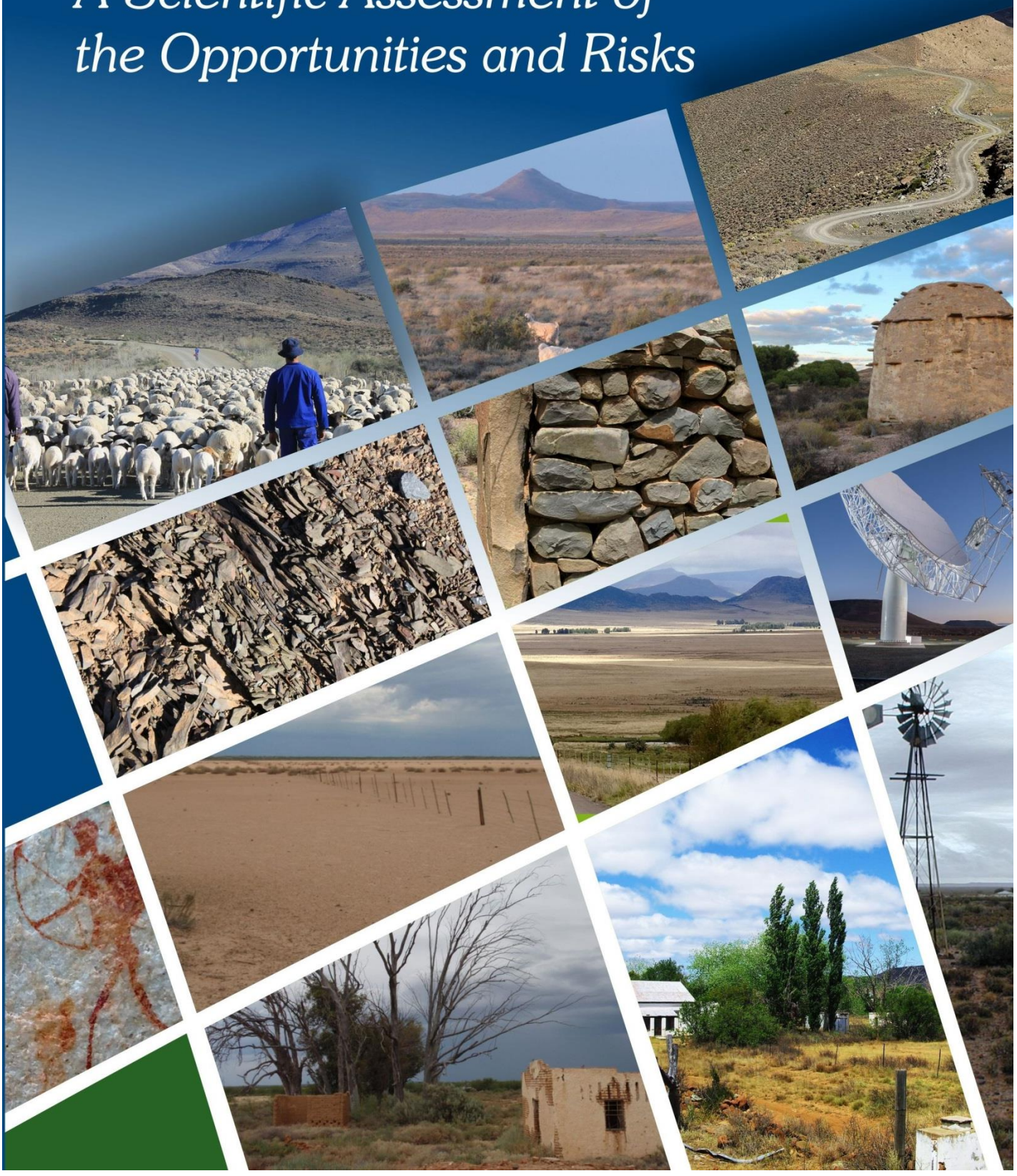
Shale Gas Development in the Central Karoo:

A Scientific Assessment of the Opportunities and Risks



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

PREFACE

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1. BACKGROUND TO THE STUDY

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 development (SGD) has been presented to the South African public and decision makers as a dichotomous trade-off between economic opportunity and environmental protection. As such, it 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 SGD was commissioned in February 2015 by the Department of Environmental Affairs of the Republic of South Africa, with the support of the National Departments of Energy, Mineral Resources, Water Affairs and Sanitation, Science and Technology, and Agriculture, Forestry and Fisheries; 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 Council for Geoscience (CGS). In addition to the national science councils, the SEA includes 135 independent authors contributing to the 18 Chapters of the assessment. The chapters have been independently reviewed by a further 25 local and 46 international independent peer review experts, and by a large number of stakeholders.

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. The 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.

The mission statement for the SEA is to provide an integrated assessment and decision-making framework to enable South Africa to establish effective policy, legislation and sustainability conditions under which SGD could occur. Note that this mission statement, developed in collaboration with government, is phrased in the conditional - it does not presume that SGD *will* occur.

The key objective of the SEA is to provide decision makers and stakeholders with an evidence base which will assist South Africa in developing a better understanding of the risks and opportunities associated with SGD. The SEA is not in itself a mandated decision-making process. The intention of the SEA is to provide the evidence base and decision support frameworks which will guide future decision-making processes, for example those associated with Environmental Impact Assessments (EIA) for specific SGD-related activities, once it becomes clear exactly what those are and where they might be located.

2. A PHASED APPROACH

The SEA has three distinct but overlapping Phases (Figure 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 governance structures, collating literature and data libraries, identifying the multi-author expert teams, undertaking team training, arranging logistics and writing the First Order Draft (FOD) of Chapter 1.

What is a Scientific Assessment?

Scientific assessments are aimed at the stakeholders (often specifically decision-makers) in society, who are intelligent but not necessarily technical specialists. The questions are posed by the stakeholders, who help to shape the assessment. Strong attempts to use jargon-free, plain language, summary tables and explanatory diagrams are made. Scientific assessments have a strong focus on balanced and inclusive governance to establish legitimacy and credibility.

The issues addressed are investigated by large and diverse teams of experts. During assessments, subjective judgements are often required, but these are made explicitly, along with statements of confidence. Balance and the elimination of bias are achieved through the establishment of broad multi-author teams representing a range of interests and/or positions, coupled with extensive and transparent review.

The assessment is independently reviewed by other experts and by stakeholders, often amounting to thousands of documented comments and responses, all of which are available in the public domain. Scientific Assessments are appropriate to problems with are both technically complex and socially contested, they are policy relevant, but not policy prescriptive.

The first of the modern scientific assessments of a complex, socially-important problem is usually considered to be the Ozone Assessment of 1986. The success of this exercise in paving the way for the Montreal Protocol led to the formation of a permanent assessment body for climate change, the Intergovernmental Panel on Climate Change, in 1990, before the United Nations Framework Convention on Climate Change was signed. The successive climate scientific assessments from 2000, 2007 and 2014 are credited with making possible the agreement by 195 countries in Paris in December 2015 to take concerted action on climate change.

Phase 2 of the SEA is the *scientific assessment* Phase, where information was organised by the multi-author expert teams, including two review rounds of their Chapters, initially by independent review experts, and then (following revision to produce the Second Order Draft [SOD]) by stakeholders plus experts. *Phase* 2 commenced with the

first author meeting on 28 September 2015, and ends with the completed final scientific assessment report, due around September-October 2016.

Phase 3 of the SEA will translates the scientific assessment into an operational Decision Making Framework. It is undertaken by the statutory science councils - CSIR, SANBI and CGS - in close consultation with the various affected National and Provincial Departments. It commences with initial drafts after the delivery of the SOD, and continues into the final revision of the scientific assessment report in October 2016. *Phase* 3 of the SEA concludes around March 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 regarding SGD. This includes guidance on legislation, regulation, monitoring and institutions. 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 have not been asked to make decisions about the development of shale gas. They have been asked to give an informed, evidence-based, scientifically-sound and balanced opinion on the consequences of different scenarios and development options for SGD into the future. The ultimate decisions regarding future 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 SEA, 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 they need to implement policy, which may be years or decades into the future.

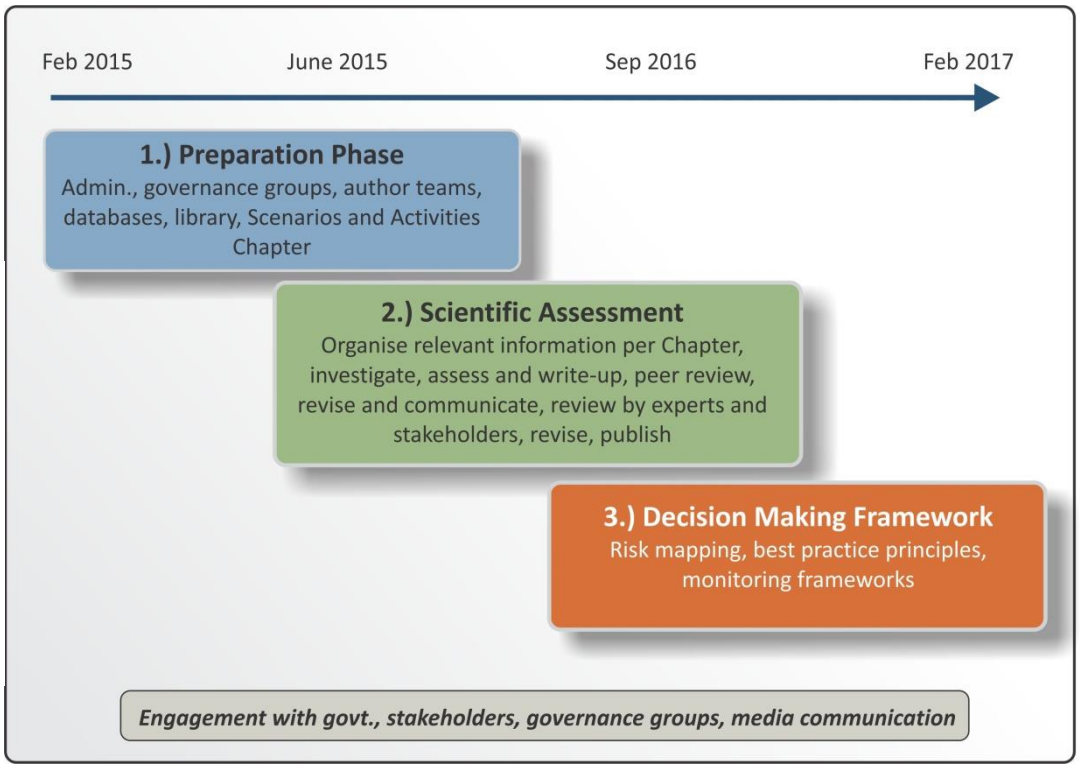

Figure 1: Shows the 3 overlapping phases of the SEA process and how the Scientific assessment is used as the evidence base from which to develop an appropriate Decision Making Framework.

3. STRUCTURE OF THE SCIENTIFIC ASSESSMENT REPORT

The Preface provides the background to the study, explaining why it was commissioned, how it is phased, how it is governed, the manner in which it has been undertaken and.

The Summary for Policy Makers (SPM) synthesises the key policy-relevant points arising from the 18 Chapters which make up the body of the SEA, in a form useable for policy makers and stakeholders. The SPM can be used as a standalone document for communicating the most important consequences related to SGD in the Central Karoo.

Report Structure

…	*Summary for Policy Makers*
…	*Preface*
Ch 1	Shale Gas Development Scenarios and Activities
Ch 2	Effects on National Energy Planning and Energy Security
Ch 3	Air Quality and Greenhouse Gas Emissions
Ch 4	Earthquakes
Ch 5	Water Resources, both on the Surface and Underground
Ch 6	Impacts on Waste Planning and Management
Ch 7	Biodiversity and Ecological Impacts: Landscape Processes, Ecosystems and Species
Ch 8	Impacts on Agriculture
Ch 9	Impact on Tourism in the Karoo
Ch 10	Impacts on the Economy
Ch 11	Impacts on Social Fabric of 34 Municipalities
Ch 12	Impact on Human Health
Ch 13	Impact on Sense of Place Values
Ch 14	Impacts on Visual, Aesthetic and Scenic Resources
Ch 15	Impacts on Heritage
Ch 16	Noise Generated by Shale Gas-Related Activities
Ch 17	Electromagnetic Interference
Ch 18	Impacts on Infrastructure and Spatial Planning

Stakeholders wanting to review the scientific assessment should use the SPM as a guideline document, directing them to the issues for topics they feel they would like to comment on.

The purpose of Chapter 1, is to describe the nature and scale of activities assumed for three SGD scenarios of increasing magnitude. The scenarios are described in the context of a reference scenario where there is no SGD. The scenarios are selected to cover a range of plausible futures. Chapter 1 serves as a common point of departure for the 17 subsequent chapters, which evaluate, for the issues on which they focus, the levels of risk associated with each of the scenarios and their main defining activities.

Chapters 2-18 are topic specific. They constitute the actual Scientific Assessment. Each Chapter has been structured in a manner which presents a clear definition of the scope of the topic in question, a review of the international literature and evidence, the relevant South African rules, institutions,

regulations and legislation; and a description of the key SGD impacts and mitigation options. Each Chapter goes through a systematic and structured risk assessment of the impacts described, assessed both with and without mitigation, and across the 3 development scenarios relative to the reference case and relative to the 'limits of acceptable change', which are based as far as possible in accepted national or international norms

On the back of the risk assessment, the multi-author teams make recommendations regarding impact mitigation best-practice in relation to that topic; and baseline and ongoing monitoring requirements which would need to be implemented if SGD were to proceed. The teams clearly identify, per topic, the areas in which there was inadequate information to adequately inform decision-making.

A detailed list of glossary terms and abbreviations is provided in Appendices 1 and 2 respectively. Appendix 3 provides summary biosketches of the Integrating and Contributing Authors who have drafted the Chapters of the scientific assessment.

4. SCIENTIFIC ASSESSMENT PROCESS

The Zero Order Draft (ZOD) of the Scientific Assessment, which provides a skeletal structure of the full assessment and the range of topics covered, was released for public comment in October 2015; and discussed and communicated with stakeholders at public briefings in November 2015 and May 2016. The scope of work for the assessment was vetted by the Process Custodians Group (PCG) and Project Executive Committee (PEC).

Based on the ZOD, the multi-author teams drafted the Chapter FODs, which were received by the management team in February 2016. The Chapter FODs were distributed for independent expert peer

Principles of a Scientific Assessment: Legitimacy, Saliency and Credibility

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. Furthermore, the process must include appropriate people and organisations within project governance structures to ensure that the process is considered legitimate in the eyes of both the public and the decision-makers tasked with using it.

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, in other words, a scientific assessment is not a research project. The assessment must consider all the material issues and legitimate stakeholder concerns associated with SGD.

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.

review. All peer review comments received on the FODs were captured by the management team and sent back to the Chapter teams prior to the second author meeting in April 2016.

The SODs, which now include the revisions made following peer review and the responses by the author teams to the peer review comments, were submitted to the management team end-May 2016. The SODs constitute the draft scientific assessment which is released for stakeholder comment for a 38 day period. All stakeholder comments submitted on the SODs were captured and responded to in a formal manner by the Chapter teams during the third and final revision.

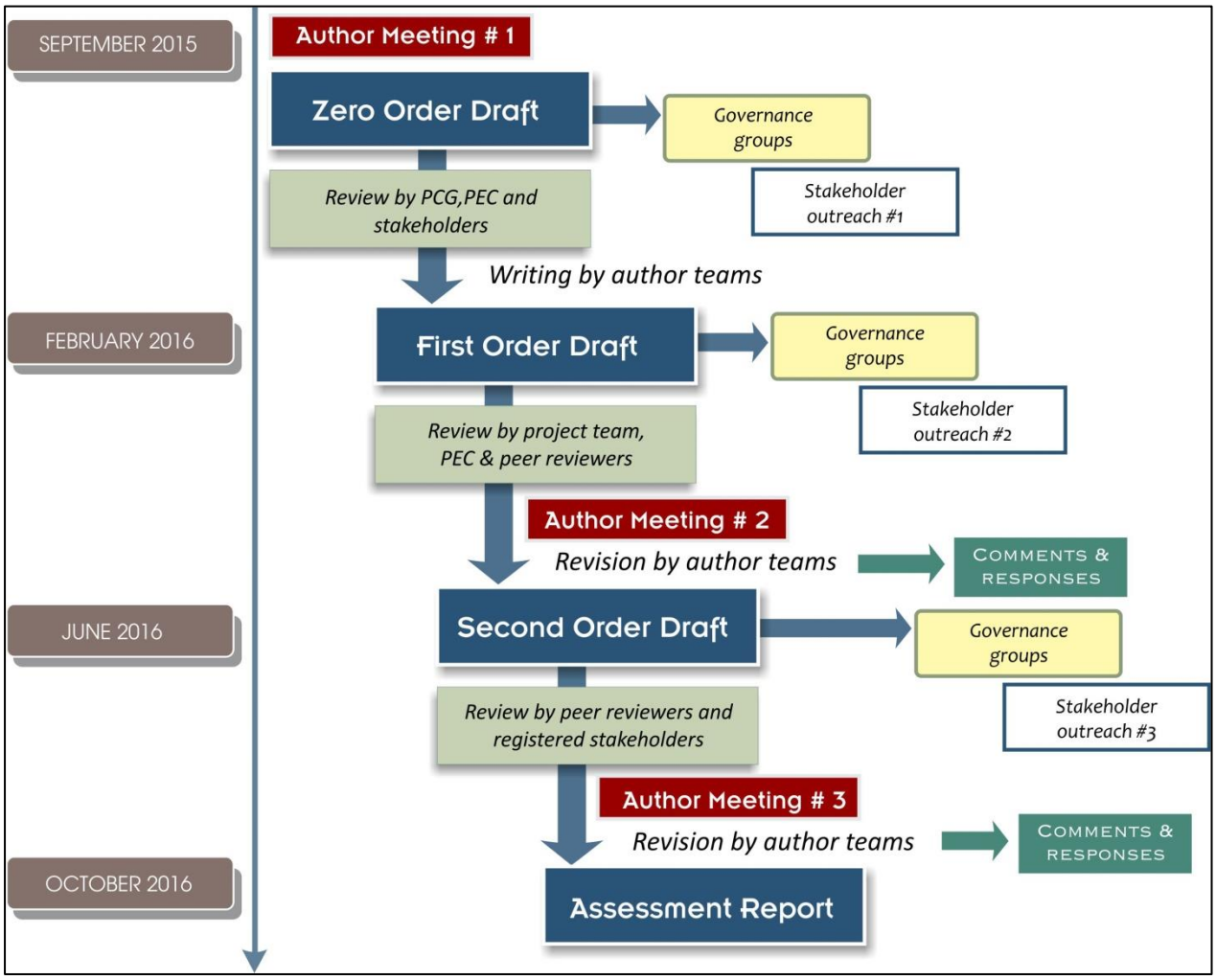

Figure 2: The scientific assessment process initiated with Author Meeting # 1 and the production of the Zero Order Draft (ZOD) in September and October 2015 respectively; and will be completed with the final Scientific assessment report around October 2016.

5. SCOPE OF THE SCIENTIFIC ASSESSMENT

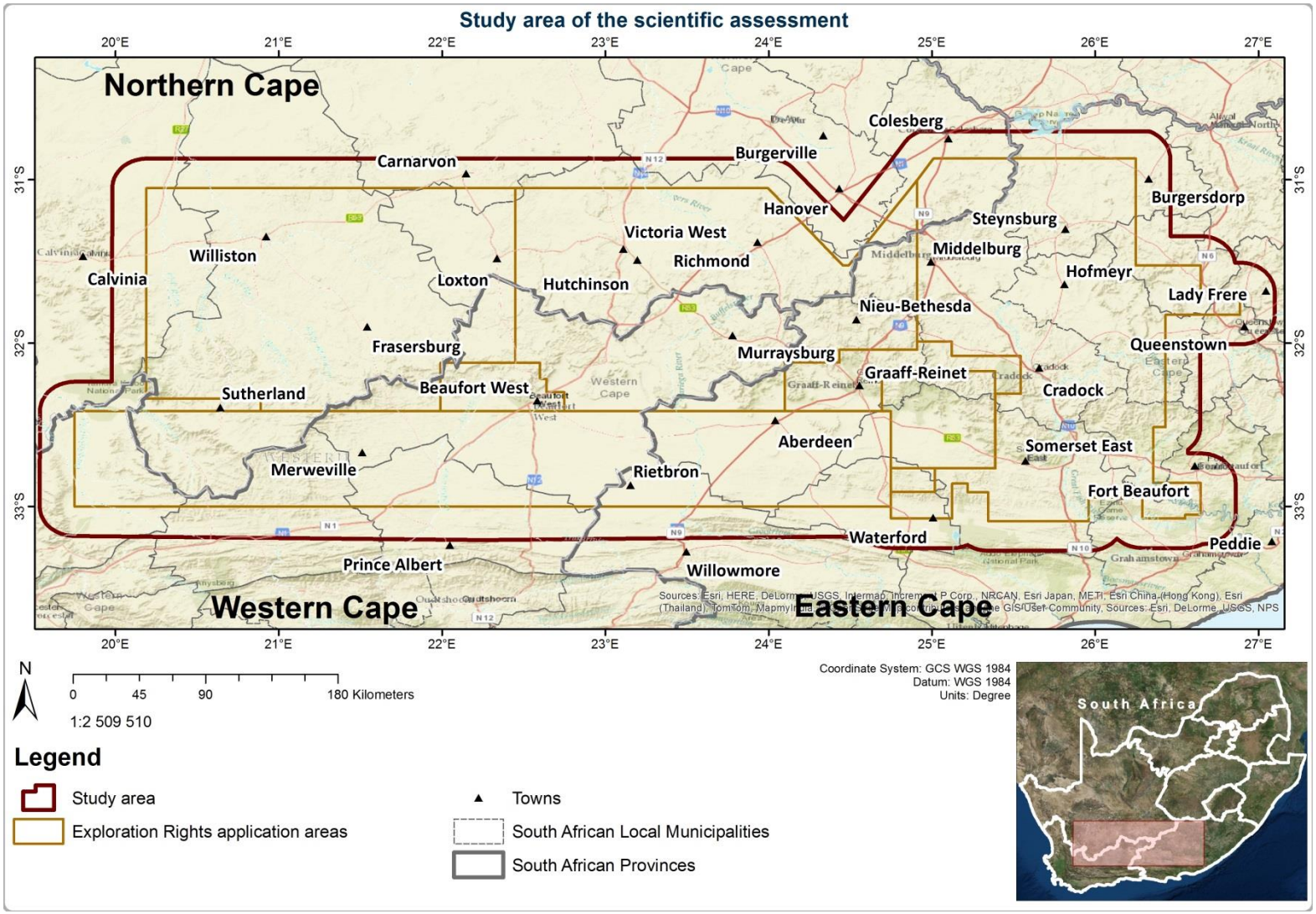

Figure 3: The Scientific assessment considers shale gas development origination in the 171 811 km^2 region of the study area delimited by the applications for Exploration Right which have been lodged by Shell, Falcon and Bundu), plus a 20 km buffer. The assessment follows the consequences of SGD in this region to the point of material impact, even if that is outside the study area.

The geographic scope of the assessment was restricted to impacts originating from SGD within the Central Karoo (Figure 3). This is not only the most promising SGD prospect, but also the only one at the date of commencement for which applications had been accepted for Exploration Right application (the Exploration Right applications are currently being considered by the Petroleum Agency South Africa [PASA]).

Unconventional gas reserves may exist in other areas of the South African onshore and offshore territory, and would need separate consideration if their development was considered. The assessment considers the shale gas exploration, production and downstream related activities, up to and including eventual closure of facilities and restoration of their sites, and includes an assessment of all the material social, economic and biophysical opportunities and risks associated with the shale gas industry across its entire lifecycle, as described in Chapter 1 (Burns *et al*., 2016). This temporal scope extends, in some instances up to 40 years into the future. The scope of issues addressed in the scientific assessment (Figure 4) was informed by an in-depth review of similar international assessments undertaken around the world and by engagement with stakeholders and governance groups.

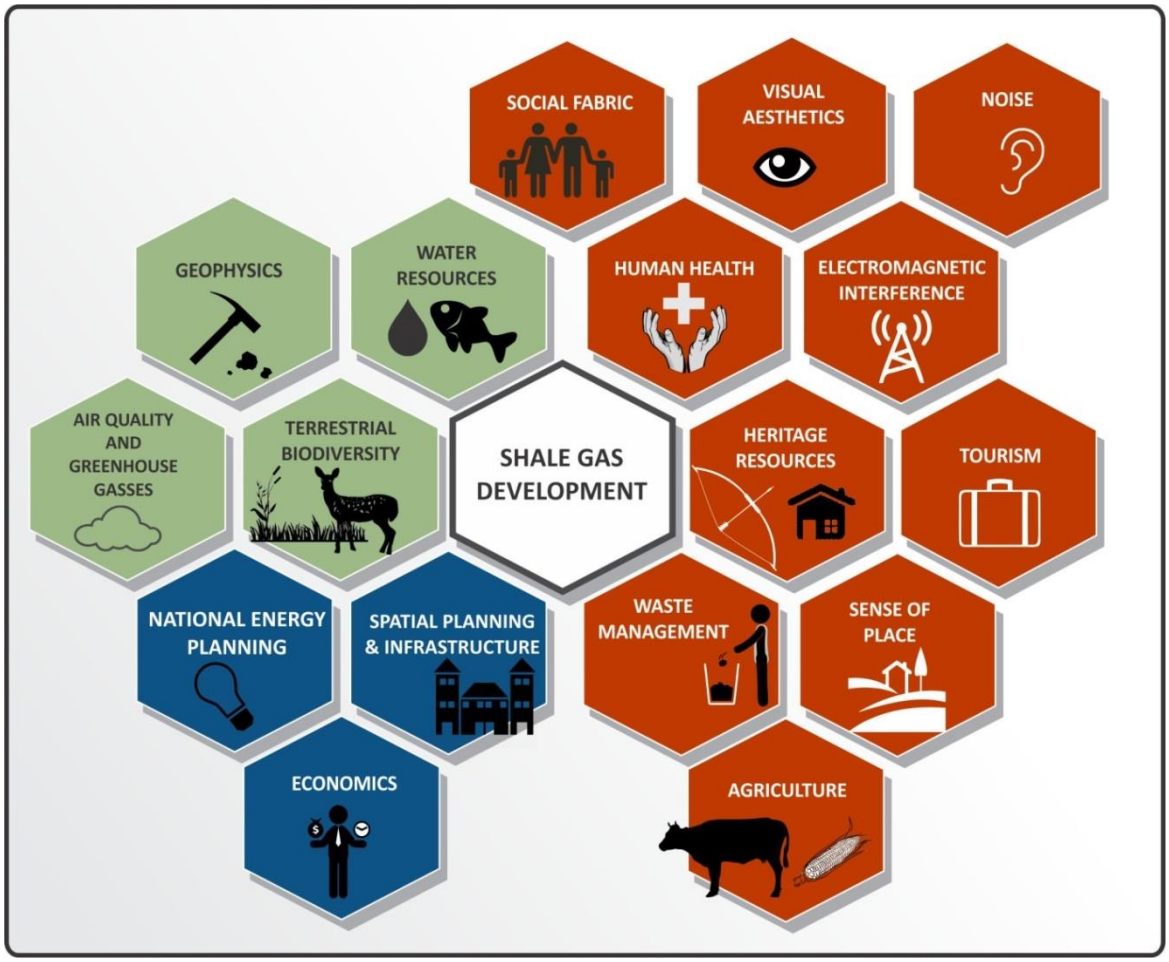

Figure 4: The 17 strategic issue topics identified through the literature review and public / governance engagement process, which now form the basis of the Scientific Assessment.

6. RISK ASSESSMENT METHODOLOGY

Each Chapter undertakes a rigorous and systematic risk assessment of the impacts relating to SGD. The risk assessment approach takes its point of departure from the fact that there is residual uncertainty about all aspects of the future, even after that uncertainty has been constrained by rigorously assessing the evidence.

The risk assessment, which is based on a transparent expert judgement process, is an approach for considering all aspects of an issue in a common way, and in a spatial context. Risk is determined by estimating the likelihood of events or trends occurring, in relation to their consequences (Figure 5).

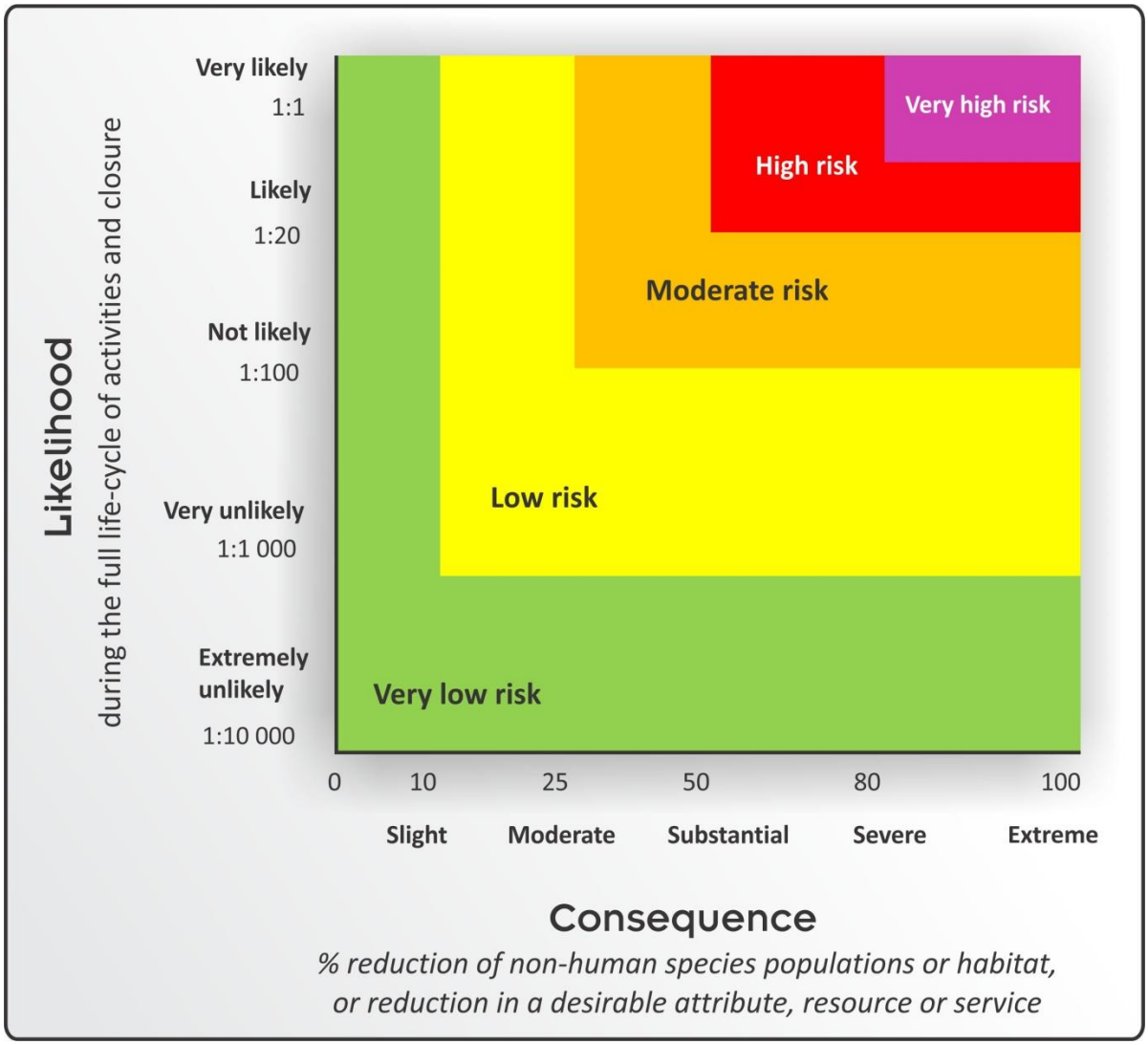

Figure 5: Risk is qualitatively measured by multiplying the likelihood of an impact by the severity of the consequences to provide risk rating ranging from very low, low, moderate, high and very high

The risk assessment is 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 is 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 1).

Table 1: Predefined set of criteria applied across the Chapters 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.

In Chapters 2-18, every author team has conducted a risk assessment in relation to its issue, starting in the FOD, and then refining the assessment in subsequent drafts as a result of independent peer review process. Following stakeholder comments on the SODs, the risk assessments will again be revised in a third iteration if new information or evidence is provided. The risk assessments will be conducted using standard approaches and terminology to improve the consistency across issues. The risk assessment will be spatially explicit to the extent that risk driver data is spatially available, and will be undertaken for the three activity scenarios and the reference case (explained below), with and without mitigation. The 'with mitigation' options will form the basis of the 'best practice' descriptions in each

of the Chapters, which will later form the basis of the guidelines developed from the scientific assessment *Phase*.

7. SCENARIOS AND ACTIVITIES

The purpose Chapter 1 is to describe, in as much detail as feasible, the scale and type of activities which would logically be associated with three SGD scenarios of increasing magnitude, in relation to the reference state which assumes other changes, but no SGD (Table 2, Figure 6).

The chapter serves as a common point of departure for the subsequent 17 Chapters, to estimate, for the Chapters, the levels of risk associated with each of the scenarios, considering the activity descriptions. As such, Chapter 1 is not itself an assessment, and nor does it make any suggestion about how likely or desirable any of the scenarios are. It simply provides a shared basis from which risk is estimated across the scenarios, across the activities and across the chapter topics which will follow in due course.

The scenarios depicted in the chapter do not presuppose that SGD will occur. They are presented in a plausible but hypothetical manner so that the strategic risks associated with the likely range of scenarios can be estimated. The outcome of that assessment will inform responsible decision-making with respect to SGD, at a later stage.

Table 2: Scenarios considered in the assessment and a brief explanation of the associated activities. Tcf is trillion cubic feet of gas. For comparison, the Mossgas resource was about 1 Tcf.

Scenario	Brief explanation
Scenario 0: Reference Case	Regional trends such as human migration, shifting economic activities and new development alternatives in the Central Karoo are realised. Climate change reduces the availability of water in the region.
Scenario 1: Exploration Only	Exploration proceeds, with results indicating that production would not be economically viable. All sites are rehabilitated, drilled wells are permanently plugged and monitoring of the abandoned wells is implemented. The national energy supply is supported by imported natural gas.
Scenario 2: Small Gas	A relatively small but economically viable shale gas discovery is made, in the region of 5 trillion cubic feet (Tcf) produced from 550 wells on about 55 well pads through the study area. Downstream development resulting in a 1 000 megawatt (MW) combined cycle gas turbine (CCGT) power station located less than 100 km from the production block.
Scenario 3: Big Gas	A relatively large shale gas discovery of 20 Tcf is made, produced from 4100 wells on about 410 well pads distributed through the study area. Downstream development results in construction of two CCGT power stations (each of 2 000 MW generating capacity) and a gas-to-liquid plant located either at the coast with a refining capacity of 65 000 barrels (bbl) per day.

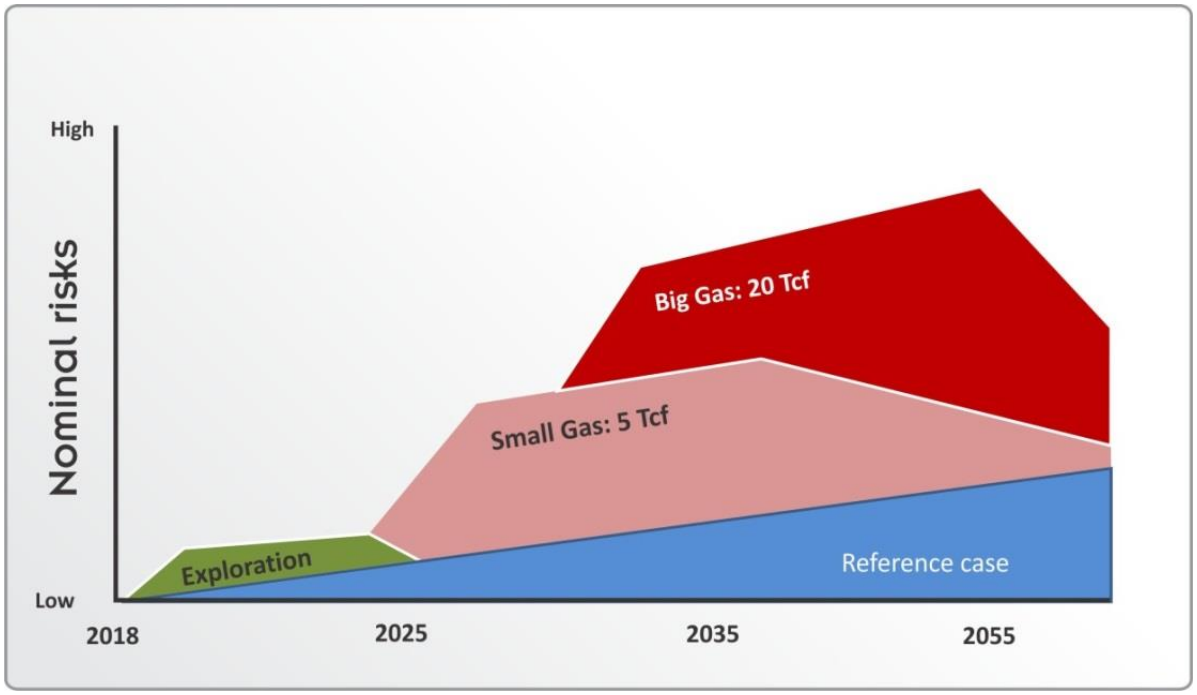

Figure 6: A 'cartoon' of the four conceptual 'Scenarios' to be considered in this assessment. Note that the scenarios are cumulative: Scenario 1 (Exploration Only) includes Scenario 0 (Reference Case); Scenario 2 (Small Gas) includes 1 and 0; and Scenario 3 (Big Gas) includes 0, 1 and 2. Thus they extend from 2018 to beyond 2055.

8. PROJECT GOVERNANCE

The Project Executive Committee (PEC) comprises representatives of Government who commissioned the SEA (all 3 *Phases*). Key responsibilities for the PEC include the coordination and communication of information, ensuring the project remains on scope, within timelines and budget and that strategic and policy questions are adequately addressed.

A key innovation, used specifically for the Scientific assessment *Phase*, is the Process Custodians Group (PCG). The PCG is designed to ensure that the Scientific assessment it is independent, thorough and balanced.

The PCG comprises 16 eminent people, drawn approximately equally from government, NGOs, 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 has no say on the content; they act as referees to ensure that the process has been undertaken in a legitimate, transparent and credible manner.

The PCG provides feedback to the PEC, ensuring that the Scientific assessment has followed the prescribed process as approved in the SEA Process Document[1]; by checking author team compositions and expertise of peer reviewers; and the credibility of the review process by checking the manner in which responses to the expert and stakeholder comments are considered. The PCG convened during the Scientific assessment phase of the SEA to discuss the ZOD in October 2015, the Scenarios and Activities Chapter FOD and SOD in October 2015 and May 2016 respectively, and the FODs of the 17 strategic issue Chapters comprising the Scientific assessment in May 2016, among other processes which were discussed such as stakeholder engagement, public outreach processes and stakeholder commenting mechanisms.

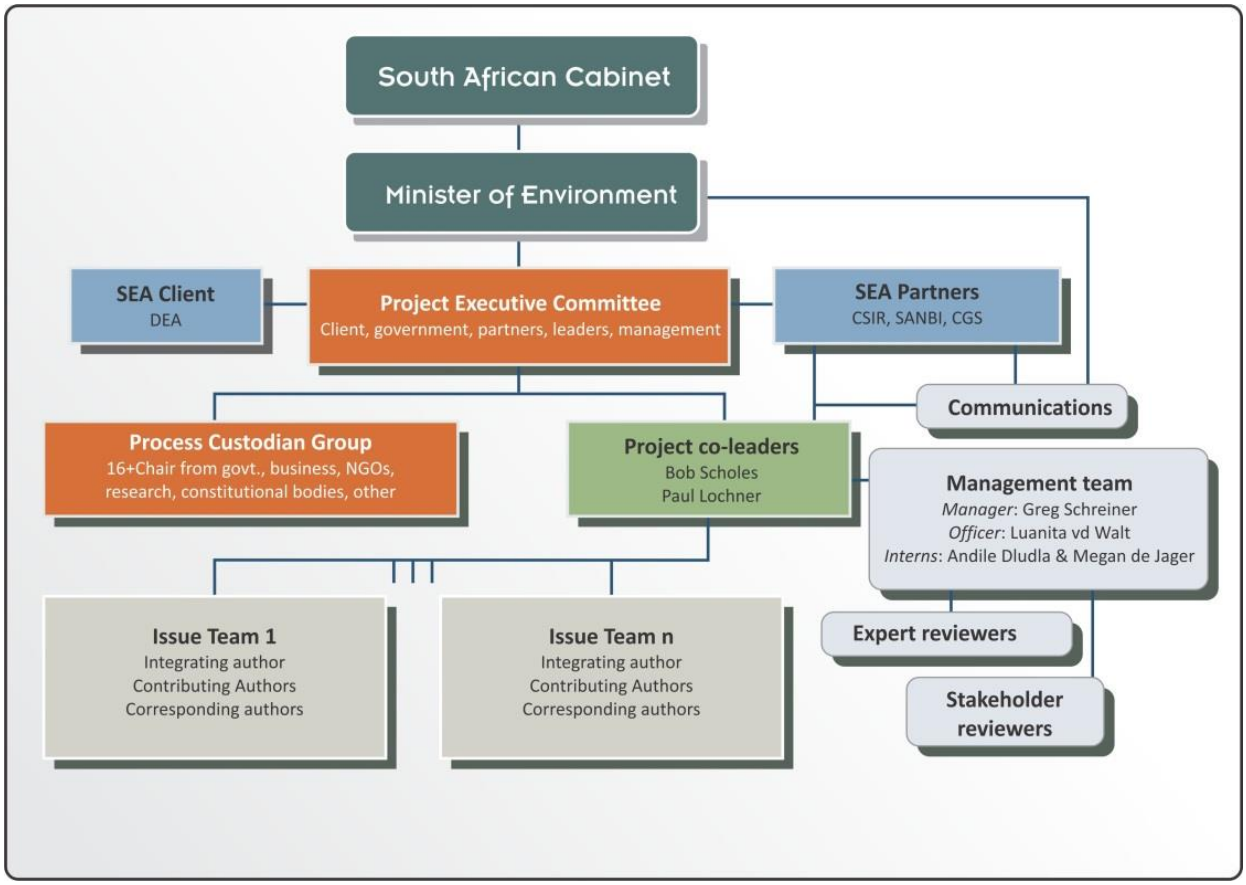

Figure 7: The project governance structure of the entire SEA process showing the interaction between the two governance groups, the SEA partners, the co-leaders and management team, the multi-authors teams, the peer review experts and stakeholders.

[1] SEA Process Document downloadable at http://seasgd.csir.co.za/library/

9. THE MULTI-AUTHOR TEAMS

In order to advance the principles of balance and comprehensiveness, the main topics in the assessment have been addressed by multi-author teams (rather than the approach often applied in EIAs of using a single consultant). Each of the Chapters has a team of four to 15 authors, selected on the basis of their acknowledged expertise.

Expertise is usually evidenced by appropriate formal qualifications and experience, but may also be evidenced by widespread peer-group agreement that the candidate has expertise on the topic and by a track record of outputs on the topic, widely acknowledged to be of value.

Authors have been drawn from a broad range of sectors, including research institutions, consultancies, government, NGOs, universities, etc. and across different regions of South Africa, to ensure a balance of interests, disciplinary background, experience and perspective is represented in the teams.

Each team includes one (in some cases two) Integrating Author, several Contributing Authors and potentially many Corresponding Authors (table 3). The latter do not attend writing meetings, but provide small amounts of text on defined, relatively narrow topics, via email.

Authors of the 18 Chapters do not represent their home organisations or any particular constituency. They are selected on a personal basis, reflecting their individual capacity to contribute to the Scientific Assessment.

Table 3: Shows the three author roles and associated author responsibilities

Integrating Authors	The ***Integrating Authors*** are responsible for ensuring that all the components written by Contributing and Corresponding Authors are delivered on time, and are incorporated in a logical fashion each Chapter; and that the scope of the Chapter, as decided at the first workshop, is covered. Integrating Authors need to ensure that the responses to comments from stakeholders and peer reviewers have been adequately addressed and/or incorporated and documented.
Contributing Authors	The ***Contributing Authors*** are expected to attend all three writing workshops and actively participate in the discussions and decisions there. They deliver text, references, tables and graphics to their Integrating Author by agreed dates, and according to agreed formats and templates. They must assist in addressing reviewer comments (especially those relating to text they have contributed) and writing the second draft. They must assist in addressing the stakeholder and expert comments on the second draft and final draft, especially on their sections.
Corresponding authors	The ***Corresponding Authors*** typically write less than one published page (often a box, a table, illustration or a few paragraphs). They must deliver text, references, tables and graphics (in rough form) to their Integrating Author by the agreed date, and according to agreed formats. They may be requested to assist in addressing reviewer comments relating to text they have contributed. Corresponding Authors do not attend the writing meetings.

10. PEER REVIEW PROCESS

The FODs of each Chapter, written by the multi-author teams, were sent to a minimum of two, and a maximum of six, peer reviewers. The expert peer reviewers were identified from existing scientific publications collected throughout the SEA process and through nominations from the project team, general stakeholders, the PEC and PCG and authors working on the Scientific Assessment. A total of 71 peer reviewers, from international, national and provincial government departments, NGOs, academia and research institutions; and the private sector provided peer review comment on the FODs. Of the 71 peer reviewers, 25 were drawn from South Africa and 46 from other regions of the world, such as the United States, Canada, Australia, the United Kingdom, the European Union and others.

The comments received for each Chapter followed a structured format. . The expert peer review submissions were collated into a database for each Chapter, and sent to the author teams prior to the second multi-author team meeting in April 2015. In addition, the SOD Chapters were sent back to the peer reviewers to check that their comments have been sufficiently addressed and at the same time they were released for stakeholder comment in mid-2016. All responses to peer review and stakeholder comments have been available and are in the public domain via the project website: http://seasgd.csir.co.za/

The stakeholders were required to follow the same prescribed structure for commenting, in which page and line numbers must be provided for each comment. As for the expert reviewers, the stakeholder comments were required to be specific, clear and constructive, and where possible, backed up with references or evidence. The authors addressed the stakeholder comments individually and incorporate appropriate comments into the final draft of the scientific assessment report.