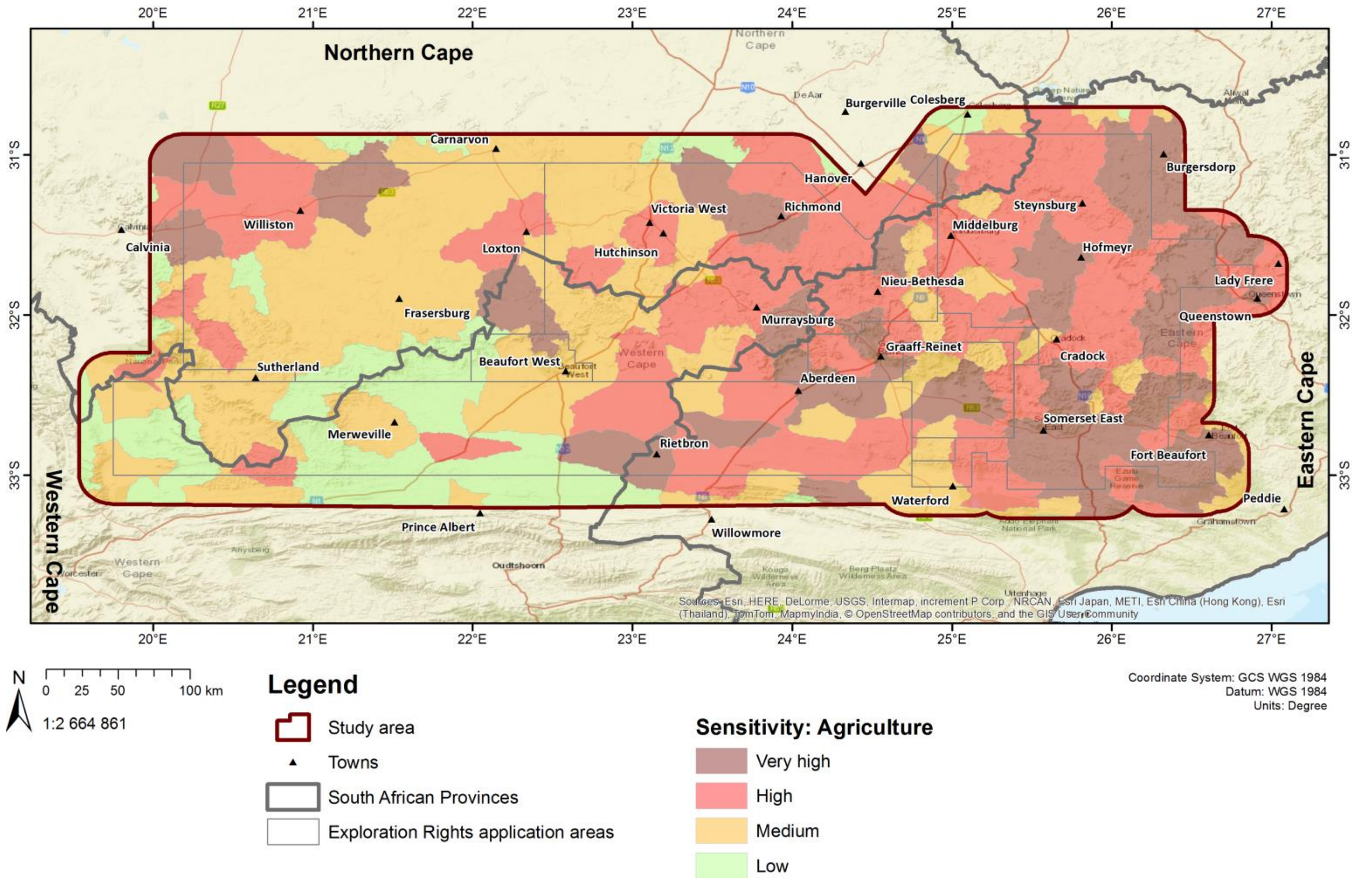

Figure 4–5: Agriculture based on metrics calculated at a quaternary catchment scale for land capability, grazing land, surface water, rivers, dams, irrigated land and cultivated fields.

4.2.6 Tourism

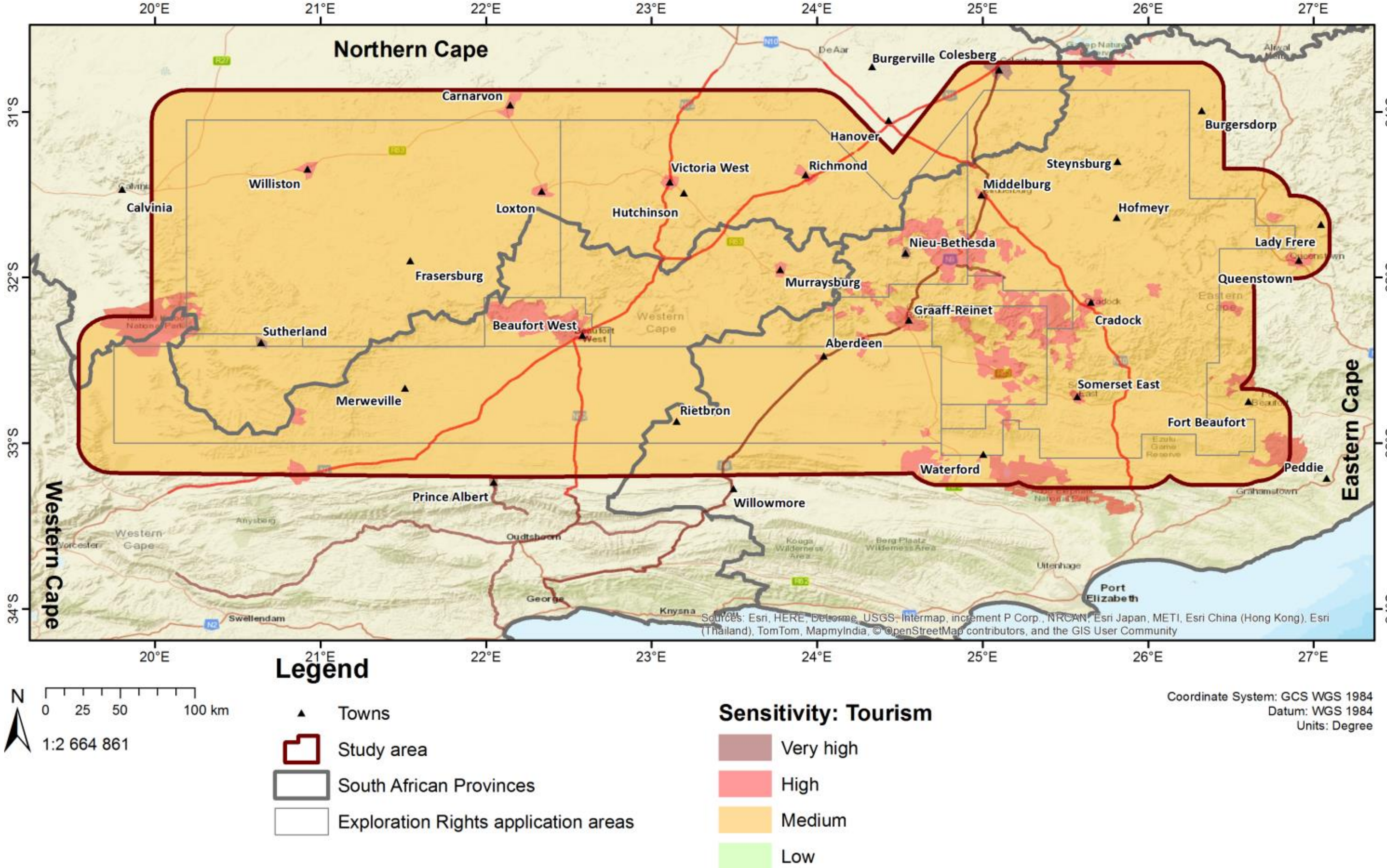

Figure 4–6: Tourism based on the number of enterprises in important town and scenic routes.

4.2.7 Visual, aesthetic and scenic resources

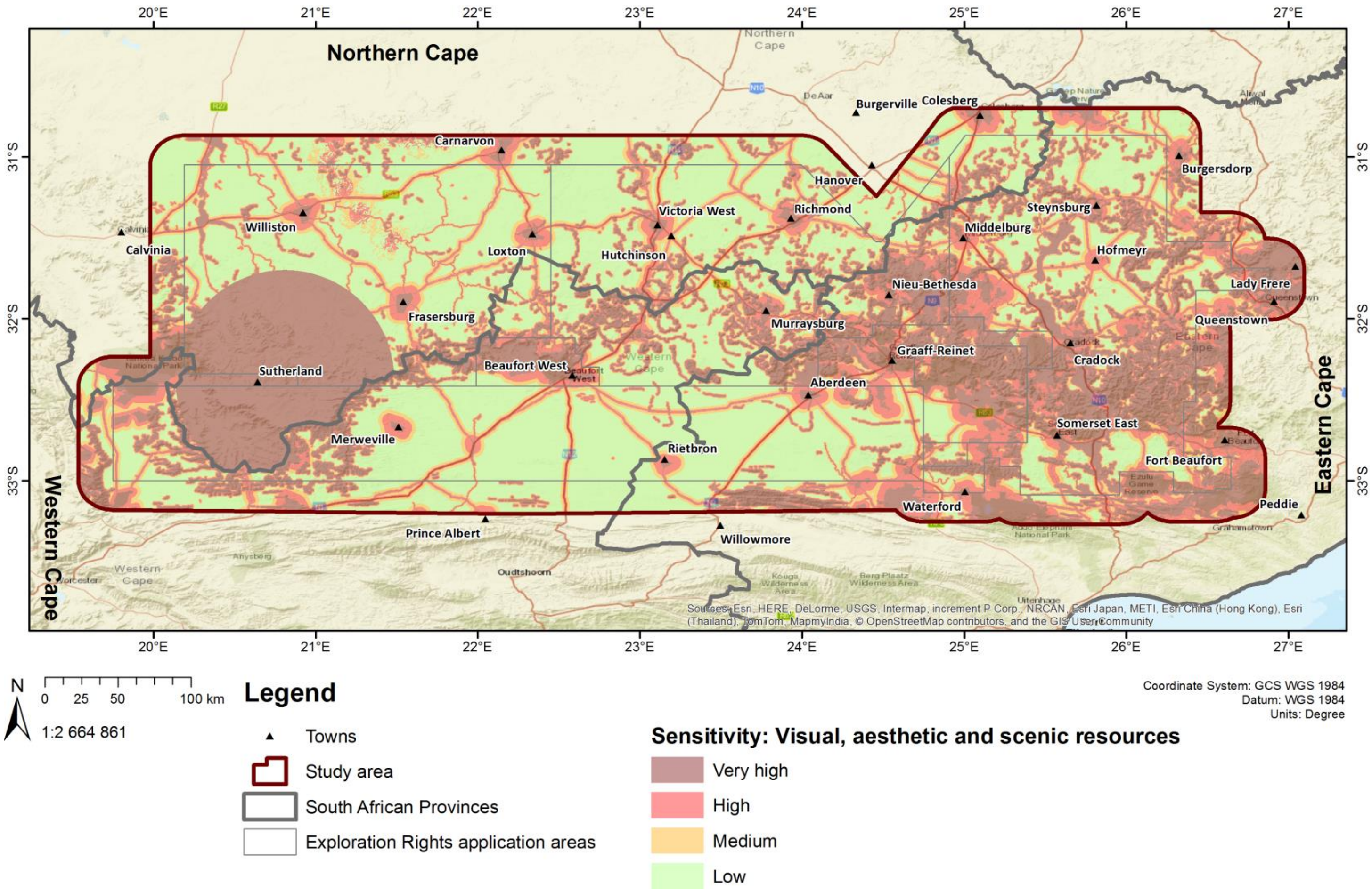

Figure 4–7: Visual, aesthetic and scenic resources based on topographic features, surface water, cultural landscapes, Protected Areas, human settlements, major roads, sites of optical astronomy – the Sutherland Large Telescope (SALT).

4.2.8 Heritage (archaeology and palaeontology)

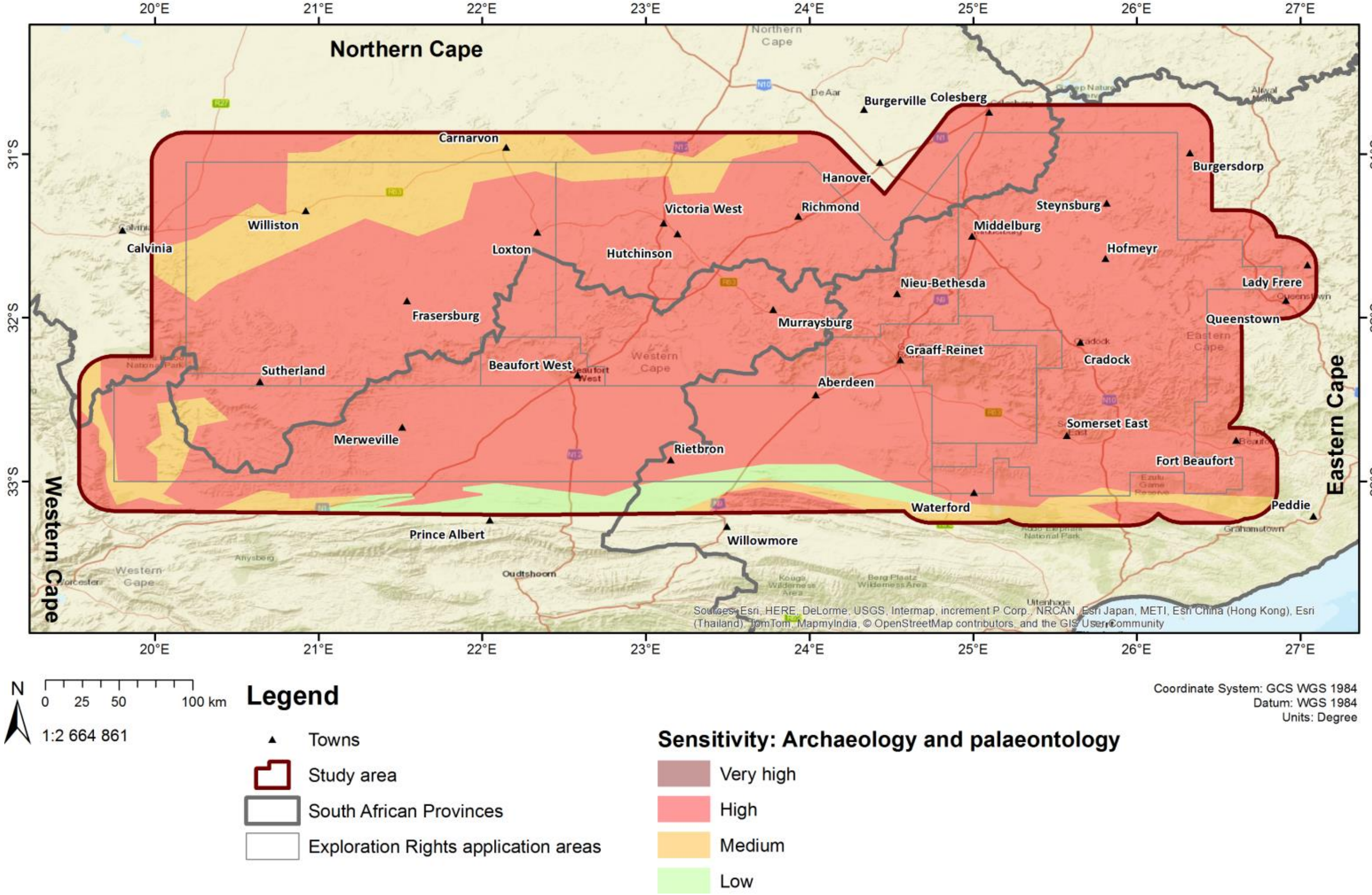

Figure 4–8: Heritage features based on archaeology (including graves) and palaeontological resources.

4.2.9 *Electromagnetic Interference with Astronomy*

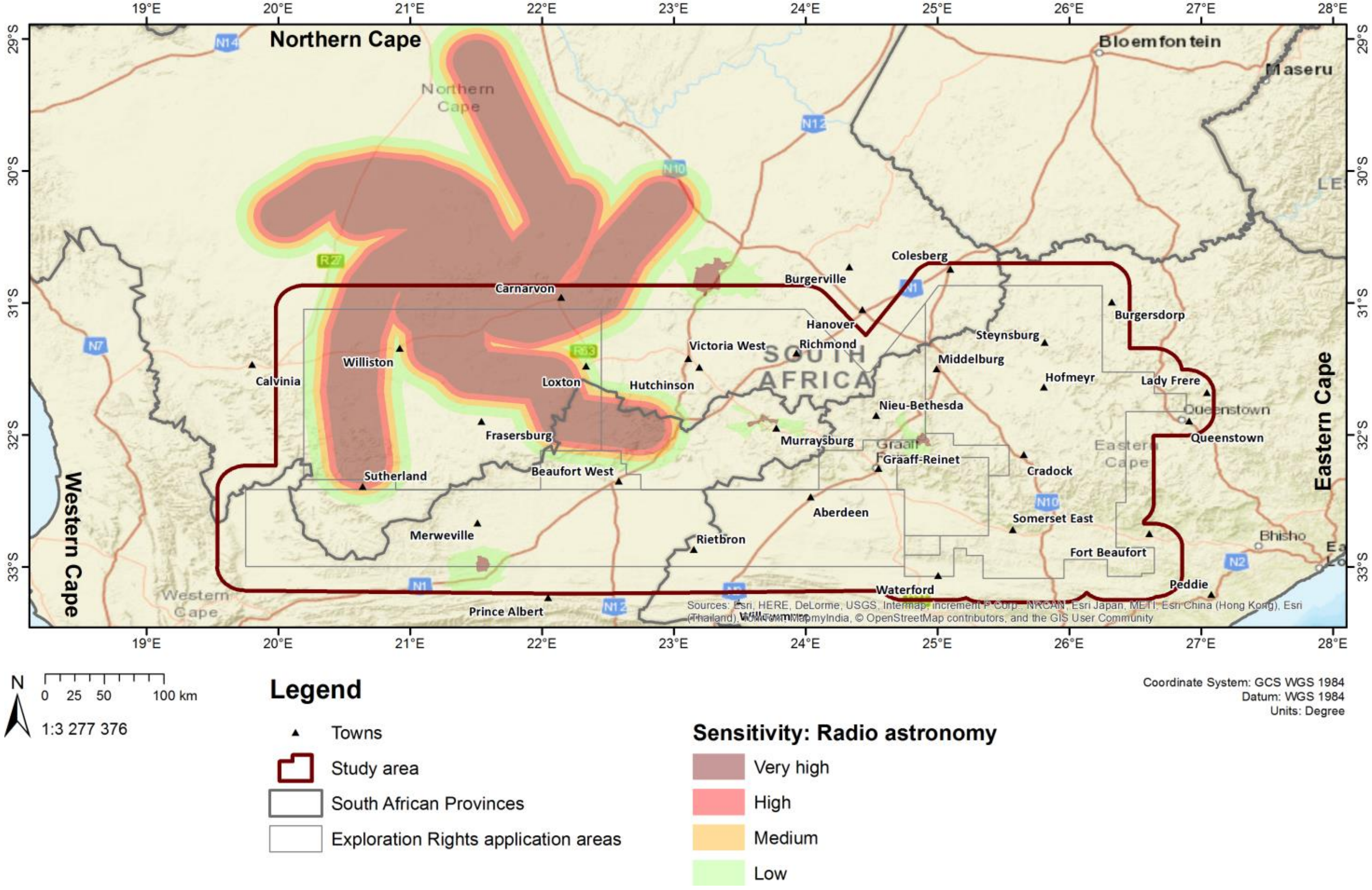

Figure 4–9: Electromagnetic interference based on full phase development of the SKA.

5. SUMMARY OF KEY IMPACTS AND RISKS

5.1 Risk Assessment Approach

The approach to the Scientific Assessment phase was based on the concept of 'risk', with specific spatial relevance to sensitive receiving environments in the Central Karoo as depicted in the previous section. The risk assessment approach was loosely based on the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change which defines risk as "the probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur" (IPCC, 2014). Risk was determined by estimating the likelihood of events or trends occurring, in relation to their consequences (Risk= likelihood x consequence, ranging from Very Low to Very High risk) (see Figure 5-1).

Consequences were calibrated for each topic based on quantitative descriptions of the consequence terms ranging from slight to extreme, which ensured consistency in the manner in which risks were measured, enabled integration across different topics disciplines, and provided a common conceptual and spatial understanding of risks (Table 5-1). The allocation of consequence levels depended on three things:

- ***Exposure***: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected;
- ***Impact***: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources
- ***Sensitivity***: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Risks were assessed with- and without mitigation, across the four scenarios, with 'Without mitigation' assuming inadequate governance capacity, weak decision-making and non-compliance with regulatory requirements, while 'With mitigation' assumed effective implementation of best practice principles, adequate institutional governance capacity and responsible decision-making. The assessment of the four scenarios, both with- and without mitigation led to increased scenario variance and provides stakeholders and decision-makers with practical estimation of the importance of strong governance and institutional functionality.

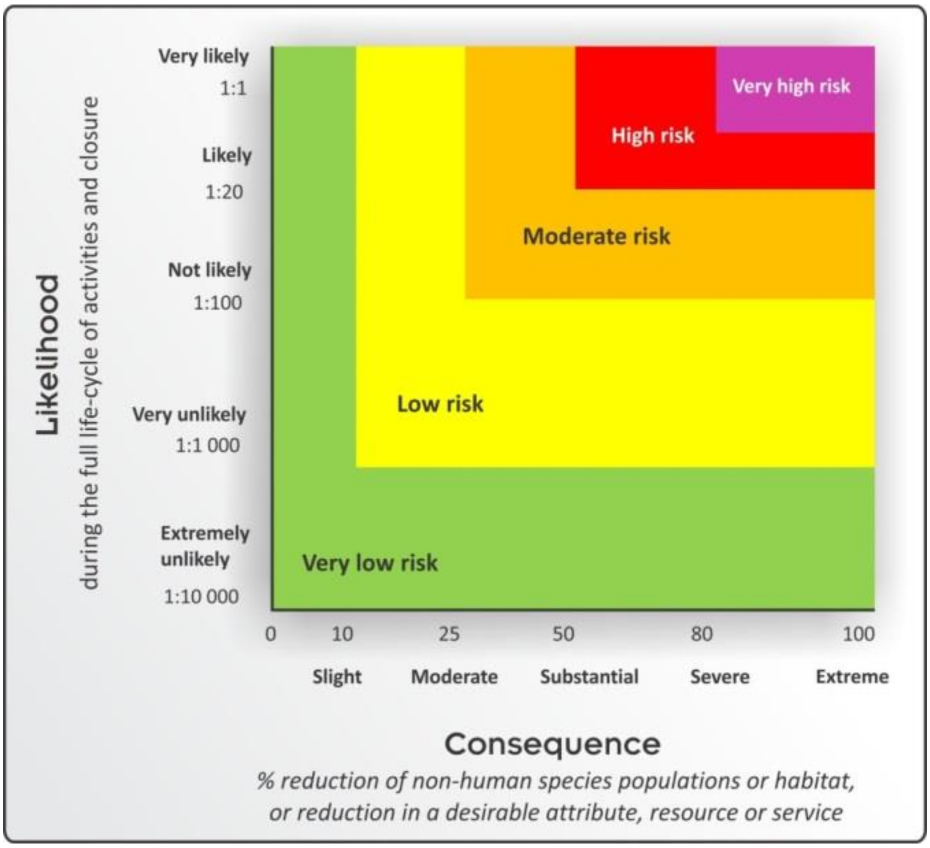

Figure 5–1: Risk is qualitatively measured by multiplying the likelihood of an impact by the severity of the consequences to provide risk rating ranging from very low, low, moderate, high and very high.

The risk assessment was based on an interpretation of existing spatial and non-spatial data in relation to the proposed activity, to generate an integrated picture of the risks related to a specified activity in a given location, with and without mitigation. Risk was assessed for each significant stressor (e.g. physical disturbance), on each different type of receiving entity (e.g. the rural poor, a sensitive wetland etc.), qualitatively (undiscernible, Very Low, Low, Moderate, High, Very High) against a predefined set of criteria (Table 5-1).

Table 5–1: Predefined set of criteria applied across the topics of the Scientific Assessment

Risk category	Definition
No discernible risk	Any changes that may occur as a result of the activity either reduce the risk or do not change it in a way that can be differentiated from the mean risk experienced in the absence of the activity.
Very low risk	Extremely unlikely (<1 chance in 10 000 of having a consequence of any discernible magnitude); or if more likely than this then the negative impact is noticeable but slight, i.e. although discernibly beyond the mean experienced in the absence of the hazard, it is well within the tolerance or adaptive capacity of the receiving environment (for instance, within the range experienced naturally, or less than 10%); or is transient (< 1 year for near-full recovery).
Low risk	Very unlikely (<1 chance in 100 of having a more than moderate impact); or if more likely than this, then the impact is of moderate consequence because of one or more of the following considerations: it is highly limited in extent (<1% of the area exposed to the hazard is affected); or short in duration (<3 years), or with low effect on resources or attributes (<25% reduction in species population, resource or attribute utility).
Moderate risk	Not unlikely (1:100 to 1:20 of having a moderate or greater impact); or if more likely than this, then the consequences are substantial but less than severe, because although an important resource or attribute is impacted, the effect is well below the limit of acceptable change, or lasts for a duration of less than 3 years, or the affected resource or attributes has an equally acceptable and un-impacted substitute.
High risk	Greater than 1 in 20 chance of having a severe impact (approaching the limit of acceptable change) that persists for >3 years, for a resource or attribute where there may be an affordable and accessible substitute, but which is less acceptable.
Very high risk	Greater than even (1:1) chance of having an extremely negative and very persistent impact (lasting more than 30 years); greater than the limit of acceptable change, for an important resource or attribute for which there is no acceptable alternative.

Chapters 2-17 of the Scientific Assessment phase undertook the risk assessment, based on the scenarios and activities (see Section 2). A number of impacts were identified associated with the seventeen topics and assessed in terms of the risk approach described. Following the results of the extensive risk assessment, 38 impacts are considered to have either a Very High or High risk before mitigation; or alternatively have a Moderate risk even after mitigation is applied. The 38 impacts identified by the assessment should provide the basis for any future site specific assessments which need to be undertaken for shale gas exploration and production activities in the near and long term future. These impacts are summarised as Table 5-2 below.

Table 5–2: A summary of the impacts, per scenario, according to location, where the risk without mitigation has been assessed as High or Very High and where Moderate risk persists after mitigation.

Topic	No	Impact	Scenario	Location	*Risk without mitigation*	*Risk with mitigation*
Energy planning	1	Energy infrastructure that does not match domestic shale gas supply	Big Gas	National	**High**	**Moderate**
Energy planning	2	Availability of sufficient network capacity to evacuate gas and gas fired power generation	Big Gas	National	**High**	**Very low**
Air quality	3	Exposure to air pollutants from flaring, dust and other activities that diminish air quality	Exploration Only, Small Gas and Big Gas	On wellpad	**High**	**Moderate**
GHG emissions	4	Fugitive GHG emissions from production well pads and supporting gas infrastructure	Big Gas	Local, regional and global	**High**	**Moderate**
Seismicity	5	Occurrence of a damaging earthquake M>5 causing damage to heritage resources and human well-being through building collapses	Big Gas	Within 20 km of towns	**Moderate**	**Moderate**
Groundwater	6	Reduced water availability of groundwater for people and other economic activities in the Central Karoo	Big Gas	In vicinity of production wellfield	**Very High**	**High**
			Small Gas		**High**	**High**
Groundwater	7	Contamination of groundwater resources caused by a loss of well integrity and via preferential pathways caused by hydraulic fracturing	Big Gas	In the vicinity of high sensitivity groundwater resources	**Moderate**	**Moderate**
Surface-water	8	Physical disturbance of watercourses during the construction of roads, well pads and other supporting infrastructure	Small and Big Gas	Much of the study area and regions of high flood risk	**High**	**Moderate**
Surface-water	9	Contamination of surface water resources as a result of spills and flowback discharge from the well pad	Small	In vicinity of watercourses and pans	**High**	**Low**
			Big Gas		**High**	**Moderate**
Surface-water	10	Contamination of surface resources as a result of contact with contaminated groundwater	Small and Big Gas	Springs, borehole-fed reservoirs, shallow aquifers	**High**	**Moderate**
Waste	11	Human exposure to hazardous and domestic waste and additional sewage loads caused by increased activities in the Central Karoo	Small and Big Gas	Near disposal or spillage site, landfills and wastewater treatment works	**High**	**Low**

Topic	No	Impact	Scenario	Location	*Risk without mitigation*	*Risk with mitigation*
Biodiversity	12	Impacts on ecological and biodiversity processes in the Central Karoo	Small Gas	Very High sensitivity areas	**High**	**Moderate**
			Big Gas	Very High sensitivity areas	**Very high**	**Moderate**
			Big Gas	High sensitivity areas	**High**	**Moderate**
Agriculture	13	Impacts of farming and agriculture as a result of shale gas exploration and production activities	Small Gas	Very High agricultural sensitivity	**High**	**Moderate**
			Big Gas		**Very High**	**High**
			Big Gas	High agricultural sensitivity	**High**	**Moderate**
			Big Gas	Medium agricultural sensitivity	**High**	**Moderate**
			Big Gas	Low agricultural sensitivity	**High**	**Moderate**
Tourism	14	Reduction in tourist numbers and enterprises in the Central Karoo and financial losses to the rural economy	Small Gas	Very High sensitivity	**High**	**Moderate**
			Big Gas		**Very high**	**High**
			Small Gas	High Sensitivity	**High**	**Moderate**
			Big Gas		**High**	**High**
			Small Gas	Medium Sensitivity	**High**	**Moderate**
			Big Gas		**High**	**High**
Economics	15	Impacts to public finances, including the budgets of Municipalities, associated with environmental externality costs	Big Gas	Local and regional	**High**	**Moderate**
Economics	16	Impacts to property values near wellpads in the Central Karoo	Big Gas	Wellpads where drilling occurs	**High**	**Moderate**
Social fabric	17	Human in-migration into the Central Karoo	Small Gas	In the region of wellfield development	**High**	**High**
			Big Gas		**Very High**	**High**
Social fabric	18	Altered physical security for residents and peoples working in the region	Exploration Only		**High**	**Moderate**
			Small Gas		**Very high**	**High**
			Big Gas		**High**	**High**
Social fabric	19	Altered social and new power dynamics	Exploration Only		**High**	**High**
			Small Gas		**High**	**High**
			Big Gas		**High**	**Moderate**
Human health	20	Exposure to pollution through water and air contamination	Small and Big Gas	Local community water sources	**High**	**Moderate**
Human health	21	Worker physical injury through contact with traffic or machinery	Small and Big Gas	On the wellpads or near roads	**High**	**Moderate**
Sense of place	22	Loss of sense of place to farmers, farm labourers, emerging farmers and land claimants	Big gas	The Central Karoo	**High**	**Moderate**

Topic	No	Impact	Scenario	Location	*Risk without mitigation*	*Risk with mitigation*
Sense of place	23	Loss of sense of place to Karretjie People	Big gas		**High**	**Moderate**
Sense of place	24	Loss of sense of place to lifestyle farmers, creatives, retirees, tourists and scientists	Small Gas		**High**	**Moderate**
Sense of place	25	Loss of sense of place to lifestyle farmers, creatives, retirees, tourists and scientists	Big Gas		**Very high**	**Moderate**
Sense of place	26	Loss of sense of place to shale gas development, low-skilled workers, unemployed youth	Reference Case		**Very high**	**Moderate**
Visual	27	Visual intrusion of shale gas development and associated activities into the landscape	Big Gas	Low visual sensitivity areas	**High**	**Moderate**
			Small Gas	Moderate visual sensitivity areas	**High**	**Moderate**
			Big Gas		**Very high**	**High**
			Exploration Only	Very High and High visual sensitivity areas	**High**	**Moderate**
			Small Gas		**Very high**	**High**
			Big Gas		**Very high**	**High**
Heritage	28	Impacts on built heritage, monuments and memorials - all impacts except earth tremors	Big Gas	High sensitivity areas - land less than 10 km from towns and settlements	**High**	**Moderate**
	29	Impacts on built heritage, monuments and memorials - earth tremors only	Big Gas	Central Karoo	**High**	**High**
	30	Impacts on archaeology and graves	Exploration Only	High sensitivity areas - uplands and areas with highly variable topography	**High**	**Low**
			Small Gas		**High**	**Low**
			Big Gas		**High**	**Low**
			Big Gas	Medium and low sensitivity areas - foothills and areas with undulating topography	**High**	**Low**
	31	Impacts on cultural landscapes	Small Gas	Central Karoo	**High**	**Moderate**
			Big Gas	Central Karoo	**Very high**	**High**
Noise	32	Disturbance to humans due to wellpad noise	Small Gas	Within 5 km of wellpads	**High**	**Moderate**
			Big Gas		**Very high**	**High**
	33	Disturbance to humans due to road traffic noise	Big Gas	Within 3 km of remote, quiet roads	**High**	**Moderate**
	34	Disturbance to sensitive species	Big Gas	Within 3 km of wellpads and remote, quiet roads	**High**	**Moderate**
SKA	35	Electromagnetic interference impact on radio	Exploration Only, Small	Very High sensitivity areas	**Very high**	**Moderate**

Topic	No	Impact	Scenario	Location	*Risk without mitigation*	*Risk with mitigation*
		astronomy	Gas, Big Gas			
			Exploration Only	High sensitivity areas	**High**	**Very low**
			Small Gas		**High**	**Low**
			Big Gas		**Very high**	**Moderate**
			Big Gas	Medium sensitivity areas	**High**	**Low**
Spatial planning	36	Local road construction and resource implications	Big Gas	Access road linkages	**High**	**Moderate**
	37	Pressure on regional road infrastructure	Big Gas	Along major regional transport corridors	**Very high**	**Moderate**
	38	Spatial and development planning, land use management and governance capacity	Reference Case	The Central Karoo	**High**	**Low**
			Exploration Only, Small Gas, Big Gas		**High**	**Moderate**

5.2 The Meaning of Mitigation

The 'mitigation' referred to in Table 5-2, is described at length in in each of the Scientific Assessment chapters which were developed as part of Phase 2 of the SEA, with various mitigation strategies proposed from the strategic level of assessment, down to site specific mitigation actions which will reduce the risk profile of the associated impact. The focus of this report, is on strategic mitigation actions which are provided via the proposed strategic exclusion areas (with an indication of which risks are being mitigated in Table 6-1), the proposed site specific exclusion areas (with an indication of which risks are being mitigated in Table 6-3), the levels of acceptable change (i.e. establishing a threshold reduces risk and hence is a mitigation action in Table 6-4) and the strategic management actions for government, which are a series of steps to reduce risk, hence are considered as mitigation actions (Table 6-5). At the strategic level of assessment, if these mitigation actions are complied with, the risk profile will substantially reduce and conform to the tents of the Precautionary Principle as envisaged in the NEMA.

5.3 The Precautionary Principle

The precautionary principle in the context of the protection of environmental rights is essentially about the assessment and management of risk. Section 2(4)(a)(vii) of NEMA applies to any organ of state that takes a decision in terms of a statutory provision connected to the protection of the environment. It requires a risk-averse and cautious approach that takes into account the limits of current knowledge about the consequences of decisions and actions. The precautionary principle provides for policy and political factors to be considered for decision making in the face of uncertainty (DEA&DP, 2012).

There is increasing support for placing the burden of proving the acceptability of a development on the applicant, and not the person arguing that it is environmentally undesirable, when there is a threat. If a proponent of a plan, programme or project fails to discharge this burden of proof, this does not necessarily mean that the plan, programme or project must be refused. It merely requires that the decision-maker in making his/her decision must, if no information has been presented to indicate otherwise, assume that there shall be serious or irreversible environmental damage (DEA&DP, 2012).

The precautionary principle is consistent with good science and good public policy, because it acknowledges the inherent uncertainty and limitations in our understanding of complex risks challenges. Therefore the precautionary principle enjoins policy-makers, scientists, members of the community etc. to develop new methods and tools to characterise these threats and focuses our attention on opportunities for prevention and innovation. The precautionary principle acknowledges that public environmental decisions in the face of great uncertainty should be informed by science, but in spite of that also acknowledges that environmental decisions are ultimately deeply political in essence. The precautionary principle implores those who are engaged in policy-making on the environment, given its complexity, to take ethical decisions based on values, accountability, democratic principles and probity. Given the arguments and facts in support of the precautionary principle, science and the precautionary principle are complementary to one another.

5.4 Spatial Extent of the Risk Assessed

Sensitivity maps were generated and are expressed in the Section 4.2. Building on this delineation of different receiving environments, an integrated risk model was developed, per scenario with- and without mitigation, based on the allocation of sensitivity ratings to geographically distinguishable receiving environments and the determination of risk profiles for these sensitive areas of the receiving environment.

Spatially explicit risk profiles were then overlayed and depicted using the ‘maximum rule’ to prioritise the highest risk areas over those of lower risk (Figure 5-2). The purpose of the risk modelling exercise is to demonstrate the evolution of the risk profile across the scenarios considered, which accounts for the full life-cycle of shale gas exploration and production activities, from cradle-to-grave, and to test the efficacy of mitigation actions in reducing risks. The purpose of the risk model is not to determine areas which should be excluded from shale gas exploration and production activities in the future, although status quo sensitivity mapping may reveal this with relatively high degrees of confidence (see Sections 4.2 and 6.1.1.1).

Table 5–3: Topics with spatially explicit risk profiles used to develop the integrated risk ‘picture’.

Topic	No.	Impact	Spatial unit
Air quality	3	Local community exposure to air pollutants	Sensitive areas identified as being within 10 km of towns
Earthquakes	5	Damaging earthquakes induced by hydraulic fracturing	Sensitive areas identified as a being within 20 km of towns
*Water**	7	Contamination of groundwater resources caused by a loss of well integrity and via preferential pathways caused by hydraulic fracturing	Water resource sensitivity maps developed based on legislated and proposed setbacks from surface and groundwater resources and associated geological structures
	8	Physical disturbance of watercourses and contamination of surface water resources through flowback discharge and contact with contaminated groundwater	

	9	Contamination of groundwater resources through surface spills and discharge	
*Biodiversity and ecology***	12	Ecological and biodiversity impacts	Sensitivity classes defined at habitat to landscape scales generally utilised in spatial biodiversity planning
Agriculture	13	Alteration of agricultural landscape and impact on agricultural resources base	Agricultural sensitivity classes defined at the quaternary catchment scale
Tourism	14	Tourism impacts	Tourism sensitivity classes defined at town, protected area, and tourism route scale
Visual	27	Visual intrusion into the landscape, altering the rural character	Visual sensitivity classes defined at the regional scenic resource scale
Heritage	28	Impacts on built heritage, monuments and memorials	Sensitive areas identified as being within 10 km from towns
	30	Impacts on archaeology and graves	Archaeology and graves sensitivity classes defined at the landscape scale.
	Impacts on palaeontology, meteorites and geological heritage – assessed as Low and Very Risk after mitigation		Palaeontology, meteorites & geological heritage sensitivity classes defined at a landscape scale
*Electromagnetic Interference****	35	Electromagnetic interference (EMI) impacts on radio astronomy receptors (SKA)	EMI sensitivity classes defined at the scale of separation distances from the SKA development footprint

* The primary mitigation measure assumed for the 'with mitigation' assessment for water resources is that shale gas exploration and production activities do not occur within the areas mapped as being of Very High and High sensitivity (see Figure 4-3).

** For biodiversity and ecosystems, 'with mitigation' assumes the following: 1.) That proclaimed protected areas are 'no-go' areas 2.); that Very High sensitivity areas are avoided 3.); and that High sensitivity areas are avoided, or at a minimum, utilised but only following securing suitable offset sites in Very High or High sensitivity areas (see Figure 4-4).

*** 'With mitigation' assumes that no shale gas exploration and production activities are permitted within Very High sensitivity areas and within the Karoo Central Astronomy Advantage Area (KCAAA) (see Figure 4-9).

Based on the evolution of the topic specific risk profiles, it is possible to trace the incremental increase of risk in relation to the increasing magnitude and shale gas volumes and development activities as described in the scenarios generated for the assessment. From this point of departure the specialist teams were able to develop proposals for what constitutes the 'limits of acceptable change' which are based on the results of the risk assessment and compared to the legislation, guidelines, rules, norms, institutions and expert judgement used as a proxy for societal values (all limits were subject to peer and stakeholder review process which acted as a calibration of the proposed limits).

The following were the key steps undertaken to produce the integrated risk model:

a) Define and map distinct receiving environments based on a sensitivity analysis for the following impacts:
   i. Local community exposure to air pollutants
   ii. Damaging earthquakes induced by hydraulic fracturing
   iii. Contamination of groundwater resources through surface spills and discharge
   iv. Contamination of groundwater resources caused by a loss of well integrity
   v. Physical disturbance of watercourses and contamination of surface water
   vi. Ecological and biodiversity impacts
   vii. Alteration of agricultural landscape and impact on agricultural resources base
   viii. Tourism impacts
   ix. Visual intrusion into the landscape, altering the rural character
   x. Impacts on built heritage, monuments and memorials
   xi. Impacts on archaeology and graves
   xii. Impacts on palaeontology, meteorites and geological heritage
   xiii. Electromagnetic interference impacts on radio astronomy receptors (i.e. SKA)
b) Define the mitigation cases from "without mitigation", to "with mitigation". Also define the legislation, rules and responsible institutions applicable.
c) Define the consequence levels for each specialist topic from (a) i-xiii
   i. What proxy indicators can be used? What established norms and standards exist?
d) For each impact:
   i. For each scenario/project specific development –
      1. Estimate likelihood
      2. Estimate consequence
      3. 1 x 2 = Risk. Test against expert judgement
   ii. Repeat with mitigation cases, legislation, rules and responsible institutions considered.
e) Use the tabulated outputs from d) with the sensitivity maps developed in a) to populate calibrated risk model for each impact. Overlay impacts to produce a composite risk model expressed across the mitigation cases.

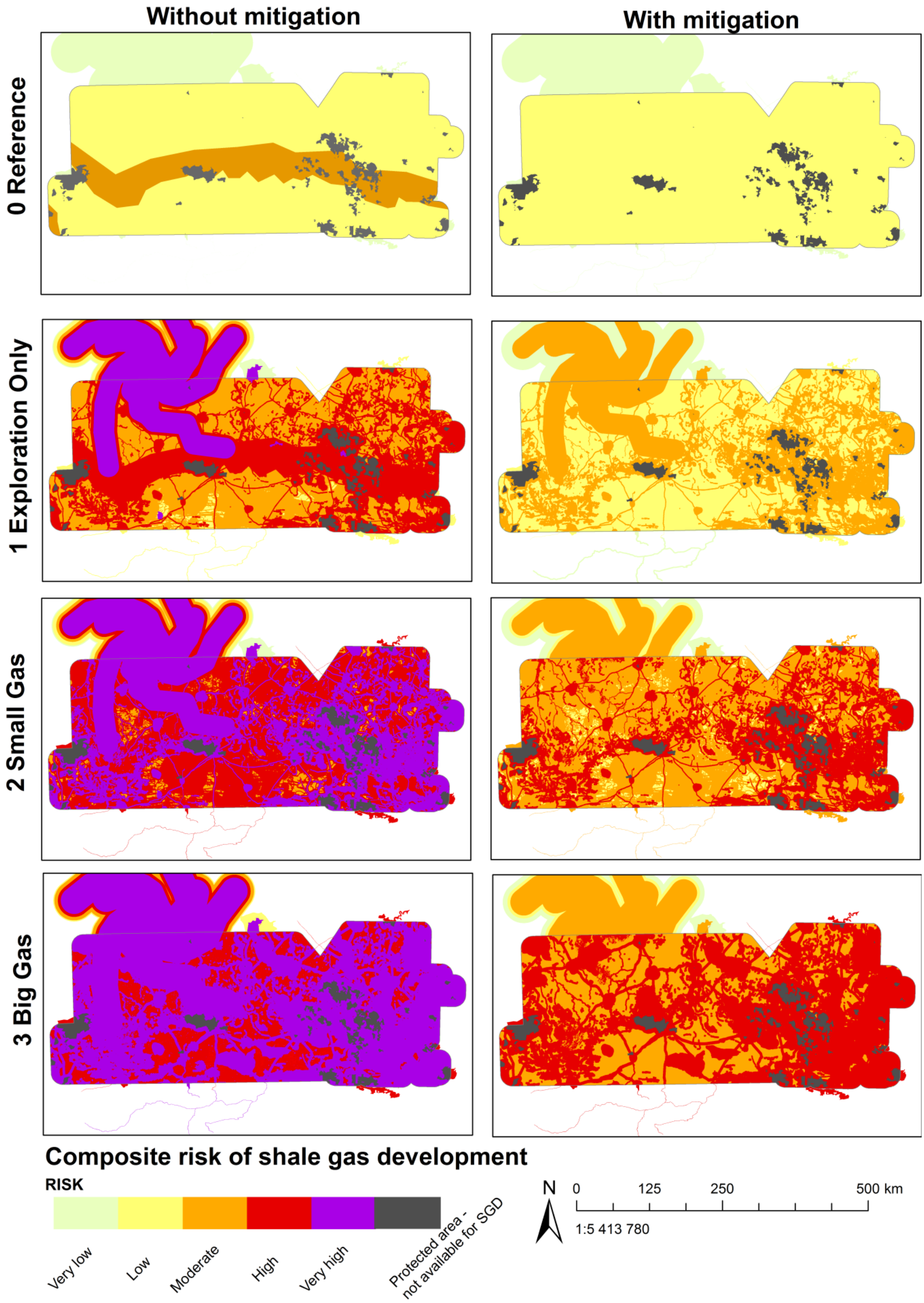

Figure 5–2: Composite map of spatially explicit risk profiles within the study area, depicting the risk of shale gas exploration and production activities (SGD) across four scenarios, without-and with mitigation.

6. STRATEGIC RISK MANAGEMENT

6.1 Defining Limits of Acceptable Change

Since only exploration for shale gas is on the 10 year horizon, it makes sense that exclusion zones would be generated for exploration and that only following field work, data acquisition, adaptive management and assumption testing, that exclusion zones could be generated for shale gas production when more information about the nature, distribution and extent of both the shale gas reserve, the sensitive features of the Central Karoo and the manner in which development activities interact with the social and ecological features are known. Thus this section is focused on the exclusion areas that are proposed for Phase I ("Exploration") and Phase II ("Appraisal").

The core principle in the determination of limits of acceptable change is the precautionary principle. The precautionary principle requires a risk-averse and cautious approach that takes into account the limits of current knowledge about the consequences of future decisions and actions. This can be primarily achieved through application of the mitigation hierarchy.

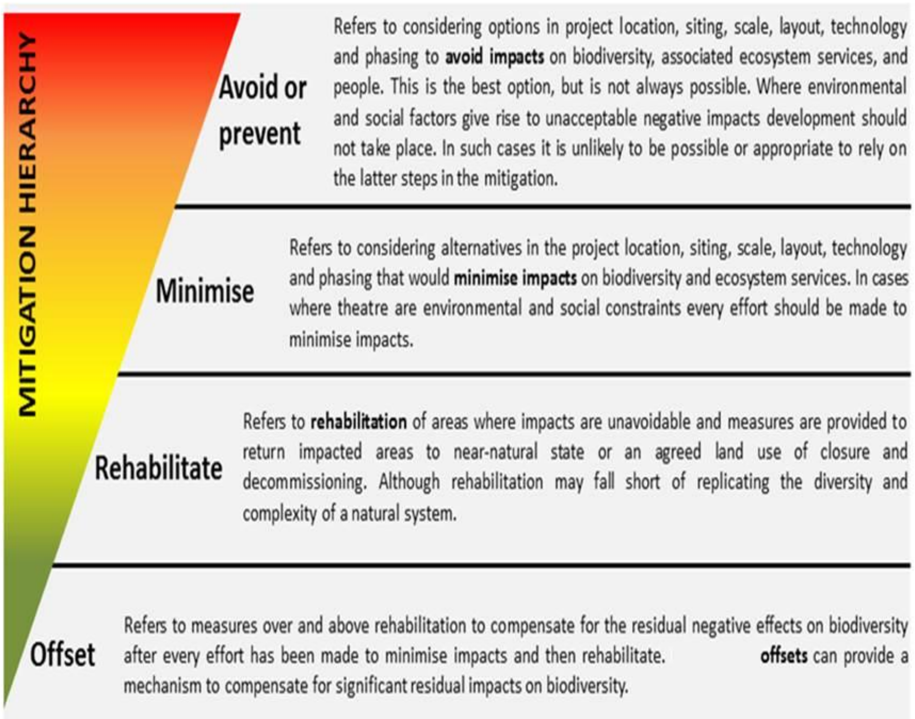

Figure 6–1: The mitigation hierarchy prescribes avoidance as the most efficient manner to minimise impact exposure and hence to reduce the risk profile. Avoidance is most commonly applied within a spatial context to delimited areas that are unacceptable for development for one reason or another (sometimes many). Avoidance can also mean the prohibition of certain development activities (e.g. types of technologies, hydraulic fracturing fluid composition) if more suitable, less consequential alternatives exist (DEA, 2013).

Even at the strategic level of assessment, many sensitive features of the Central Karoo are known to occur in this region and can easily be avoided during a shale gas exploration campaign. This includes regions which contain important groundwater and surface water resources, areas of high biodiversity sensitivity, scenic areas important to the cultural landscapes, vulnerable people living in populated communities, and the footprint of the SKA development phases.

During the Exploration Only scenario, which assumes extensive seismics plus vertical and horizontal drilling from 30 exploration wellpads (in excess of that which is actually proposed by Shell, Bundu and Falcon), only < 0.0001 % of the study area will be directly affected by shale gas activities. Even for the Small and Big Gas scenarios, at most, 0.0009 % of the surface area within the Central Karoo would be directly affected upon by exploration and production activities including the construction of new roads, wellpads, pipelines and gas combustion infrastructure[9].

This effectively means that > 99 % of the surface area of the Central Karoo will not be directly affected by shale gas exploration and production, even at the Big Gas scenario, meaning that it will be entirely possible to use avoidance as the primary mitigation mechanism in reducing the risks posed by shale gas exploration Phase I ("Exploration") and Phase II ("Appraisal"). There is more than sufficient evidence, that from a perspective of geographical footprint, that shale gas exploration can reach reasonably large proportions without impinging on other land-uses in Central Karoo provided that appropriate avoidance and site-specific mitigation is employed.

With this in mind, the prescription of exclusion areas for shale gas exploration is an effective approach to risk mitigation and the determination of limits of acceptable change. Exclusions areas can be delimited at two scales: at a course scale – where regional species, trends, features and populations which occur should be protected (the focus of a strategic-level study); and at fine scale – where sensitive features can be 'groundtruthed' and mapped onsite at fine-scale (the focus of an EIA-level investigation).

6.1.1.1 Proposed Exclusion Areas at a Strategic Level of Assessment

As discussed, under the Exploration Only scenario, < 0.0001 % of the surface area within the Central Karoo will be directly impacted by shale gas activities. Having said that, there are still significant concerns about the cumulative and interactive risk of activities related to shale gas exploration at the

[9] It is acknowledged that direct impact does not account for 'scale of impact, which may be spatially larger when one considers cumulative impacts such as those associated with increased traffic.

landscape scale, particularly through activities on the land surface that fragment the landscape, and the risk of the resulting impacts on spatially extensive ecological, economic and social processes. While > 99 % of the study area will not be directly affected by shale gas exploration, it is a near certainty that ancillary activities and infrastructure and activities will have a wider ranging spatial risk on the landscape if not adequately mitigated.

Figure 5-2 demonstrates the most effective way to mitigate cumulative and interactive risk is through application of the mitigation hierarchy conforming to avoidance first. What follows in Table 6-1, is a synthesis of the key spatial layers which are recommended for exclusion areas for exploration Phase I Exploration and Phase II Appraisal. Given that these layers are considered at the strategic level of assessment, the following two criteria had to be met in order for the layer to be included:

1. **Confidence**: There is a high degree of confidence in the data used to develop the layer, in other words, experts agree that the features represented in the layer almost certainly occur in the regions they are mapped. Note that the layers used to develop the exclusion areas represent proof of presence of sensitive features within the exclusion areas; but are not proof of absence of sensitive features in the areas located out of the proposed exclusion areas; and
2. **Significance**: Using the layer as a regional exclusion area would have a significant effect in reducing the risk profile associated with the some of 38 key impacts related to shale gas exploration at a regional scale which could not necessarily otherwise be mitigated at an EIA level of assessment. Significance also relates to the legislative framework and the existing provision as a region of exclusion for shale gas activities e.g. Protected Areas in terms of the NEMBA, the SKA in terms of the AGAA.

Section 49 of the MPRDA provides the DMR Minister with the power to "prohibit or restrict prospecting or mining. The Minister may prohibit or restrict the granting of any reconnaissance permission, prospecting right, mining right or mining permits in respect of land identified by the Minister for such period and on such terms and conditions as the Minister may determine". In addition, in terms of Section 24 of the NEMA, the DEA Minister is given the mandate to identify "geographical areas based on environmental attributes, and specified in spatial development tools adopted in the prescribed manner by the environmental authority, in which specified activities may be excluded from authorisation by the competent authority". At the strategic level of investigation, the declaration of exclusion areas for shale gas exploration with significantly help to mitigate the risks associated with a number of the 38 key impacts – these are captured in Table 6-1.

Table 6–1: Impact, feature of exclusion from shale gas Phase I Exploration and Phase II Appraisal and the supporting rational to apply the exclusion area at the strategic level of assessment.

PROPOSED EXCLUSION AREAS FOR PHASE I EXPLORATION *2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing*			**PROPOSED EXCLUSION AREAS FOR PHASE II APPRAISAL** *All development and ancillary activities up to and including hydraulic fracturing*		
Mitigation of impacts	**Feature / exclusion buffer**	**Rationale**	**Mitigation of impacts**	**Feature / exclusion buffer**	**Rationale**
8, 9, 10, 12, 14, 27, 34	National Protected areas and regions of Very High and High ecological sensitivity as mapped in Figure 4-4	High confidence in spatial data. Rehabilitation efforts in the Central Karoo environment are very challenging, and disturbance can persist for decades or even centuries. This means that the preferred mitigation measures in this environment are to avoid or minimise impacts at the landscape level. This effectively makes regions of Medium and Low sensitivity available for shale gas exploration and production from an ecological perspective.	8, 9, 10, 12, 14, 27, 34	National Protected areas and regions of Very High and High ecological sensitivity as mapped in Figure 4-4	High confidence in spatial data. Rehabilitation efforts in the Central Karoo environment are very challenging, and disturbance can persist for decades or even centuries. This means that the preferred mitigation measures in this environment are to avoid or minimise impacts at the landscape level. This effectively makes regions of Medium and Low sensitivity available for shale gas exploration and production from an ecological perspective.
35	Shale gas exploration and production activities within <u>both</u> Very High sensitivity regions as mapped in Figure 4-9 and within the KCAAA	High confidence in spatial data. The acceptable threshold level of interference is determined by the SARAS protection level. Any received signal that is in excess of this protection level is deemed to be an interference source. Shale gas activities in Very High sensitivity regions <u>and</u> within the KCAAA are not permitted in terms of the AGAA. All shale gas development activities outside of the KCAAA, but within the sensitivity classes would be subject to	35	Shale gas exploration and production activities within <u>both</u> Very High sensitivity regions as mapped in Figure 4-9 and within the KCAAA	High confidence in spatial data. The acceptable threshold level of interference is determined by the SARAS protection level. Any received signal that is in excess of this protection level is deemed to be an interference source. Shale gas activities in Very High sensitivity regions <u>and</u> within the KCAAA are not permitted in terms of the AGAA. All shale gas development activities outside of the KCAAA, but within the sensitivity classes would be

PROPOSED EXCLUSION AREAS FOR PHASE I EXPLORATION ***2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing***			**PROPOSED EXCLUSION AREAS FOR PHASE II APPRAISAL** ***All development and ancillary activities up to and including hydraulic fracturing***		
Mitigation of impacts	**Feature / exclusion buffer**	**Rationale**	**Mitigation of impacts**	**Feature / exclusion buffer**	**Rationale**
		specific mitigations per class.			subject to specific mitigations per class.
14, 24, 25, 26, 31	Regions of Very High visual sensitivity as mapped in Figure 4-7.	High confidence in spatial data. Visual, aesthetic and scenic resources based on known topographic features, cultural landscapes, human settlements, major roads, sites of both optical and radio astronomy.	14, 24, 25, 26, 31	Regions of Very High visual sensitivity as mapped in Figure 4-7.	High confidence in spatial data. Visual, aesthetic and scenic resources based on known topographic features, cultural landscapes, human settlements, major roads, sites of both optical and radio astronomy.
14, 24, 25, 27, 31, 36, 37	N9 between George and Colesberg and mountain passes such as the Swartberg, Outeniqua, Wapadsberg, Lootsberg, Huisrivier and Robinson mapped in Figure 4-6.	High confidence in spatial data. The idea of the exclusion of trucks from specific routes is will significantly reduce impact risk for tourism (Toerien et al., 2016), road infrastructure (van Huysstteen et al., 2016) and visual impact (Oberholzer et al., 2016). Exclusionary roads networks for high volume trucks are not new and have been applied successfully in the protection of scenic routes, for example, in the USA (Toerien et al., 2016).	14, 24, 25, 27, 31, 36, 37	N9 between George and Colesberg and mountain passes such as the Swartberg, Outeniqua, Wapadsberg, Lootsberg, Huisrivier and Robinson mapped in Figure 4-6.	High confidence in spatial data. The idea of the exclusion of trucks from specific routes is will significantly reduce impact risk for tourism (Toerien et al., 2016), road infrastructure (van Huysstteen et al., 2016) and visual impact (Oberholzer et al., 2016). Exclusionary roads networks for high volume trucks are not new and have been applied successfully in the protection of scenic routes, for example, in the USA (Toerien et al., 2016).
9	250 m buffer around pans	Pans are not expected to be in direct contact with groundwater nor do they form part of significant conveyance corridors for sediment and contaminants. A less stringent 250m buffer zone is suggested for non-intrusive ancillary activities (versus stimulation well activities) for all geological	9	300 m buffer around pans	Pans are not expected to be in direct contact with groundwater nor do they form part of significant conveyance corridors for sediment and contaminants. Thus a lower stimulation well setback of 300m is proposed vs the 500m stimulation well setback for wetlands. A high confidence

PROPOSED EXCLUSION AREAS FOR PHASE I EXPLORATION *2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing*			**PROPOSED EXCLUSION AREAS FOR PHASE II APPRAISAL** *All development and ancillary activities up to and including hydraulic fracturing*		
Mitigation of impacts	**Feature / exclusion buffer**	**Rationale**	**Mitigation of impacts**	**Feature / exclusion buffer**	**Rationale**
		features, under which pans resort. A high confidence that the regionally mapped data does indeed occur at the specified localities in the field.			that the regionally mapped data does indeed occur at the specified localities in the field.
7	250 m buffer from kimberlites and diatremes	A less stringent 250m buffer zone is suggested for non-intrusive ancillary activities (versus stimulation well activities) for all geological features, under which kimberlites and diatremes resort. There is a high degree of confidence that the regionally mapped data does indeed occur at the specified localities in the field.	7	500 m buffer from kimberlites and diatremes	Kimberlites have complex associated emplacement models and the surface and underground morphology of these structures may be quite large and varied, with surface outcrop morphology varying from 1 ha to >15 ha. A 500 m buffer zone is recommended based on expert input. There is a high degree of confidence that the regionally mapped data does indeed occur at the specified localities in the field.
7	250 m buffer from faults, shear zones and fold axes	A less stringent 250m buffer zone is suggested for non-intrusive ancillary activities (versus stimulation well activities) for all geological features, under which shear zones and fold axes resort. There is a high degree of confidence that the regionally mapped data does indeed occur at the specified localities in the field.	7	1 000 m buffer from faults, shear zones and fold axes	Fold axes must be treated separately as their fold axis limb angles should be considered which may push the distance to several kilometres. A buffer of 1 000 m is thus recommended. There is a degree of confidence that the regionally mapped data does indeed occur at the specified localities in the field.
	1 000 m buffer from artesian boreholes and artesian Soekor wells	Artesian aquifer zones represent areas of possible deep/shallow groundwater connectivity. A less stringent 1000m buffer		5 000 m buffer from artesian boreholes and artesian SOEKOR	Artesian aquifer zones represent areas of possible deep/shallow groundwater connectivity. High confidence in current

PROPOSED EXCLUSION AREAS FOR PHASE I EXPLORATION ***2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing***			**PROPOSED EXCLUSION AREAS FOR PHASE II APPRAISAL** ***All development and ancillary activities up to and including hydraulic fracturing***		
Mitigation of impacts	**Feature / exclusion buffer**	**Rationale**	**Mitigation of impacts**	**Feature / exclusion buffer**	**Rationale**
	(KL 1/65, SA 1/66, VR 1/66, CR 1/65)	zone is suggested for non-intrusive ancillary activities (versus stimulation well activities). High confidence in current mapped localities of specified Soekor wells and artesian wells identified by DWS.		wells (KL 1/65, SA 1/66, VR 1/66, CR 1/65)	mapped localities of specified Soekor wells and artesian wells identified by DWS.
7	1 000 m from town water supply wellfields	Shallow groundwater resources are at higher risk of contamination from exploration, appraisal and hydraulic fracturing activities. Ancillary activities including storage and transport of fracking fluids, chemicals or waste water are all considered potential contamination activities in terms of spills and leaks, representing a risk to water resources. A setback of 1 000 m is a conservative width (much larger than any current regulated setbacks) that takes cognisance of the possible high concentration of impacts/disturbance associated with the activity and risks associated with surface spills of contaminated flowback water or stored waste. High confidence in current mapped data.	7	5 000 m from town water supply wellfields	5 000 m between a stimulation well and municipal water wellfields are in line with GNR 466 setback distance for stimulation well activities. This setback distance is sufficient based on known hydraulic properties of shallow Karoo aquifers. These shallow groundwater areas are considered of high sensitivity and there is high confidence in current mapped data, however, more newly drilled town water supply wells may be identified during the EIA phase.
9, 10	500 m buffer upslope of cold springs	Ancillary activities are usually non-intrusive, hence the 500 m buffer upslope	9, 10	1 000 m buffer upslope of cold springs	All springs represent zones where there is probable vertical/horizontal connectivity

PROPOSED EXCLUSION AREAS FOR PHASE I EXPLORATION *2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing*			PROPOSED EXCLUSION AREAS FOR PHASE II APPRAISAL *All development and ancillary activities up to and including hydraulic fracturing*		
Mitigation of impacts	**Feature / exclusion buffer**	**Rationale**	**Mitigation of impacts**	**Feature / exclusion buffer**	**Rationale**
9, 10	500 m buffer downslope of cold springs	downslope for cold springs. Due to the sensitive nature of thermal springs (associated closely with deeper geological structures), usually with faults and folds and dykes, definite indications of deep connections and source recharge areas possibly many kilometres from the spring discharge area, the setback distance remains the same as for stimulation well activities. Cold and thermal springs with associated seismic activity may be associated with active geological structures where drilling and well stimulation may trigger earthquakes, and would need a larger setback. Thermal springs within seismically active areas would need a 5000 m setback. Regions of seismic activity would however first need to be clearly delineated before identifying such springs. High confidence in currently mapped spring localities, however, more springs may be identified during EIA activities.	9, 10	500 m buffer downslope of cold springs	between surface and groundwater resources, hence the 1 000 m buffer upslope and 500 m downslope for cold springs. Thermal springs specifically are associated closely with deeper geological structures, usually with faults and folds as well as dykes. High water temperatures as well as thermogenic methane associated with some thermal springs indicate definite deep connections. Thermal springs are also likely to have source recharge areas many kilometres from the spring discharge area and these must be delineated during the EIA prior to setting site-specific setback distances. Cold and thermal springs with associated seismic activity may be associated with active geological structures where drilling and well stimulation may trigger earthquakes, and would need a larger setback. Thermal springs within seismically active areas would need a 5 000 m setback. Regions of seismic activity would however first need to be clearly delineated before identifying such springs. High confidence in currently
9, 10	1 000 m buffer around thermal springs		9, 10	1 000 m buffer around thermal springs	

PROPOSED EXCLUSION AREAS FOR PHASE I EXPLORATION ***2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing***			**PROPOSED EXCLUSION AREAS FOR PHASE II APPRAISAL** ***All development and ancillary activities up to and including hydraulic fracturing***		
Mitigation of impacts	**Feature / exclusion buffer**	**Rationale**	**Mitigation of impacts**	**Feature / exclusion buffer**	**Rationale**
					mapped spring localities.
				10 km buffer from towns and highly populated areas within the Central Karoo	High confidence in spatial data. Significantly reduce risks posed to ambient air quality (Winkler et al., 2016), building collapse due to induced seismicity (Durrheim et al., 2016; Orton et al., 2016), human health (Genthe et al., 2016), noise impacts (Wade et al., 2016) and towns dependent on groundwater and surface water (Hobbs et al., 2016). Towns are known to occur at this mapping scale, there is no requirement for groundtruthing their presence.

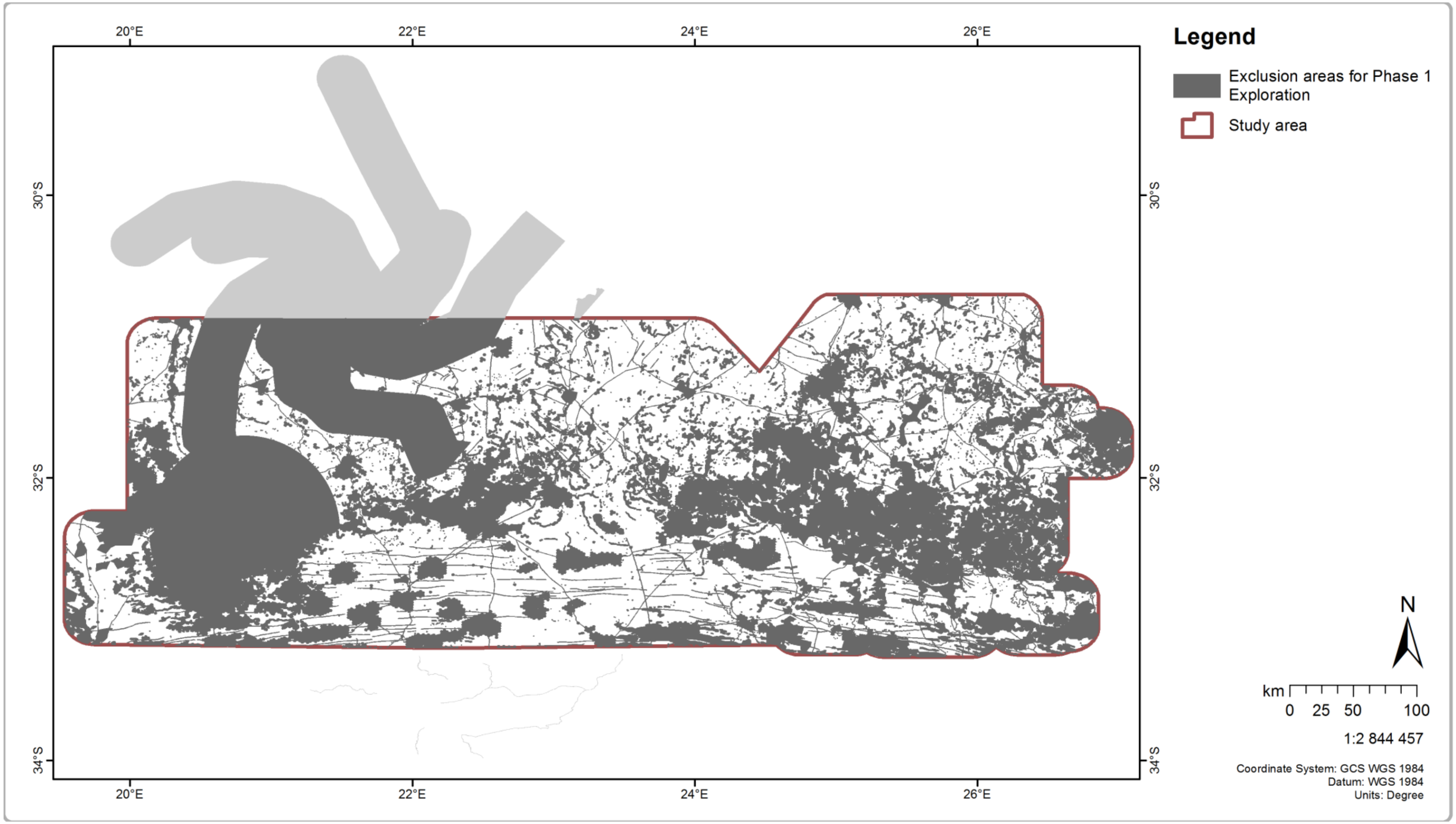

Figure 6–2: Proposed exclusion areas for Phase I Exploration – all activities associated with shale gas exploration excluding hydraulic fracturing

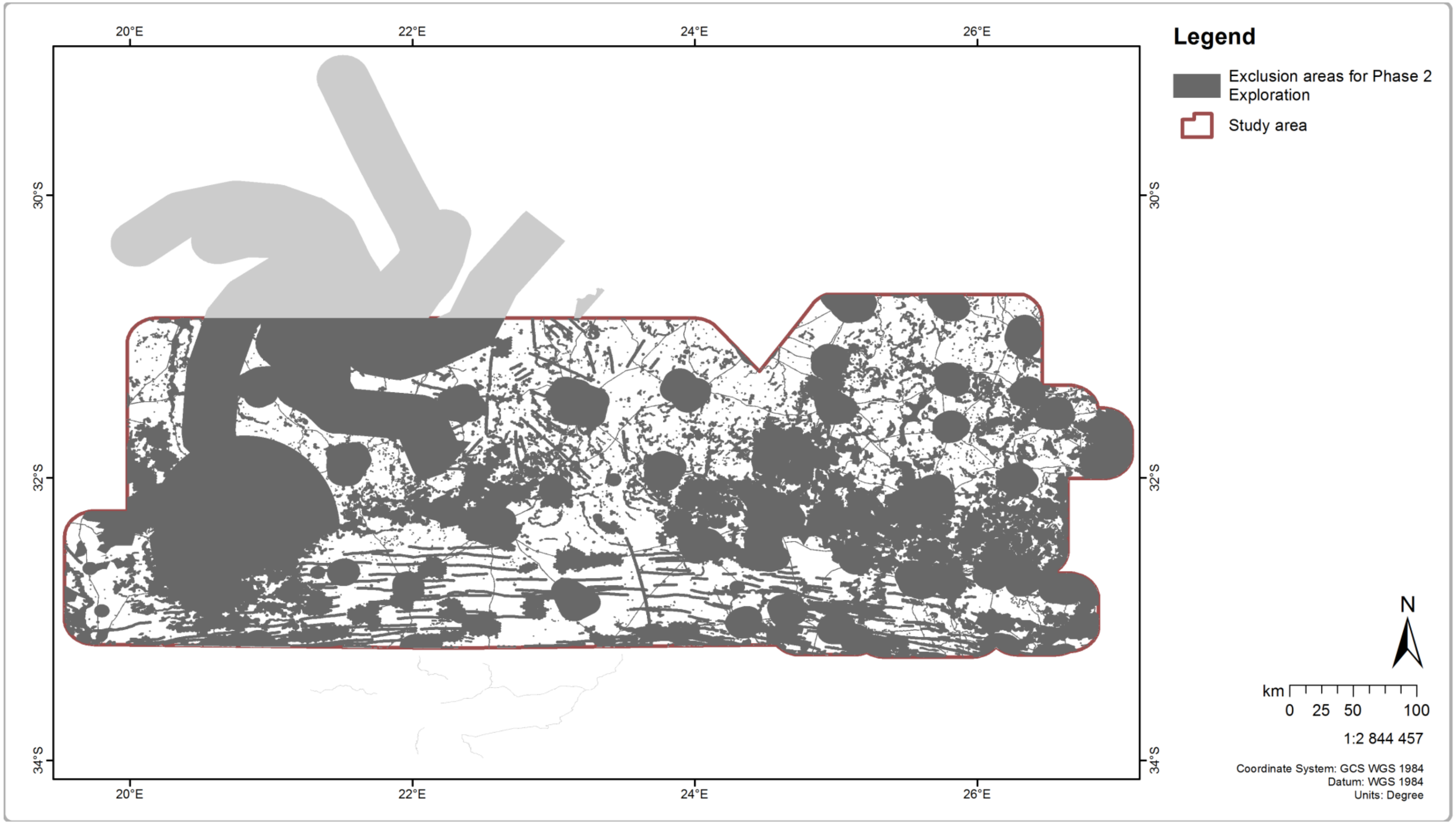

Figure 6–3: Proposed exclusion areas for Phase II Appraisal – all activities up to and including hydraulic fracturing

Table 6–2: Percentage coverage of each exclusion layer within the study area for Exploration Phase I and Appraisal Phase II

EXCLUSION AREAS FOR PHASE I EXPLORATION *2-D seismics, 3-D seismics, vertical X-wells, horizontal Y-wells, roads, trucks, water management, waste management – all ancillary activities associated with shale gas exploration other than hydraulic fracturing*			**EXCLUSION AREAS FOR PHASE II APPRAISAL** *All development and ancillary activities up to and including hydraulic fracturing*		
Feature / exclusion buffer	**Area (km^2)**	**% study area**	**Feature / exclusion buffer**	**Area (km^2)**	**% study area**
National Protected areas and regions of Very High and High ecological sensitivity	30815.95	17.94%	National Protected areas and regions of Very High and High ecological	30816.0	17.94%
Shale gas exploration and production activities within both Very High sensitivity regions and within the KCAAA	16104.65	9.37%	Shale gas exploration and production activities within both Very High sensitivity regions and within the KCAAA	16104.7	9.37%
Regions of Very High visual sensitivity, including optical astronomy	49790.52	30.98%	Regions of Very High visual sensitivity, including optical astronomy	49785.2	30.98%
N9 between George and Colesberg and mountain passes such as the Swartberg, Outeniqua, Wapadsberg, Lootsberg, Huisrivier and Robinson.	0.995	0.001%	N9 between George and Colesberg and mountain passes such as the Swartberg, Outeniqua, Wapadsberg, Lootsberg, Huisrivier and Robinson.	1.0	0.001%
250 m buffer around pans	2913.08	1.70%	300 m buffer around pans	3558.8	2.07%
250 m buffer from kimberlites and diatremes	12.56	0.01%	500 m buffer from kimberlites and diatremes	50.3	0.03%
250 m buffer from faults, shear zones and fold axes	2571.3	1.50%	1 000 m buffer from faults, shear zones and fold axes	10819.9	6.30%
1 000 m buffer from artesian boreholes and artesian SOEKOR wells (KL 1/65, SA 1/66, VR 1/66, CR 1/65)	34.55	0.02%	5 000 m buffer from artesian boreholes and artesian SOEKOR wells (KL 1/65, SA 1/66, VR 1/66, CR 1/65)	863.7	0.50%
1 000 m from town water supply wellfields	74.42	0.04%	5 000 m from town water supply wellfields	624.7	0.36%
500 m buffer upslope and downslope of cold springs	11.74	0.01%	1 000 m buffer upslope of cold springs and 500 m buffer downslope of cold springs	44.4	0.03%
1 000 m buffer around thermal springs	15.69	0.01%	1 000 m buffer around thermal springs	15.7	0.01%
			10 km buffer from towns and highly populated areas within the Central Karoo	27438.3	15.97%
Total	**81067.8**	**49.18%**		**99050.46**	**59.65%**

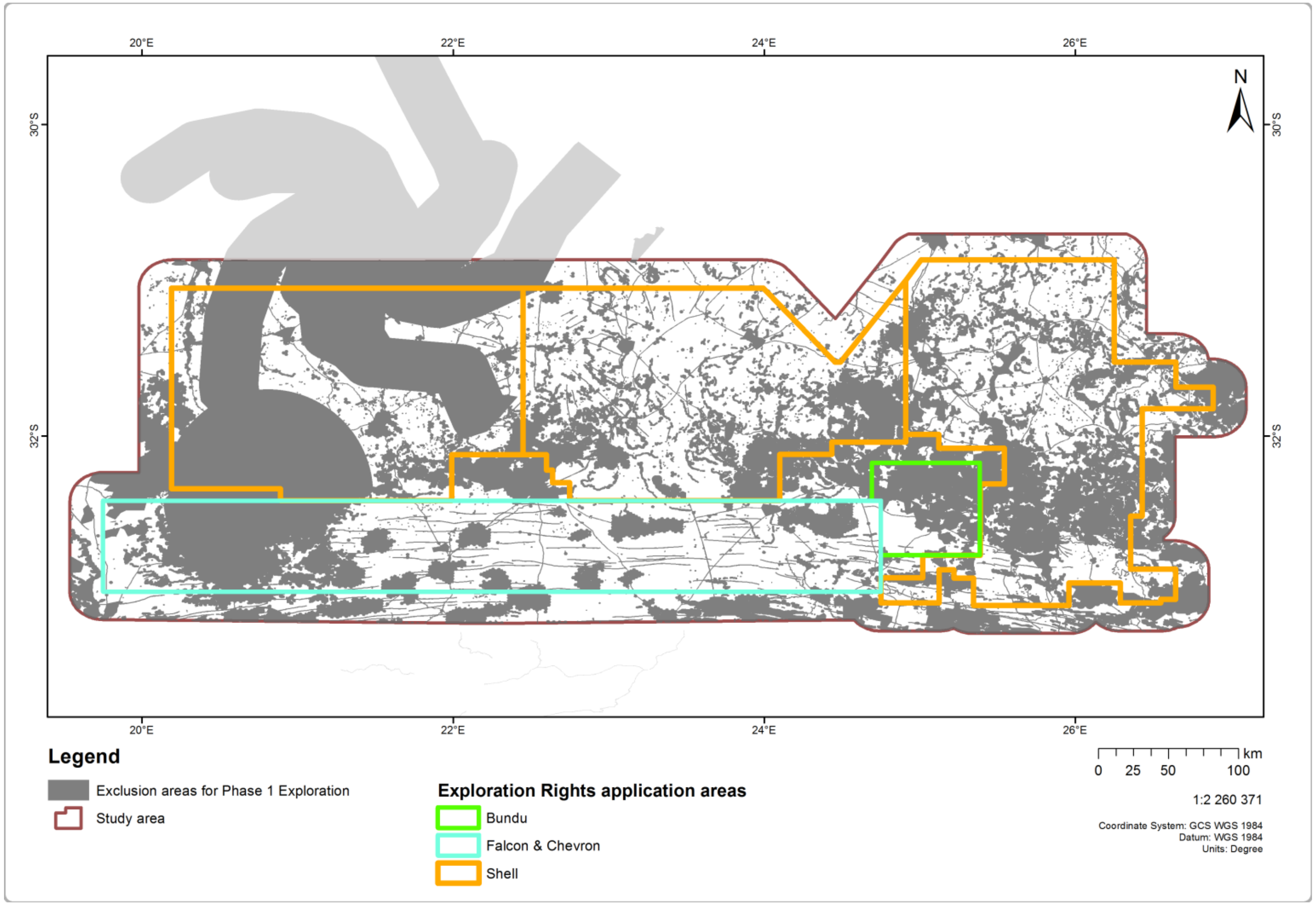

Figure 6–4: Proposed exclusion areas for Phase I Exploration in relation to the current EMPr licence applications

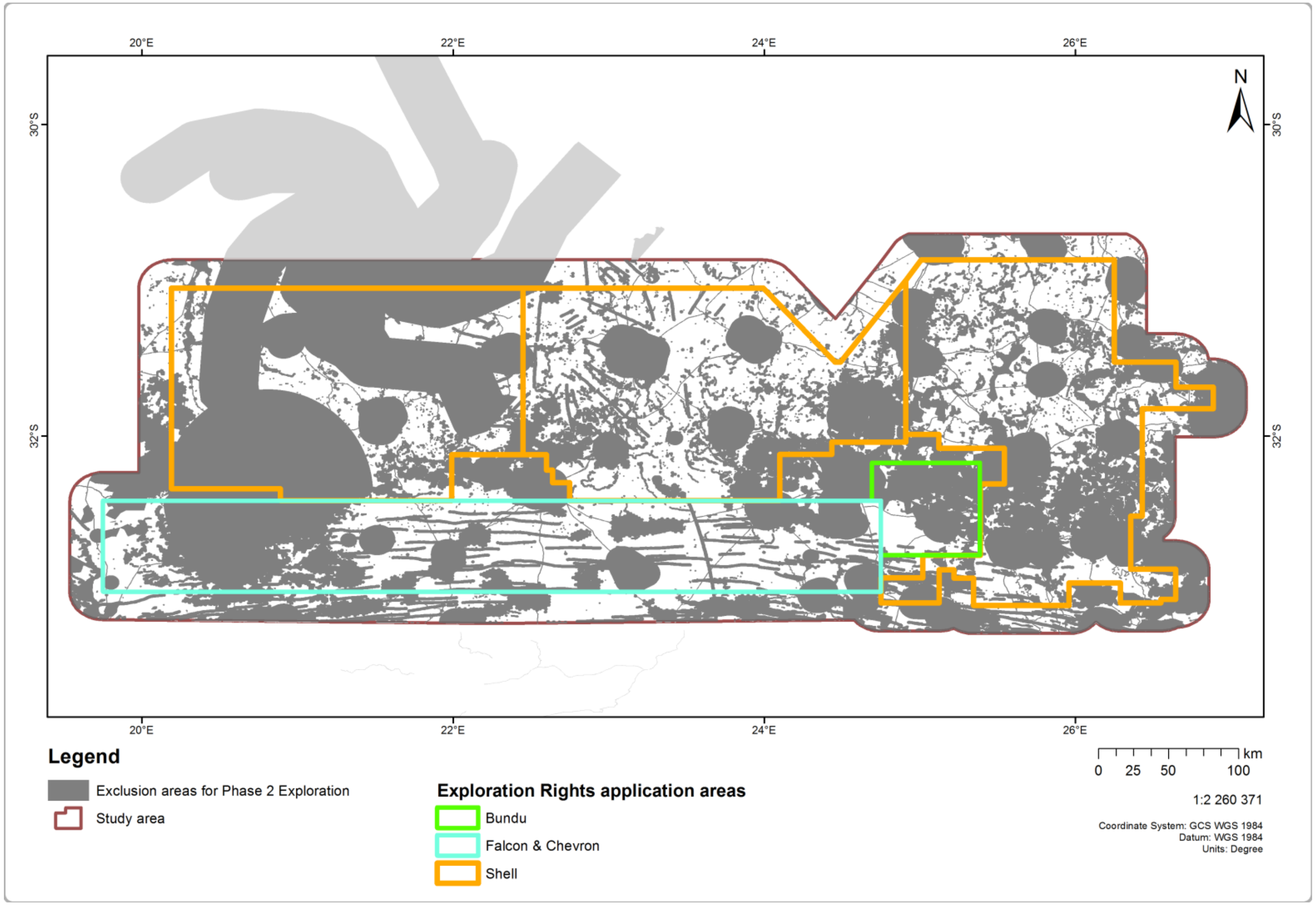

Figure 6–5: Proposed exclusion areas for Phase II Appraisal in relation to the current EMPr licence applications

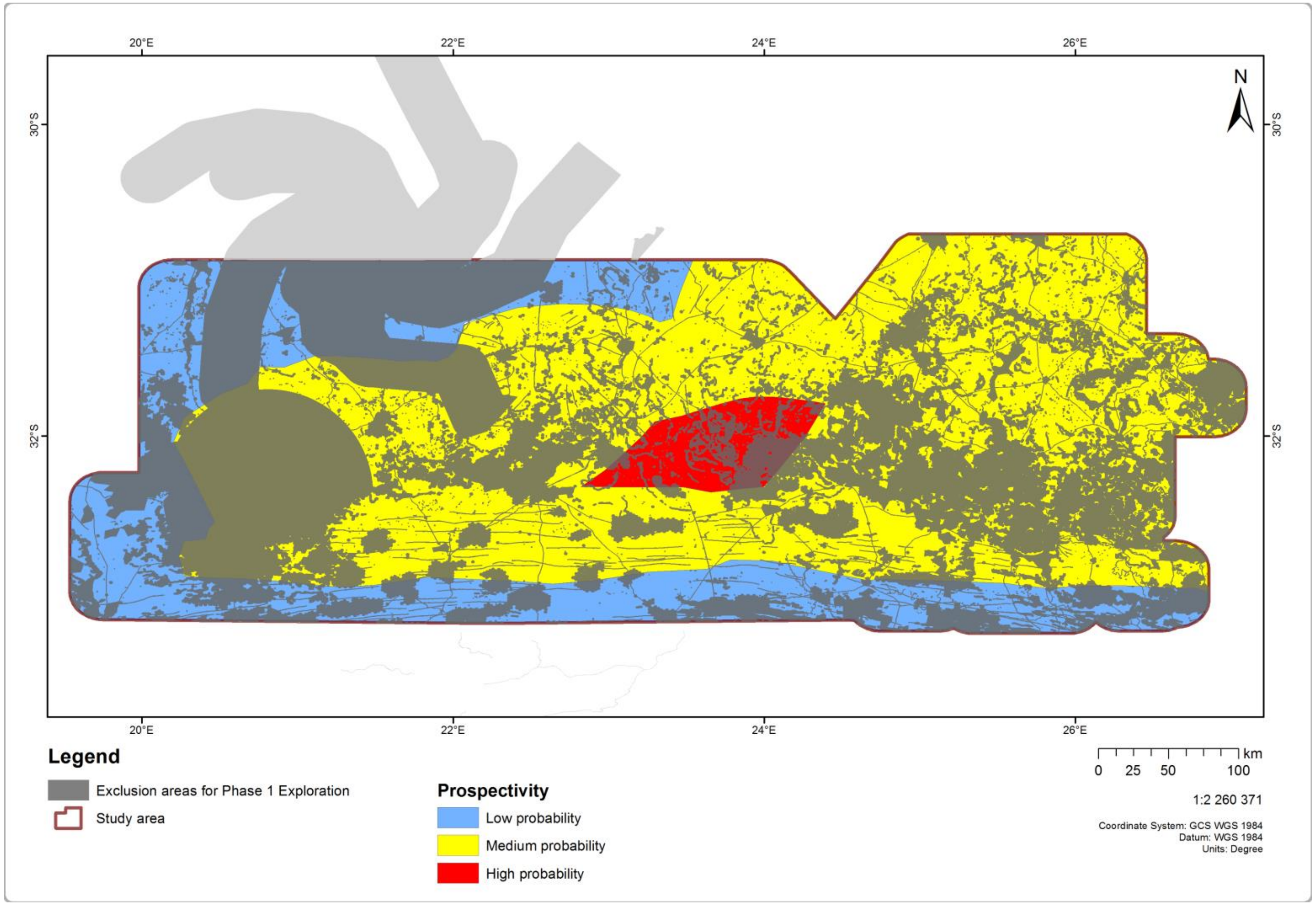

Figure 6–6: Proposed exclusion areas for Phase I Exploration in relation to current understanding of shale gas prospectivity

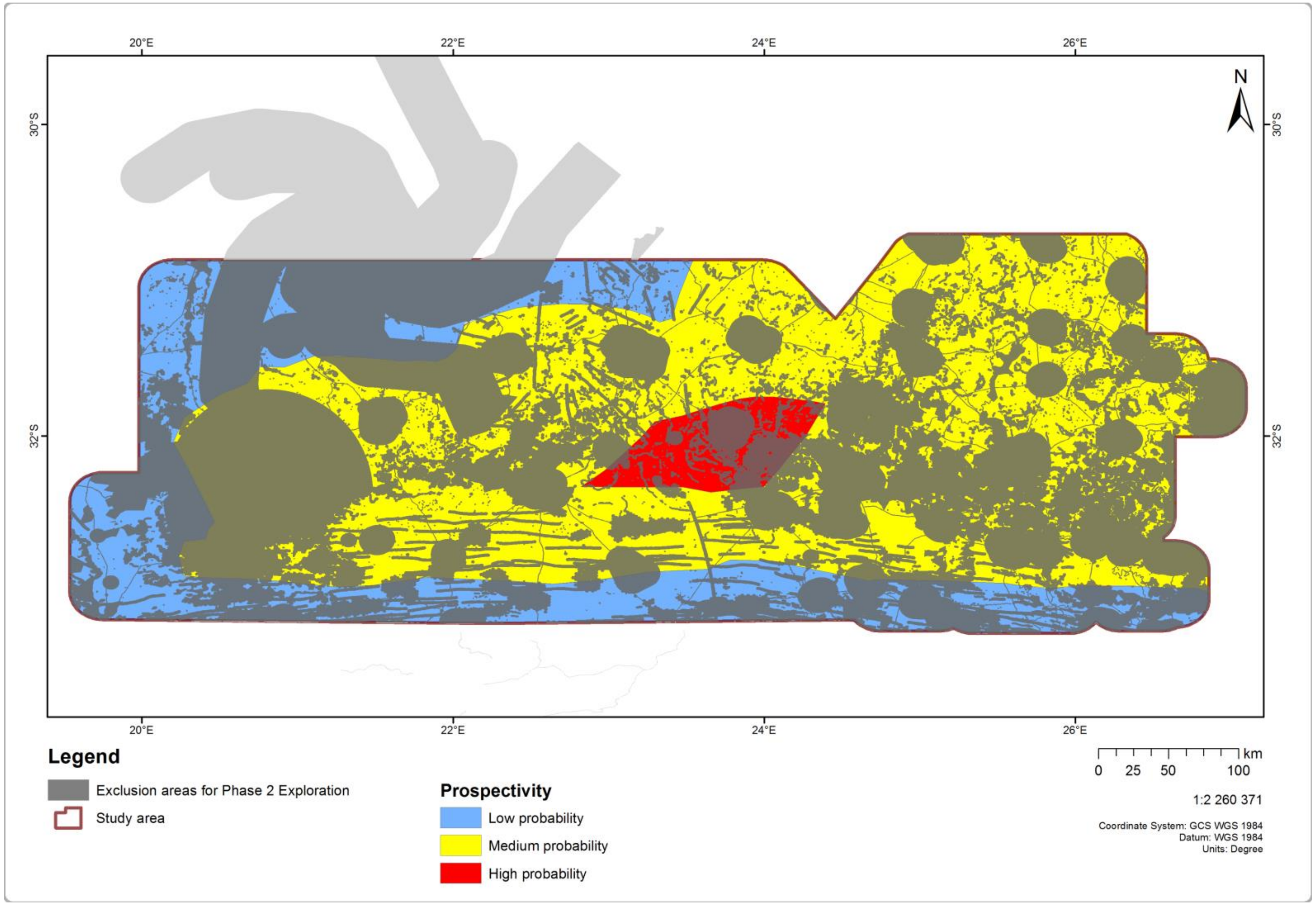

Figure 6–7: Proposed exclusion areas for Phase II Appraisal in relation to current understanding of shale gas prospectivity

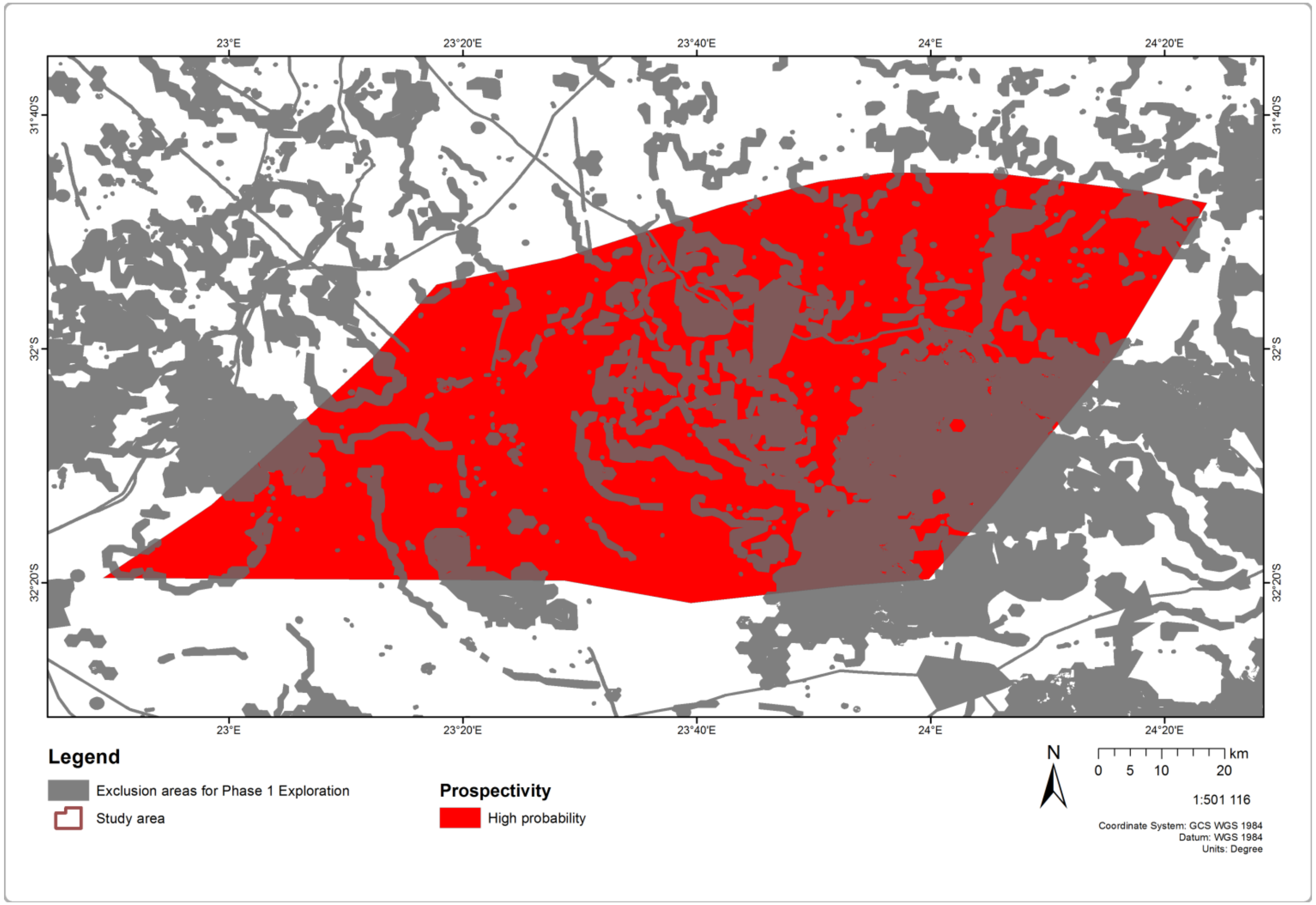

Figure 6–8: Proposed exclusion areas for Phase I Exploration in relation to shale gas prospectivity – "zoomed" into area of highest prospectivity

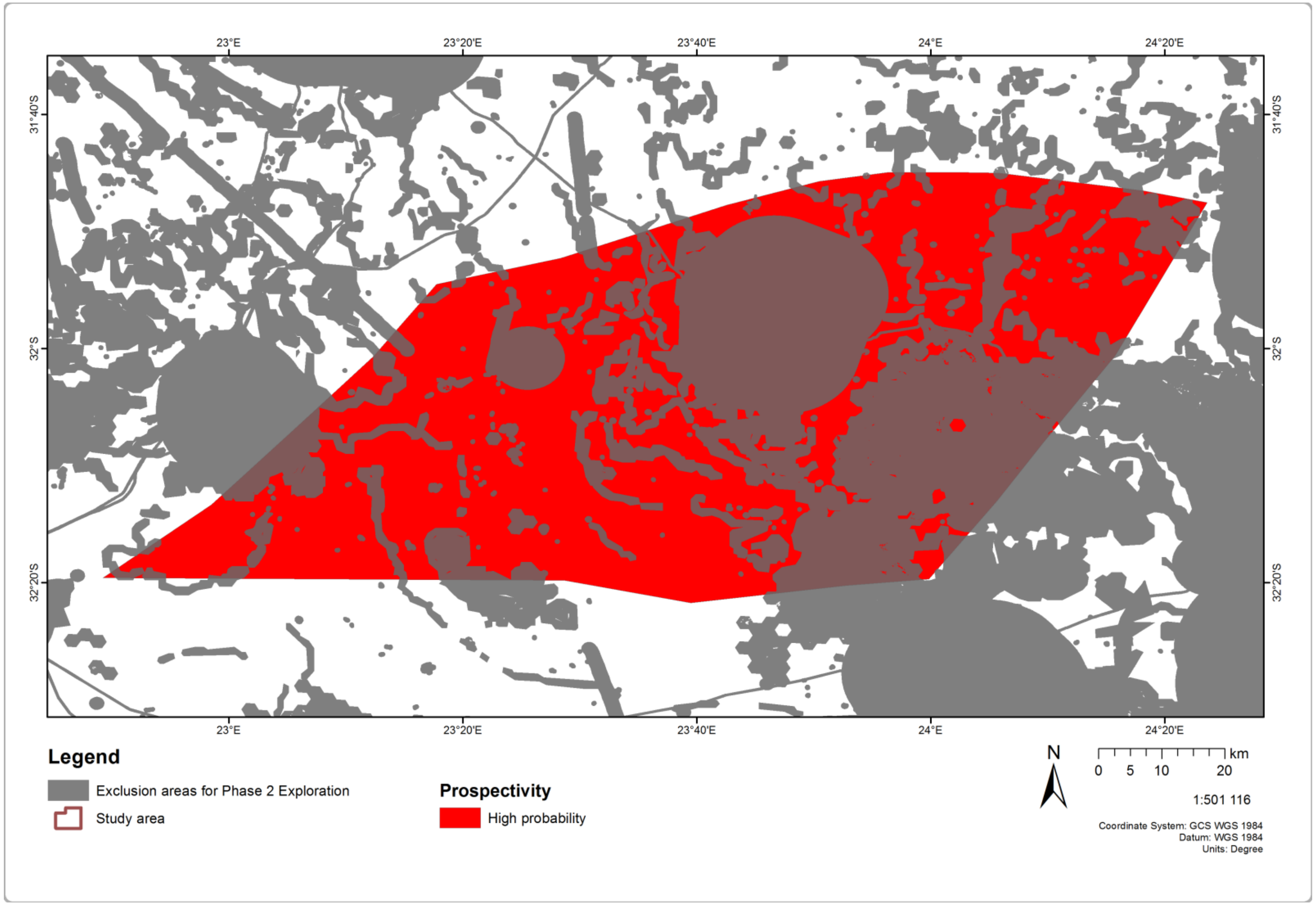

Figure 6–9: Proposed exclusion areas for Phase II Appraisal in relation to shale gas prospectivity – "zoomed" into area of highest prospectivity

6.1.1.2 Proposed Exclusion Areas at a Site-Specific Level of Assessment

Because of the uncertainty in aspects of the spatial data at the strategic level of assessment, the following features must be delimited during a site-specific EIA process with buffer areas applied which are appropriate to the site-specific spatial context. Table 6-3 outlines these buffer areas and provides guidelines for the buffer distances, which will have to be determined at a site-specific level, on a case by case basis.

Table 6–3: Site-specific buffer guidelines to be determined during the EIA level of investigation

Feature/s	Mitigation of impacts	Buffer distance recommendations
Exploration Phase I ("Exploration")		
Deep recharge zones	6, 7	Investigate these zones in detail during the EIA to delineate any flowpaths to shallow aquifers and then buffer accordingly on a case-by-case basis.
Artificial recharge areas (current and future)	6, 7	Exclude areas 5 km around artificial recharge areas, based on the setback distance in regulations GN R466 for water supply wellfields. Should such areas be managed in terms of inducing maximum drawdowns, then site-specific studies must be carried out to determine the required setback.
Groundwater source zones	6, 7	Not within 5 km of groundwater source zones, based on setback distance for wellfields in GN R466.
Water resources (water courses including mapped dry river courses, wetlands, pans, shallow aquifers, cold and thermal springs) and water supply infrastructure (water supply boreholes, wellfields, water storage dams)	6, 7, 8, 9, 10	Exclude areas where the wet season groundwater lies at 10 m or closer to the surface. No closer than 1 km from water supply sources infrastructure (domestic, stock watering or irrigation supply borehole or downslope storage dam or water supply wellfields). Where town wellfield is not known, identify town water source, if groundwater or a combination of groundwater and surface water, then use built-up area of town and buffer by 1 km, in accordance with precautionary principle. No closer than 500 m from any thermal spring or cold spring. No closer than 500 m from any identified watercourse or other wetland type without a detailed ecological, hydrological and geohydrological investigation. Setback distance = 5 km from cold or hot springs within region of known seismic activity. Example: Middelburg cold springs area. Leeu-Gamka hot spring area. Springs with associated seismic activity may be associated with active geological structures where drilling may trigger earthquakes, and would need a larger setback than normal. As a general guideline, structures and infrastructure should be located at least 100 m from the delineated edge of any watercourse or other wetland and such that they do not impact on their condition, characteristics or function.
Faults, shear zones, fold axis, dolerite	6, 7, 8, 9, 10,	No hydraulic fracturing chemicals storage, waste or waste water management infrastructure, fuel depots or

Feature/s	Mitigation of impacts	Buffer distance recommendations
dykes and sills, kimberlites and diatremes	11	sanitation infrastructure within 250 m of geological features without a detailed geohydrological investigation.
Regions of ecological sensitivity	8, 9, 10, 12, 14, 27, 34	National Protected areas and regions of Very High and High ecological sensitivity mapped at a fine scale during the EIA process would be considered exclusion areas.
Regions of EMI sensitivity	35	The SKA will undertake a high level assessment for a specific site - a quick desktop analysis which takes into account the local conditions at that site. If SKA identify any potential risks, they would do a more detailed assessment and propose mitigation strategies. It is highly likely that SKA would do this for the first few - and as they build up a level of confidence in the risks associated with shale gas development (types of equipment being used, profile of EMI emissions), SKA could provide significantly quicker turnaround times and perhaps provide a template for mitigation (as they are starting to do with renewable energy facilities). The mitigation required per sensitivity class, is 5 dB for Low sensitivity regions, 10 dB for Medium sensitivity regions, 15 dB for High sensitivity regions, and > 20 dB for Very High sensitivity regions.
Regions of visual sensitivity including popular tourist routes	14, 24, 25, 27, 31	Regions of Very High and High Visual sensitivity, confirmed at an EIA level of assessment would be considered exclusion areas. At the local project scale this would be determined through viewshed mapping and public participation, and by means of the regulatory framework, usually as part of the EIA process. Sensitive landscape features should normally be identified during SDF and EMF planning processes. Setbacks and exclusion zones would to some degree define levels of acceptable change and may relate to: • Topographic features • Restricting development on steep slopes (>10^{o}), elevated landforms • Away from major rivers, water bodies (see previous impacts on water) • Cultural landscapes • Graded heritage sites and cultural landscapes • National Parks • Nature Reserves • Provisions included in local authority planning documents • Scenic routes and passes • SALT exclusion zone
All sites formally protected under the NHRA including National and Provincial Heritage Sites, Grade I, Grade II and Grade III Sites and all heritage register	28, 29, 30	> 1 km buffer

Feature/s	Mitigation of impacts	Buffer distance recommendations
sites in the Northern and Eastern Cape		
Other archaeological sites, graves and graveyards and palaeontologically sensitive areas	28, 30, 31	> 50 m from all shale gas exploration activities
Exploration Phase II ("Appraisal")		
Identifying relevant geological structures	5, 14, 16, 18, 22-25, 28-31, 35	The sub-surface should be mapped prior to hydraulic fracturing operations for the presence of faults, shear zones, fold axis, dolerite dykes and sills, kimberlites and diatremes and the measurement of their properties as well as other relevant structures of concern. Artesian features and hot springs must also be mapped, noting that geological structures plotted on the 1:1 000 000 scale data from the Council for Geoscience (CGS) does not show all possible geological features that are present, and need to be identified on a more localised scale. During the EIA, 1:50 000 geological structure data should be used to determine setback distances for these features. Seismic data may also be used to determine sensitive geological structures, and the CGS has deployed six new seismic stations in the proposed Shell exploration areas, of which three, near Graaff- Reinet, are already operational. The setback distance should be based on a reasonable risk analysis of hydraulic fracturing increasing the pressures within the fault/fracture. The properties of the target shale gas formation and upper bounding formations should be verified, post-hydraulic fracturing, to assess how the hydrogeology will change.
Municipal water well fields, artificial recharge areas, areas of shallow groundwater (<10m) or groundwater source zones.	6, 13,15, 20,	Not within 5 km, measured horizontally, from the surface location of an existing municipal water wellfield and identified future wellfields and sources and directional drilling may not be within 2.5 km of municipal wellfields. Apply this setback distance for artificial recharge areas and groundwater source zones as well. Where town wellfield is not known, identify town water source, if groundwater or a combination of groundwater and surface water, then use built-up area of town and buffer by 5 km, in accordance with precautionary principle. Exclude areas where the wet season water table lies at or closer to 10 m from the surface.
Water supply boreholes or water storage dams	6, 13,15, 20	Not within 500 m, measured horizontally, from the surface location of existing water borehole and directional drilling may not be within 500 m of the borehole. No closer than 1 000 m from any domestic, stock watering or irrigation supply borehole or downslope storage dam, and directional drilling may not be within 500 m of the borehole.
Watercourses	8, 9, 12, 13	No closer than 500 m from the 1:100 year floodline or outer edge of the riparian zone (whichever is the

Feature/s	Mitigation of impacts	Buffer distance recommendations
		greater) of any watercourse or from the temporary or other outer edges of any other wetland type
Pans (isolated wetlands)	8, 9, 12, 13	No closer than 300 m from the delineated temporary edge of any perched, isolated seasonal pan (i.e. not on a drainage line)
Cold springs	8, 9, 12, 13	1 000 m buffer upslope of cold springs. 500 m buffer downslope of cold springs.
Thermal springs (water temperature >25º C), artesian boreholes, artesian aquifer zones and artesian SOEKOR wells.	8, 9, 12, 13	Calculate buffer zone after Hobbs et al., 2016. Guideline is setback distance of 1 000 m from centre point where no temperatures available and setback distance of 5 000 m from thermal springs within region with known seismic activity.
Dykes	4, 6, 7, 8, 9, 10	Dyke width can be measured in the field, estimated from high-resolution aerial photography or aeromagnetic imagery, or by using of the equations in Hobbs et al., 2016. If the estimated width of the calculated dyke buffer is <250 m, set buffer to 250 m.
Kimberlites and diatremes	4, 6, 7, 8, 9, 10	500 m radius from centre point of structure
Faults, shear zones and fold axis	4, 6, 7, 8, 9, 10	1 000 m from centre line of structure
Dolerite sills	4, 6, 7, 8, 9, 10	250 m from rim of surface outcrops
Undifferentiated geophysical anomalies	4, 6, 7, 8, 9, 10	1 000 m from centre line of feature
Regions of ecological sensitivity	8, 9, 10, 12, 14, 27, 34	National Protected areas and regions of Very High and High ecological sensitivity mapped at a fine scale during the EIA process would be considered exclusion areas.
Regions of EMI sensitivity	35	The SKA will undertake a high level assessment for a specific site - a quick desktop analysis which takes into account the local conditions at that site. If SKA identify any potential risks, they would do a more detailed assessment and propose mitigation strategies. It is highly likely that SKA would do this for the first few - and as they build up a level of confidence in the risks associated with shale gas development (types of equipment being used, profile of EMI emissions), SKA could provide significantly quicker turnaround times and perhaps provide a template for mitigation (as they are starting to do with renewable energy facilities). The mitigation required per sensitivity class, is 5 dB for Low sensitivity regions, 10 dB for Medium sensitivity regions, 15 dB for High sensitivity regions, and > 20 dB for Very High sensitivity regions.
Regions of visual sensitivity including popular tourist routes	14, 24, 25, 27, 31	Regions of Very High and High Visual sensitivity, confirmed at an EIA level of assessment would be considered exclusion areas. At the local project scale this would be determined through viewshed mapping and public participation, and by means of the regulatory framework, usually as part of the EIA process. Sensitive landscape features should normally be identified during SDF and EMF planning processes. Setbacks and exclusion zones would to some degree define levels of acceptable change and may relate to: • Topographic features

Feature/s	Mitigation of impacts	Buffer distance recommendations
		• Restricting development on steep slopes (>10^{o}), elevated landforms • Away from major rivers, water bodies (see previous impacts on water) • Cultural landscapes • Graded heritage sites and cultural landscapes • National Parks • Nature Reserves • Provisions included in local authority planning documents • Scenic routes and passes • SALT exclusion zone
All sites formally protected under the NHRA including National and Provincial Heritage Sites, Grade I, Grade II and Grade III Sites and all heritage register sites in the Northern and Eastern Cape	28, 29, 30	> 10 km buffer
Other archaeological sites, graves and graveyards and palaeontologically sensitive areas	28, 29, 30	> 50 m from all shale gas exploration activities

6.1.2 Spatial Risk Modelling to Determine Production Level Thresholds

The risk model presented in Section 5.2 shows a mosaic of cumulative risk, evolving across the scenarios. Risks range from Low to Very High in the study area, with higher risk areas prevalent towards the eastern portion of the study area. This may be attributed to more variable landscape features in the east which are characterised by a denser distribution of towns (Burns et al., 2016), more diverse habitats and a greater concentration of protected and sensitive areas (Holness et al., 2016), higher agricultural production potential (Oettlé et al., 2016) and an increased concentration of scenic resources and landscapes (Oberholzer et al., 2016).

Without mitigation, the risks associated with shale gas development from the Exploration Only to Big Gas scenarios increase incrementally from Moderate - Very High; to High - Very High. Effective implementation of mitigation and best practice principles may reduce the risk profile to low-moderate for Exploration Only, and overall Moderate - High for the Small- and Big Gas scenarios.

At the strategic-level of assessment, the risks associated with Exploration Only could be mitigated to between Low and Moderate (considering both spatial and non-spatial risks). Good practice mitigation is reliant on the veracity of the future decision-making processes. These should be guided by evidence-based policies, robust regulatory frameworks and capacitated institutions in a manner that is ethical, responsible and transparent.

In the Exploration Only scenario, there are some Moderate risks even after mitigation is applied. These include impacts to physical security and altered local social dynamics; occupational exposure to air pollutants on drilling sites; EMI within Very High sensitivity areas; local road construction and regional pressure on road infrastructure; spatial and development planning and governance capacity. The impact of altered power dynamics is the sole impact assessed as High after mitigation within the Exploration Only scenario.

With mitigation, the Small Gas scenario shows mosaics of Low and Moderate risk scattered through the study area, with the eastern highlands dominated by High risk landscapes. There are reasonably sizeable regions of Moderate risk located in or around the location of the highest shale gas prospectivity (between Beaufort West and Graaff-Reinet). Moderate risk is defined as: Unlikely (1:100 to 1:20 of having a moderate or greater impact); or if more likely than this, then the consequences are substantial but less than severe, because although an important resource or attribute is impacted, the effect is well below the limit of acceptable change, or lasts for a duration of less than 3 years, or the affected resource or attributes has an equally acceptable and un-impacted substitute.

With mitigation, the Big Gas scenario demonstrates increased proportions of High risk regions and fewer regions of Moderate and Low risk. As defined at the outset of the risk assessment and modelling process, High risk is considered to mean: Greater than 1 in 20 chance of having a severe impact (approaching the limit of acceptable change) that persists for >3 years, for a resource or attribute where there may be an affordable and accessible substitute, but which is less acceptable.

The risk modelling indicates that based on the twelve spatial impacts modelled spatially, it would seem that as gas resources increased upwards of 5 tcf (decades into the future), decision-makers will need to pause and reassess the scale and extent of shale gas production activities and the degree to which they conform with international, national and local development agendas for energy resources. This is the basis upon which it is proposed in Table 3-1, that an additional EIA process is undertaken should shale gas production exceed 5 tcf.

The limits of acceptable change associated with shale gas exploration and production can be conceptually developed through predicative landscape modelling exercises as has been undertaken above; they can also be developed in specific response to the 38 key impacts posed by shale gas exploration and production developed per chapter topic in the independent Scientific Assessment phase of the SEA. These topic specific limits of acceptable change are based on national policy, plans, legislation, regulations and guidelines plus key learning from international best practice and are detailed in Table 6-4 below.

Should exploration activities ever advance to production, even the risk associated with production can be largely offset by using avoidance as the primary mechanism of mitigation. Within a resource and infrastructure scarce environment like the Central Karoo means that if shale gas is ever produced in the volumes contemplated in the Small and Big Gas scenarios, it would be concentrated within gas "sweet-spots" which would be determined based on a proved petroleum reserve in the Central Karoo following intensive seismics programmes and exploratory drilling, which may last up to and exceeding 10 years. The sweet-spots areas of hypothetical production would in turn need to be supported by, within near-immediate spatial proximity, industrial processing facilities to generate inputs to the shale gas development cycle e.g. water, proppant, hydraulic fracturing fluids, traffic volumes etc. and to manage the outputs of the shale gas development cycle e.g. product gas and associated infrastructure, wastes streams, traffic volumes etc.

The significance of this is that shale gas production in the Central Karoo will, in all technical likelihood, be concentrated within contained development wellfields, about 30 x 30 km in size. The need for any extensive production of shale gas reserves to be undertaken within confined well-fields is further accentuated by the depth at which Economically Recoverable shale gas might exist in the Karoo Basin. Current estimates are that hydraulic fracturing and recover of gas would only occur at depths, probably in excess of 2.5 km beneath the surface of the earth. This is significantly deeper (and hence more expensive) than the vertical wells drilled in the USA. Thus, in order to make shale gas in the Central Karoo a technical possibility, a significant number of horizontal wells (> 10) will need to be drilled from the vertical borehole in order to make it a financially viable option. This means that only 55 wellpads would be required for Small Gas and 410 wellpads for Big Gas assuming 10 production wells were drilled per well pad (this could reduce, if say, 15-20 well are drilled which is entirely plausible).

Should exploration move into production, the concentration of production wellfields and very low surface area that they would cover, would allow for suitable and strategic management of risks based on the avoidance of sensitive features in the receiving environment. This would follow a significantly different development path compared to that of, for example the USA, which was undertaken under substantially different geological conditions; with the free availability of skills, infrastructure and services; under markedly different regulatory conditions (i.e. where land owners owned the petroleum reserve); and at a time when the international market was ‘gas hungry’. The potential for rapid, unchecked and sprawling growth of shale gas production in the Central Karoo is thus very low given the geological, technological and regulatory environments of South Africa and the Central Karoo.

6.1.3 Limits of Acceptable Change as Non-Spatial Guidelines

Table 6–4: Guidelines on non-spatial limits of acceptable change

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
1	Energy infrastructure that does not match domestic shale gas supply	IEP 2015, IRP 2010, IRP 2013, GUMP 2015 (draft).	**Stranded or unutilised infrastructure is not acceptable.** In addition, a lack of sufficient infrastructure to process gas and evacuate electricity is equally unacceptable. The IEP 2015, IRP 2010, IRP 2013, GUMP 2015 (draft) will ensure that unnecessary energy infrastructure is not constructed without proving the viability of a long-term commercially extractible resource. In addition, the documents provide the framework to ensure that, if shale gas is found in sufficiently large volumes and at flow rates that promote a commercial viability, there will be sufficient energy infrastructure to allow for generation and evacuation of gas or electricity.
2	Availability of sufficient network capacity to evacuate gas and gas fired power generation		
3	Exposure to air pollutants	NEM:AQA 2004, NAAQS 2009, Hazardous Chemical Substances regulations of the Occupational Health and Safety Act of 1993, the MPRDA technical regulations 2015.	**Any legal person undertaking shale gas exploration or production will require an AEL which must be based on the community exposure standards from NAAQS (2009)**. The Hazardous Chemical Substances regulations of the Occupational Health and Safety Act of 1993 specify the allowed exposure limit over eight hour shifts, and are generally based on the guidelines produced at regular intervals by the American Conference of Governmental Industrial Hygienists. Best practice regarding worker risk to silica inhalation is found in the Controls and Recommendations to Limit Worker Exposures to Respirable Crystalline Silica at Hydraulic Fracturing Work Sites (2013) see http://www.tandfonline.com/doi/suppl/10.1080/15459624.2013.788352/suppl_file/uoeh_a_788352_sm4302.pdf
4	Fugitive emissions	The Paris Agreement of 2016,	**The most complete set of emission standards for unconventional gas exploration and recovery has been**

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
		National Climate Change Response White Paper of 2011, Nationally Determined Contribution of 2015, Priority Air Pollutants of 2016 (draft), Pollution Prevention Plans of 2016, GHG reporting guideline of 2015.	**developed by the United States Environmental Protection Agency.** These rules are currently undergoing further review and refinement see https://www.gpo.gov/fdsys/pkg/FR-2012-08-16/pdf/2012-16806.pdf. National climate policy requires reporting of GHG emissions that is mandatory for entities that emit more than 0.1 Mt of GHGs annually. DEA has published for comment draft regulations declaring GHGs as priority air pollutants, regulations requiring the submission of Pollution Prevention Plans and GHG reporting guidelines. With shale gas exploration and production likely to exceed 0.1 Mt CO_2-eq per year, it is expected that developers will be subject to these and any further regulations, including possible company-level carbon budgets. Such reporting will contribute to South Africa's implementation and achievements of its Nationally Determined Contribution, as required under the Paris Agreement. South African standards do not exist for levels of air pollution related to impacts on crops and vegetation. Internationally, there are guidelines for critical levels for air pollution related to impacts on crops and vegetation (Convention on Long-range Transboundary Air Pollution). Ozone impacts agriculture and ecosystems at concentrations lower than ambient air quality standards for health, partially due to the importance of cumulative exposure of crops and vegetation. The United Kingdom critical level using AOT40 for ozone (i.e. cumulative exposure above 40 ppb during daylight hours over a three month growing season) for crops and semi-natural vegetation is 3000 ppb hours (Air Pollution Information System). However, it is not known what the critical level may be for the vegetation in the study area see https://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/1979.CLRTAP.e.pdf
5	Occurrence of a damaging earthquake M>5	The MPRDA technical regulations.	**Damaging earthquakes (M>5) in populated regions or areas which contain high concentrations of heritage resources are not acceptable.** Many thousands of hydraulic fracture wells have been drilled worldwide. Most only caused micro-seismic events (M<3) imperceptible to humans, while none of the few felt events have caused any damage. The occurrence of a damaging earthquake (M>5) anywhere in the study area is considered to be very unlikely. To date, all damaging events associated with fluid injection are associated with the disposal of large volumes of waste water, not hydraulic fracturing. The disposal of waste water by injection into underground aquifers is forbidden by current South African legislation. Identification of Very

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			High and High sensitivity regions from a seismicity perspective are indicated as a 20 km buffer around towns in Figure 4-2. While a 20 km buffer area around towns would reduce the risk of hydraulic fracturing from Moderate to Low, it would not at this this stage make sense to delimit areas 20 km around towns as 'exclusion areas' for the reason of seismicity alone.
6	Reduced water availability for people and other economic activities	The NWA, the Water Services Act of 1997 and the and SANS for Drinking Water and Waste Streams of 2015	**Water for utilised for shale gas development from existing local sources is unacceptable**. Water availability in the study area is severely constrained. Surface water availability is generally low, and in many areas over-allocated. Landowners rely mainly on groundwater resources for domestic and stock water. Groundwater recharge is typically low and sporadic. The use of groundwater is increasing, particularly during drought years. In many areas, groundwater already supplies 100% of the use. The availability of groundwater to meet the demand of even the Reference Case (where there is no development), is already seriously constrained. The additional demand under the Small and Big Gas scenarios could not be met from known local potable resources and would be considered a Very High risk if local resources were utilised. The Water Services Act governs the provision of water services and promotes effective water resource management and conservation. Municipalities must ensure that water of a specific quality is provided, must ensure assurance of supply and must ensure sanitation.
8	Physical disturbance of watercourses	The NWA and the NEMA	• Regulation 4 (NWA, GN 704): No person in control of a mine or activity may locate or place any residue deposit, dam, reservoir together with any associated structure or any other facility within the 1:100 year floodline or within a horizontal distance of 100 m from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on water-logged ground, or on ground likely to become water-logged, undermined, unstable or cracked. • Regulation 5 4 (NWA, GN 704): No person in control of a mine or activity may use any residue or substance which causes or is likely to cause pollution of a water resource for the construction of any dam or other impoundment or any embankment, road or railway, or for any other purpose which is likely to cause pollution of a water resource. Other relevant regulations are GN 1199, which specifies conditions for impeding or diverting flow or altering the bed, banks, course or characteristics of a watercourse to persons using water under Sections 21 (c) and (i)

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			of the NWA. In these regulations, no water use is allowed within a 500 m radius from the boundary of a wetland. Also, **altering the bed, banks, course or characteristics of a watercourse is not allowed within the 1:100 floodline or within the riparian habitat,** whichever is the greatest. The most effective management action is to avoid Very High and High sensitivity water resources. These have been mapped, at a high-level in Figure 4-4. The sensitive areas are deliberately conservative, considering the low confidence in scale and available data. Additional investigations will be required at EIA level to determine 'no-go' areas. It can be stated with reasonably high confidence that shale gas activities located in areas of Medium-Low sensitivity will reduce the risk profile to Low and Very Low for all direct water impacts. **Any impact that results in deterioration in resource quality of high negative significance if assessed at an EIA level of investigation – even if associated with only one attribute or one water quality variable, would be considered unacceptable.** The water quality guidelines for aquatic ecosystems and agriculture should be used as a guide to what constitutes a significant change in a water quality variable, bearing in mind that pre-shale gas development conditions might already exceed some of these thresholds. This emphasises the importance of undertaking extensive pre-development monitoring.
9	Contamination of surface water resources as a result of spills and flowback discharge into surface systems	The NWA and the South African Water Quality Guidelines of 1996.	**Any impact that would result in degradation of any aspect of water resource to a level less than the desired Management Class (MC) for that resource component is unacceptable.** The MC represents the desired characteristics of the resource and outlines those attributes that the custodian (DWS) and society require of different water resources. The outcome of the Classification Process will be the setting of the MC, Reserve and Resource Quality Objectives (RQO's) for every significant water resource. The aim of this process is therefore to help facilitate a balance between protection and use of the nation's water resources. Note that the MC has not yet been set for the study area, and would need to be set before any shale gas development-associated resource use is considered in the Central Karoo. Target water quality ranges for surface water use are provided for in the South African Water Quality Guidelines (1996) – for (1) Agricultural Water Use for Irrigation, (2) Agricultural Water Use for Livestock Watering and for (3) Aquatic Ecosystems.
10, 7	Contamination of surface resources as a result of		

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
	contact with contaminated groundwater		
11	Exposure to hazardous and domestic waste and additional sewage load	The MPRDA technical regulations; NEMA, NEM:WA, NWA, National Nuclear Regulator Act of 1999, National Road Traffic Act of 1996, Disaster Management Act for 2002	**Discharge of hydraulic fracturing fluids, flowback, and produced water into a water source is unacceptable and is prohibited by the technical regulations.** In terms of the regulations, treated surplus water not recycled back into the operations may be discharged into surface water resources provided that it meets quantity and quality limits stated in the applicable water use licence (see previous section on water); however this does not conform to the principles of the waste management hierarchy. Facilities for the disposal of domestic solid waste, generated by workers deployed to the study area and migrants are limited to small and communal disposal sites. As at 2007, only twelve sites were estimated to have 15 years or more airspace remaining, the other sites are likely to be filled up by now. Additional waste generated for all development scenarios will put pressure on these already constrained waste disposal facilities. All landfills in the study area require upgrades to meet the requirements of the National Norms and Standards for Disposal of Waste to Landfill. Recycling initiatives in the Karoo are limited due to relative low volumes and large transport distances to markets for recyclables. Many of the waste water infrastructure facilities in the Central Karoo have been placed under regulatory surveillance or require immediate interventions. The risk associated with treatment of fluid waste at municipal waste water treatment facilities relates to design capacity, operational flow, and number of non-compliance trends in terms of effluent quality and compliance or non-compliance in terms of technical skills. **As such, disposal of liquid waste at domestic waste water treatment facilities is not acceptable.** Liquid waste from Exploration Only to Small Gas could be dealt with by modular, on-site treatment facilities which are commercially available for liquid waste volumes in the region of 101 400 m^3 – 6 000 000 m^3 respectively. For waste volumes exceeding 6 000 000 m^3 and up to 40 000 000 m^3 (in the case of Big Gas), construction of a new on-site or centralised disposal facility could be triggered. The cost of establishing or upgrading of treatment facilities for treatment of liquid waste from shale gas development should be for the account of the developer and not that of the municipality. All Type 1 hazardous waste generated will have to be transported to a suitably designed and authorised hazardous waste disposal site in

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			Gauteng, Port Elizabeth or Cape Town. The shale gas development industry, and not local municipalities, should be responsible for the treatment of waste streams onsite and safe disposal thereof emanating from exploration and production operations. Transportation and disposal of waste must be undertaken in accordance with the National Road Traffic Act of 1996, Disaster Management Act for 2002. Naturally occurring Radioactive Materials must be managed in line with the National Nuclear Regulator Act of 1999.
12	Impacts on ecological and biodiversity processes	The NEMBA, The National Environmental Management: Protected Areas Act of 2003, National Biodiversity Strategy and Action Plan (NBSAP), the NBA, the NPAES, Atlas of FEPAs, and provincial spatial biodiversity plans	**No loss or degradation of Very High sensitivity areas is acceptable**. These areas are irreplaceable and no ecologically equivalent areas exist for securing the features they contain. **In High sensitivity areas, loss or degradation is acceptable only if ecologically equivalent sites are identified and secured through biodiversity offsets or equivalent mechanisms.** An ecologically equivalent site means a site that contains equivalent ecological processes, ecosystems and species, and that compensates for the full ecological impact of the activity as identified through a detailed study. In addition, loss or degradation of High sensitivity areas will result in the need to identify additional sites from within Medium sensitivity areas for inclusion into High sensitivity areas, in order to meet targets for ecological processes, ecosystem and/or species. The limits of acceptable change in High sensitivity areas are determined by the ability to find ecologically equivalent sites in the remaining intact Medium sensitivity areas. **Loss or degradation of Medium sensitivity areas is acceptable, as long as there is no impact on Very High and High sensitivity areas**. Activities that are authorised in Medium sensitivity areas need to be assessed for potential impacts on Very High and High sensitivity areas. In Low Sensitivity areas, site-level impacts are not significant from a biodiversity or ecological point of view. Change is acceptable as long as it does not impact on Very High or High Sensitivity areas. Refer to Figure 4-4 which indicates corresponding sensitivity classes Very High, High, Medium and Low for biodiversity and ecosystem services.
13	Impacts of farming and agriculture	The Conservation of Agricultural Resources of 1983.	**Shale gas development activities cannot compete with water currently used for local agricultural purposes. Any contamination of existing water resources will be an unacceptable level of change.**
14	Reduction in tourist numbers and	NDP (2012), Medium Term Strategic Framework for 2014	**>20% of tourism enterprises, tourism job losses of >2 660, and a losses >R 500 million Gross Value Add are unacceptable.** Additionally, limits of acceptable change can be determined through identifying activities

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
	enterprises	– 2019, National tourism plans and Provincial and regional tourism plans	that should be prohibited entirely or within certain regions. In this regard, it is suggested that risk can be significantly reduced by lessening the impacts of traffic densification by 1.) creating "no-go" roads for heavy load haulage and 2.) promoting the use of railway rather than tourist roads which are mapped as Very High sensitivity (see Figure 4-6). Routes that should be considered "no-go" areas are the N9 between George and Colesberg and mountain passes such as the Swartberg, Outeniqua, Wapadsberg, Lootsberg, Huisrivier and Robinson. The idea of the exclusion of trucks from specific routes is not new. For instance, in California commercial vehicles with three or more axles, or a gross vehicle weight of >4 000 kg, are prohibited on Route 2 between the City of La Canada Flintridge and County Route N4 see special route restrictions at http://www.dot.ca.gov/trafficops/trucks/restrict-list.html.
15	Impacts to public finances associated with externality costs	The Constitution, the MPRDA, the NEMA – polluter pays principle, financial provisioning	Establishing that a given action is economically desirable generally requires that one can show that it is still likely to result in a net benefit to society even when all externalities are taken into account or 'internalised'. The most effective way to achieve this is through mitigation or compensation to the point when externalities are effectively dealt with. **The limit of acceptable change is then up to the point at which externalities cannot be mitigated or compensated for.** Going beyond this point generally results in significant and pervasive risks to other sectors thereby risking the emergence of an unsustainable, under-diversified and far less robust economy. It is anticipated that while, in the short term, the Central Karoo will benefit from increased job opportunities and economic activity associated with well establishment, the benefits will decline in the long term. The benefits associated with the production of shale gas will be remote from the Central Karoo (e.g. gas processing facilities and power generation). It will therefore be important to ensure that the gas industry contributes to investing in a legacy of sustainable alternative livelihoods for local communities.
16	Impacts to property values near wellpads		Compensation payments to landowners for the use of their land during shale gas development would need to be guided by the principle of comfortably compensating landowners for all impacts and losses. They would need to be based on best practice and include elements for loss of land value, future income, assets or infrastructure and have a solatium element. There is a need to establish the appropriateness and legitimacy of compensation through dialog with stakeholders. This dialogue should include agreeing on the compensation principles to be applied and, to the degree possible, fair minimum amounts or conventions/formulas for

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			establishing compensation (see Measham, T.G., Fleming, D.A. and Schandl, H. 2016. A Conceptual Model of the Socioeconomic Impacts of Unconventional Fossil Fuel Extraction. Global Environmental Change, 36, 101-110 available at: https://mpra.ub.uni-muenchen.de/68523/). Establishing acceptable compensation payments to landowners for shale gas development that are guided by processes such as the Independent Power Producers Programme is thus recommended. Aside from ensuring the fair treatment of landowners, compensation which goes beyond what is strictly required by law should also play an important role in facilitating the development of shale gas development. Interactions with land owners would be less likely to be acrimonious, reaching agreement would take less time and turning to the law to force landowners to grant access to their land is less likely to be necessary (under the MPRDA, companies with mineral exploration or extraction rights can force land owners (i.e. surface rights holders) to grant them access to their land).
17	Human in-migration	The Constitution, the NEMA, the Social Assistance Act of 2004.	**Some degree of in-migration is acceptable, as long as it does not place the local housing market under severe strain.** If there is some strain, it may kick-start private investors to expand their housing stock, which may benefit these towns in the long run (see Equitable Origin Standards for Onshore Conventional Oil and Gas Operations at: https://www.equitableorigin.org/eo100-for-responsible-energy/eo100tm-for-conventional-onshore-oil-gas/)
18	Physical security		**Decreasing municipal capacity in policing, disaster management, traffic management and significantly increased social pathologies are unacceptable.** Recruitment of labour exclusively from outside of the Central Karoo with a disregard for local employment and non-transparent procurement process is unacceptable. A fair and transparent hiring system will reduce social tensions. Racial marginalisation of groups in the Central Karoo leading to physical violence is the beyond the limits of acceptable change. A significant increase in family violence, alcohol and drug abuse and sexual crimes showing correlation and causality to shale gas development is an unacceptable limit.
19	Altered local power and social dynamics		**The widespread erosion of farmers associations, churches and other social fabric institutions is unacceptable.** Any decrease in local governance performance in planning and administering municipal services is a limit of acceptable change. Any significant increase in corruption and nepotism behaviours beyond the current levels is not acceptable.

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
20	Exposure to pollution through water contamination	The NWA, the South African Water Quality Guidelines of 1996, the MPRDA technical regulations, the Health Act of 2003.	**Standards for drinking water and purification of waste waters are legislated.** The SANS specifies the minimal quality of drinking water, defined in terms of microbiological, physical, chemical, and taste-and odour parameters at the point of delivery to the consumer. The Water Services Act of 1997, updated as SANS (2015a: 2015b), requires that water provided by water services authorities meets the specified standards. It should be noted that these standards apply only to water to be delivered to the consumer, and not to water in rivers or aquifers, where only the relevant guidelines apply. Standards are drawn from: • SANS. 2015a. SANS 241-1. Drinking water. Part 1: Microbiological, physical, aesthetic and chemical determinants. Edition 2. Standards South Africa. • SANS. 2015b. SANS 241-2. Drinking water. Part 2: Application of SANS 241-1. Edition 2. Standards South Africa. Standards were also set in the 1956 Water Act for some 23 constituents in effluents and waste waters entering a stream. While the updated version modifies the legal limits of some constituents, no additional constituents are considered. The values set for most or all of the constituents listed in the current list are derived from the South African Guidelines for Aquatic Ecosystems. One definition of acceptable risk that has been widely accepted in environmental regulation, although is not relevant to microbiological parameters, is if lifetime exposure to a substance increases a person's chance of developing cancer by one chance in a million or less. This level, which has come to be taken as 'essentially zero', was apparently derived in the US in the 1960s during the development of guidelines for safety testing in animal studies. A figure, for the purposes of discussion, of 1 chance in 100 million of developing cancer was put forward as safe. This figure was adopted by the Food and Drug Administration in 1973, but amended to one in a million in 1977. This level of 10^{-6} has been seen as something of a gold standard ever since. The US Environmental Protection Agency (EPA) typically uses a target reference risk range of 10^{-4} to 10^{-6} for carcinogens in drinking water, which is in line with WHO guidelines for drinking water quality which, where practical, base guideline values for genotoxic carcinogens on the upper bound estimate of an excess lifetime cancer risk of 10^{-5} (see http://apps.who.int/iris/bitstream/10665/42442/1/924154533X.pdf).
21	Worker physical	Health Act of 2003	An overall fatality rate of 27.5 deaths per 100 000 workers was recorded by National Institute for

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
	contact - traffic or machine injury		Occupational Safety and Health in 2012 in the USA oil and gas industry, a total that is more than seven times the death rate for all other industries (3.9 for all US workers). In South Africa, the fatality rates are considerably higher than developed countries with five times the fatality rate of developed countries. Assuming these data, 5 x 27.5 = 137.5 deaths per 100 000 workers working on shale gas development projects in South Africa. This is 7 times higher than the fatality rate of 19.2 per 100 000 for all industries currently operating in South Africa according to Department of Labour data. **137.5 deaths per 100 000 workers is thus not an acceptable fatality rate which should be less than 20 deaths per 100 000 workers, as delimited by the USA experience and Department of Labour data.**
22	Loss of sense of place to farmers, farm labourers, emerging farmers and land claimants	The NEMA and NHRA	At an EIA level of investigation, sense of place indicators should be developed through existing development processes like Environmental Management Frameworks (EMFs) and SDFs and used as limits of acceptable change. It is important to distinguish sense of place indicators as different from biophysical, cultural and natural indicators. This is because sense of place indicators are essentially relational indicators that are about the significance a particular community places on a natural or cultural artefact or space at a point in time. Sense of place values are not static but influenced by new technologies, alternative forms of energy generation, political opportunism, social movements and changes in small and multi-national business interests. The constructed nature of sense of place values means they are dynamic and open to change. They shift as individuals and communities needs and interests change. **Exactly what is understood as acceptable change is in theory open to negotiation with the stakeholders involved.** For example, some farmers may be willing to sell their farms to shale gas developers for the right price and relocate to other parts of the country. Other farmers on the other hand, might regard this as an irrevocable loss of cultural heritage and identity. Because of its intangible nature, most senses of place 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
23	Loss of sense of place to Karretjie People		
24	Loss of sense of place to lifestyle farmers, creatives, retirees, tourists and scientists		
25	Loss of sense of place to lifestyle farmers, creatives, retirees, tourists and scientists		

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
26	Loss of sense of place to shale gas development, low-skilled workers, unemployed youth		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.
27	Visual intrusion into the landscape	NEMA, MPRDA technical regulations, NHRA, National Parks Act, Provincial Ordinances and Municipal Bylaws, SDFs, EMFs, Municipal Zoning Schemes and Overlay Zoning Schemes, Regulations in terms of the AGAA, 2007	**Shale gas development in regions of Very High sensitivity is not acceptable** (see Figure 4-7). At the local project scale limits would be determined through viewshed mapping and public participation, and by means of the regulatory framework, usually as part of the EIA process. Sensitive landscape features should normally be identified during SDF and EMF planning processes. Setbacks and exclusion zones would to some degree define levels of acceptable change and may relate to: • Topographic features • Restricting development on steep slopes (>10^{o}), elevated landforms • Away from major rivers, water bodies (see previous impacts on water) • Cultural landscapes • Graded heritage sites and cultural landscapes • National Parks • Nature Reserves • Provisions included in local authority planning documents • Scenic routes and passes • SALT exclusion zone • SKA exclusion zone
28	Impacts on built heritage, monuments and memorials - all impacts except	The NHRA and the NEMA	**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.** During field assessment at an EIA level, 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

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
	earth tremors		required. Change would only be allowed in exceptional circumstances if it is impossible to avoid the resource.
29	Impacts on built heritage, monuments and memorials - earth tremors only		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 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 shale gas development 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.
30	Impacts on archaeology, graves and palaeontology		Greater than 90% of recorded archaeological and palaeontological heritage resources 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. Archaeological resources are unique and 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. 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 to archaeological and palaeontological heritage resources 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 and palaeontological 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. 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.
31	Impacts on 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.

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			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 shale gas development 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.
32	Disturbance to humans due to wellpad noise	the Western Cape Noise Control Regulations (2013) and national standards, the NEMA, the NEMBA	**Noise impacts which have the potential to result in significant losses to human wellbeing are unacceptable.** The NCRs state that a disturbing noise is created if the activity noise raises the ambient noise level by 3 or 7 dBA or more above the residual noise level depending on the NCR applicable to the province. A noise nuisance is created if a noise impairs the peace of a person. This is a subjective assessment, and is often closely related to audibility of the noise source, and whether the person approved of the activity related to the noise. Shale gas development must avoid obviously noise sensitive areas, such as residential properties, resorts, areas where the quiet and calm nature of the place is material to its appeal. A noise impact assessment for the planned site must be done at the EIA phase according to the methods of SANS 10328. Follow the best practice guidelines in British Standard (BS) 5228-1 for controlling noise on open sites (see BSI British Standards. 2009. BS 5228-1 Code of practice for noise and vibration control on construction and open sites - Part 1: Noise, BSI.). The predicted noise excess over residual noise from shale gas development activities at 4 km are provided in the table below. The extent to which these will be acceptable or unacceptable will have to
33	Disturbance to humans due to road traffic noise		

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			be determined on a case by case basis, especially within 5 km of point or source noise to sensitive receptors.

Activity	Noise level L_p, dBA at 4 km from the activity	
	Daytime	Night time
None	0	0
Access road construction	4	12
Wellpad construction	-1	7
Rotary air well drilling	-4	4
Horizontal drilling	-5	3
Fracking	23	31

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
34	Noise disturbance to sensitive species		Animal species differ in their sensitivities to noise exposure. Some animals will be negatively impacted, for example if they require a quiet environment to hunt or to hear predators. Consequentially, prey could thrive if their natural predators can no longer find them using hearing. The extent to which noise impacts faunal species will have to be investigated on a case by case basis as part of an EIA process.
35	Electromagnetic interference impact on radio astronomy	the SARAS protection level of the AGAA, 2007	**The acceptable threshold level of interference is determined by the SARAS protection level.** Any received signal that is in excess of this protection level is deemed to be an interference source. No increase in the background EMI environment is acceptable at each of the SKA stations if it is to increase the level of EMI (as detected by an SKA station) above the SARAS protection level. Shale gas development activities in Very High sensitivity regions and within the KCAAA are not permitted in terms of the AGA. All shale gas development activities outside of the KCAAA, but within the sensitivity classes would be subject to specific mitigations per class. At a site specific level the SKA would need to be informed of the exact location of the development activities. The SKA will undertake a high level assessment for a specific site (quick desktop analysis which takes into account the local conditions at that site). If SKA identify any potential risks, they would do a more detailed assessment and propose mitigation strategies. It is highly likely that SKA would do this for the first few - and as they build up a level of confidence in the risks associated with shale gas development (types of equipment being used, profile of EMI emissions), SKA could provide significantly quicker turnaround times and perhaps provide a template for mitigation (as they are starting to do with

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			renewable energy facilities). The mitigation required per sensitivity class (see Figure 4-9), is 5 dB for Low sensitivity regions, 10 dB for Medium sensitivity regions, 15 dB for High sensitivity regions, and > 20 dB for Very High sensitivity regions.
36	Local road construction and resource implications	Municipal Systems Act of 2000, the SPLUMA, Land Use Planning Ordinance, 15 of 1985, Development Facilitation Act of 1996 and Intergovernmental Relations Framework Act of 2005 Spatial and integrated development planning and governance instruments	• **Any further increase in maintenance requirement would be unacceptable** unless fully financed by the developers - the latter could be difficult to apportion fairly and must be negotiated prior to development. • **Any increase in normal maintenance cycles for roads or the requirement of new roads to be constructed at the expense of the municipality is beyond the limit of acceptable change.** • **More finance than what is available in provincial and local budgets is beyond the limit of acceptable change.**
37	Pressure on regional road infrastructure		• **Any increase in current maintenance budget requirement and cycle is unacceptable.** • **Any increase in the maintenance costs beyond the existing cycle is unacceptable.** • **Any increase in normal maintenance cycles for roads or the requirement of new roads to be constructed at the expense of the municipality is beyond the limit of acceptable change.** • **Any additional budget requirements as budgets are already constrained are unacceptable.** • **Any increase in accidents and road deaths above current levels is unacceptable is unacceptable.**
38	Spatial and development planning, land use management and governance capacity		• **Any increase in housing and service delivery backlog is unacceptable.** • **Any above average growth in informal – green fields or 'backyard' settlements is unacceptable.** • **Any increase in operation and service cost with increase in budget deficits is unacceptable.** • **Any increase in the demand for water and other bulk services beyond the planned delivery targets, or when the demand exceeds the projected resource availability and bulk infrastructure capacity is unacceptable.** • **Any exceedance of capacity and accessibility to social services and municipal services such as education, health social services and sport facilities, land fill sites, etc. is unacceptable.** • **Any increase in inequality as measured by the average for the Gini-coefficient in the relevant regional and provincial context is unacceptable.**

No.	Impact	Relevant national policy, plans, legislation, regulations and guidelines which will guide the implementation of mitigation measures specific to the impact in question	The limits of acceptable change based on national policy, plans, legislation, regulations and guidelines, the risk assessment and spatial modelling plus key learning from international best practice
			• **The absence of forward planning (IDP/SDFs) and of credible SDFs (based on existing growth rates) is unacceptable.** • **Absence of regulatory framework and administration. Legal certainty must be regarded as the acceptable norm.** The minimum municipal planning bylaws needed for most municipalities should be expected to be promulgated • **The absence of consideration of projected and cumulative impacts of separate but inter-related land use changes and developments is unacceptable.** • **The absence of municipal skills development programmes to fulfil their mandates is unacceptable.**

6.2 Strategic Management Actions

Table 6–5: Strategic management actions with key action items and responsible parties for implementation.

Impact No	Key action items	Responsible Parties
1	**Communicate to Government that production of shale gas is not a *fait accompli*, it could only occur following promising results during a detailed and comprehensive 10 year exploration programme.** Obsolete infrastructure to connect potential shale gas to demand areas could be a risk. In order to mitigate this, there should only be investment decisions made on pipeline infrastructure once reasonable expectation and evidence of commercial scale shale gas resources are found. Localised and limited power generation in the study area should be pursued initially with imported LNG and/or regional piped gas being sought while initial production is being undertaken. Only once significant shale gas volumes at proven low prices is feasible, should pipeline infrastructure be considered for transport of gas to demand areas. Obsolete LNG import infrastructure, which is a natural outcome of a Big Gas scenario (a consequence of success), could materialise, but the associated storage facilities could potentially be converted to support liquefaction for LNG export and thus would not be stranded. Gas reticulation infrastructure for residential/industrial/commercial end-use may become stranded if developed too quickly. Similar to large pipeline infrastructure from the study area to demand areas around the country, developments in this regard should be moderated initially until significant shale gas volumes at feasible prices are established. There is a risk of gas end-users converting processes to gas and then having sub-optimal outcomes as a result of higher gas prices and needing to convert to other energy sources if gas prices increase. The switch to gas as a primary energy source should only be sought once domestic gas volumes and prices are better defined (early adoption will prove risky). As for power generation, the risk of stranded assets is relatively low, as a gas fleet built on the assumption of large and cheap shale gas supply can be utilised in a Big Gas scenario and in a solar PV/wind/LNG or solar PV/wind/piped gas scenario alike (with lower load factors – which does not affect the unit cost much for relatively cheap-to-build gas-fired power stations). The clear requirement for pipeline infrastructure to get shale gas to demand centres not located in the study area is a risk. However, planning for and implementation of significant pipeline infrastructure from the study area to demand centres will only take place once considerable	Key actors to mitigate against obsolete infrastructure investment would include DoE at a national level as well as Transnet, iGas PetroSA, DMR, DoE, Nersa and downstream industry stakeholders.

Impact No	Key action items	Responsible Parties
	verification of the shale gas resource has taken place and risk of stranded infrastructure is minimised.	
2	**Promote strategic energy planning for shale gas development, should it prove to be a commercially viable resource.** The development of sufficient network infrastructure to evacuate gas-fired power generation as well as transport natural gas to demand centres from relevant geographical locations (not only in the study area) becomes more essential at high shale gas volumes. It will become increasingly critical to ensure that sufficient electrical and natural gas network planning is periodically performed and updated in order to ensure sufficient network capacity at appropriate timescales in the study area.	Key actors to mitigate against insufficient transmission network infrastructure would include current state-owned enterprises like Eskom and Transnet while private industry midstream operators and developers would also play a key role. Key actors in ensuring sufficient gas distribution and reticulation infrastructure would likely include DoE, Nersa and downstream industry stakeholders.
3, 4, 20, 21	**(1) Implement good practice guidelines for air quality management.** Good practice guidelines are needed to minimise adverse impacts on air quality and human health. This could include application of NEM:AQA, possible amendments of its regulations and / or a SEMA. See examples of controls from: - The International Energy Agency Golden rules for a golden age of gas (2012) - The Global Gas Flaring and Venting Reduction Voluntary Standard (2004) - The IFC Environmental, Health, and Safety Guidelines for Onshore Oil and Gas Development (2007) - The United Kingdom Department of Energy and Climate Change. Fracking UK shale: local air quality (2014) Implementation of these would require strengthening of capacity within district municipalities to ensure licensing and implementation; especially given that district municipalities in the affected areas have had limited experience in the practice of air quality management and shale gas is a unique combination of emissions hitherto unknown in South Africa. **(2) Develop standards for GHG emissions**. It is recommended that national departments develop and legislate domestic "best practice" emissions standards for shale gas development.	(1) Led by the DEA in collaboration with the Shale Gas Monitoring Committee (SGMC) and Department of Health, the Eastern Cape, Northern Cape and Western Cape provincial governments; including Local and District Municipalities. (2) DEA, as the focal point for climate change should work with the DoE, DMR, Science & Technology and Water & Sanitation in developing an effective regulatory framework for GHG emissions associated with shale gas exploration and production.

Impact No	Key action items	Responsible Parties
	(3) Develop, implement and maintain an air quality and GHG monitoring station in the Central Karoo. There is an urgent need for at least one monitoring station for local air quality and GHG within the study area, well before shale gas exploration and development begins with the capacity to measure for NOx, SO_2, Particulate Matter, Volatile Organic Compounds, CO_2 and N_2O. A baseline air quality monitoring study should be at least 12 months long in order to capture seasonal differences, however studies longer than a year are needed to understand differences between years. There are currently no ambient air quality monitoring stations in the study area. As more information on the location of drilling and exploration activities is made available, sites should be identified for intensive air quality monitoring. This baseline information should be made publicly available to inform stakeholders on the current status of the area. It may be possible to use high precision measurement combined with inverse modelling, and information about local wind patterns, to improve attribution, if shale gas exploration and development takes place. The immediate priority, as for air quality, should be to establish baseline values for any methane emissions in the Karoo	(3) Led by the DEA in collaboration with the SGMC and Department of Health, the Eastern Cape, Northern Cape and Western Cape provincial governments; including Local and District Municipalities. Further monitoring requirements for air quality and GHGs must be identified in the Minimum Information Requirements currently being led by DEA.
5	**Install additional seismicity monitoring stations in the study area.** Current monitoring stations operated by the CGS, should be densified in the study area, for baseline monitoing. The CGS currently operates two seismograph stations within the study area, and another four stations close to its perimeter. It is desirable that sufficient stations are installed so that all events exceeding M1 are recorded in any part of the area where shale gas exploration and production is likely to take place. These areas will only become apparent when the exploration and appraisal phase nears completion. At the present time (August 2016) a further six stations were being installed by the CGS in the study area. This should improve the threshold of completeness to M1.	CGS should lead this in collaboration with DMR, DST (especially considering their SKA interest), DEA and DWS.
6, 20, 21	**Develop a policy statement regarding the use of water in the Central Karoo.** Each well requires in the region of 10 500 m^3 of water to be fractured. The exact amount of water required depends on hole depth, geological conditions and the number of fracturing stages required. Assuming water re-use at 50% of drill fluid and 30% of fracking fluid, in the region of 6 000 000 – 45 000 000 m^3 would be required for the Small Gas and Big Gas scenarios respectively. The quality of the water does not have to be of a potable standard and can be	The SGMC and shale gas SEA PEC consisting of DEA, DST, DMR, DWS, DoE and DAFF

Impact No	Key action items	Responsible Parties
	salty or 'brackish'. There is not capacity to supply water for shale gas exploration and production from existing local sources. Water availability for existing users in the study area is severely constrained. Surface water availability is generally low, and in many areas over-allocated. Landowners rely mainly on groundwater resources for domestic and stock water. Groundwater recharge is typically low and sporadic. The use of groundwater is increasing, particularly during drought years. In many areas, groundwater already supplies 100% of the use. The availability of groundwater to meet the demand of even the Reference Case, is already seriously constrained. The additional demand under the Small and Big Gas scenarios could not be met from known local potable resources and would be considered a very high risk if local resources were utilised. This should be captured as a clear policy statement and the following text should be inserted into the current technical regulations: *"Evidence has demonstrated an insufficient availability of water resources in the Central Karoo to supply the needs of shale gas exploration and production, as such existing water resources are prohibited from use. All water required for shale gas exploration and production operations should be sourced from deep saline groundwater and treated to industry standards or sourced from outside the Central Karoo region, as demarcated by the study area of the strategic environmental assessment for shale gas development (2017)".*	
7, 9, 10, 20, 21	**Ensure baseline and ongoing water monitoring data is adequately collected.** Monitoring of water resources is important for minimising, controlling and mitigating against the effects of shale gas exploration and production. For Phase 1 Exploration where vertical drilling will be undertaken without hydraulic fracturing, there is little baseline monitoring that can be usefully undertaken. This process in itself, as the first step of exploration acts as a monitoring opportunity to test groundwater as holes are drilled and sampled. Prior to Phase 2 ("Appraisal"), where hydraulic fracturing is undertaken, a comprehensive understanding of groundwater conditions is required prior to the commencement to ensure proper interpretation of changes in groundwater over time. Monitoring data would also be used for calibration and verification of prediction and assessment models, for evaluating and auditing the success of management plans, and for assessing the extent of compliance with prescribed standards and regulations. Furthermore, it would be difficult, if not impossible, to identify the effects of shale gas development on surface and groundwater systems without baseline monitoring. Long-term data would therefore need to be collected, preferably over at least five years, to	MIRs must provide the structure for the submission of monitoring plans which will be included in applications for EA. DEA is leading the process to development the MIRs along with the shale gas SEA PEC and the SGMC. More broadly, oil and gas companies, government or its appointees, and perhaps independent monitoring institutions, should be involved in monitoring. Strict reporting requirements, to government and/or other independent institutions, should be in place and results should be

Impact No	Key action items	Responsible Parties
	identify trends in the biophysical conditions and functioning of these systems in the absence of development activities. The proposed action is that MIRs are developed and include the need and requirements for baseline and ongoing water monitoring, especially for Phase 2 (“Appraisal”), where hydraulic stimulation is planned.	independently verified. Government should play an oversight role, which might include verification sampling. It may be necessary to establish an independent laboratory for monitoring aspects such as natural isotopes, constituents of fracking fluids, and uncommon organic substances emanating from fracked wells and local groundwater.
11, 20, 21	**Develop a policy statement regarding the disposal of waste in the Central Karoo.** Municipal landfills in the study are not designed or equipped to receive waste generated by shale gas development activities, and municipal staff do not currently have the skills or experience to manage it responsibly. As such, waste effluent should be treated on site by the industry for reuse in fracking operations. The waste streams from shale gas exploration and production are new to South Africa and therefore capacity needs to be created to evaluate licence applications efficiently and responsibly. There is insufficient laboratory capacity in South Africa able to perform the volume of analyses necessary for operational waste classification under the Big or Small Gas scenarios. The analyses must be undertaken at South African National Accreditation System accredited laboratories, very few of which have accreditation for the prescribed tests. Additional laboratory capacity will be needed to deal with the volume of analyses that would be required for shale gas operations. Currently, no sites are licensed for Type 1, 2 or 3 hazardous waste disposal in the study area. This should be captured as a clear policy statement and the following text should be inserted into the current technical regulations: *All waste streams emanating from shale gas exploration and production must be treated on-site by the industry and at their expense for reuse in continued hydraulic fracturing operations. Municipal landfills and treatment works cannot accept waste from shale gas exploration and production. Hazardous wastes must be transported out of the Central Karoo as there are no sites currently permitted to receive these wastes.*	The SGMC and shale gas SEA PEC consisting of DEA, DST, DMR, DWS, DoE and DAFF. Local Institutional Governance Programmes for Shale Gas must be initiated by each Province in collaboration with Local Municipalities so that a baseline inventory of municipal waste services and capacity is clary established and so that regional staffs are aware of what is planned over the next 10 years as regards shale gas exploration and appraisal activities.
12	**Develop a landscape biodiversity baseline monitoring programme.** Institutional arrangements and responsibilities are fundamental to the success of baseline monitoring	Implementation of these recommendations require proactive

Impact No	Key action items	Responsible Parties
	efforts. There is a need for independent monitoring by third parties, not just monitoring by the shale gas companies themselves. This will generally be led by government. Shale gas companies could be required to contribute to the cost of such government-led monitoring in proportion to the scale of their activities. The implementation of the strategic approach to mitigation, assumes the existence of appropriate capacity in a range of organs of state including regulatory authorities. Capacity is currently weak with regard to some of the mitigation measures, and would need to be strengthened in order to support their successful implementation. It is important for monitoring efforts to be co-ordinated. In addition, a system or process should be in place for integrating monitoring data from the site level, the ecosystem level and the landscape level into a coherent set of information for the study area as a whole, which can be used to inform planning and decision-making. Information from monitoring should feed into SANBI's programme of monitoring and reporting on the state of biodiversity nationally. A strategic analysis for identifying and filling capacity gaps within the current institutional framework should be initiated, using the recently approved Business Case for Biodiversity Stewardship (SANBI, 2015) as the first point of reference.	support from the DEA and National Treasury to unlock resources for strengthening biodiversity stewardship programmes.The development of a landscape level monitoring plan for the Central Karoo should be shared across several organisations, led by the South African Environmental Observation Network, which has an important role in landscape-level monitoring and maintaining benchmark sites for the evaluation of shale gas extraction impacts. Partner organisation would include SANBI, provincial conservation authorities and DWS.
14, 15	**Develop an adequate financing and fund review model for abandoned or decommissioned wells.** The South African experience in mining shows that funds are too often insufficient and/or not properly secured for mine closure. Similar experience can be found in other countries such as the USA for mining and hydraulic fracturing. In the future this should be investigated and an adequate financing and fund review model for abandoned or decommissioned wells should be put in place using the amended regulations for financial provisions in mining as a departure point. It will be particularly important that sound mechanisms are put in place to deal with all potential long-term legacy (i.e. latent and residual) risks including those which may remain beyond the ten year period post-closure for which financial provisions must be made in mining. This could, for example, include considering the potential role for industry-wide financial mechanisms that allow for the pooling of risks among producers in order to protect water resources drawing on lessons from the mining industry. A future shale gas industry would have the rare opportunity to learn from mining and put such mechanisms in place from the start thereby enhancing the chances of achieving sustainability goals. The benefits of shale gas production to the national Gross Domestic Product will only be realised if externality costs are not borne by local	Plan of action to be developed jointly by the DEA, the DMR, the DoE, National Treasury and DEA&DP. DEA&DP have initiated an internal process for this and have a working draft covering the adequacy of the financial provisioning regulations to cover latent or legacy shale gas impacts. This document should be used as the point of departure in further analyses of the financial provisioning regulations.

Impact No	Key action items	Responsible Parties
	municipalities and residents. This will require shareholding, purchasing agreements, local hiring and training programmes as envisaged in Social and Labour Plans and developer requirements as established by the Renewable Energy Independent Power Producers Procurement Programme with unambiguous compensation mechanisms for landowners in the event of an externality cost occurring.	
16, 17, 18, 19, 22-26, 27, 32-34, 35, 36-38	**Ensure institutional capacity development and integrated governance.** A large number of national, provincial and local government departments will be responsible for authorisation processes for shale gas exploration and production activities – these need to be undertaken in a participatory, integrated and streamlined manner as envisaged in the Constitution and the OES. Institutional capacity and governance programmes should focus on educating local municipalities about shale gas exploration and good governance. National and provincial departments must work together with local government to identify gaps in knowledge, key questions, skill interventions, training programmes and infrastructure requirements. This information must be fed into broader regional planning processes such as SDF, IDP, EMF, Integrated Tourism Plans and Regional SDFs so that planning for shale gas exploration and production is strategic and integrated. The Western Cape DEA&DP are piloting such a programme. This programme must investigate the potential for pro-actively releasing land for housing, and installing infrastructure, so that in-migrants can build informal housing if required (in the short-term), or provide public housing (in the longer-term). Upgrades to water, electricity and sewerage infrastructure, as well as local streets and stormwater drainage, to cope with the additional demand should be assessed. This will be the responsibility of Local Municipalities, as part of their spatial planning responsibility; however, it may also require financial and technical support by provincial authorities. Assistance should be provided to the local business sector, particularly through Business Chambers, to understand and respond to new opportunities created by shale gas exploration and production. Where such chambers do not exist, they need to be established by municipalities and the business community working together.	Led by the provincial Departments in the Western, Eastern and Northern Cape and Local Municipalities, with the participation of the Department of Co-operative Governance and Traditional Affairs, the Department of Transport, the EDD and others.
28-31	**(1) Develop guidelines for heritage assessments and monitoring.** The South African Heritage Resources Authority (SAHRA), under Section 38 and with input from provincial and local authorities, should draft a set of guidelines for the implementation of shale gas exploration and production which will serve to guide the assessment and monitoring of all	The SAHRA and PHRAs

Impact No	Key action items	Responsible Parties
	activities. For the same reason, where necessary, SAHRA, with input from provincial and local authorities, should be responsible for comments and decisions related to shale gas. **(2) Develop a Memorandum of Understanding between SAHRA and each Provincial Authority.** 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 in the EIA context) be encouraged by heritage resource authorities in order to monitor Development Phase impacts, especially those associated with built heritage. **(3) Update provincial heritage registers.** In terms of Section 30 of the NHRA, all Provincial Heritage Resource Authorities (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. 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.	
36-38	**Investigate the feasibility of using rail to mitigate road risks.** Transnet should assess the following questions: • Is it possible to move the volumes of materials as contemplated in the Small and Big Gas scenarios? • What are the costs to move these materials, considered per scenario and also considered for the three different railway links proposed? i.e. Cape Town-Beaufort West, Port Elizabeth- Beaufort West and Beaufort West –Johannesburg. • What are the costs relative to the cost saving derived from not requiring the same extent of road maintenance? • What are the costs for each scenario, for each railway link compared against	Department of Transport, Department of Public Works, Transnet, DEA

Impact No	Key action items	Responsible Parties
	conventional trucking costs? i.e. Is the freight rail option cost competitive? • Considering the tonnes per annum assumed for the Small Gas scenario versus the tonnes per annum required for the Big Gas scenario, at what gas production volume i.e. ranging from 5 – 20 tcf (and corresponding material metrics) does the use of freight rail become really cost competitive?	

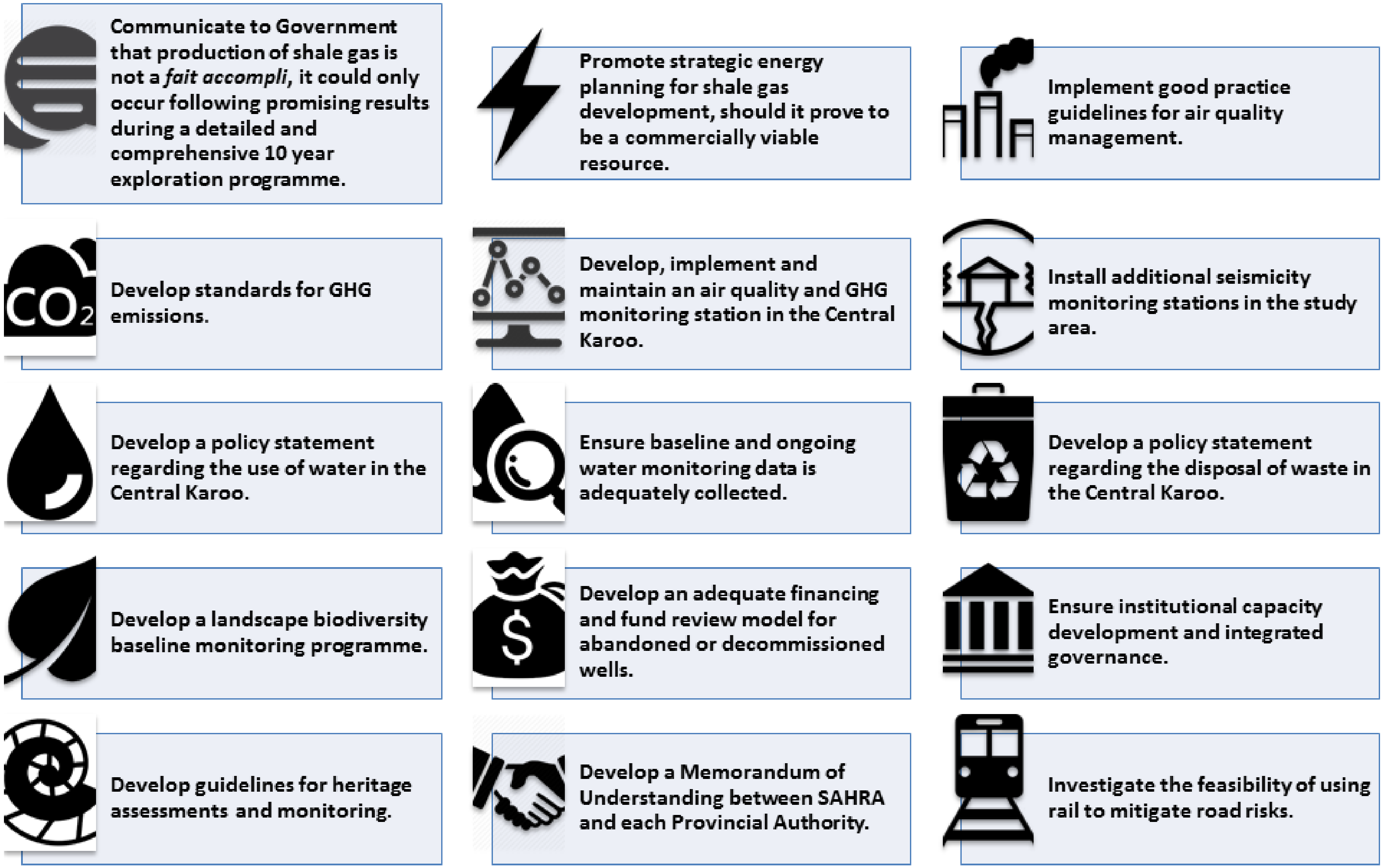

Figure 6–10: Summary of the strategic management actions to assist strategic level risk mitigation

7. CONCLUSION

It is a common misconception that the ‘decision’ regarding shale gas exploration and production is binary: ‘yes’ or ‘no’. In fact, there are a number of decisions, via a number of decision-making processes, made across all three spheres of government and civil society; all of which will be made over a protracted period of time. Most of the decisions which will need to be taken are conditional rather than absolute - a certain activity may be permitted in one location and not another, or with a given set of requisite mitigating actions to reduce risk. All of this will depend on the nature of the activities proposed and the location within which they are proposed. This will be determined, to a large extent, by the site specific environmental assessment processes, such as EIAs which will be required prior to an activity obtaining EA, as discussed in Section 2.6.3.1.

Evidence suggests that the risks associated with the Exploration Only scenario could be mitigated to within acceptable levels. This however depends of the veracity of the specific EIA processes undertaken for decision-making, the quality of baseline and on-going monitoring programmes, the ability of South Africa to develop adequate human capacity and skills in all sectors, the strength of our institutions; and a collective commitment to cooperative and transparent governance. These processes must be guided by the NEMA MIRs, as detailed in Appendix 3 to this report.

The nature of shale gas development makes it relatively easy to avoid sensitive features which pose the greatest risk. For Small Gas and Big Gas, while only a fraction (0.0002 % and 0.0009 % respectively) of the study area will be directly impacted, the risk profile does increase because of indirect and cumulative impacts. The most critical aspect of shale gas exploration and production at significant scale is the development of suitable baseline data for water, air, human health, noise and biodiversity. Adequate data collection may take in the region of 3-5 years to accumulate if it is to be usable in litigation processes into the future.

In South Africa, as a democratic country with a strong developmental focus, it is essential that governance is informed by inclusive, iterative and deliberative knowledge generation and scientific assessment procedures that are based on technically sound, scientifically credible and publically acceptable information, and that involves numerous stakeholders during policy formulation and strategic decision making. Governance relates to all processes of exerting power or decision-making capacity and is a function performed by government, the private sector and civil society by using laws or other participatory processes. The success of ‘resource governance’ is fundamentally dependent on processes which seek to include broader society in both the evidence base which informs the science-policy interface and the subsequent decision-making processes made relative to that shared and co-generated evidence base.

Decisions related to shale gas exploration and production in South Africa can have lasting, and in some cases, irreversible impacts on the Central Karoo. Given the sensitivity of the receiving environment, in particular, the scarcity and value of potable water in the region, even with a relatively non-invasive exploration campaign, there is no margin for error. Effective and functional governance systems, at all levels of government and broader society, need to be in place, even prior to the exploration phase.

This will require a step-wise approach, rooted in the concept of adaptive management which, at its core, rests on the notion that it is crucially important to gather baseline and ongoing information and use it to test critically both the management actions employed to mitigate undesired outcomes and the assumptions which underpin those actions. As a starting point, South Africa is in the advantageous position of being able to accumulate such a dataset and start building the institutions capable of collecting, managing and analysing that data in a responsible and transparent manner.

Ongoing research is also required to ensure that environmental policies and regulations keep pace with new developments. This is not to suggest that no development should ever take place until all risk is mitigated to zero – this is a philosophical and practical impossibility. Rather, if South Africa does choose to proceed with the exploration of shale gas, and assuming an economically and technically suitable reserve that can be developed is discovered, then the decision-making process to arrive at that point must be grounded in scientifically acceptable and publically accepted evidence and participatory processes.

8. REFERENCES

Academy of Science South Africa (ASSAf). 2016. South Africa's Technical Readiness to Support the Shale, doi: http://dx.doi.org/10.17159/assaf.2016/0003

Adair, S.K., Pearson, B.R., Monast, J., Vengosh, A. and Jackson, R. 2012. Considering shale gas extraction in North Carolina: Lessons from other states. Duke Environmental Law & Policy Forum, 22(257), 257-301

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., Herndon, S. C., Kolb, C. E., Fraser, M. P., Hill, A. D., Lamb, B. K., Miskimins, J., Sawyer, R. F., & Seinfeld, J. H. 2013. Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences, 110(44), 17768–17773. http://doi.org/10.1073/pnas.1304880110

American Petroleum Institute. 2009. Environmental protection for onshore oil and gas production operations and leases. API Recommended Practice 51R. 1st Edition, July 2009.

Ash, H. 2011. EPA launches hydraulic fracturing study to investigate health and environmental concerns while North Dakota resists regulation: Should citizens be concerned? North Dakota Law Review, 87(717), 717- 741.

Atkinson, D., Schenk, R., Matebesi, Z., Badenhorst, K., Umejesi, I. and Pretorius, L. 2016. Impacts on Social Fabric. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Blohm, A., Peichel, J., Smith, C. and Kougentakis, A. 2012. The significance of regulation and land use patterns on natural gas resource estimates in the Marcellus shale. Energy Policy, 50(2012), 358-369. http://dx.doi.org/10.1016/j.enpol.2012.07.031

Boersma, T. and Johnson, C. 2012. The Shale Gas Revolution: U.S. and EU Policy and Research Agendas. Review of Policy Research, 29(4), 570-576. DOI: 10.1111/j.1541-1338.2012.00575.x

Brantley, S. L., Yoxtheimer, D.A., Arjmand, S., Grieve, P., Vidic, R.D., Pollak, J., Llewellyn, G.T., Abad, J.D. & Simon, C. 2014. Water resource impacts during unconventional shale gas development: The Pennsylvania Experience. International Journal of Coal Geology, 126, 140 - 156. doi:DOI: 10.1016/j.coal.2013.12.017.

British Standards Institution (BSI). 2009. BS 5228-1 Code of practice for noise and vibration control on construction and open sites - Part 1: Noise, BSI.

Brundage, T.L., Clark-Teisher, S., Jacquet, J., Kelsey, T.W., Ladlee, J.R., Lorson, J.F., Michael, L.L. and Murphy, T.B. 2011. Pennsylvania Marcellus Shale Workforce Needs Assessment, MSETC (Marcellus Shale Education and Training Centre) www.shaletec.org/reports.html

Burns, M., Atkinson, D., Barker, O., Davis, C., Day, L., Dunlop, A., Esterhuyse, S., Hobbs, P., McLachlan, I., Neethling, H., Rossouw, N., Todd, S., Snyman-Van der Walt, L., Van Huyssteen, E., Adams, S., de Jager, M., Mowzer, Z. and Scholes, B. 2016. Scenarios and Activities. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Centner, T.J. and Kostandini, G. 2015. Local governments want authority to address problems: The case of horizontal drilling and hydraulic fracturing in the United States. Land Use Policy, 49(2015), 227-235. http://dx.doi.org/10.1016/j.landusepol.2015.08.012

Cole, D.I. 2014. How does geology influence shale gas recovery in the Karoo? Geoclips, 39, 6-7.

Decker, J. and Marot, J. 2012. Resource assessment. In: Department of Mineral Resources Working Group, Report on hydraulic fracturing in the Karoo Basin of South Africa, Annexure A, 1-13.

Department of Environmental Affairs (DEA), 2013. The Valuation of Ecosystem Services in the Context of the new South African Mining and Biodiversity Guidelines: Implications for Theory and Practice. ALCRL 2014 International Conference on Responsible Leadership. DOI: 10.13140/2.1.3899.9847

Department of Environmental Affairs (DEA). 2004. National Ambient Air Quality Standards (NAAQS), under the National Environmental Management: Air Quality Act No. 39 of 2004. Government Notice 32815, No. 1210, 24 December 2009, Pretoria.

Department of Environmental Affairs (DEA). 2015. Draft National Greenhouse Gas Emission Reporting Regulations, under the National Environmental Management: Air Quality Act No. 39 of 2004 (NEM:AQA). Government Gazette, No. 38857, Notice 541 of 2015. Pretoria.

Department of Environmental Affairs and Development Planning (DEA&DP). 2012. Western Cape Intra-Governmental Shale Gas Task Team Report: Interim Report on the Potential Opportunities and Risks Related to Shale Gas Extraction in the Western Cape.

Department of Mineral Resources (DMR). 2012. Report on the investigation of hydraulic fracturing in the Karoo Basin of South Africa. Sunnyside: Department of Mineral Resources.

Department of Mineral Resources (DMR). 2015. Regulations for Petroleum Exploration and Production, under the Mineral and Petroleum Resources Development Act (No. 28 OF 2002), Government Gazette, No 38855, Notice 466, 3 June 2015, Pretoria.

Department of Minerals and Energy (DME). 1998. White Paper on Energy Policy for South Africa. Pretoria: DME.

Drohan, P. J., Brittingham, M., Bishop, J. & Yoder, K. 2012. Early Trends in Landcover Change and Forest Fragmentation Due to Shale-Gas Development in Pennsylvania: A Potential Outcome for the Northcentral Appalachians. Environmental Management, 49(5), 1061–1075. doi:10.1007/s00267-012-9841-6

Durrheim, R., Doucouré, M. and Midzi, V. 2016. Erthquakes. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Equitable Origin Inc. 2015. EO100™ Standard Technical Addendum: EO100.1: Onshore Conventional Oil and Gas Operations. 7pp. Available at https://www.equitableorigin.org/eo100-for-responsible-energy/eo100tm-for-conventional-onshore-oil-gas/

Esterhuyse,S., Avenant, M., Watson, M., Redelinghuys, N., Kijko, A., Glazewski, J., Plit, L.A., Kemp, M., Smit, A., Sokolic, F., Vos, A.T., Reynolds, D., von Maltitz, M., van Tol, J., Bragg, C., van Soelen, B., & Ouzman, S. 2014. Development of an Interactive Vulnerability Map and Monitoring Framework to Assess the Potential Environmental Impact of Unconventional Oil and Gas Extraction by Means of Hydraulic Fracturing. Water Research Commission Report No. 2149/1/14. ISBN 978-1-4312-0589-9

Fernández, R.J. 2016. How to be a more effective environmental scientist in management and policy contexts. Environmental Science & Policy, 64(2016), 171-176.

Geel, C., De wit, M., Booth, P., Schultz, H.M. and Horsfield, B. 2015. Palaeo-environment, diagenesis and characteristics of Permian black shales in the lower Karoo Supergroup flanking the Cape Fold Belt near

Jansenville, Eastern Cape, South Africa: implications for the shale gas potential of the Karoo Basin. South African Journal of Geology, 118(3), 249-274. doi: 10.2113/gssajg.118.3.249

Genesis Analytics and Digby Wells Environmental. 2015. Evaluation of the effectiveness of environmental governance in the mining sector. Report commissioned by the Department of Planning Monitoring and Evaluation (DPME). DPME, Pretoria.

Genthe, B., Maherry, A., Steyn, M., Rother, A., London, L., and Willems, M. 2016. Impacts on Human Health.In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Golder Associates. 2011. Environmental Management Plan South Western Karoo Basin Gas Exploration Application. PASA Reference No. 12/3/219

Golder Associates. 2013. Shell Karoo Project: Preliminary Site Selection Report; Desktop Identification of Areas Within which Exploration Sites Could be Positioned. Prepared for Shell Exploration Company BV. Report number: 11613619-11787-2

Golder Associates. 2015. Updated Environmental Management Programme Report in support of application for Petroleum Exploration Rights within the Magisterial Districts of Somerset East, Graaff-Reinet, Cradock, Pearston and Jansenville, Eastern Cape Province. Prepared for Bundu Gas and Oil Exploration (Pty) Ltd. Report number: 1400417-13204-1

Grant Thornton. 2014. Northern Cape tourism master plan review. Kimberley: Northern Cape Department of Economic Development and Tourism.

Hobbs, P., Day, E., Rosewarne, P., Esterhuyse, S., Schulze, R., Day, J., Ewart-Smith, J., Kemp, M., Rivers-Moore, N., Coetzee, H., Hohne, D., Maherry, A. and Mosetsho, M. 2016. Water Resources. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Holness, S., Driver, A., Todd, S., Snaddon, K., Hamer, M., Raimondo, D., Daniels, F., Alexander, G., Bazelet, C., Bills, R., Bragg, C., Branch, B., Bruyns, P., Chakona, A., Child, M., Clarke, R.V., Coetzer, A., Coetzer, W., Colville, J., Conradie, W., Dean, R., Eardley, C., Ebrahim, I., Edge, D., Gaynor, D., Gear, S., Herbert, D., Kgatla, M., Lamula, K., Leballo, G., Lyle, R., Malatji, N., Mansell, M., Mecenero, S., Midgley, J., Mlambo, M., Mtshali, H., Simaika, J., Skowno, A., Staude, H., Tolley, K., Underhill, L., van der Colff, D., van Noort, S. and von Staden, L. 2016. Biodiversity and Ecological Impacts: Landscape Processes, Ecosystems and Species. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Howarth, R.W., Santoro, R., & Ingraffea, A. 2011. Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change, 106(4), 679–690. http://doi.org/10.1007/s10584-011-0061-5

Glazewski, J., Esterhuyse, S (eds). 2016. Hydraulic Fracturing in the Karoo: Critical Legal and Environmental Perspectives. ISBN: 9781485118183. Cape Town: Juta

Jackson R.B., Vengosh A., Darrah T.H., Warner, N.R., Down, A., Poreda, R.J., Osborn, S.G. Zhao, K. and Karr, J.D. 2013. Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. Proceedings of the National Academy of Sciences, 110(28): 11250–11255.

Kargbo, D.M., Wilhelm, R.G. and Campbell, D.J. 2010. Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities. Environmental Science and Technology, 44, 5679-5684

Klausmann, A. M., Pollack, J. A., & DesAutels, C. 2011. Managing Air Quality Issues Associated with hydraulic fracturing. Exponent Health Sciences, 11, 1-6. Retrieved from http://www.exponent.com/files/Uploads/Documents/Newsletters/Health News_Vol 11_2011.pdf

Kuuskraa, V., Stevens, S., Van Leeuwen, T. and Moodhe, K. 2011. World Shale Gas Resources: An initial assessment of 14 regions outside the United States. US Energy Information Administration, 1–365. Prepared by: Advanced Resources International, Inc. http://www.eia.gov/analysis/studies/worldshalegas/pdf/fullreport.pdf

Kuuskraa, V., Stevens, S., Van Leeuwen, T. and Moodhe, K. 2013. World shale gas and shale oil resource assessment. Prepared for United States Energy Information Administration, 2013. Technically recoverable shale oil and shale gas resources: An assessment of 137 shale formations outside the United States. Available at: http://www.eia.gov/analysis/studies/worldshalegas/pdf/fullreport.pdf

Measham, T.G., Fleming, D.A. and Schandl, H. 2016. A Conceptual Model of the Socioeconomic Impacts of Unconventional Fossil Fuel Extraction. Global Environmental Change, 36, 101-110. Available at: https://mpra.ub.uni-muenchen.de/68523/

Mowzer, Z. and Adams, S. 2015. Shale gas prospectivity analysis of the southern main Karoo Basin. Petroleum Agency South Africa contribution to the Strategic Environmental Assessment, Agency report FG 2015, 1-57.

Myers, T. 2012. Potential contaminant pathways from hydraulically fractured shale to aquifers. Ground Water, 50(6), 872-882.

National Planning Commission (NPC). 2013. National Development Plan 2030. Online: https://www.environment.gov.za/sites/default/files/docs/national_development_plan_2030vision.pdf

Northern Cape Province. 1998. Northern Cape Planning and Development Act No. 7 of 1998. Northern Cape Provincial Gazette, 56 pp. Available at http://cer.org.za/wp-content/uploads/2014/02/planningdevelopment.pdf

Norton, B.G. 2005. Sustainability: A philosophy of adaptive ecosystem management. University of Chicago Press.

Oberholzer, B., Lawson, Q., Klapwijk, M., Young, G., Anderson, M. and Orton, J. 2016. Visual, Aesthetic and Scenic Resources. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Oelofse, S., Schoonraad, J. and Baldwin, D. 2016. Impacts on Waste Planning and Management. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks, CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Oettle, N., Lindeque, L., du Toit, J., Samuels, I., Osler, A., Vetter, S. and van Garderen, E.A. 2016. Impacts on Agriculture. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Orton, J., Almond, J., Clarke, N., Fisher, R., Hall, S., Kramer, P., Malan, A., Maguire, J. and Jansen, L. 2016. Impacts on Heritage. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Osborn, S.G., Vengosh, A., Warner, N.R. and Jackson, R.B. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences, 108(20), 8172-8176.

Rahm, D. 2011. Regulating hydraulic fracturing in shale gas plays: The case of Texas. Energy Policy, 39(2011), 2974-2981

Republic of South Africa (RSA). 1983. Conservation of Agricultural Resources Act No. 43 of 1983. Government Gazette, No. 8673, Notice 883, 27 April 1983, Cape Town.

Republic of South Africa (RSA). 1989. Environment Conservation Act No. 73 of 1989. Government Gazette, Vol. 288, No. 11927, Notice 1188, 9 June 1989, Cape Town.

Republic of South Africa (RSA). 1993. Occupational Health and Safety Act No. 181 of 1993. Government Gazette, Vol. 342, No. 15369, Notice 2471, 29 December 1993, Cape Town.

Republic of South Africa (RSA). 1995. Development Facilitation Act No. 67 of 1995. Government Gazette, Vol. 364, No. 16730, Notice 1526, 4 October 1995, Cape Town.

Republic of South Africa (RSA). 1996. Constitution of the Republic of South Africa. Act No. 108 of 1996.

Republic of South Africa (RSA). 1996. National Road Traffic Act No. 93 of 1996. Government Gazette, Vol. 377, No. 17603, Notice 1892, 22 November 1996, Cape Town.

Republic of South Africa (RSA). 1997. Water Services Act No. 108 of 1997. Government Gazette, Vol. 390, No. 18522, Notice 1662, 19 December 1997, Cape Town.

Republic of South Africa (RSA). 1998. National Environmental Management Act 107 of 1998 (NEMA). Government Gazette, Vol. 401, No. 19517, Notice 1540, 27 November 1998, Cape Town.

Republic of South Africa (RSA). 1998. National Water Act 36 of 1998 (NWA). Government Gazette, Vol. 398, No. 19182, Notice 1091, 26 August 1998, Cape Town.

Republic of South Africa (RSA). 1999. National Heritage Resources Act No. 25 of 1999 (NHRA). Government Gazette, Vol. 406, No. 19974, Notice 506, 28 April 1999, Cape Town.

Republic of South Africa (RSA). 1999. National Nuclear Regulator Act No. 47 of 1999. Government Gazette, Vol. 414, No. 20760, Notice 1537, 20 December 1999, Cape Town.

Republic of South Africa (RSA). 1999. World Heritage Convention Act No. 49 of 1999. Government Gazette, Vol. 414, No. 20717, Notice 1485, 9 December 1999, Cape Town.

Republic of South Africa (RSA). 2000. Local Municipality: Municipal Systems Act No. 32 of 2000. Government Gazette, Vol. 425, No. 21776, Notice 1187, 20 November 2000, Cape Town.

Republic of South Africa (RSA). 2001. Gas Act No. 48 of 2001. Government Gazette, Vol. 440, No. 23150, Notice 217, 21 February 2002, Cape Town.

Republic of South Africa (RSA). 2002. Disaster Management Act No. 57 of 2002. Government Gazette, Vol. 451. No. 24252, Notice 98, 15 January 2003, Cape Town.

Republic of South Africa (RSA). 2002. Mineral and Petroleum Resources Development Act No. 28 of 2002. Government Gazette, Vol. 448, No. 23922, 10 October 2002. Cape Town.

Republic of South Africa (RSA). 2003. National Environmental Management: Protected Areas Act No. 57 of 2003. Government Gazette, Vol. 464, No. 26025, Notice 181, 18 February 2004, Cape Town.

Republic of South Africa (RSA). 2003. National Health Act No. 61 of 2003. Government Gazette, Vol. 469, No. 26595, Notice 869, 23 July 2004, Cape Town.

Republic of South Africa (RSA). 2004. National Environmental Management: Air Quality Act No. 39 of 2004 (NEM:AQA). Government Gazette, Vol. 476, No. 27318, Notice 163, 24 February 2005, Cape Town.

Republic of South Africa (RSA). 2004. Social Assistance Act No. 13 of 2004. Government Gazette, Vol. 468, No. 26446, Notice 714, 10 June 2004, Cape Town.

Republic of South Africa (RSA). 2005. Intergovernmental Relations Framework Act No. 13 of 2005. Government Gazette, Vol. 482, No. 27898, Notice 825, 15 August 2005, Cape Town.

Republic of South Africa (RSA). 2006. Electricity Regulation Act No. 4 of 2006. Government Gazette, Vol. 493, No. 28992, Notice 660, 5 July 2006, Cape Town.

Republic of South Africa (RSA). 2007. Astronomy Geographic Advantage Act No. 21 of 2007. Government Gazette, Vol. 516, No. 31157, Notice 666, 17 June 2008, Cape Town.

Republic of South Africa (RSA). 2008. National Energy Act No. 34 of 2008. Government Gazette, Vol. 521, No. 31638, Notice 1263, 24 November 2008, Cape Town.

Republic of South Africa (RSA). 2008. National Environmental Management: Waste Act No. 59 of 2008 (NEM:WA). Government Gazette, Vol. 525, No. 32000, Notice 278, 10 March 2009, Cape Town.

Republic of South Africa (RSA). 2013. The Spatial Planning and Land Use Management Act No. 16 of 2013 (SPLUMA). Government Gazette, Vol. 578, No. 36730, No. 559, 5 August 2013, Cape Town.

Robbins, K. 2013. Awakening the Slumbering Giant: How horizontal drilling technology brought the endangered species act to bear on hydraulic fracturing. Case Western Reserve Law Review, 63(4), 13-16

South African National Biodiversity Institute (SANBI). 2015. *The Business Case for Biodiversity Stewardship*. A report produced for the Department of Environmental Affairs. Developed by Cumming, T., Driver, A., Pillay, P., Martindale, G., Purnell, K., McCann, K. & Maree, K. South African National Biodiversity Institute, Pretoria.

Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). (2016). Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Seeliger, L., de Jongh, M., Morris, D., Atkinson, D., du Toit, K. and Minnaar, J. 2016. Impacts on Sense of Place. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Souther, S., Tingley, M., Popescu, V., Hayman, D., Ryan, M., Graves, T., Terrell, K. 2014. Biotic impacts of energy development from shale: Research priorities and knowledge gaps. Frontiers in Ecology and the Environment, 12(6), 330–338

SRK. 2015. Petroleum Exploration Right – Environmental Management Programme: Seismic Survey, Southern Karoo Basin. Prepared for Falcon Oil & Gas Limited. Report Number: 424473/04

Stephens, D.B. 2015. Analysis of the groundwater monitoring controversy at the Pavillion, Wyoming natural gas field. Groundwater, 53(1), 29-37.

Tiplady, A., van der Merwe, P. and Otto, B. 2016. Electromagnetic Interference. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (Eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Toerien, D., du Rand, G., Gelderblom, C. and Saayman, M. 2016. Impacts on Tourism in the Karoo. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Tollefson, J. 2012. Air sampling reveals high emissions from gas field. Nature, 482(7384), 139–140. http://doi.org/10.1038/482139a

United Nations Intergovernmental Panel on Climate Change (IPCC), 2014. Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130.

United States Department of Energy. 2009. Modern shale gas development in the United States: A Primer. Washington, D.C.: United States Department of Energy.

United States Energy Information Administration (U.S. EIA). 2013. Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States. Washington DC: US Department of Energy.

United States Environmental Protection Agency (US EPA). 2015. Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft). US Environmental Protection Agency, Washington, DC, EPA/600/R-15/047, 2015. www.epa.gov/hfstudy (draft)

Van Huyssteen, E., Green, C., Paige-Green, P., Oranje, M., Berrisford, S., McKelly, D. 2016. Impacts on Integrated Spatial and Infrastructure Planning. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Van Zyl, H., Fakir, S., Leiman, T. and Standish, B. 2016. Impacts on the Economy. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Wade, A., Jongens, A. and van Niekerk, W. 2016. Noise Generated by Shale Gas- Related Activities. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Western Cape Province. 1985. Cape Land Use Planning Ordinance No. 15 of 1985. Provincial Administration, Western Cape. 22 November 1985, 32 pp. Available at http://www.conservationatwork.co.za/sites/default/files/legislation-legal/15b.%20land_planning_ordinance_WC.pdf

Wiseman, H. 2009. Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation. Fordham environmental Law Review, 115(2009), pp. 55

Wiseman, H. 2014. The Capacity of States to Govern Shale Gas Development Risks. Environmental Science & Technology, 48(15), 8376-8387. DOI: 10.1021/es4052582.

Wright, J., Bischof-Niemz, T., Carter-Brown, C., and Zinaman, O. 2016. Effects on National Energy Planning and Energy Security. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the

Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Zuckerman, G. 2013. The Frackers: The Outrageous Inside Story of the New Billionaire Wildcatters. Portfolio/ Penguin, New York.